APPENDIX A

SECTION 1

1959 Final Hazards Summary

(NASA, December 1959)

APPENDIX A

PREVIOUS PBS AND PBRF REPORTS

Section 1: 1959 Final Hazards Summary (NASA, December 1959)
Section 2: 1981 Deep Rock Core Description (Weeks, August 1981)
Section 3: 1990 Contamination Evaluation (IT, March 1990)
Section 4: 1990 Closure Assessment for Tanks 21, 22, and 23 (Ebasco Environmental, May 1990)
Section 5: 1991 Underground Storage Tank Study (Ebasco Environmental, November 1991)
Section 6: 1993 Preliminary Site Investigation, USTs (Morrison Knudson Ferguson Group, 1993)
Section 7: 1995 Closure Work Plan for Reactor Area (URS, September 1995)
Section 8: 1997 Records Review Report (Dames & Moore, April 1997a)
Section 9: 1997 Site-wide Groundwater Investigation (Dames & Moore, April 1997b)
Section 10: 1997 Site-wide Groundwater Investigation (IT, September 1997)
Section 11: 1999 Summary Report, Site-Wide Groundwater Monitoring, 1997-1998 (IT, June 1999)
Section 12: 2000 Amended Closure Plan (URS Greiner Woodward Clyde, March 2000)
Section 13: 2001 Environmental Baseline Survey (Tetra Tech, 2001)
Section 14: 2002 Report: 2001 Groundwater Remedial Investigation (IT, March 2002)
Section 15: 2003 Groundwater Well Installation (CATI, 2003a and 2003b)
Section 16: 2003 Report: 2002 Groundwater Data Summary and Evaluation Report (Shaw, June 2003)

Rodney J. Malkoff

FINAL HAZARDS SUMMARY
NASA PLUM BROOK REACTOR FACILITY

PART II

by

Lewis Research Center Staff
Cleveland, Ohio

December, 1959

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APPENDIX D

MEMORANDUM ON THE GEOLOGY AND HYDROLOGY OF A PROPOSED REACTOR SITE NEAR SANDUSKY, OHIO

By Stanley E. Norris[1]

INTRODUCTION

Purpose and Scope

The purpose of this report is to discuss, with special reference to the disposal or unintended loss of radioactive fluid to the ground, the geology, and hydrology of a proposed reactor site at the Plum Brook Ordnance Works near Sandusky, Ohio. The report was prepared at the request of the National Advisory Committee for Aeronautics as an aid to the Committee on Reactor Safeguards of the U.S. Atomic Energy Commission in evaluating the feasibility of operating a nuclear power reactor at the site in question.

Previous Work and Acknowledgments

Data on which this report is based are from well records in the files of the Ohio Division of Water, from publications and manuscript maps of the Ohio Division of Geological Survey, from publications of the Ohio Division of Shore Erosion, and from engineering data collected by the U.S. Corps of Engineers. A brief reconnaissance was made of the site area by the writer and R. K. Cash, of the Geological Survey, in company with officials of the National Advisory Committee for Aeronautics and personnel of the Plum Brook Ordnance Works. Mr. Cash also spent time in the field collecting well data and information on water use in the area.

This report was prepared under the general supervision of A. N. Sayre, Chief of the Ground Water Branch, U.S. Geological Survey. The writer is indebted to Mr. N. P. Miller of the National Advisory Committee for Aeronautics for his assistance in furnishing engineering data of the site, and to Mr. R. E. Lamborn of the Ohio Division of Geological Survey for making available the manuscript maps prepared by Frank Carney, showing the extent of the beach ridges in the Sandusky area.

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[1] District Geologist, Ground Water Branch, U.S. Geological Survey, Columbus, Ohio.

AREA OF INVESTIGATION

Location and Extent

As shown on figure D.1, the Plum Brook Ordance Works occupies an area of between 15 and 20 square miles, chiefly in Perkins and Oxford townships, Erie County, Ohio. The proposed reactor site lies in the northern part of the ordnance works grounds, five miles south-southeast of the Court House in Sandusky, Ohio.

Topography and Drainage

The area under discussion lies near the southern shore of Lake Erie, on the flat plain which in glacial time was a portion of the lake bottom. The land surface slopes gently toward the lake, descending from an elevation of 700 feet above sea level at Prout Station, at the southern boundary of the ordnance works, to the level of the lake, about 573 feet[2] above sea level. The topography is very flat, the principal relief being afforded by the old beach ridges and sand hills which mark the former shoreline. The present shoreline, in the vicinity of Sandusky, is one of submergence, characterized by drowned stream mouths and large areas of marshland (Metter, ref. D.3, p. 5).

The drainage in the area of the ordnance works is by short streams which flow north across the lake plain in relatively straight courses to empty into Lake Erie. As shown on the map, the streams draining the immediate area of the proposed reactor site include a tributary of Pipe Creek on the western side, an unnamed stream in the central part, and Plum Brook in the eastern portion of the site area. These streams have very low average flows and are intermittent except in their lower courses near the lake where they enter the marshland along the shore.

GEOLOGY

Soils

The soils in the general vicinity of the proposed reactor site are derived from very fine sand, silt, and clay, except in areas of the beach ridges where they are developed on deep sand or sand over clay. Natural drainage is classified as good on the beach ridges and poor to very poor in the intervening areas (Conrey et al., ref. D.1, pp. 21-25).

Surficial Deposits

The surficial deposits in the area are comprised of lacustrine clay, thinly underlain by glacial till, with local patches of sand along the

[2] During the summer of 1951; Metter, ref. D.3, pp. 7-9.

old beach ridges. The unconsolidated deposits generally are thin, not more than about 20 feet in thickness, with bedrock exposed at many places. Within the ordnance works is a fairly extensive area underlain by sand deposits which formerly were a source of molders sand.

The unconsolidated deposits along the lake shore, both in the marshy areas near the stream mouths and beneath the shallow offshore waters, are considerably thicker than the unconsolidated deposits in the area of the ordnance works. As reported by Metter (ref. D.3, p. 13):

"The Sandusky city engineers have made a series of auger bore holes in the marshy region from the new Cedar Point entrance road westward to within about 300 yards of Willow Point. The borings were made at 1000-foot intervals in nine north-south rows 1000 feet apart. The westernmost line of borings encountered bedrock at an elevation of approximately 550 feet, overlain by gravel, sand, clays, and swamp muck - approximately 25 feet of unconsolidated material. The next line of probings, 1000 feet farther east, encountered bedrock at an elevation of 545 feet, and there is no more record of bedrock elevations eastward along the shore of the peninsula. Borings at the Plum Brook Intake went down to elevations of 516 feet without encountering rock, giving a minimum thickness here of approximately 60 feet for the unconsolidated material."

Consolidated Rocks

Consolidated rocks underlying the area are sedimentary in origin and of Devonian age. A generalized geologic section, compiled from Stout (ref. D.5, p. 359) and other sources is as follows:

Name	Approximate thickness, ft
Ohio shale	300
Olentangy shale (includes the Prout limestone member of Stauffer near the top)	40
Delaware limestone	70
Columbus limestone	65

The regional dip of the strata is easterly and younger rocks crop out progressively from west to east. The bedrock is limestone in the western part of the ordnance works property and shale in the eastern part. On the map is shown the line of demarcation between the Columbus and Delaware limestones on the west and the Olentangy and Ohio shales on the east. Also shown on the map are locations of quarries and other exposures of the bedrocks.

The carbonate rocks in the Sandusky area are described by Stout (ref. D.6, p. 363, 365-366) as follows:

"The stone in the Columbus formation shows considerable variation, both physical and chemical, in different parts of the section. In composition, it changes upward from a dolomite bearing a little free calcium carbonate to a limestone containing from 10 to 25 percent magnesium carbonate. The stone in the upper part is blue in color and lies in thin to medium beds rather uniform in thickness. Formerly this part was quarried extensively near Sandusky along Mills Creek, was known to the trade as "Sandusky stone," and was employed for building, paving, and flagging purposes. In the middle portion the strata are more massively bedded, are from bluish to light brown in color, and locally contain some chert. The dolomite in the lower portion is well crystallized, massive bedded, and commonly light brown . . ."

"The youngest of the carbonate rock formations in Erie County is the Delaware which extends in a strip from four to five miles in width from the lake and bay near Sandusky southwestward across the area to Huron County. It covers central Portland, western Perkins, southeastern Margaretta, western Oxford, and eastern Groton townships. The general color of the Delaware limestone is bluish gray but owing to the effects of organic pigments parts assume brown and dark sooty shades. The stone is finely crystalline, hard, dense, and fossiliferous. Locally it contains chert, usually in the nodular form, localized along bedding planes, and varying much in color depending upon the state of weathering. Ordinarily the strata are rather uniformly bedded in layers from 2 to 10 inches. This formation has been rather extensively quarried south of Sandusky for building stone and crushed rock products."

The Olentangy and Ohio shales were exposed in former years at two localities within the ordnance works, in the railroad cut about a mile north of Prout Station, and along Plum Brook about two miles northeast of Prout Station. Based on the description by Stauffer (ref. D.4, p. 120-121 the Olentangy shale, below the Prout limestone member, is at least 30 feet thick and is a soft, blue shale, marly in composition, containing layers and nodules of hard, fossiliferous limestone. At the top of the Olentangy shale is a prominent limestone bed approximately 9 feet thick which Stauffer called the Prout limestone and described (ref. D.4, p. 120) as a "very hard silicious blue limestone with a layer of cherty pyrite at the top."

The Ohio shale, which overlies the Olentangy shale, is a black, thinly bedded shale, containing pyrite and much bituminous matter. The upper portion of the Ohio shale was called the Huron shale in older reports.

GROUND-WATER HYDROLOGY

Source and Occurrence of Ground Water

Ground water in the area of the ordnance works has its source in local precipitation. The limestone beds are the principal aquifer and, in areas where they comprise the bedrock, furnish supplies to most of the farms and suburban homes. Yields from the limestone deposits range generally between 5 gallons a minute and 10 gallons a minute, though variations over a considerable range - from 3 gallons a minute or less to more than 25 gallons a minute - are not uncommon. Water in limestone beds occur principally in joint cracks, along bedding planes and in other openings, some of which may be enlarged by solution to form interconnecting passages through which water may move in much the same manner as a surface stream. This is the case at Castalia, about 6 miles west of the proposed reactor site, where water issues in great volume from a famous spring called the "Blue Hole." According to Stout (ref. D.6, p. 278):

"The rocks forming the highlands to the south of Castalia are limestones and dolomites of the Columbus and Detroit River formations. They are highly pitted with sink holes as far south as Bellevue, nine miles away. These are the source for the water of the great Blue Hole and other springs issuing in the vicinity of Castalia. The flow into the Blue Hole alone is more than 7,000,000 gallons daily. Water is close to the surface throughout the entire Castalia Prairie of over 4000 acres."

No large limestone springs are known to the writer in the vicinity of the ordnance works, nor do sink holes, such as those which give rise to the underground flow at Castalia, appear to characterize the area. Most wells in the limestone deposits in the vicinity of the ordnance works range between 50 and 80 feet in depth. The quality of the water deteriorates rapidly with increased depth, and wells deeper than about 100 feet generally yield sulphur water.

Ground water conditions change abruptly east of the line which marks the boundary between areas underlain by limestone and those in which the bedrock is shale. The shales are relatively impermeable and wells drilled into these beds generally yield less than about 3 gallons a minute, a quantity barely sufficient for limited farm or domestic use. Many wells drilled into the shales are failures and in such cases property owners commonly resort to cisterns for their water supplies. Wells drilled through the shales, into the underlying limestone beds, generally encounter water of poor quality, unusable in most cases.

Table D.1 is a list of representative wells in the Plum Brook Ordance Works area, compiled from well records in the files of the Ohio Division of Water.

TABLE D.1. - RECORDS OF REPRESENTATIVE WELLS, PLUM BROOK ORDNANCE WORKS AREA

Number	Name	Altitude at well, ft above sea level	Depth to bedrock, ft	Depth of well, ft	Principal water-bearing bed	Static water level below land surface, ft	Yield, gal/min	Type of well	Diameter of well, in.	Remarks
1	Diamond Fertilizer Co.	580	25	102	ls		70	Dr	8	
2	Joe L. Strickfaden, Jr.	600	11	105	ls			Dr	5 5/8	Water sulphurous
3	Seitz Amusement Co.	585	40	94	sh ls	9	3	Dr	6	
4	M. Crillis	590	29	135	sh ls			Dr	5 3/16	"Dry hole"
5	Albert Schenk	600	2	30	sh	10		Dr	5	
6	Elmer Stengor	590	2	279	sh ls	6		Dr	5 5/8	Water sulphurous
7	Don Christotel	615	14	80	sh ls			Dr		"Dry hole"
8	Wm. C. Young	625	19	35	ls	15	10	Dr	5	
9	Carl Schemenauer	645	3	51	sh	12		Dr	5	
10	Jack Ehrhard	635	4	43	sh	3	1/2	Dr	5	
11	J. C. Klaholz, Jr.	630	2	40	sh	4		Dr	5	
12	Wm. Dempsey	645	6	63	sh	10		Dr	5	
13	Clarence Ohlemacher	625	26	45	sh	6		Dr	5	
14	Robert Bennett	615	48	53	sh	10		Dr	5	
15	Harry Kuhl	630	39	55	sh	8	1	Dr	6 1/4	
16	Don Taylor	630	49	62	sh			Dr	5	
17	Everett Hunter	695	6	40	sh	5	1	Dr	7	
18	C. H. Stanley	705	13	41	sh	4		Dr	5	
19	Robert Stewart	695	7	45	sh	10		Dr	5	
20	Wensink Brothers	705	7	46	sh	6		Dr	6 1/4	
21	Harold Lippus	640	26	43	sh			Dr	6	"Dry hole"
22	Avery Paper Corp.	650	31	210	sh ls	10	5	Dr		
23	Perry Balcom	645	49	68	sh			Dr	5 5/8	
24	F. G. Mileham	638	8	40	sh	5		Dr	6	
25	J. C. Klaholz	612	11	40	sh	7		Dr	5 5/8	
26	Harold Stevens	620	27	55	sh	11		Dr	6	

Explanation:
Dr - drilled
ls - limestone
sh - shale

Movement of Ground Water

Based on well records and foundation data furnished by the U.S. Corps of Engineers, the water table in the area of the ordnance works is within a few feet of the surface, the general range in depth is between 5 and 15 feet. The configuration of the water table is a subdued replica of the surface topography. The flow of ground water, therefore, is similar in direction to the course of the surface runoff. The average hydraulic gradient in the area is very low, less than about one percent, and the rate of ground water movement probably is no greater than a foot or two per day in the limestone beds, and certainly is much less than this in the shales. These estimates are based in part on percolation rates in typical materials as given by Tolman (ref. D.7, p. 219) and on other factors.

SURFACE WATER SUPPLIES

Lake Erie

Two principal water supplies in the area of the proposed reactor site are from Lake Erie. These are the Sandusky water supply and the water supply of the Plum Brook Ordnance Works. Both supply intakes are located east of Sandusky, as shown on figure D.1. The Plum Brook pumping plant has a capacity of 51 million gallons a day (mgd). Maximum pumpage, when the ordnance works was operating at near capacity was 28 mgd. The City of Sandusky presently uses about 3.3 mgd in the winter and up to 11 mgd in the summer.

Drainage from the area of the proposed reactor site enters the lake about midway between the Sandusky intake and the Plum Brook intake. Crucial questions relative to the hazards of contaminated water entering either the Sandusky intake or the Plum Brook intake involve the effects of dilution by the lake waters and the direction of the lake currents.

Direction of Lake Erie currents. - The Ohio Division of Shore Erosion has been making studies of the Lake Erie shoreline for the past several years in cooperation with the Ohio Division of Geological Survey. Studies in 1951 revealed important facts about the direction of flow of longshore currents in the Sandusky area. As reported by Metter (ref. D.3, p. 44):

"The Cedar Point shore line trends nearly N. 45° W., and wind producing waves from north of N. 45° E. would impinge upon the shore in such a manner as to produce an eastward current. Waves must approach from east to N. 45° E. to produce a resultant current toward the west. This concept of the cause of direction of longshore currents was borne out during the summer of 1951, when currents were observed to flow from the west on all but two of the days that the author was in the area, and on those two days, the wind was from the E.N.E.

Explanation:
Dr - drilled
ls - limestone
sh - shale

From the above reasoning, it would follow that during the times that the waves were from N. 45° E. on around to the northwest, longshore currents would carry sediments to the east. During the severe storms usually associated with waves from the east the movement would be to the west."

From Metter's observations, it would follow that the principal hazard associated with the discharge of radioactive fluids into Lake Erie between the Sandusky intake and the Plum Brook intake would be more apt to involve the water supply of the ordnance works than the Sandusky supply. A potential hazard would confront both, however.

EARTHQUAKE ACTIVITY

The State of Ohio has experienced at least 11 earthquake shocks which had their epicenters within the State boundary. According to Heck (ref. D.2), six of the shocks had an intensity of 6 or more on the Rossi-Forel scale of intensity. All but one of the six most severe earthquakes had their epicenters in northwestern Ohio, in Auglaize and Shelby counties. The area of these epicenters is about 110 miles southwest of Sandusky. Damage from earthquakes does not appear to be an important consideration in the Sandusky area.

CONCLUSIONS

Owing to the proximity of Lake Erie, and the absence of any large-scale ground water developments along the principal flow routes between the proposed reactor site and the lake, the hazards of ground water contamination resulting from the spillage of radioactive fluid appear negligible compared to the potential hazards to surface water supplies.

The short flow routes and the poor infiltration properties of the soils and surficial deposits over which a contaminant must move, would seem to assure its entry into the lake with but little prior dilution and perhaps only slight dimunition in quantity. The latter condition would hold true especially in times when the ground is frozen or saturated. Conversely, infiltration would be greatest when the soil is dry, such as during periods of large moisture deficiency which commonly occur during the growing season.

The course of a spilled liquid, should it reach the water table, would be toward Lake Erie where it would discharge into the lake through springs and seeps along the shore. In the course of its underground journey, it is possible that a contaminant might, under present conditions be diverted to wells that supply some of the farms and suburban homes in the area. However, owing to its very slow movement through either the underlying limestone beds or shale deposits, time would be available for remedial measures. Areas subject to possible ground water contamination are not large and auxiliary supplies doubtless could be provided where required during such an emergency.

If a contaminant were to enter Lake Erie in volume, a much more critical problem would arise. Under average wind and weather conditions, the currents probably would carry the contaminated water in the direction of the Plum Brook intake. If so, it would be a potential hazard to personnel of the ordnance works while in proximity to the intake crib. It might require closing the intake until the contaminant had moved safely to leeward or until dilution to a nonhazardous level had occurred.

Should lake currents carry a contaminant toward the Sandusky intake, hazards would be of similar nature, though perhaps somewhat more critical. The Sandusky intake is closer to the potential source of contamination and it is reasonable to suppose there would be less dilution of wastes at that point than in the vicinity of the Plum Brook intake.

Additional hazards caused by the discharge of radioactive fluids into Lake Erie would involve the safety of bathers at the Sandusky beach and the possible contamination of fish. Sandusky is the center of an important fishing industry which could be adversely affected if fish in the area were contaminated. In this connection it should also be borne in mind that the international boundary between the United States and Canada is in Lake Erie within a few miles of Sandusky.

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D.2. Heck, N. H.: 1947, Earthquake History of the United States (Exclusive of California and Western Nevada) and Alaska: U.S. Dept. of Commerce, Coast and Geodetic Survey, Serial No. 609, Revised Edition, p. 1, Continental United States.

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D.4. Stauffer, C. R.: 1909, The Middle Devonian of Ohio: Geol. Surv. of Ohio, 4th Ser., Bull. 10.

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D.6. Stout, Wilber, Ver Steeg, Karl, and Lamb, G. F.: 1943, Geology of Water in Ohio: Geol. Surv. of Ohio, 4th ser., Bull. 44.

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FINAL HAZARDS SUMMARY
NASA PLUM BROOK REACTOR FACILITY
PART III

by

Lewis Research Center Staff
Cleveland, Ohio

December, 1959

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

CA-1 back

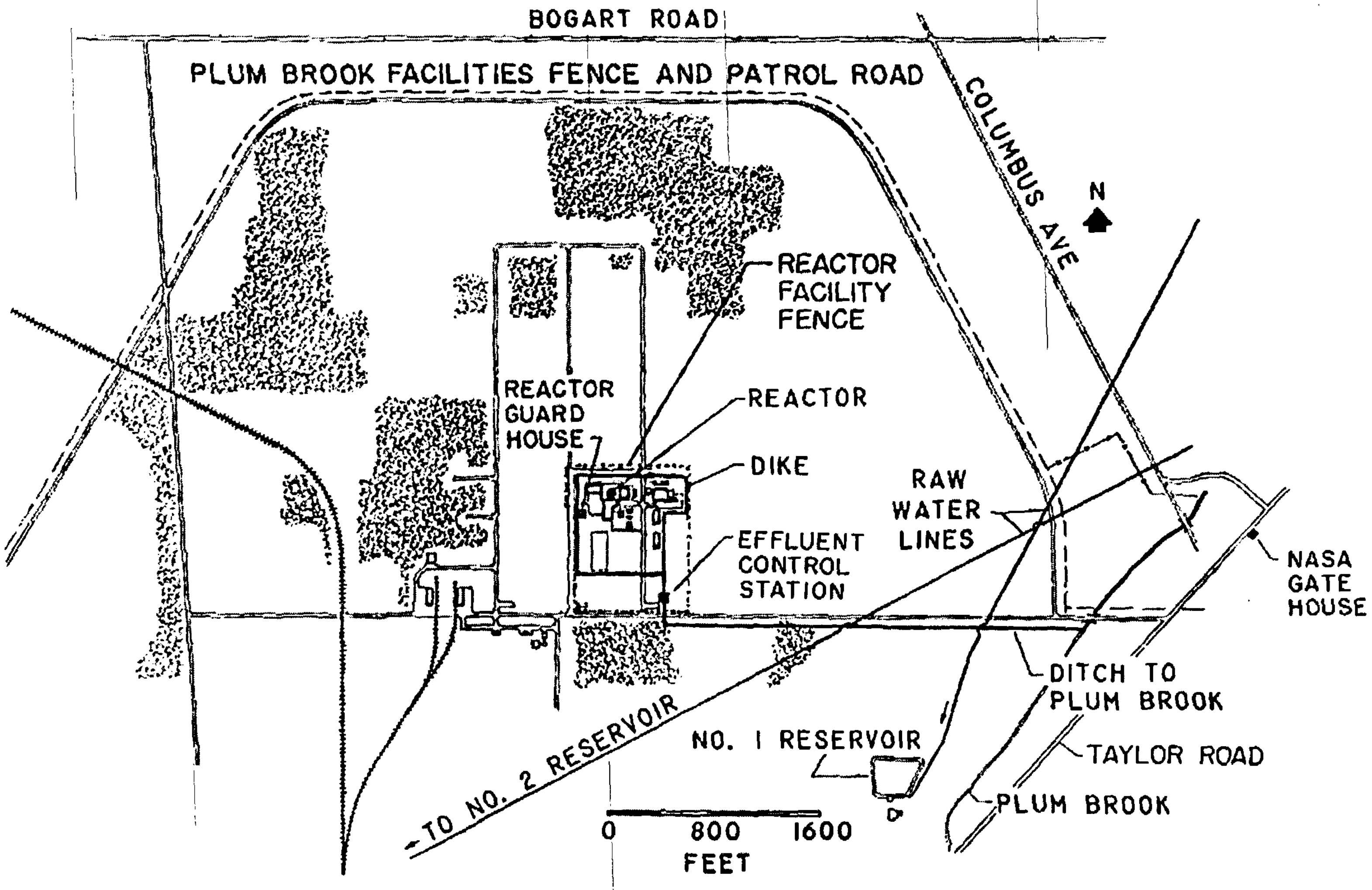

Figure 2.3 - Reactor facility on NASA site.

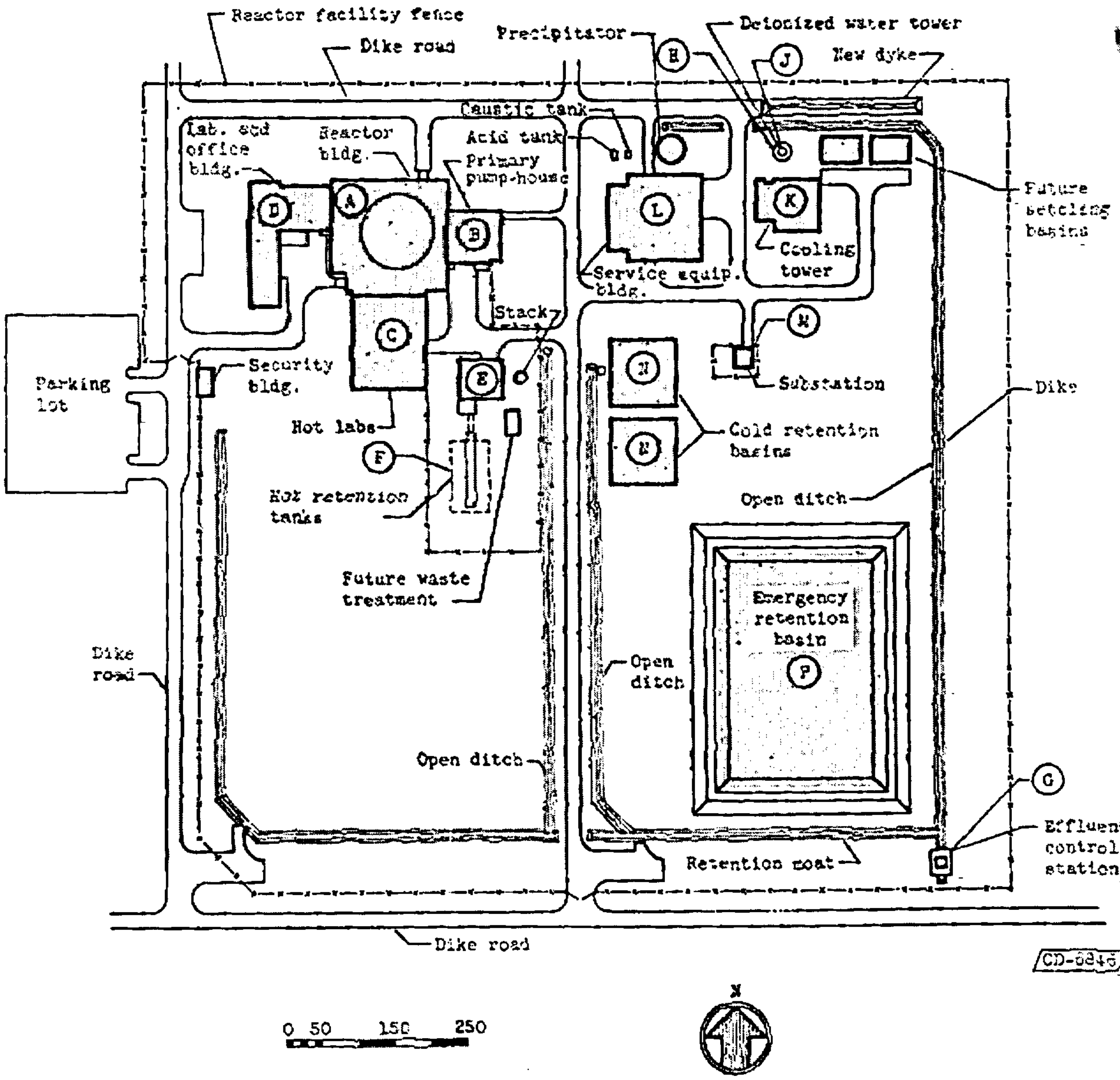

Figure 2.4. - Plot plan of reactor facility.

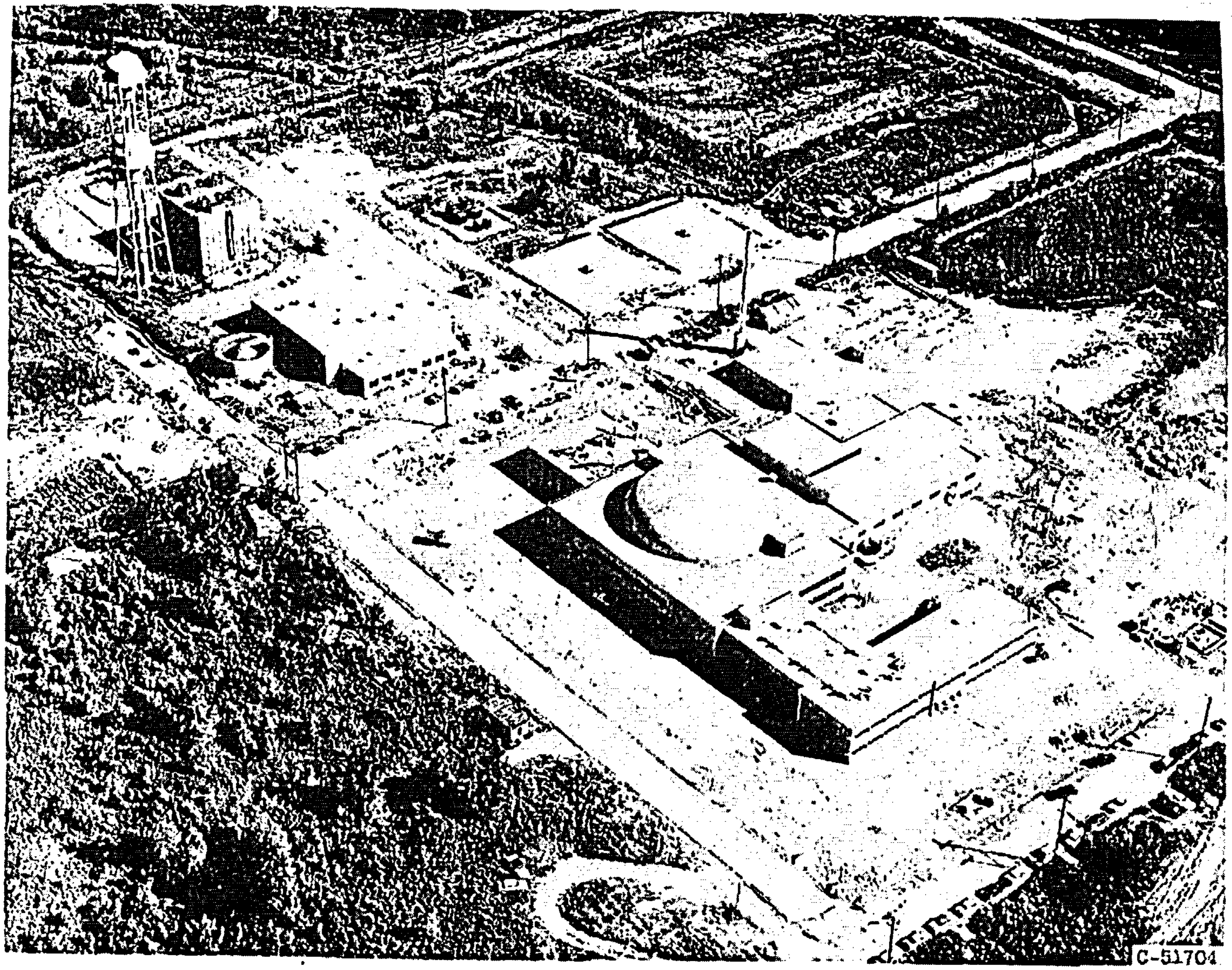

Figure 2.5. - NASA reactor facility.

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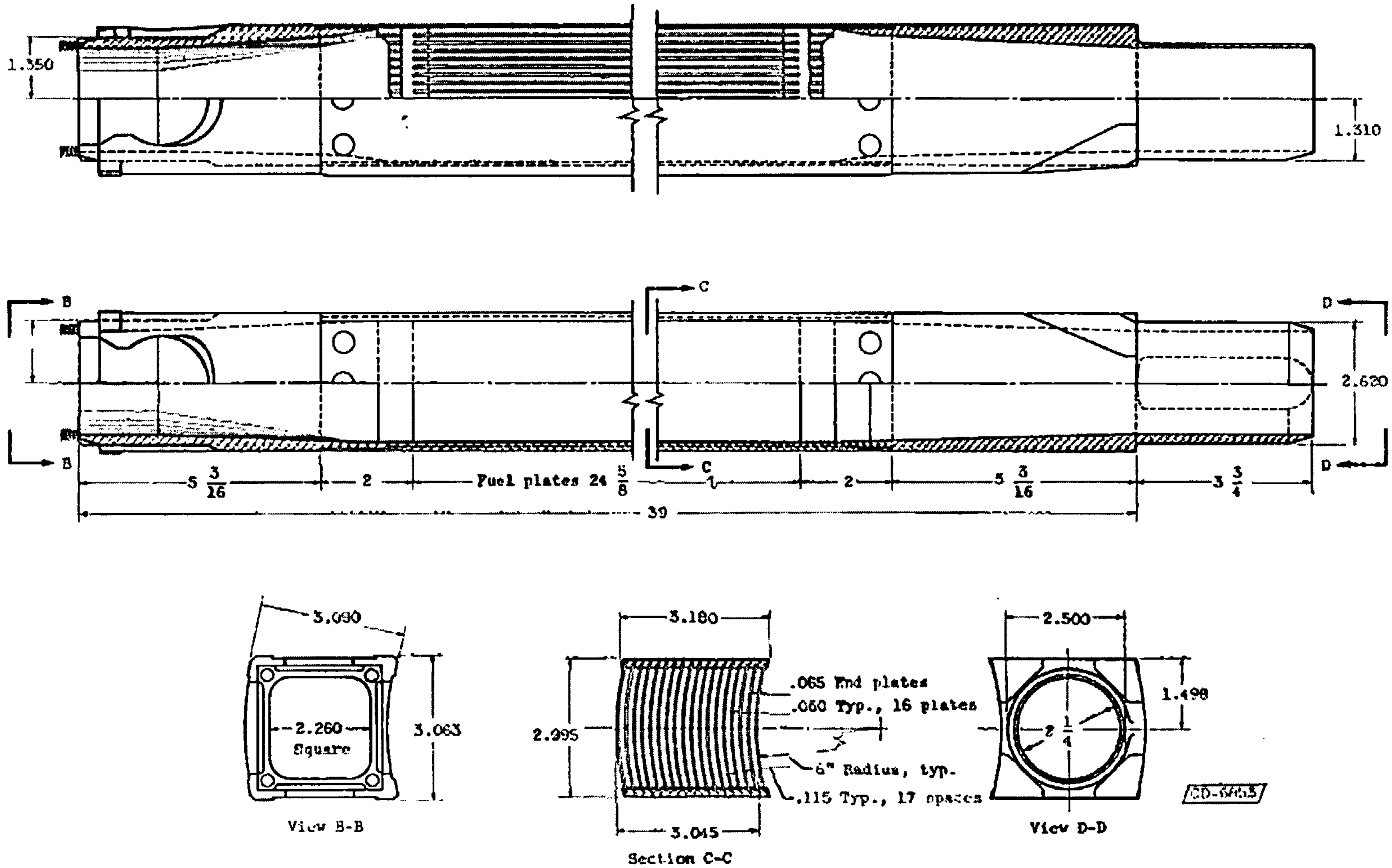
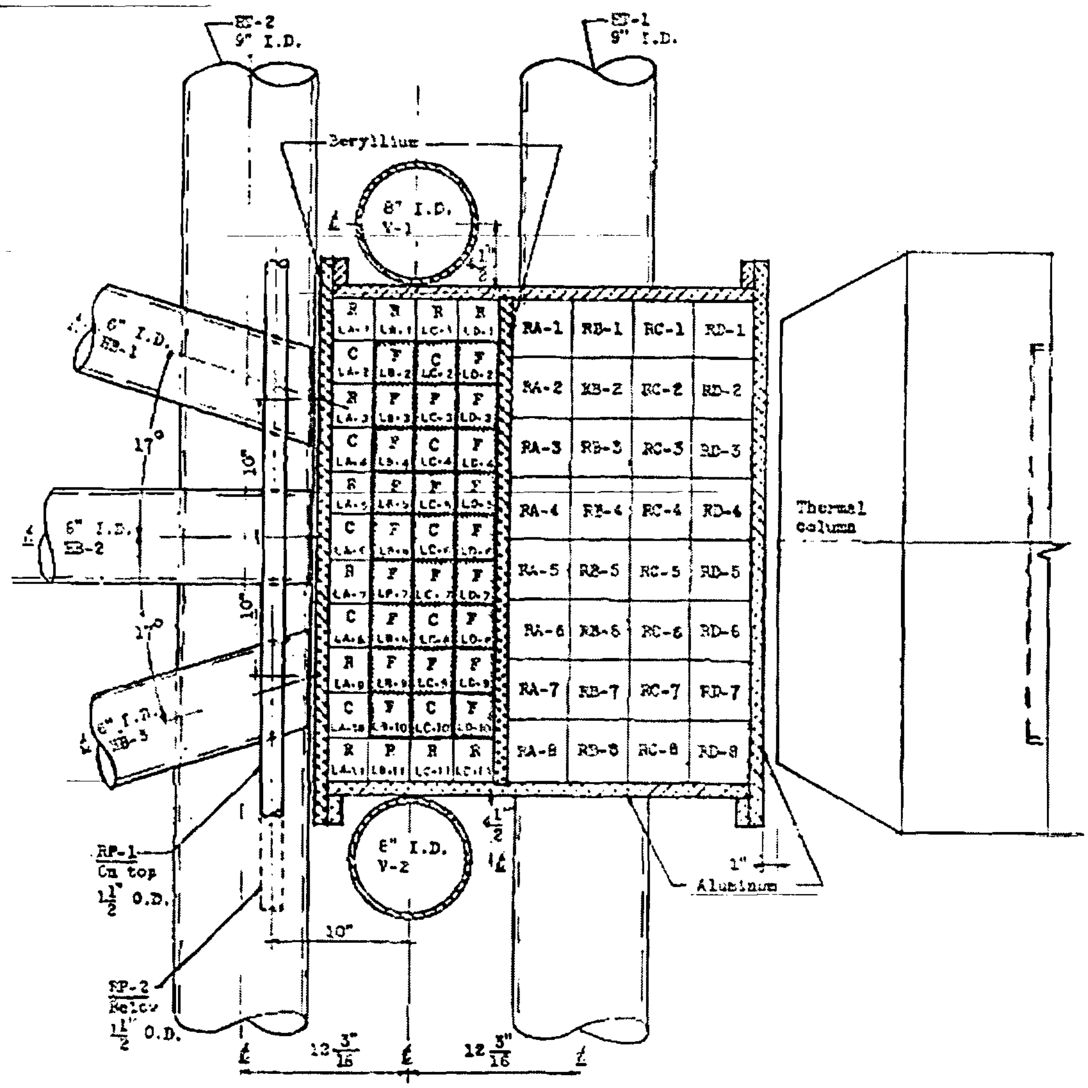


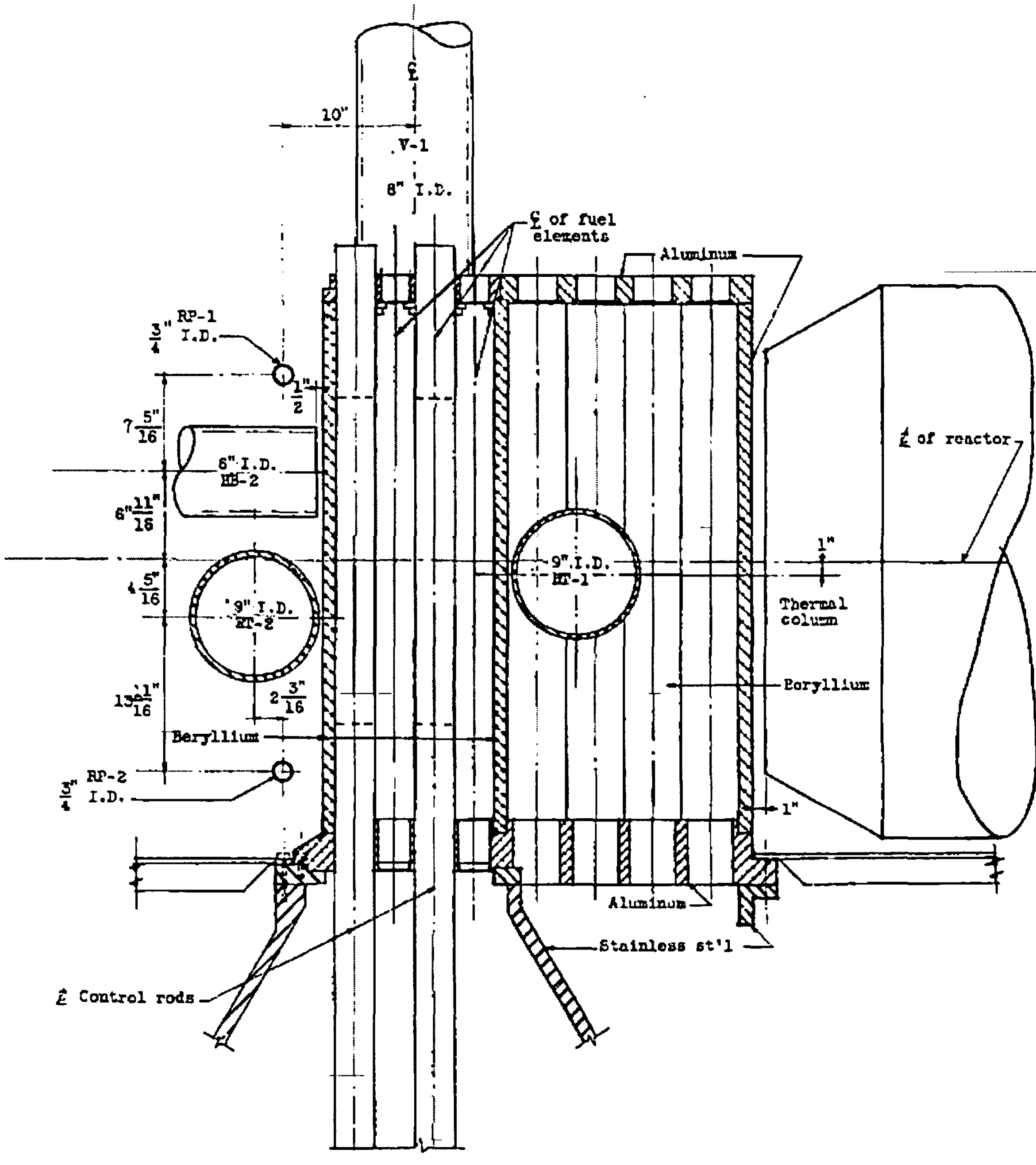
Figure 2.6. - Fuel element. (All dimensions in inches.)



(a) Horizontal section

Figure 2.7. - Reactor core.

8



(b) Vertical section

Figure 2.7. - Continued. Reactor core.

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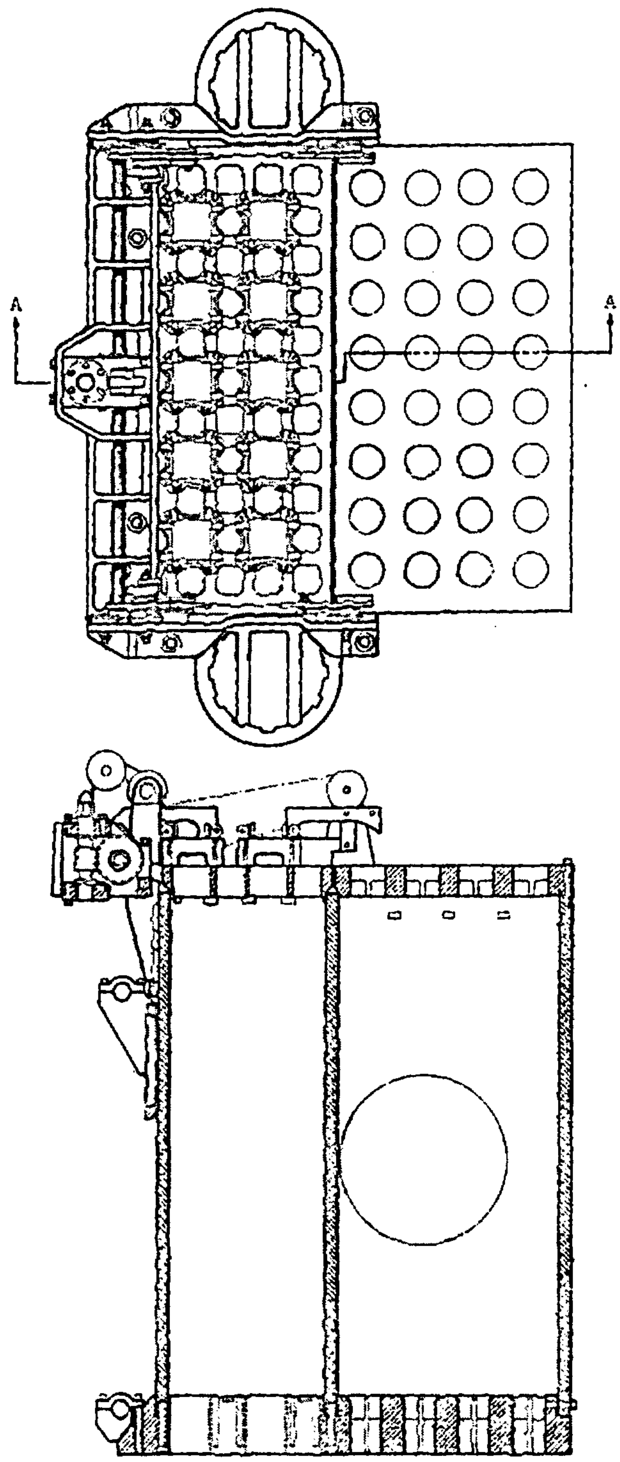
CA-2



Section A-A

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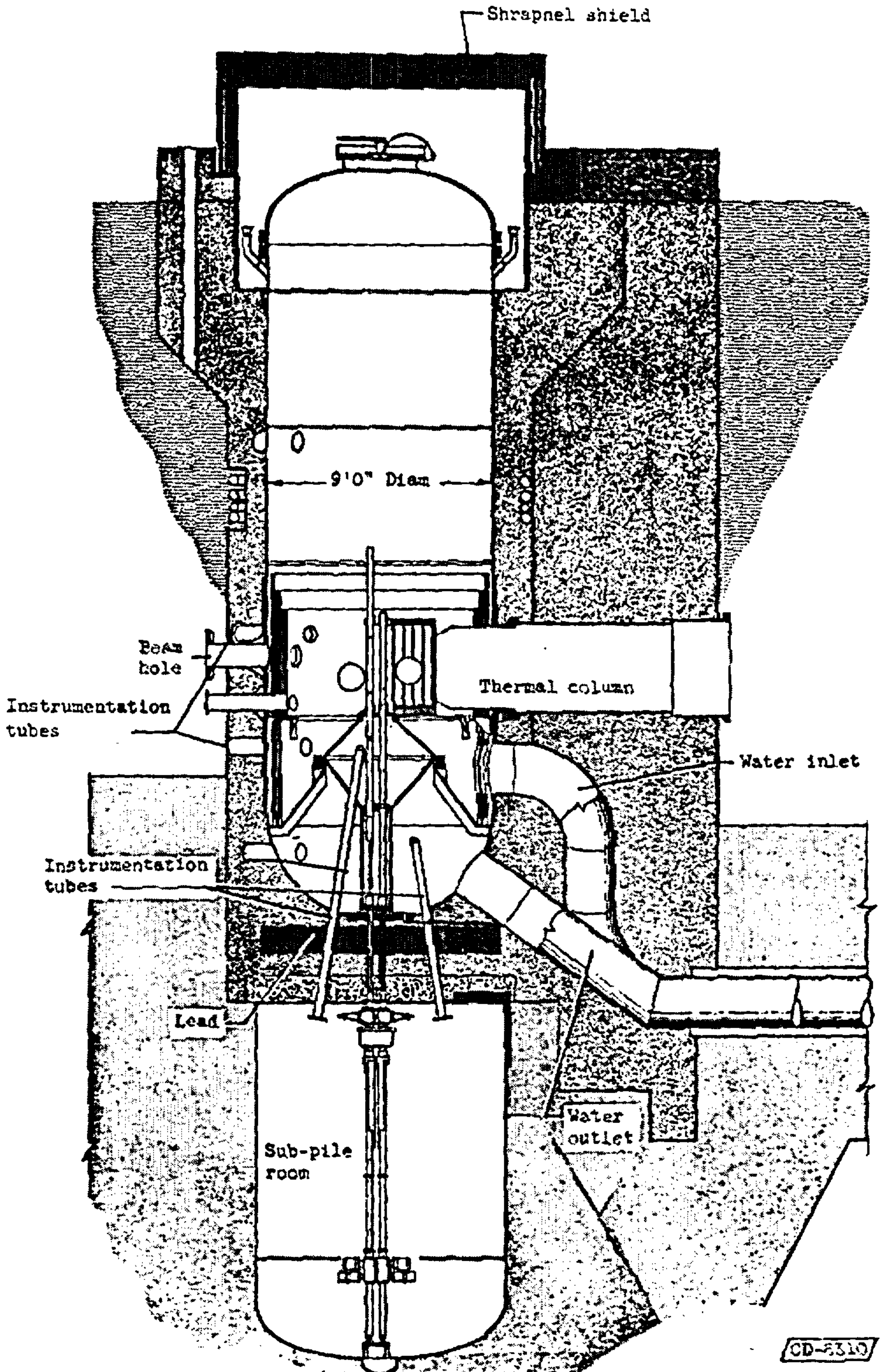
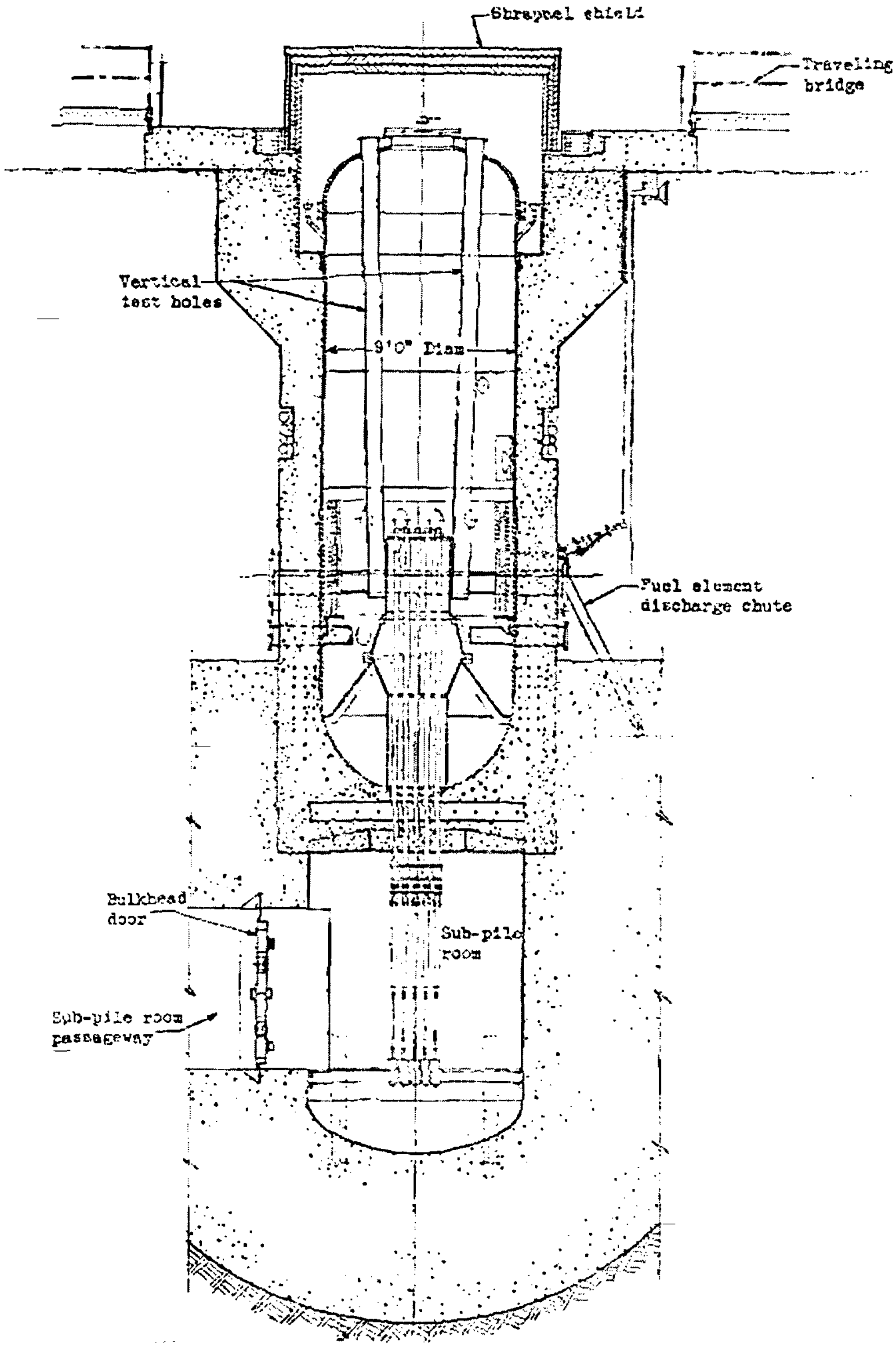
(c) Core box.

Figure 2.7. - Concluded. Reactor core.



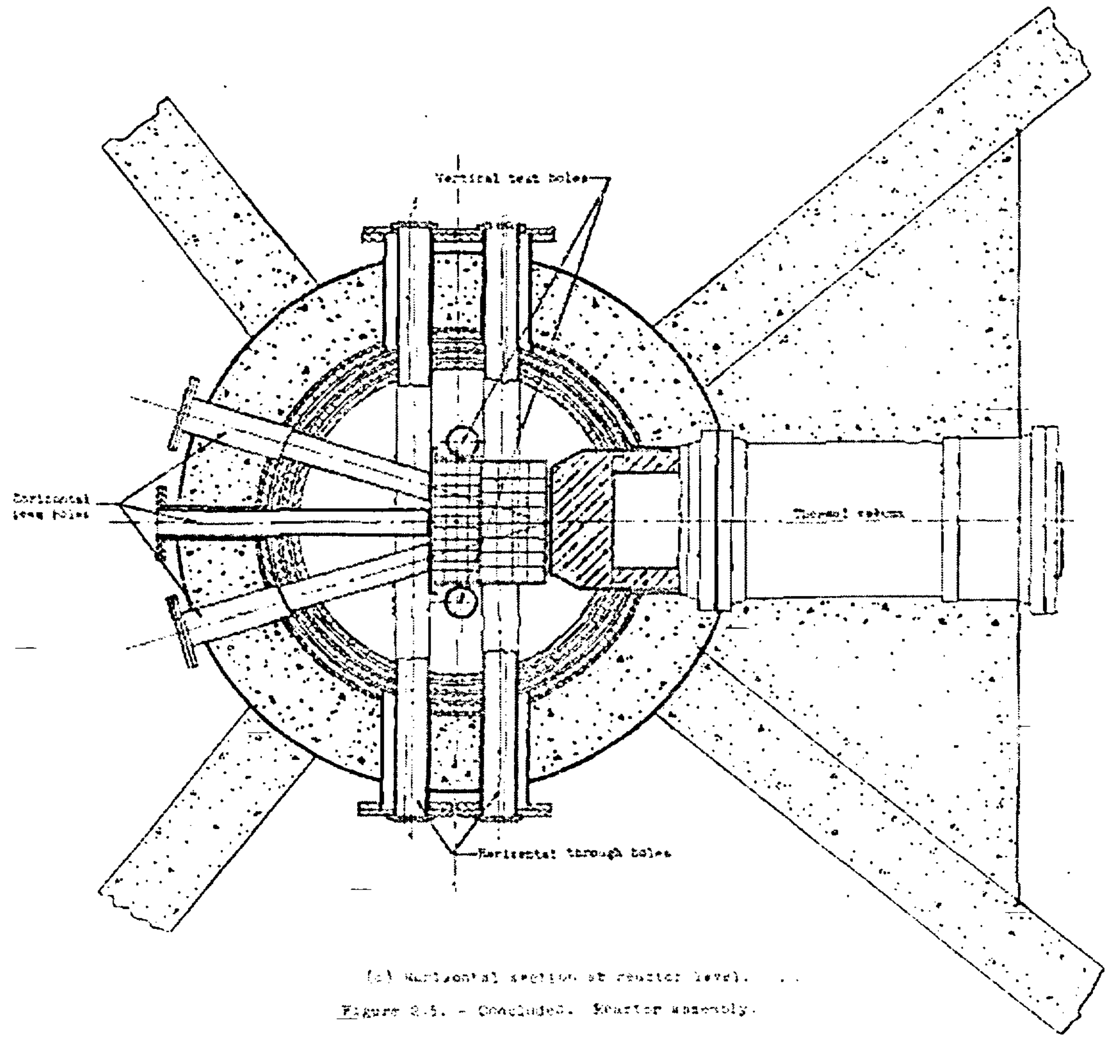
(a) Vertical section perpendicular to wide face of reactor.

Figure 2.8. - Reactor assembly.



(b) Vertical section perpendicular to narrow face of reactor.

Figure 2.6. - Continued. Reactor assembly.



(c) Horizontal section at reactor level.

Figure 2.5. - Concluded. Reactor assembly.

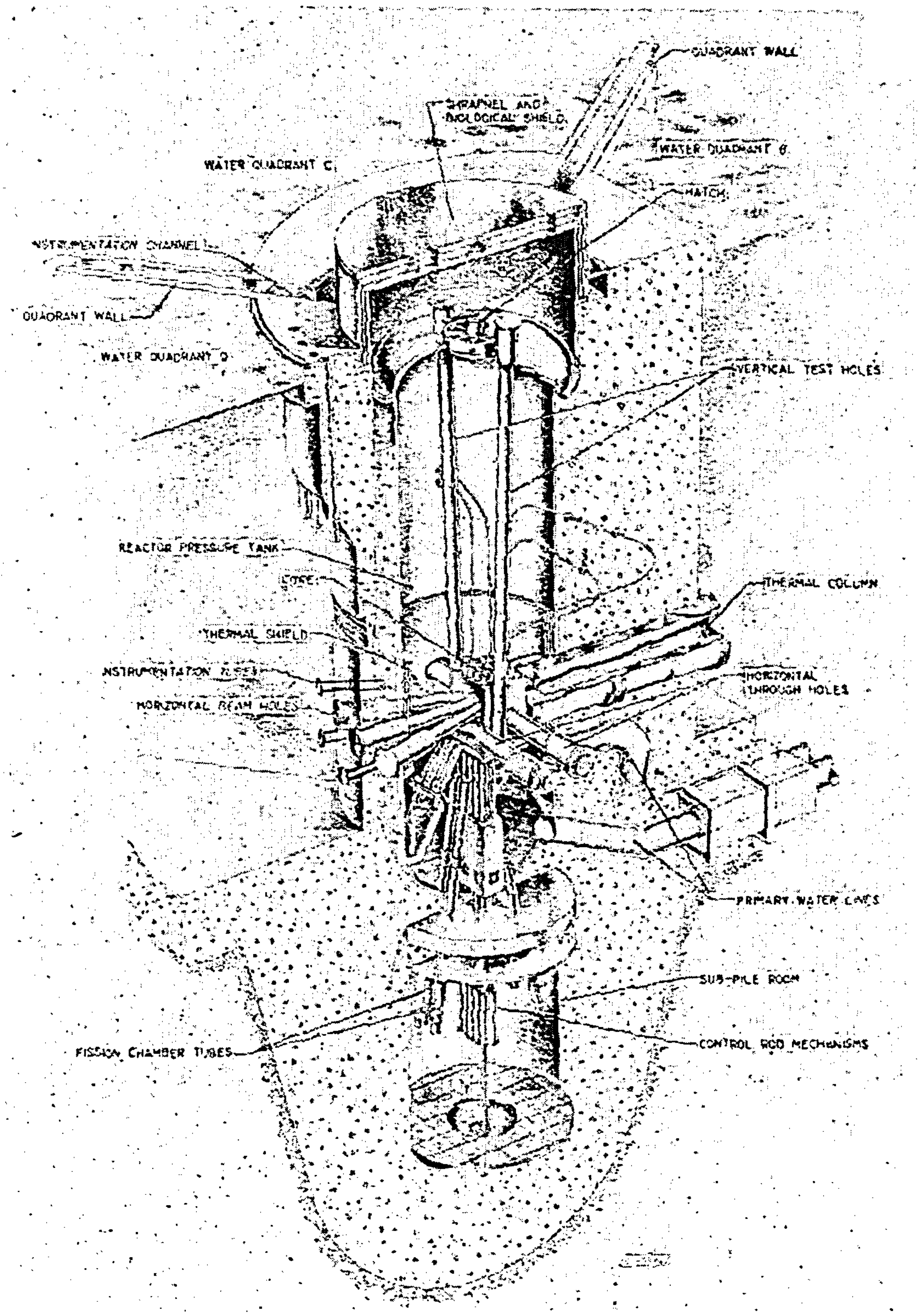


Figure 2.9. - Cutaway perspective drawing of reactor tank assembly.

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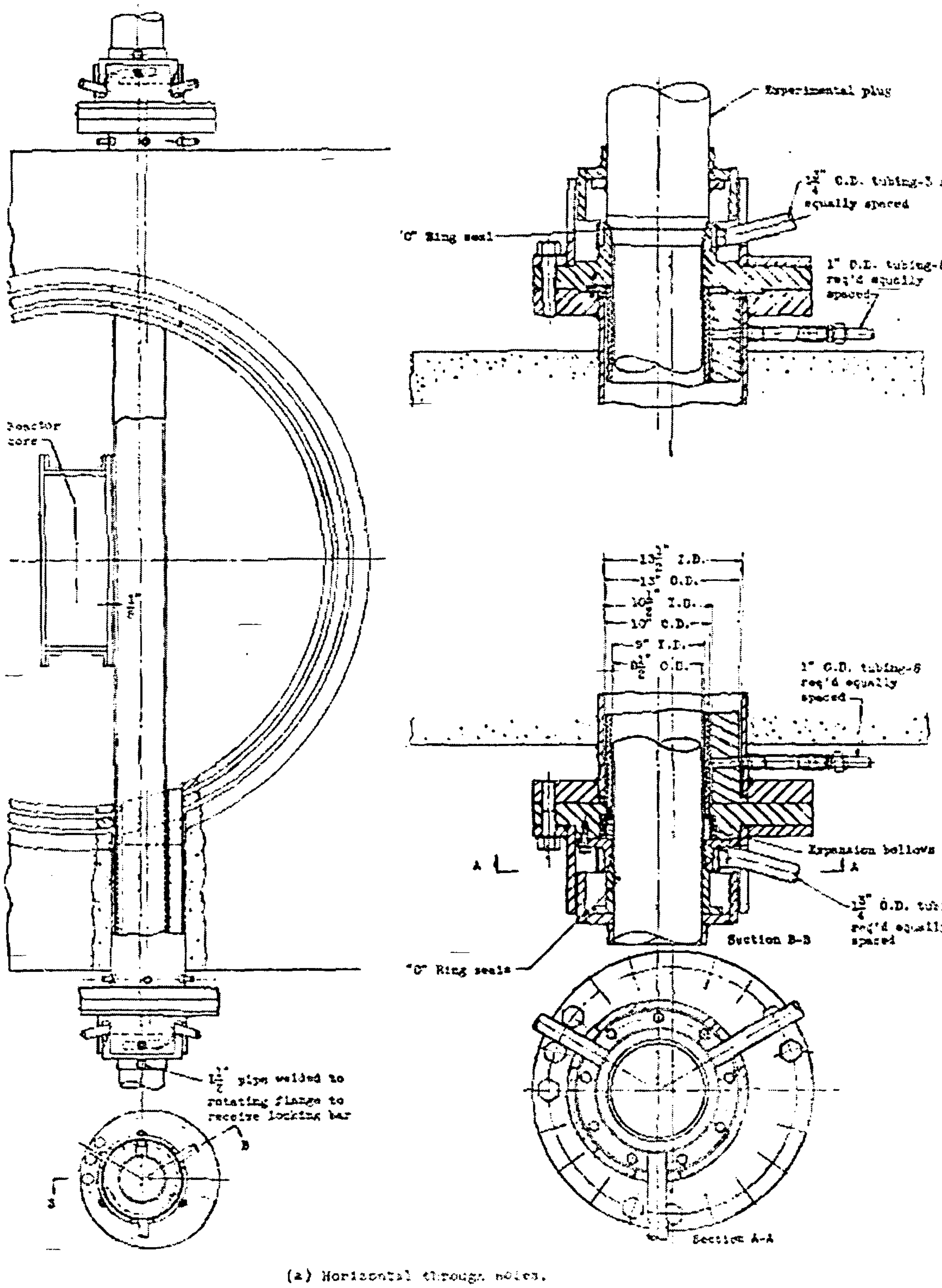
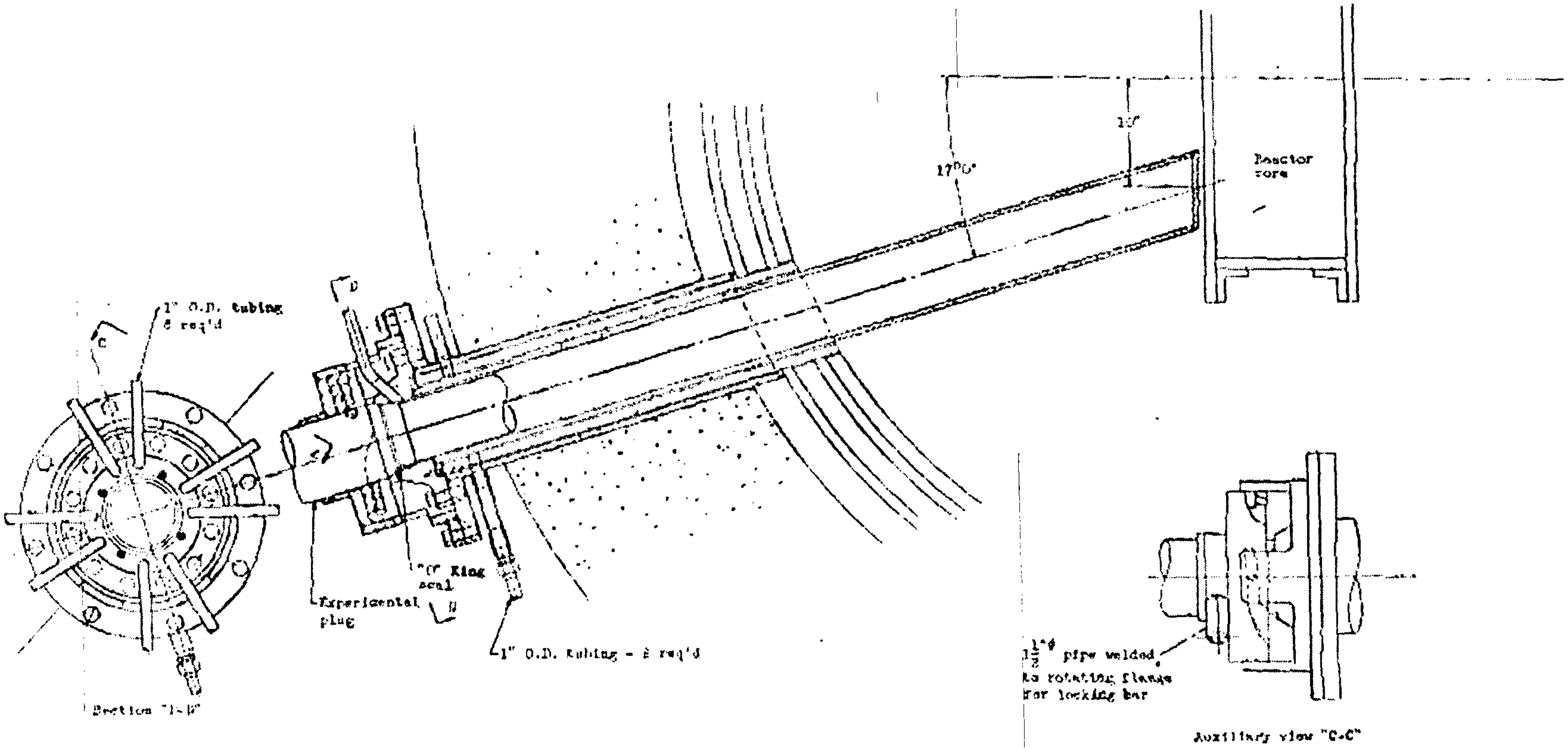


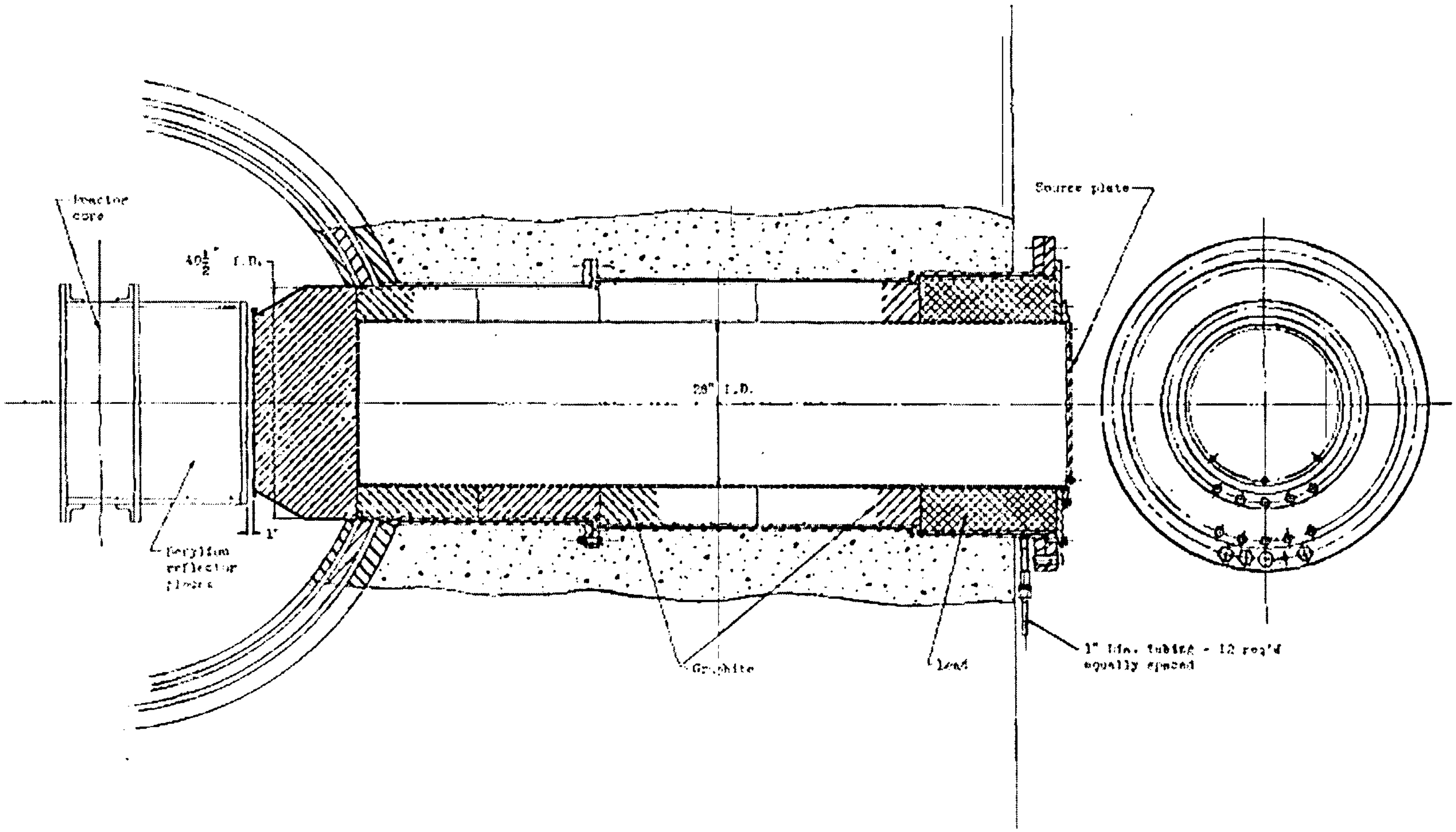
(a) Horizontal through holes.

Figure 2.10. - Details of experimental test holes.



(b) Horizontal beam holes.

Figure 2.10. - Continued. Details of experimental test holes.



(c) Thermal column.

Figure 2.10. Concluded. Details of experimental test holes.

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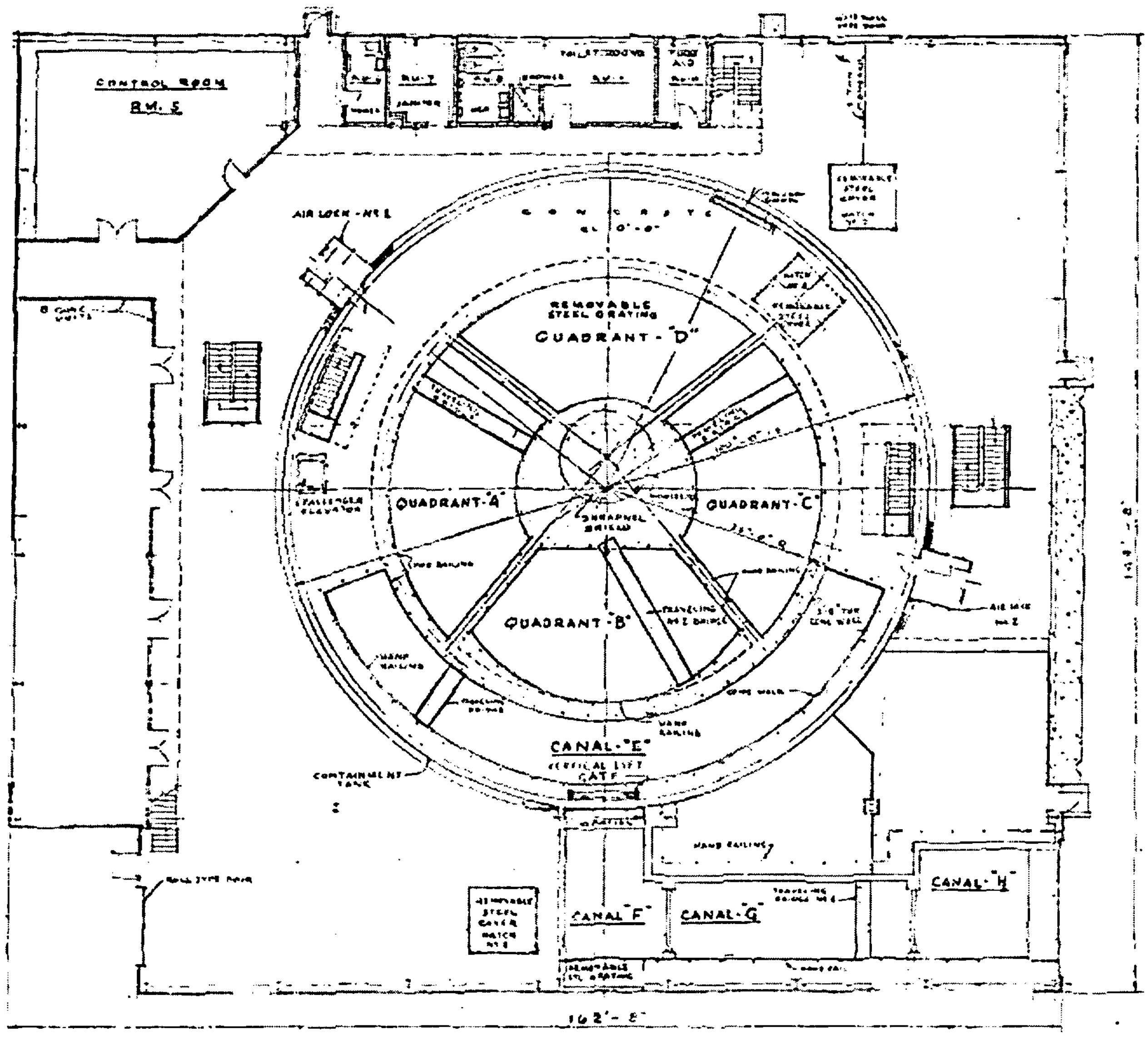
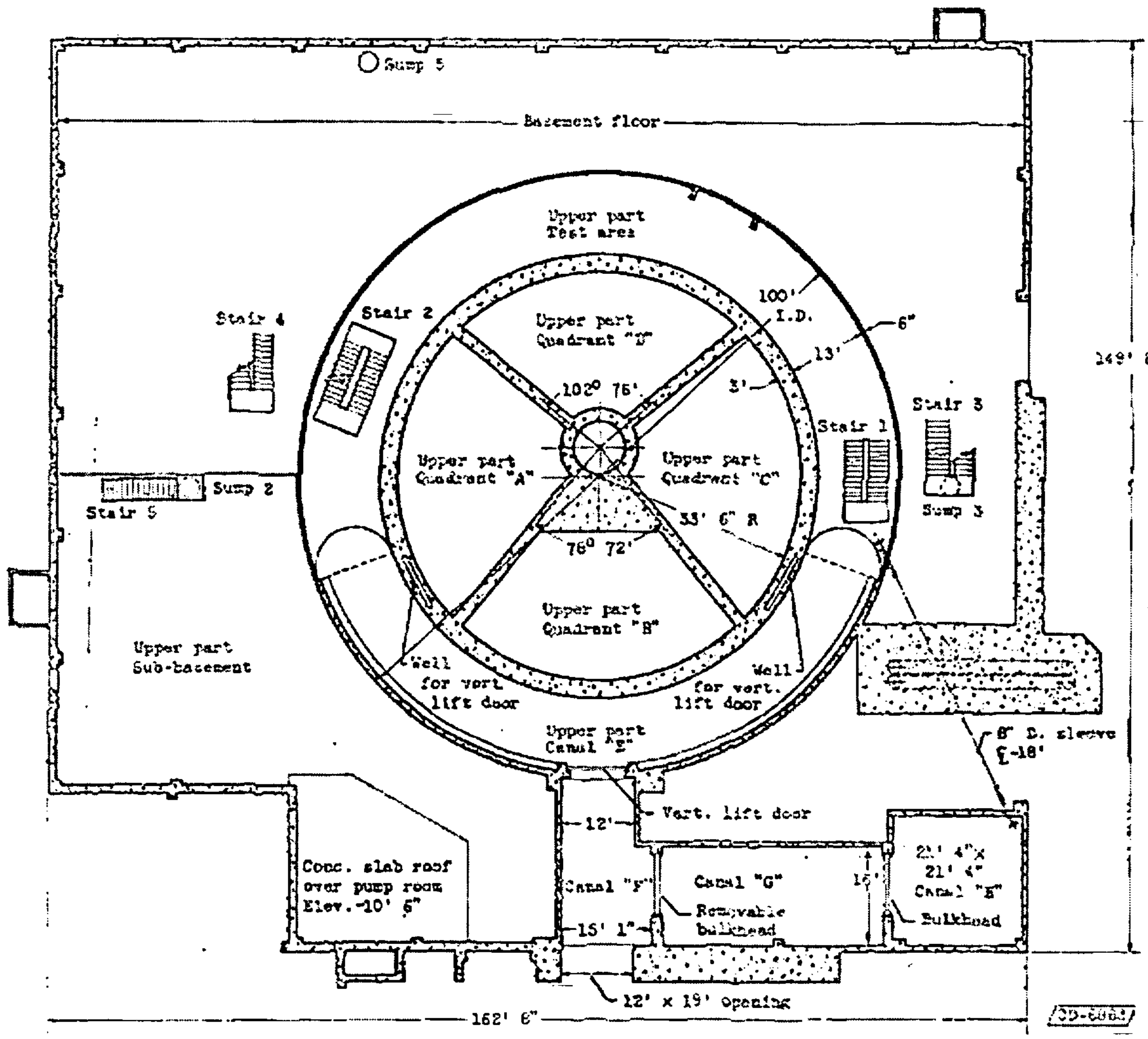
CA-3



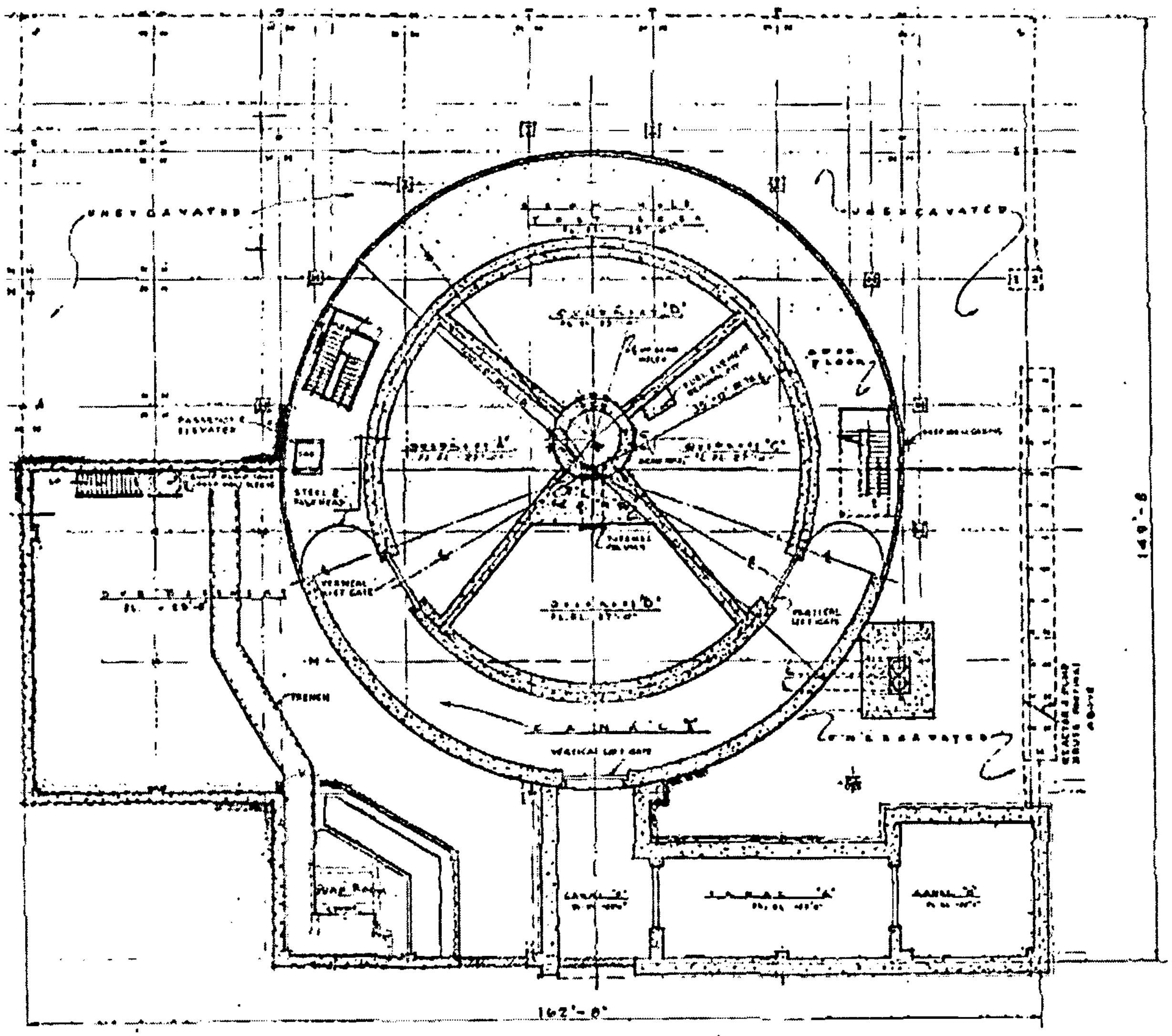
(a) First floor plan.

Figure 2.11. - Horizontal section of the reactor building.



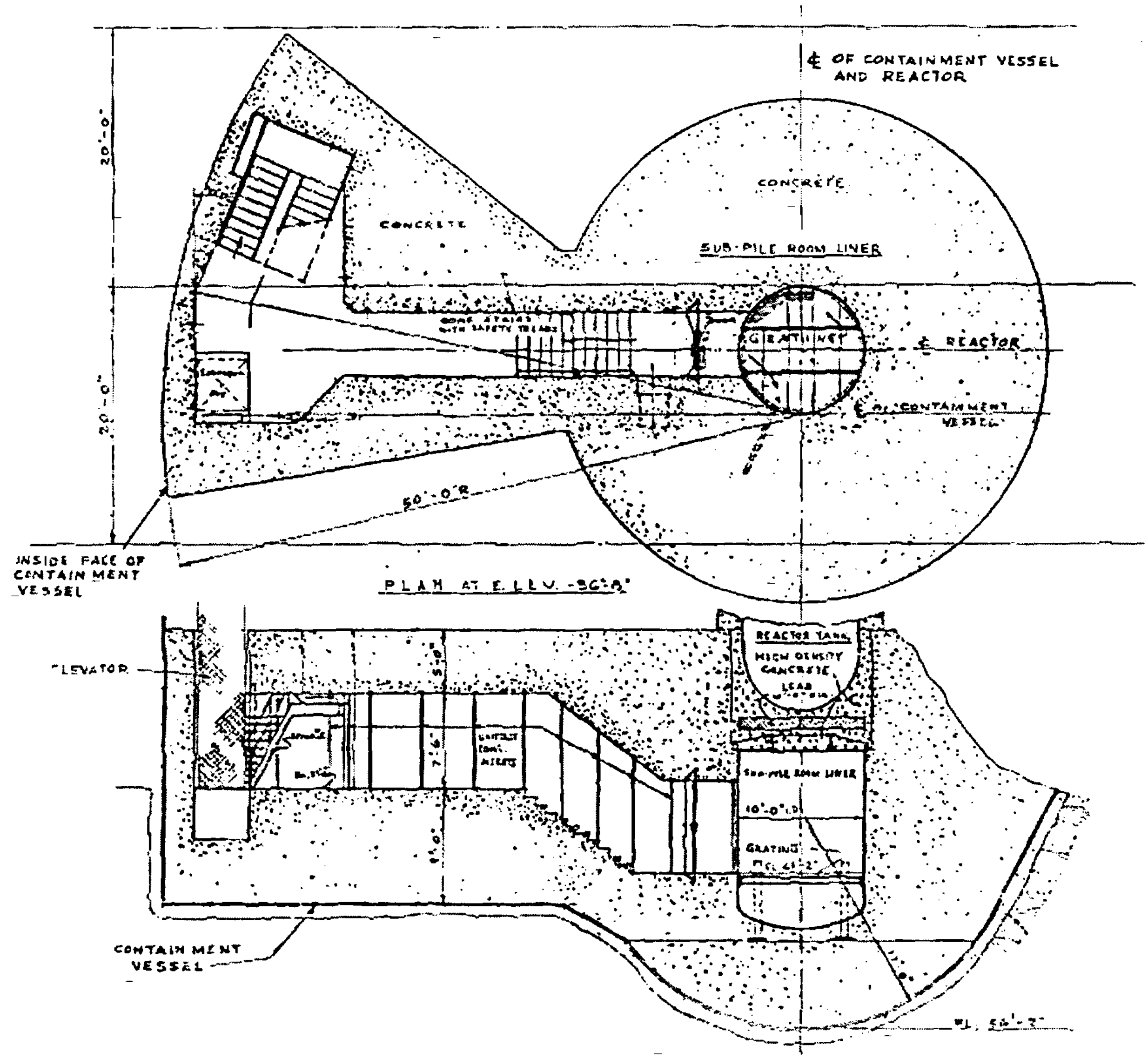
(b) Basement plan (-15 ft. elevation).

Figure 2.11. - Continued. Horizontal section of the reactor building.



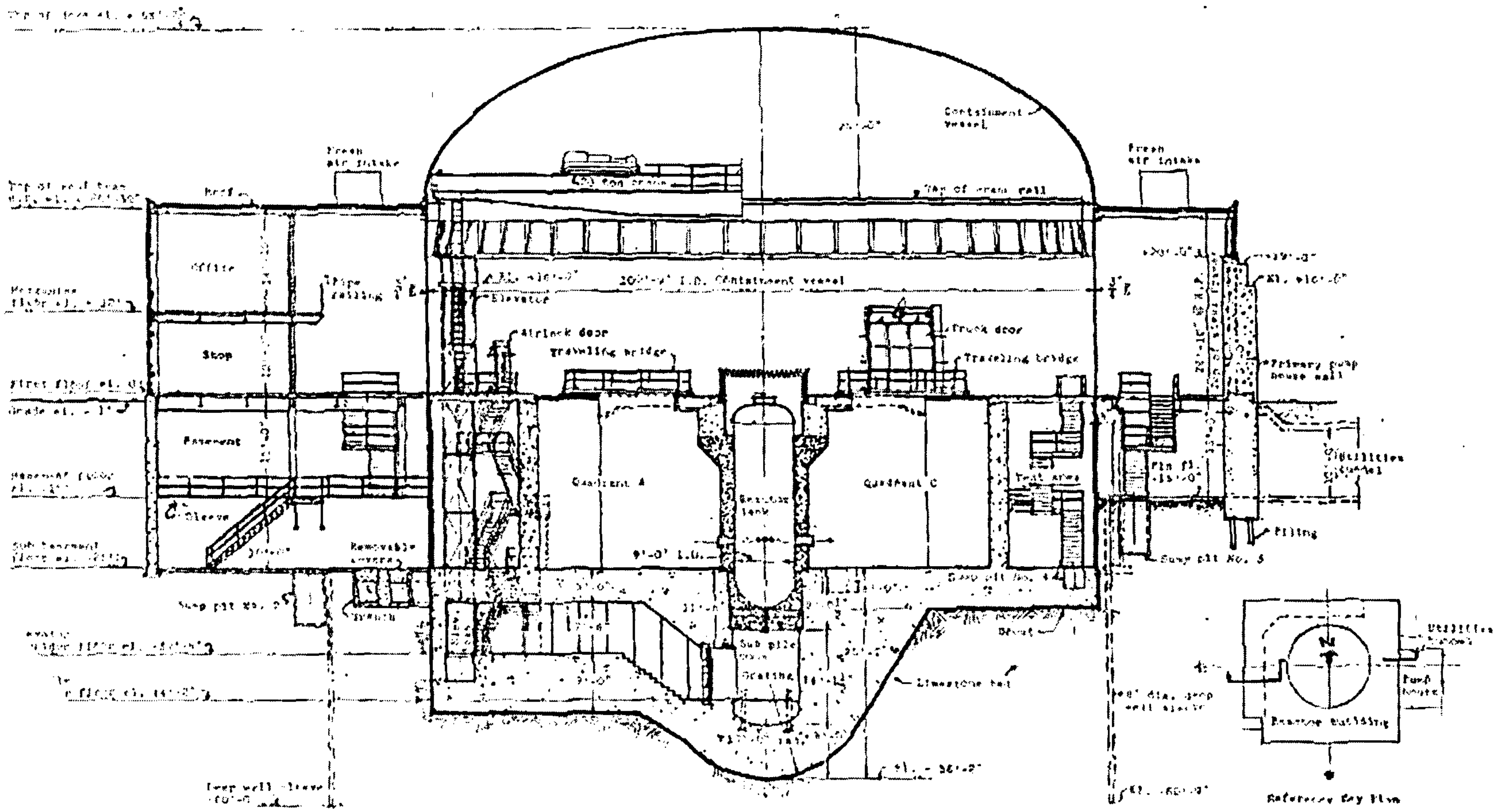
(c) Basement plan (-25 ft elevation).

Figure 2.11.- Continued. Horizontal section of the reactor building.



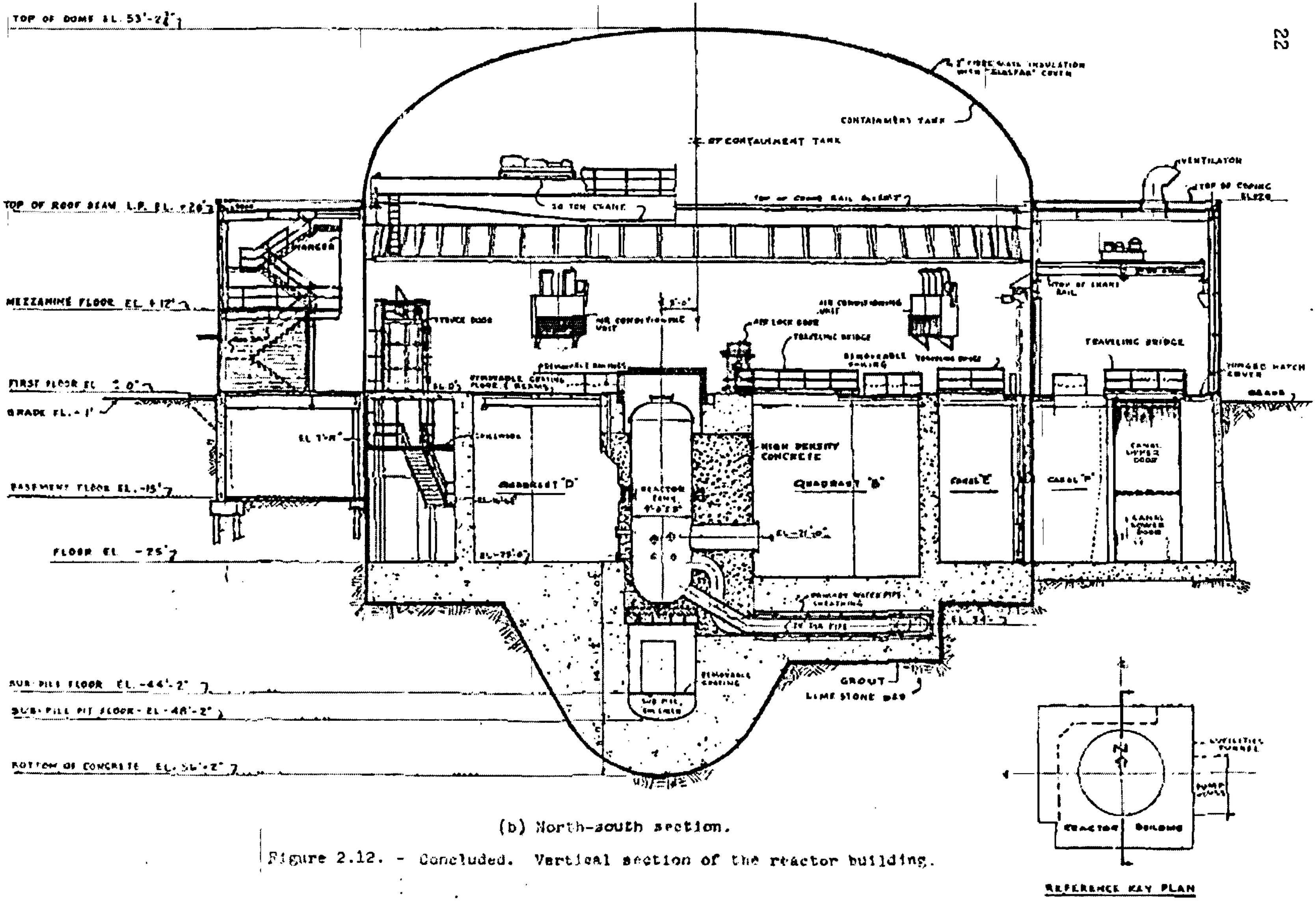
(d) Sub-pile room plan and section.

Figure 2.11. - Concluded. Horizontal section of the reactor building.



(a) East-west section.

Figure 2.12. - Vertical section of the reactor building



(b) North-south section.

Figure 2.12. - Concluded. Vertical section of the reactor building.

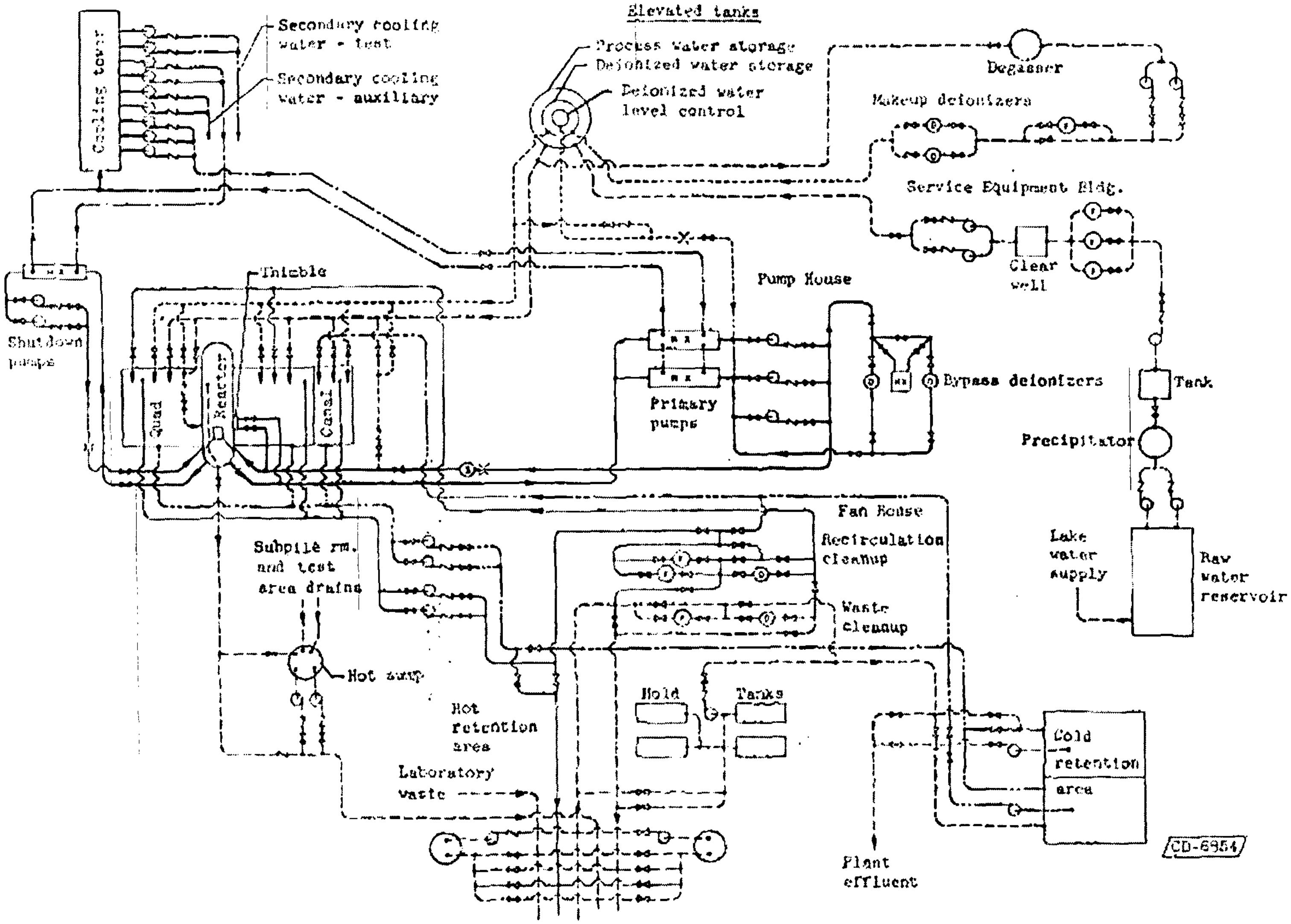


Figure 2.13. - Schematic drawing of water systems.

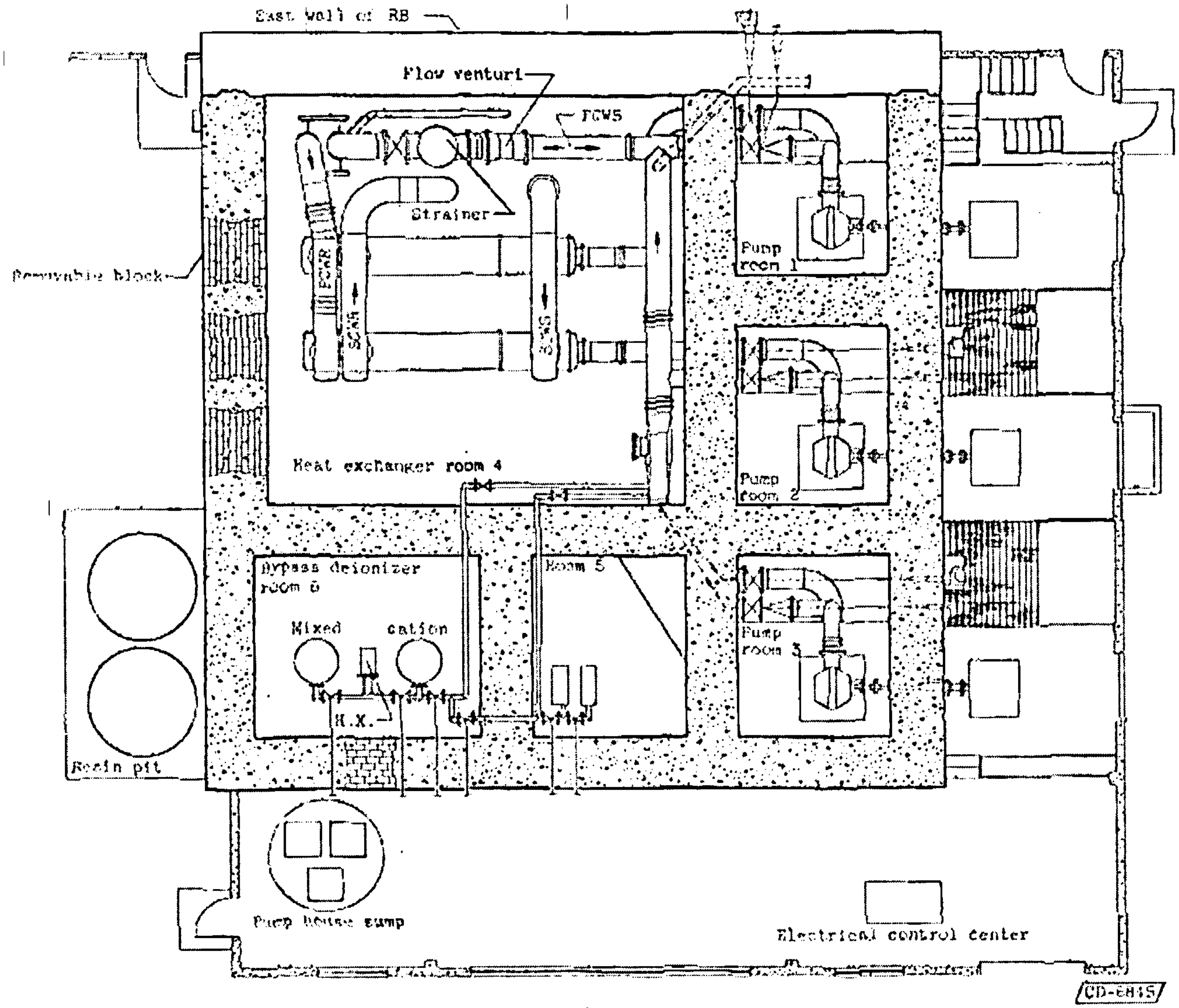


Figure 2.14. - Primary water Pump House.

E-678

CA-4

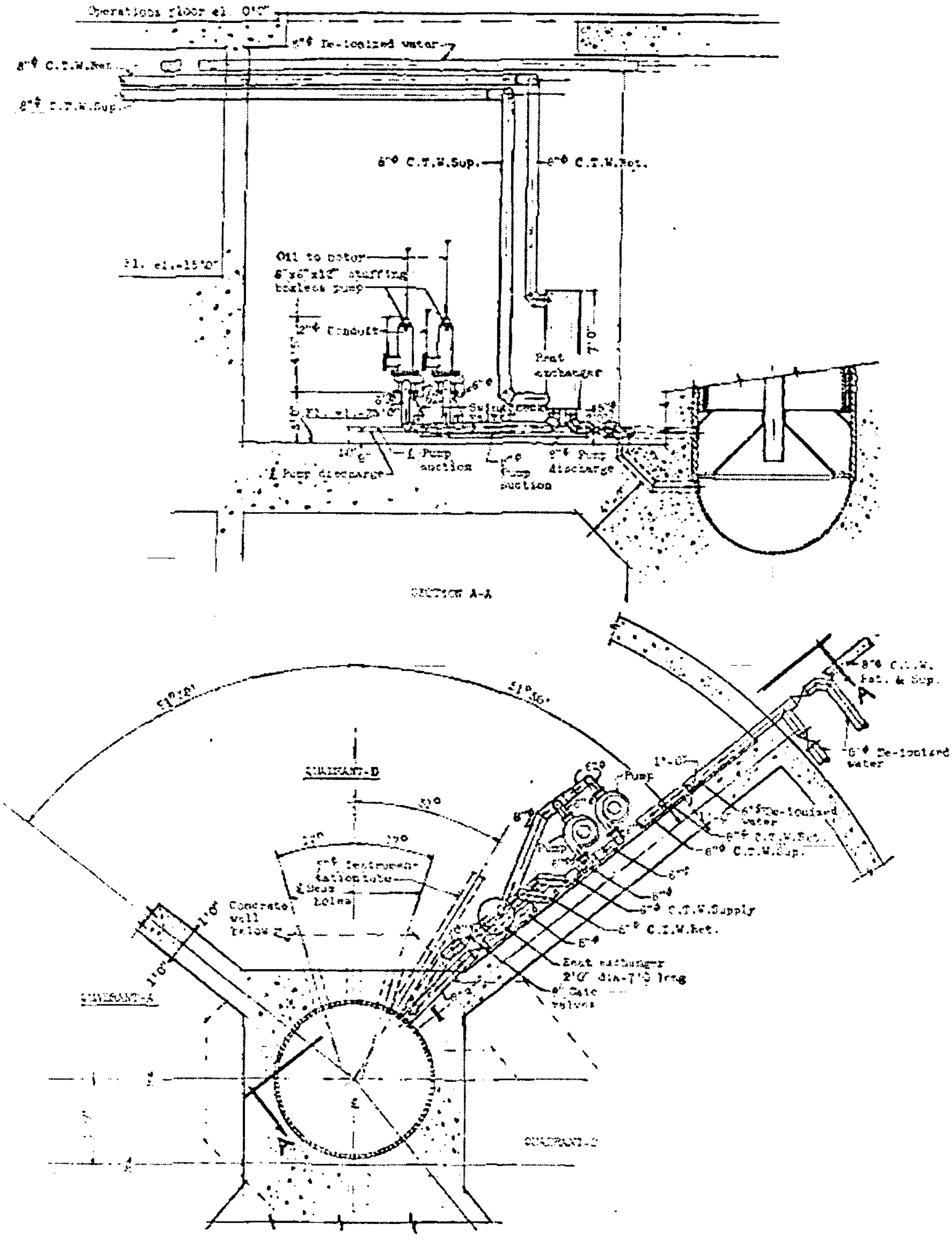


Figure 3.15. - Shut-down cooling system.

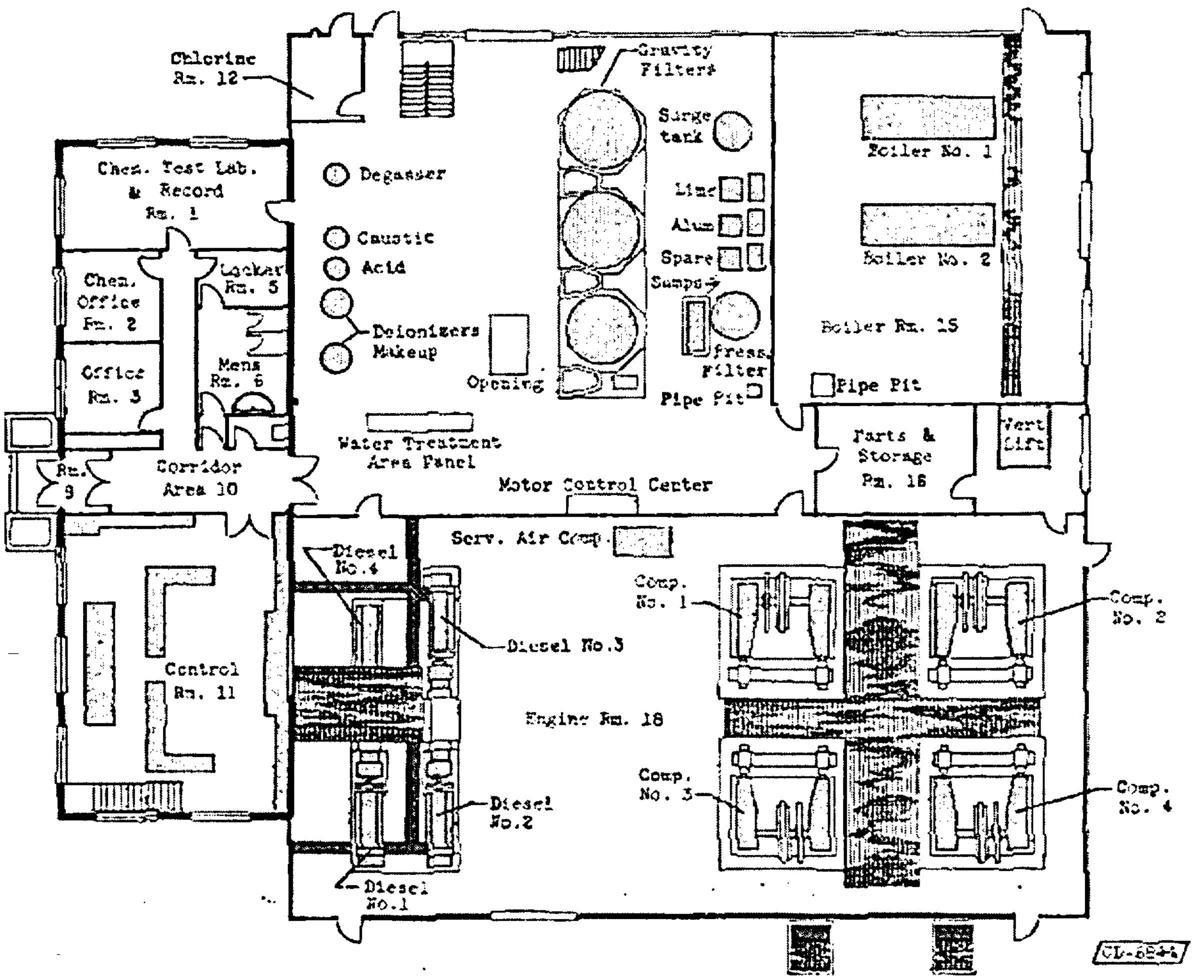
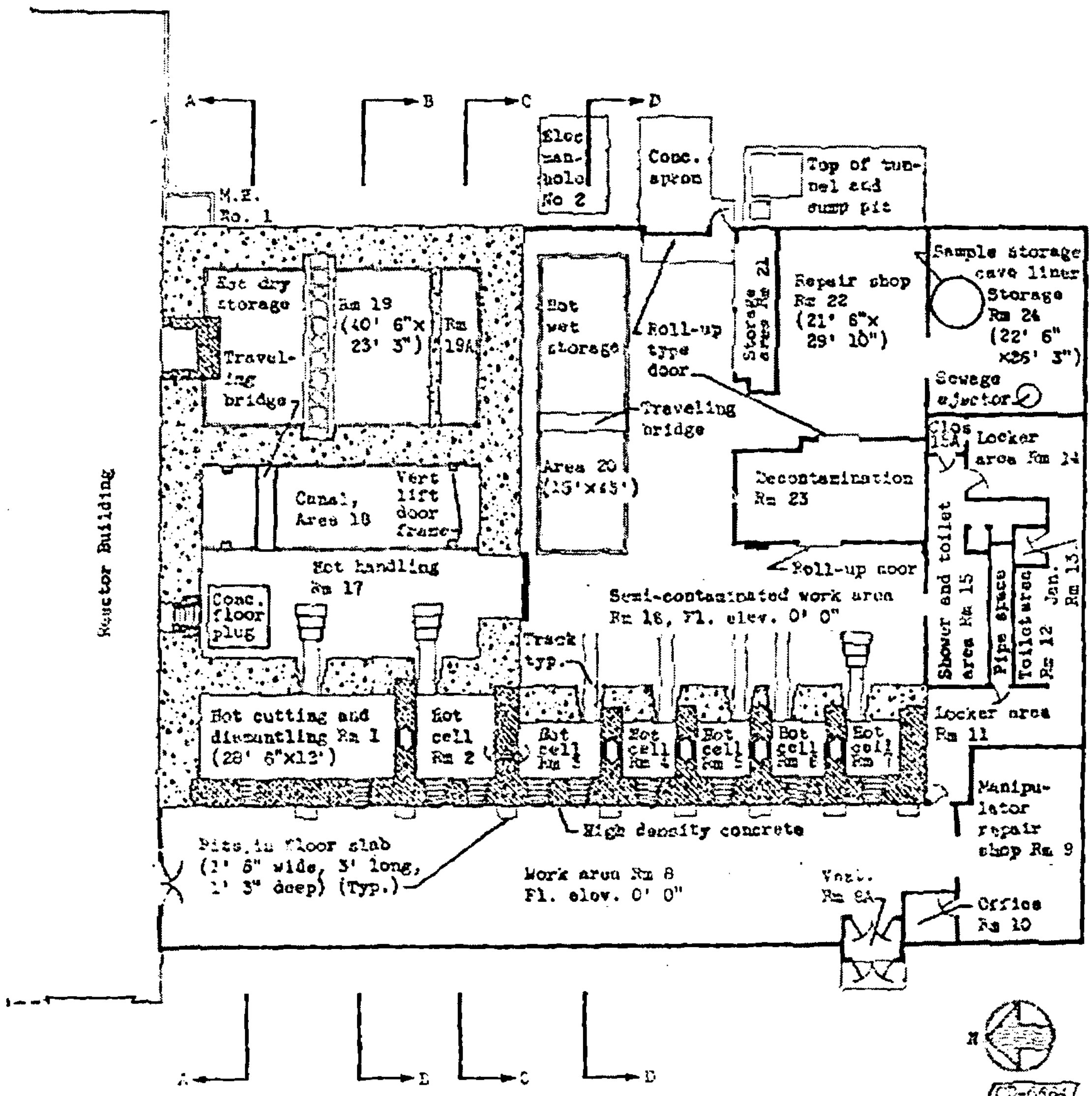
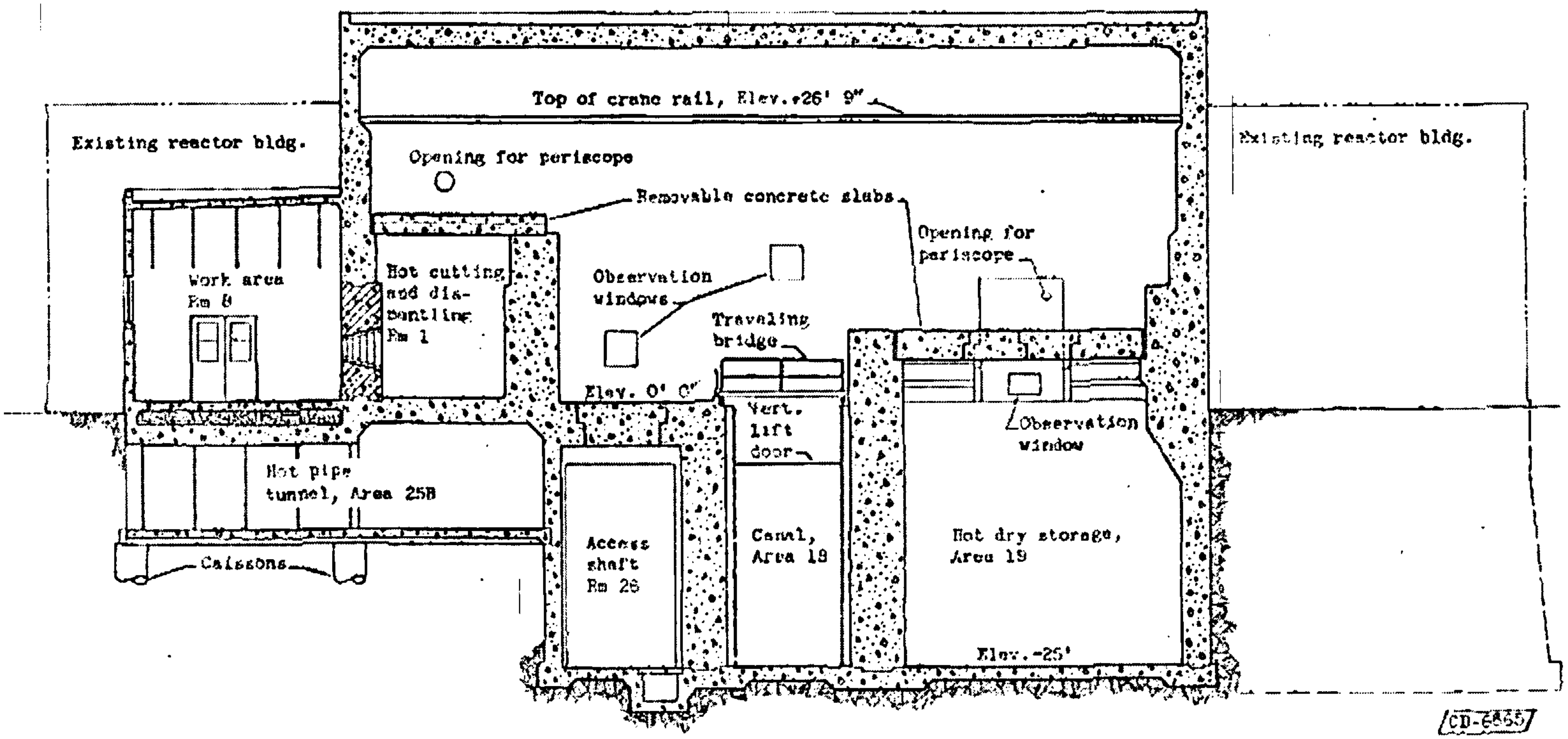


Figure 2.16. - Service Equipment Building.



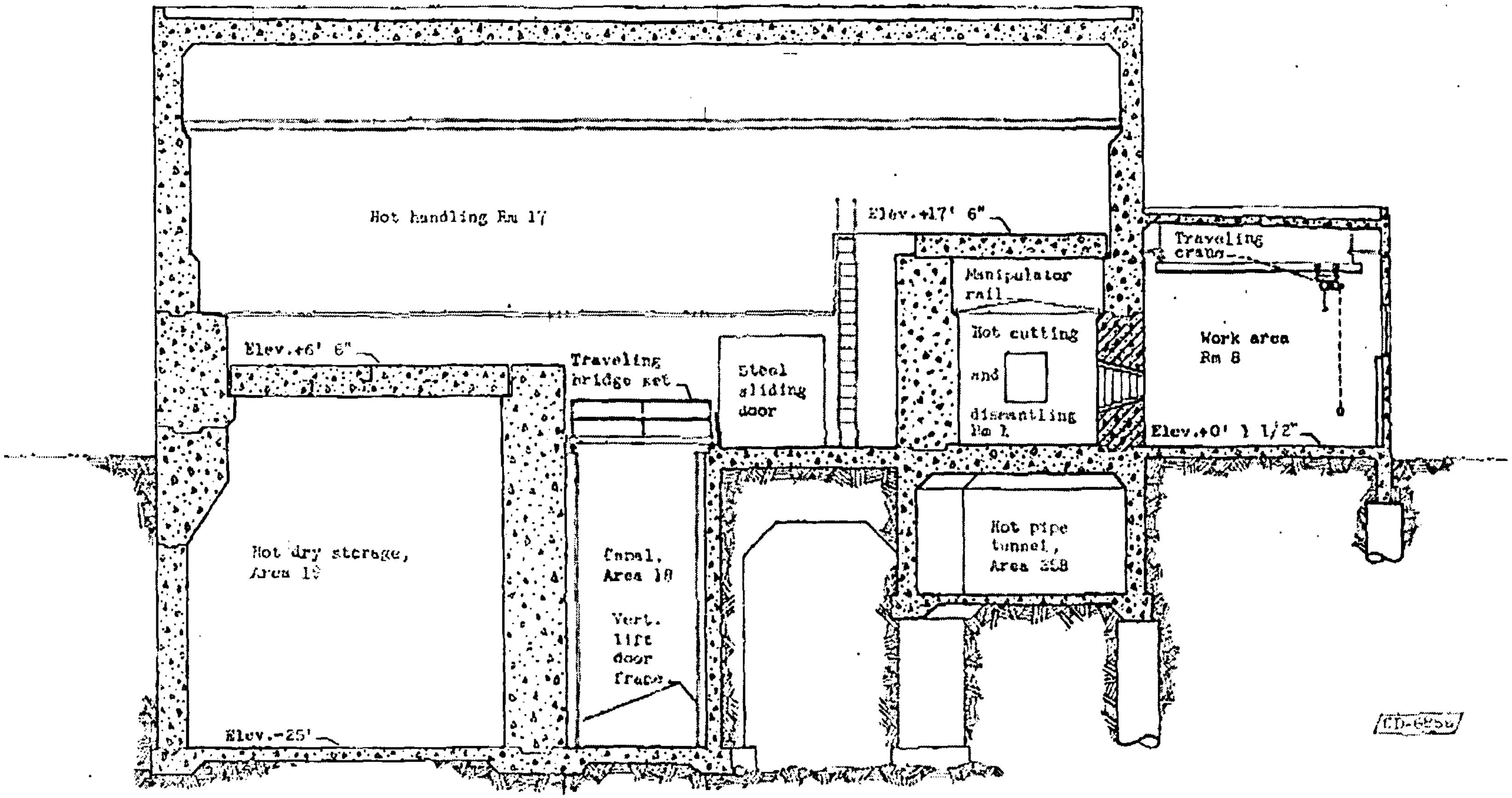
(a) Ground floor plan (elevation + 4'6").

Figure 2.17. - Hot Laboratory Building.



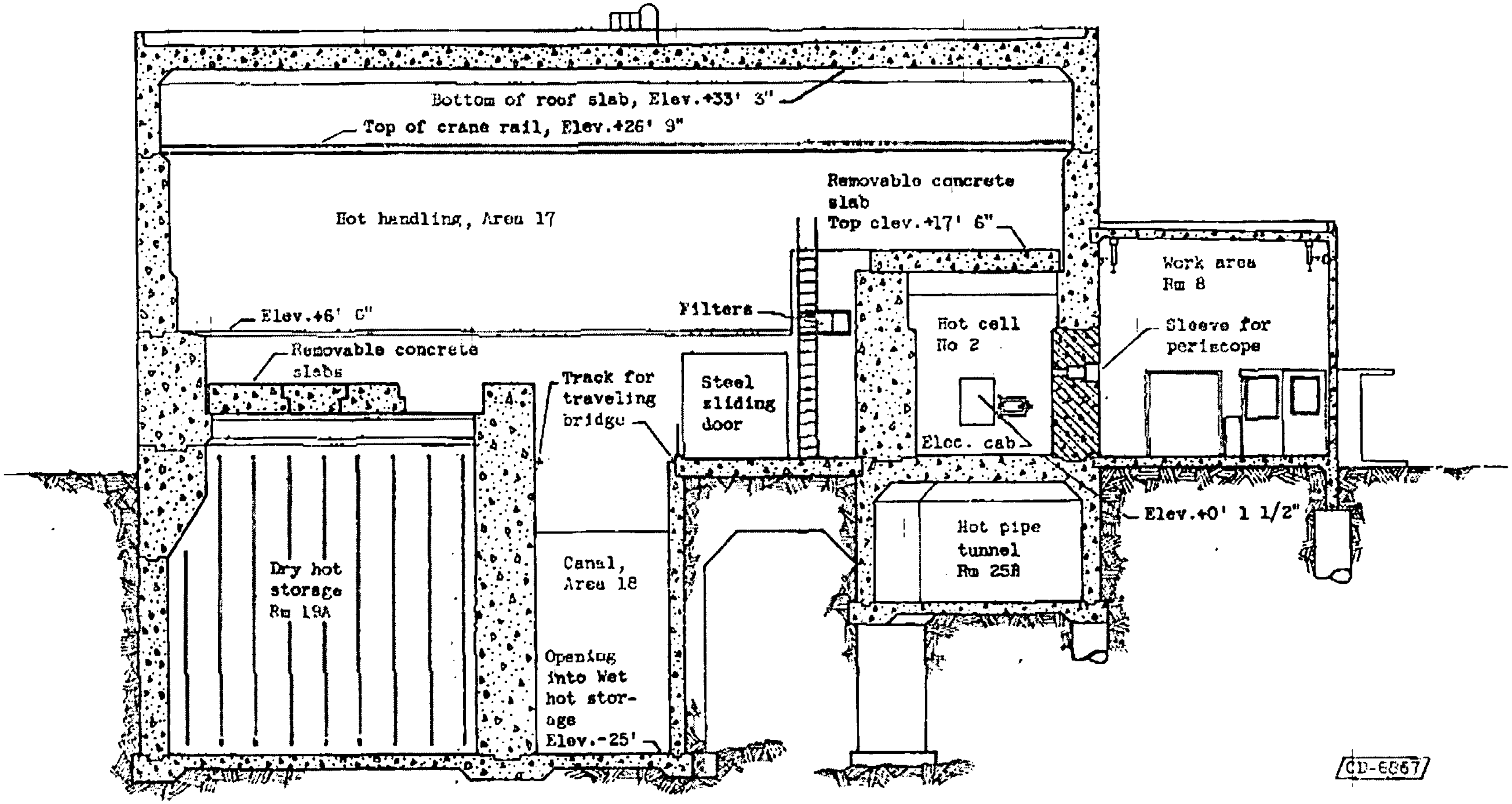
(b) Section A-A.

Figure 2.17. - Hot Laboratory Building.



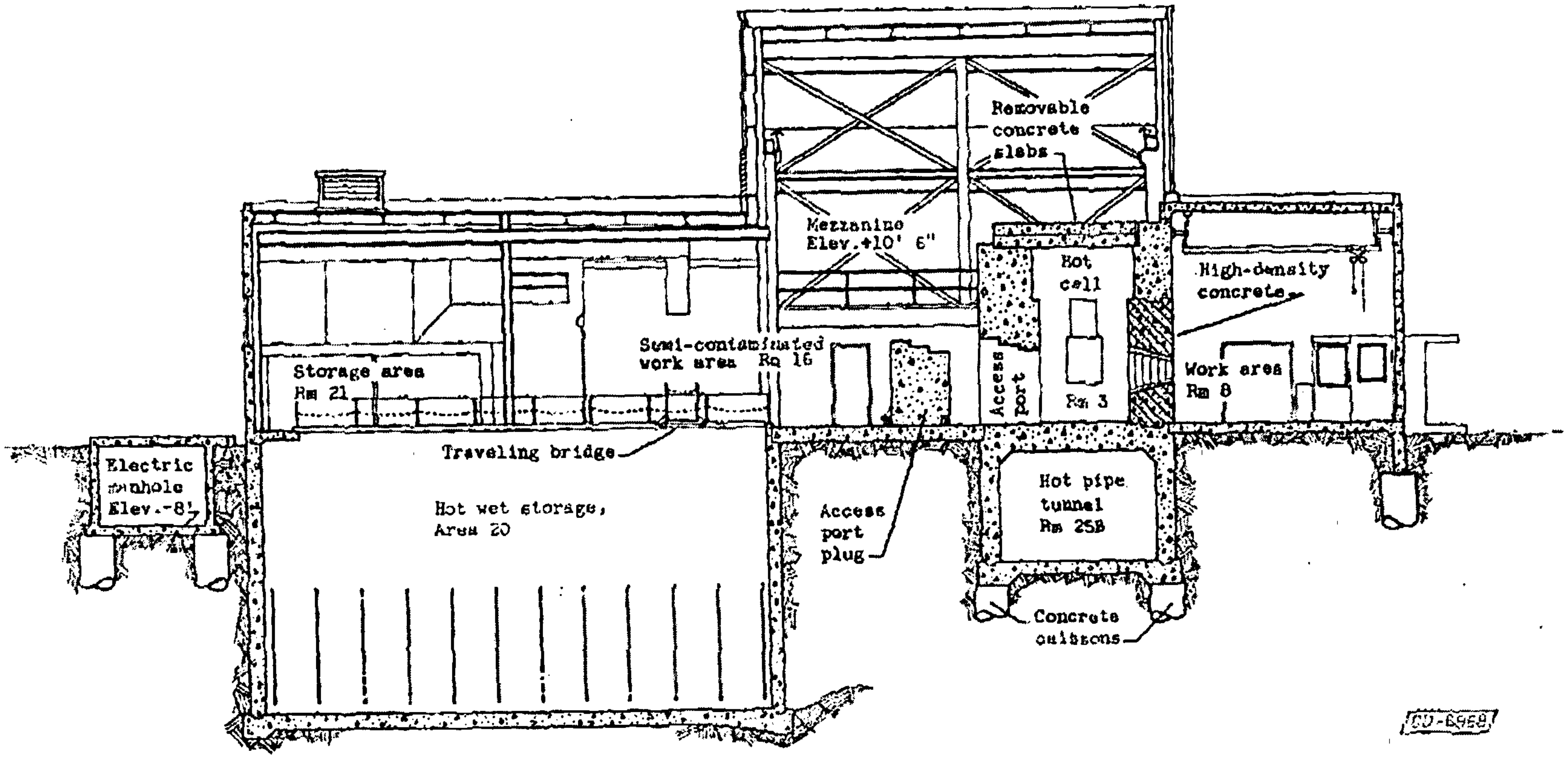
(c) Section B-B.

Figure 2.17. - Continued. Hot Laboratory Building.



(d) Section C-C.

Figure 2.17. - Continued. Hot Laboratory Building.



(c) Section D-D.

Figure. 2.17. - Concluded. Hot Laboratory Building.

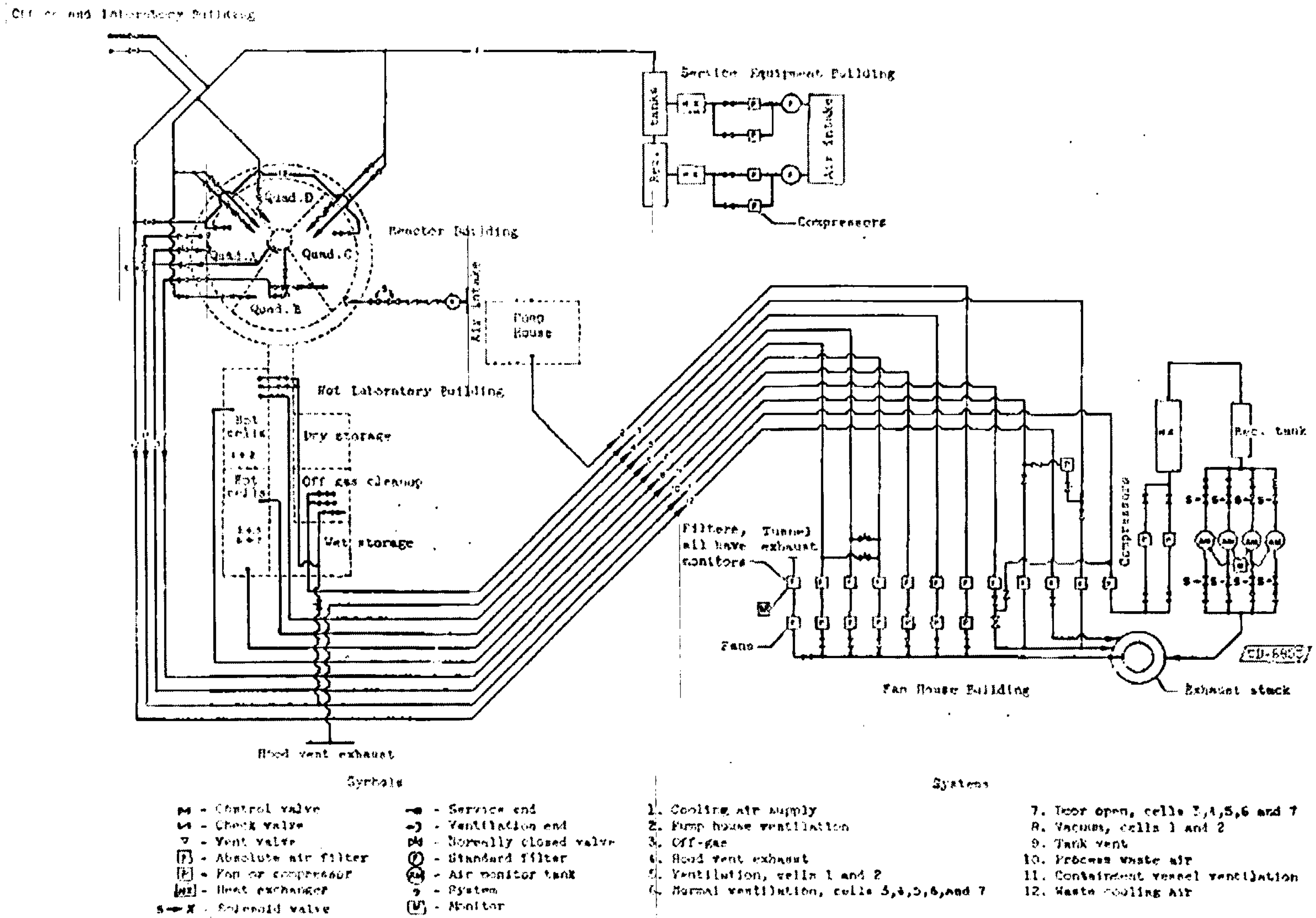


Figure 2.18. - Schematic drawing of service air and ventilation systems.

APPENDIX A

SECTION 2

1981 Deep Rock Core Description

(Weeks, August 1981)

LITHOFACIES AND PALEOENVIRONMENTS
OF A SILURIAN CORE,
SANDUSKY, OHIO

by

Alan F. Weekes

A Thesis
Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
Department of Geology
at the State University College, Fredonia, New York

August 1981

Donald J. Crowley
Professor of Geology

Donald J. Crowley
Chairman
Department of Geology

Minda Rae Amiran
Dean for Special Programs and General Studies

System	Series	Stage	Group	Unit	Subdivision	TOPS
Silurian	Cayugan Series	Ludlovian	Salina Group	B Unit		
				A Unit	A-2 Carbonate	720.9
					A-2 Anhydrite	815.3
					A-1 Carbonate	834.0
					A-1 Anhydrite	879.0
	Niagaran Series			A-0 Carbonate		
				Undifferentiated Lockport Fm.		908.9
		Wenlockian		Rochester Fm.		1103.0
				Dayton Fm.	Upper Dolomite Member	1113.5
					Middle Shale Member	1117.3
					Lower Dolomite Member	1119.0
	Alexandrian Series	Llandoverian	Cataract Group	Cabot Head Fm.		1128.3
				Brassfield Fm.		1243.5
Ordivician	Cincinnatian Series	Ashgillian		Queenston Fm.		1267.0

TABLE 1 Stratigraphy of the core

After Jannsens (1977) and Shaver et al. (1978).

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APPENDIX A

SECTION 3

1990 Contamination Evaluation

(IT, March 1990)

ENGINEERING REPORT FOR THE CONTAMINATION EVALUATION AT THE
FORMER PLUM BROOK ORDNANCE WORKS
SANDUSKY, OHIO

Submitted to:

Department of the Army
Nashville District, Corps of Engineers
Nashville, Tennessee

and

Huntsville Division, Corps of Engineers
Huntsville, Alabama

DRAFT

DERP Project No. G050H001800

Prepared by:

IT Corporation
Knoxville, Tennessee

IT Project No. 409658

March 1990

CEE2980COV
04/17/90 F2

2.0 GENERAL

2.1 INTRODUCTION

Background

The U.S. Army is conducting a study of the environmental impact of suspected hazardous waste sites at previously owned U.S. Department of Defense (DOD) properties. This work is being pursued by the U.S. Army Corps of Engineers (COE) under the Defense Environmental Restoration Program (DERP). This project is being managed by the Nashville, Tennessee COE District Office.

The federal government entered into a contract with E. B. Badger and Sons Company (Badger) on December 21, 1940 to build the Plum Brook Ordnance Works. On December 28, 1940, a subsequent contract was signed with Trojan Powder Company (Trojan) for the purpose of manufacturing trinitrotoluene (TNT), dinitrotoluene (DNT), pentolite, and nitric and sulfuric acids. Badger started surveying the 9,009-acre site on February 3, 1941, with ground breaking activities following on April 15, 1941. The first TNT and DNT processing lines were completed and ready for operation on December 9, 1941. Operations for the manufacturing of TNT originally started on December 16, 1941. Production of explosives ceased 2 weeks after V-J Day, having manufactured in excess of one billion pounds of explosives during the 4-year operating period.

Between V-J Day and September 22, 1945, the entire Ordnance Inspection Department was abolished. Decontamination of TNT, acid, pentolite, and DNT manufacturing lines was completed during the last quarter of 1945. On December 17, 1945, the physical custody of the plant was transferred from Trojan to the Ordnance Department. At this time, the Ordnance Department assumed liability and the U.S. Engineers assumed responsibility for maintenance and custodial duties. U. S. Engineers maintained stand-by operations from December 1945 to September 1946. The property was subsequently transferred to the War Assets Administration after it was certified by the U.S. Army to be decontaminated.

Matthew-Levio and Sons served as the protection and maintenance contractor from September 1946 to May 1949. The property was then transferred to the General Services Administration (GSA).

The National Aeronautics Space Administration (NASA) acquired the Plum Brook Ordnance Works on March 15, 1963 and is presently using the site. On April 18, 1978, NASA declared approximately 2,152 acres of land as excess. The Perkins Board of Education acquired 46 acres of the excess and utilizes its area as a bus transportation center. GSA retains the remaining acreage and currently has a use agreement with the Ohio National Guard for 604 acres of the land. NASA presently controls 6,453.5 acres and is currently using its site to conduct space research as a satellite operation of NASA's Lewis Research Center in Cleveland, Ohio.

Chemical contamination caused by DOD activities was expected to exist at the former Plum Brook site in Sandusky, Ohio (Figure 2-1). Interest was focused to address the possible chemical contamination at the wastewater (red water) retention areas and the suspect burial and burn areas site. The work effort involved the investigation of the remaining DOD structures and the contiguous ground water, surface water, and soil for possible contamination by any hazardous substances associated with the operation, maintenance, and deactivation of the Plum Brook site.

Records Review and Evaluation

Types of potential hazardous waste and disposal facilities associated with the operation, maintenance, and deactivation of the site are as follows:

- Containerized facilities
- Landfill disposals
- Seepage lagoons.

Four specific sites were targeted for investigation to confirm or deny the presence or absence of residual chemical contamination from operational activities during DOD control. These sites are:

- Waste Disposal Area 1
- Waste Disposal Area 2
- Scheid Road Burning Grounds
- Rubbish Burning Grounds.

With respect to the containerized facilities, a search of existing records of the Plum Brook site revealed that six underground storage tanks (USTs), installed during the period of DOD control, are inventoried. Three of the six tanks are currently in use and two of the three hold waste oil and solvents. Two tanks, installed in 1942, are permanently out of use and are located at the former vehicle service station, Building 7132. Current contents of the abandoned USTs are water and gasoline or diesel (Table 2-1).

2.2 PROJECT OBJECTIVES AND SCOPE OF WORK

The purpose of this project is to conduct a preliminary investigation to confirm or deny the presence or absence of residual chemical contamination from operational activities conducted at the site during DOD control. This work is being done under Delivery Order 004 of COE Contract No. DACA87-87-D-0089.

The scope of this investigation, performed by IT Corporation (IT) in accordance with the Final Work Plan dated September 1989 (IT, 1989), included the following tasks:

- Constructing six shallow (approximately 25 feet deep) ground water monitoring wells
- Collecting ground water samples from the six new ground water monitoring wells for analysis
- Collecting 36 soil/subsoil samples (six per well) during monitoring well construction for physical testing for engineering properties
- Collecting composite soil/subsoil samples at 19 locations to a depth of 2 feet for chemical contaminant analytical testing (one of these locations will be for a background sample; the other 18 will be for contamination evaluation)
- Calculating in situ hydraulic conductivity for the monitoring well zones
- Collecting individual surface water samples from each of the four streams that drain the site

Table 2-1. Department of Defense Underground Storage Tank Inventory[a]
Former Plum Brook Ordnance Works

Tank ID	Status of Tank	Bldg	Location	Date Installed	Capacity	Construction Material	Current Contents	Previous Contents	Interior Protection	Exterior Protection
7121-1	Currently in use	7121	E side of bldg between roads	1942	3,000	Steel	Waste oil and solvent	Waste oil and solvent	None	None
7131-1	Currently in use	7131	NE side of bldg	1942	1,500	Steel	Waste oil and solvent	Waste oil and solvent	None	None
7132-1	Permanently out of use	7132	North tank	1942	9,000	Steel	Water and gasoline	Gasoline	None	None
7132-2	Permanently out of use	7132	Center tank	1942	9,000	Steel	Water and diesel fuel	Diesel fuel	None	None
7132-3	Currently in use	7132	South tank	1942	9,000	Steel	Gasoline	Gasoline	None	None
8133-2	Permanently out of use	8133	W side	1942	250	Steel	Water	Unknown, gasoline, possibly a waste oil	None	None

[a]Current as of December 1988.

- Analyzing soil, ground water, and surface water samples and quality assurance (QA) samples
- Evaluating laboratory analysis of field and QA samples
- Preparing the site investigation report, including completion of the Hazardous Ranking System (HRS) form.

2.3 SITE DESCRIPTION

Location and General Description

The Plum Brook site is located approximately 4 miles south of Sandusky, Ohio and is specifically located in the Perkins and Oxford Townships. The site is bounded on the north by Bogart Road, on the south by Mason Road, on the east by U.S. Highway 250, and on the west by County Road 43 (Figure 2-1). The former Plum Brook site consists of 9,009 acres and lies in an area that is primarily rural and agricultural with low population density.

Topography and Physiography

The Plum Brook site is located on what was originally a flat lake bottom from glacial melt waters. The ground surface slopes gradually northward toward Lake Erie at an average slope of less than 6 percent. Elevations at the site range from 675 feet above mean sea level (msl) at the southwest edge of the site to 625 feet msl in the northern portion of the property at Bogart Road. A topographic map of the site is presented in Figure 2-2.

The Plum Brook site derives its name from the major stream passing through its boundaries. Eleven streams, six of which originate within the site boundaries, flow northerly or northeasterly into Lake Erie. Plum Brook and Pipe Creek originate south of the site and flow independently into Lake Erie, east and west of the airport, respectively. Kuebeler Ditch, Ohlemacher Ditch, Scherer Ditch, and Zorn Beutal Ditch originate at the southwest edge of the property and connect into Harris Ditch south of Fox Road.

Soil Characterization

Most of the soils at the Plum Brook site were formed from deposits from glaciers or from glacial melt waters. The dominant soil material was deposited as glacial till, outwash, and lacustrine deposits.

Glacial till is material laid down directly from glaciers with minimum water action. Typically, it consists of particles of different sizes. Some smaller pebbles in glacial till have sharp corners, indicating that they have not been rounded or worn by water.

Outwash materials were deposited by running water from melting glaciers. The size of the particles that make up the outwash material varies according to the speed of the water in which particles were carried. Outwash deposits generally consist of layers of particles of similar size, such as sand and gravel.

Lacustrine deposits, material settled from still, ponded glacial melt water, contain only the finer particles such as very fine sand, silt, and clay because the coarser material dropped out as outwash.

The U.S. Department of Agriculture (USDA) Soil Conservation Service Soil Survey (1971) identifies the majority of soils at the site as being from the Arkport-Galen association (Figure 2-3). Arkport soils consist of gently sloping to moderately sloping, well-drained soils formed in the sandy material deposited at the edge of a glacial lake. Arkport soils are generally loamy fine sand and fine sand. Galen soils are mostly level and moderately well-drained formed as small sandy deposits on outwash plains and deltas. Galen soils have a fine sand or sandy loam surface layer, a subsurface of fine sand and loamy fine sand that is underlain by silt or clay. Runoff is slow, permeability is rapid, and the available moisture capacity is low. Wind erosion is a problem in this soil association.

The southern portion of the station has soils in the Prout association. Prout soils are moderately deep to deep, nearly level to gently sloping, somewhat poorly drained soils that have a subsoil of heavy silt loam to silty clay loam. These soils are commonly on uplands, with runoff and permeability slow.

The Lewisburg association occupies a small isolated part of the Plum Brook site. The soils are moderately deep to deep, nearly level in depressions, and are narrow strips along natural drainageways. Runoff is slow, permeability is moderately slow, and the available moisture capacity is high.

Geologic Setting

In the Paleozoic Era, large tropical inland seas covered the Plum Brook site. As the seas began to recede, deposits of carbonate material slowly lithofied into thick layers of limestone and dolomite. Likewise, deposits of mud and clay formed shales and quartz, while other silicate materials formed sandstone.

Later in geologic time, glacial ice scoured the area, cutting out the river valleys. The resistant bedrock that covers most of the area was not deeply cut by the glaciers.

The majority of the site is underlain by lacustrine glacial deposits making up the Huron shale. The shale is grayish black, hard, dense and abundantly carbonaceous. The area is also underlain by Plum Brook shale and Delaware and Prout limestones. The shales are low in porosity, while the limestones are massive with calcareous shale partings and are moderately porous. The bedrock is limestone in the western part of the site and shale in the eastern part. The regional dip is easterly, and younger rocks crop out progressively from west to east (USGS, 1954).

Hydrogeologic Setting

Ground water in the area of the Plum Brook site has its source in local precipitation. The limestone beds underlying the site are the principal aquifer. Yields from limestone deposits range generally between 5 and 25 gallons per minute (Figure 2-4). Water in limestone beds occurs principally in joint cracks along bedding planes and in other openings. Most wells in the limestone deposits in the vicinity of the station range between 50 and 80 feet in depth. The quality of the water deteriorates rapidly with increased depth, and wells deeper than approximately 100 feet generally yield sulfur water. There are no wells used as a source of water supply within the Plum Brook site.

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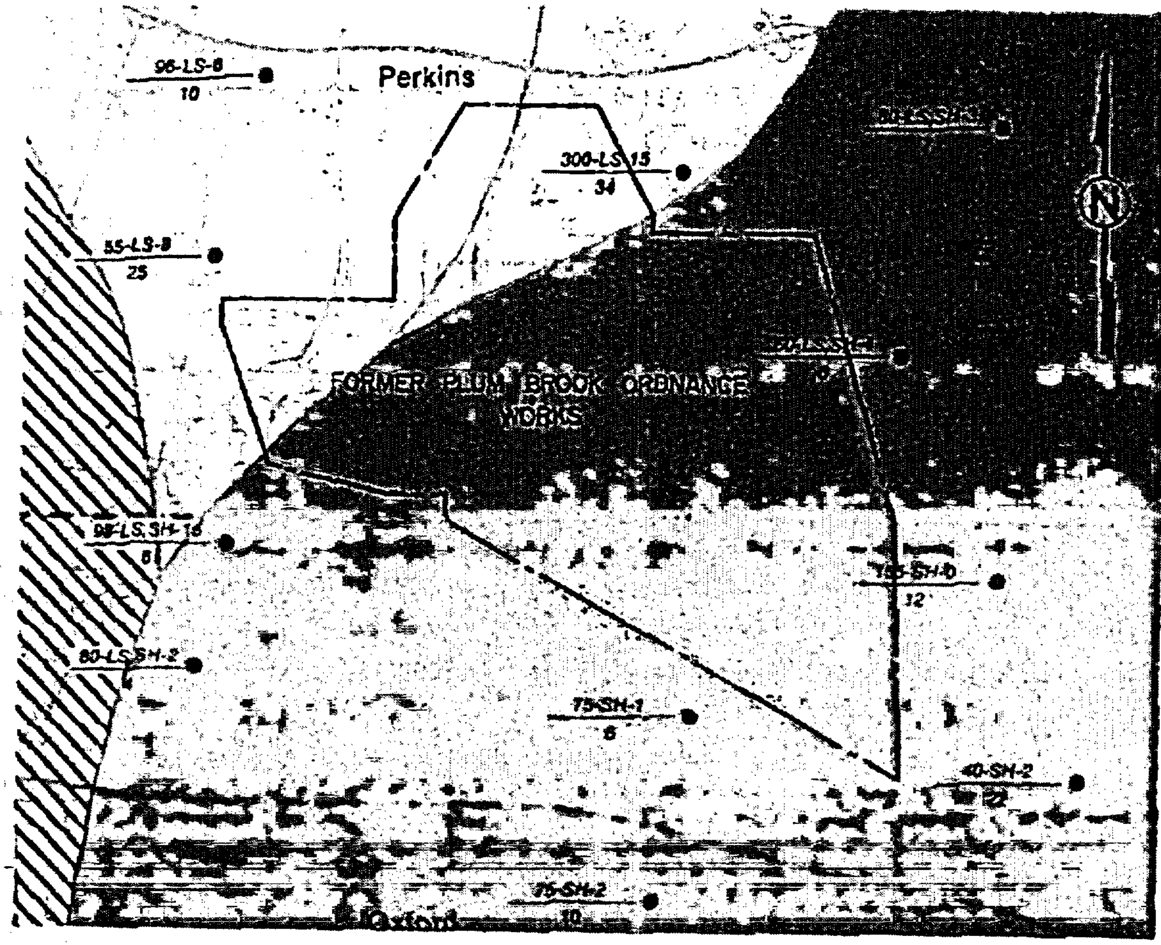

LEGEND

AREAS IN WHICH YIELDS OF 100 TO 500 GALLONS PER MINUTE MAY BE DEVELOPED

Yields of more than 500 gallons per minute have been developed at depths of less than 200 feet in cavernous limestone and dolomite. Domestic supplies are generally obtained at depths of around 100 feet.

Hydrogen sulfide, in varying amounts, may be encountered in the bedrock.

Areas in which there is a potential concentration of contamination due to the underground disposal of storm wastes from Bellevue.

AREAS IN WHICH YIELDS OF 5 TO 25 GALLONS PER MINUTE MAY BE DEVELOPED

Yields of 15, or less, gallons per minute are developed from wells drilled into the limestone. Hydrogen sulfide may be present in varying amounts.

AREAS IN WHICH YIELDS SELDOM EXCEED 3 GALLONS PER MINUTE

Limited quantities of ground water are obtained from thin, discontinuous sand and gravel deposits interbedded in fine, sandy clay or from the underlying shale. Drilling deeper than 30 feet into the shale is not recommended. Occasional gas or salt noted in the eastern half of the county.

Larger yields may be obtained in western Huron and Oxford townships and southeastern Perkins Township. Wells may encounter water-bearing limestone beneath as much as 60 feet of impervious shale.

● Existing Domestic Wells

SCALE

1 0 1 mile

FIGURE 2-4

GROUND WATER RESOURCES

FORMER PLUM BROOK ORDNANCE WORKS
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

STARTING DATE: 4-26-89 | DATE LAST REV.: 2-27-90 | INITIATOR: D. BURTON | DRAWING NO: 409658-A-WP11
DRAWN BY: S. MOORE | DRAWN BY: P.L. SUAREZ | PROJ. MGR: D. BURTON | PROJECT NO: 409658

Surface water leaves the site through naturally occurring surface creeks. All streams may have zero flow in severe winter freezes and extended summer droughts. NASA currently monitors three streams for National Pollutant Discharge Elimination System (NPDES) discharge at the Plum Brook site criteria. The three streams are Plum Brook, Ransom Brook, and Kuebeler Ditch. The impacts on the surface or ground water hydrology resulting from the operations of the Plum Brook site are minimal. The existence of buildings, roads, parking lots, and other impervious areas has caused an insignificant increase in the amount of storm water runoff during rainfall events.

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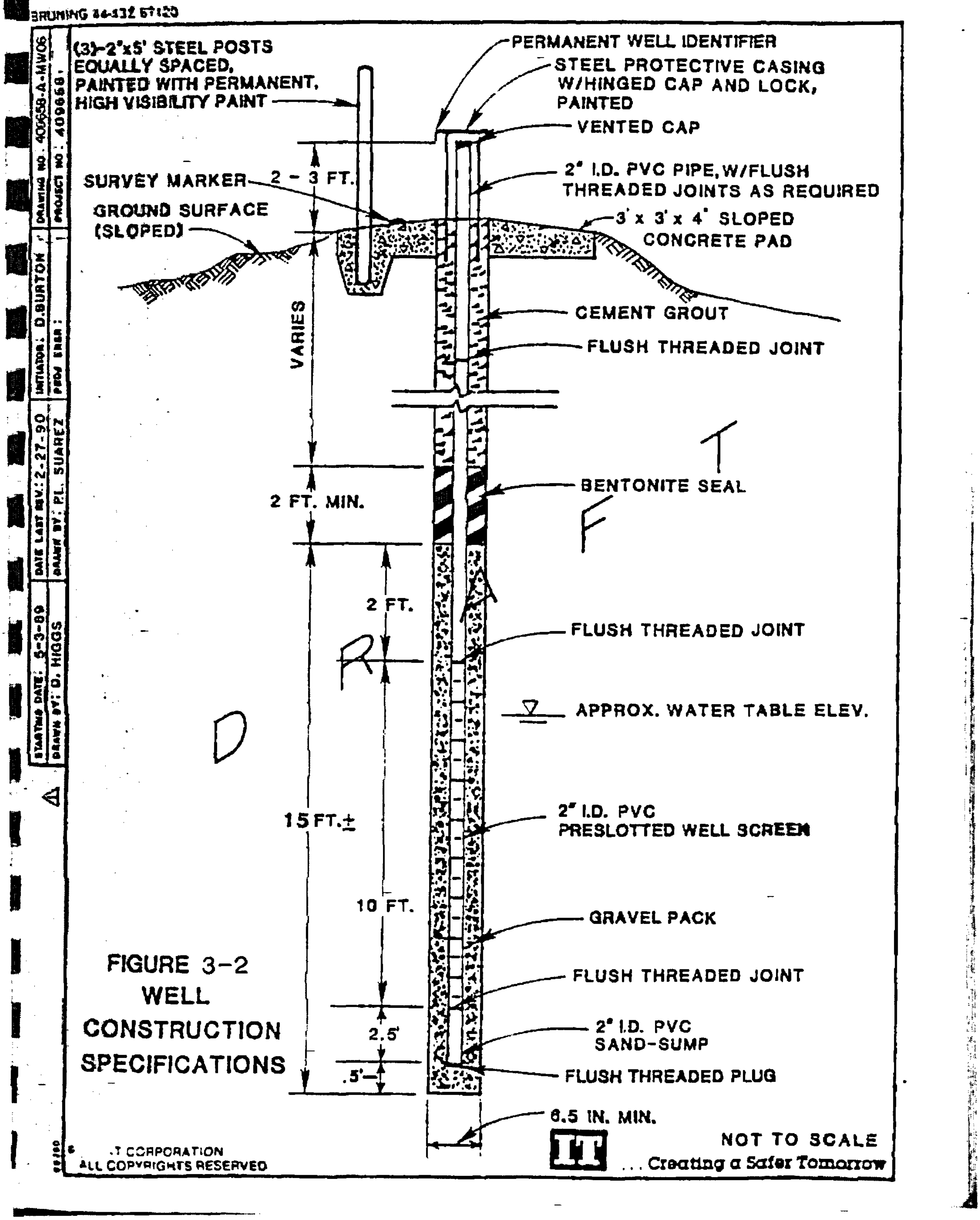

FIGURE 3-2
WELL
CONSTRUCTION
SPECIFICATIONS

water from each well. After recharge of the wells for 18 hours, water levels ranged from 64 (MW-06) to 94 (MW-01) percent of their original water level. Well development time for the wells, including the time required for recharge, ranged from 24 hours for MW-01, MW-05, and MW-06 to 3 hours for MW-02. Fine sand present in the filter pack was removed during the surging and bailing and the wells appeared to produce clear water.

Field Hydraulic Conductivity Tests

A rising head "slug" test was performed at monitoring well MW-02 on October 23. Because of the very slow recharge observed in the wells, a variance was sought and approved to eliminate hydraulic conductivity tests on wells showing extremely low recharge. Equipment used in these tests included:

- A 0- to 15-pound per-square-inch (psi) pressure transducer equipped with an atmospheric pressure compensation tube
- ENVIRO-LABS model DL-120-MCP data logger.

The test at MW-02 was set up by lowering the pressure transducer below the static water level and initiating the data recording sequence on the data logger. The data logger is equipped with a segmented interval logging (SILOG) feature allowing water level recording at 1- to 60-second intervals. The test was considered finished when the water column above the pressure transducer had returned to 90 percent of the original level. Evaluation of the field hydraulic conductivity tests are included in Appendix C.

3.3 VARIANCES TO THE WORK PLAN

Field procedures varied slightly from the procedures set forth in the original work plan. Seven changes were implemented to adjust procedures for conditions encountered in the field. Variances were noted in the Field Activity Daily Logs and recorded on Variance Log Forms included in Appendix D. These changes are discussed below:

- Decontamination wastewaters were not collected and stored on site; rather, wastewater was allowed to run off from the decontamination area and enter a sewer system. This procedure was approved in advance by the NASA project contact.

- Because the bedrock was encountered at a high level in MW-01, only one sample was submitted for geotechnical analysis.

- Bedrock was encountered in MW-01 and MW-06 and, to avoid creating a potential conduit into a lower aquifer, boreholes were terminated even if saturated sandy materials were not encountered 10 feet above the borehole base.

- Hydraulic conductivity tests would not be run where recharge rates were significantly low such that recovery to 90 percent would not occur within 24 hours or there would be insufficient water column to remove two bails from the well.

- The burn areas were very highly vegetated and exhibited no evidence of surface contamination. In contrast, Waste Disposal Area 1 exhibited extensive contamination at the surface. In response to these observations, COE representatives authorized the following modifications to the sampling plans:

  - The monitoring wells planned for the burn areas were to be deleted and replaced with deep soil borings at Waste Disposal Area 1. In the deep soil borings, the sample was to be taken from above the first significant clay layer.

  - Where surface contamination was evident, soil samples were to be collected from the 0- to 2-foot interval.

- At Waste Disposal Area 2, a COE representative requested that a soil sample from MW-02 taken above the water table be submitted for chemical analysis. This reduced the amount of material recovered from borehole MW-02 and only three soil samples could be submitted for geotechnical analysis. The sample submitted for chemical analysis from MW-02 was substituted for SB-08.

3.4 SAMPLING PROGRAM

Soil, surface water, and ground water sampling locations are shown on Figures 3-1, 3-3, 3-4, 3-5, and 3-6.

Soil Samples for Geotechnical Testing

Soil samples for geotechnical testing were collected from each monitoring well borehole during well construction. Individual subsurface samples from each well were taken continuously for the first 10 feet and on 5-foot intervals thereafter where capable. From the intervals sampled, two geotechnical samples were selected for grain-size distribution testing, two geotechnical samples were selected for Atterberg limits, and two geotechnical samples were selected for moisture content determination. Sampling was accomplished using a split spoon sampler (ASTM-D-1586-87). Drilling and sampling equipment was

BORING NO. MW01

COORDINATES N 616864.39 E 1945986.24

FIELD ENGINEER J. SHIREMAN DATE BEGAN 10/18/89
EDITED BY D. BURTON DATE FINISHED 10/18/89
CHECKED BY ______ GROUND SURFACE EL. 674.52

DEPTH IN FEET	LABORATORY TEST DATA: SAMPLE NO.	SAMPLE DEPTH	ATTERBERG LIMITS: LIQUID LIMIT (%)	PLASTICITY INDEX (%)	MOISTURE CONTENT (%)	WELL SUMMARY/ BACKFILL	PENETRATION RESISTANCE (BLOWS/FT) "SAMPLE"	USCS	PROFILE	DESCRIPTION
0	GS1879°	0-2	46	17.8	26.3			cl		SILTY CLAY, REDDISH GREY (10 yr 6/6). UPPER 2 FEET CONTAINS GRASS
			(GRAIN SIZE)							
	MW01	2-3 1/2								SAMPLING DEPTH 3.5 FEET
5										SHALE, WEATHERED BEDROCK, PARTINGS ARE .05 TO .15 INCHES APART
										SHALE BECOMES HARD
10										TOTAL BORING DEPTH 9.5 FEET AUGER REFUSAL AT 9.5 FEET
15										
20										
25										
30										
35										

NOTE:

° – Geotechnical sample

Screen: B & K schedule 40, 2 inch threaded PVC, 0.01 inch from 4 to 9 feet.
Riser: B & K schedule 40, 2 inch threaded PVC, approximately 7.2 feet. (including stick up.)
Bentonite: 1/4 inch bentonite pellets from 2 to 1 feet in depth.
Filter Sand: 40/60 mesh silica sand, tremied through augers from 9.5 to 2 feet in depth.
Grout: Portland cement with 3% bentonite from 0 to 1 feet.
Well Protection: Locking steel well protector and concrete apron with (3) 3 foot guard posts.
Static Water Level: 5.03 feet from top of riser, 10/21/89

ACAD\GENERAL\409658-1

PROJECT NO. 409658
CLIENT: PLUM BROOK

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APPENDIX D
APPENDIX E

BORING NO. MW02

COORDINATES N 622474.41 E 1941725.48

FIELD ENGINEER J. SHIREMAN DATE BEGAN 10/17/89
EDITED BY D. BURTON DATE FINISHED 10/17/89
CHECKED BY ____ GROUND SURFACE EL. 636.53

DEPTH IN FEET	LABORATORY TEST DATA: SAMPLE NO.	SAMPLE DEPTH	ATTERBERG LIMITS: LIQUID LIMIT (%)	PLASTICITY INDEX (%)	MOISTURE CONTENT (%)	WELL SUMMARY/ BACKFILL	PENETRATION RESISTANCE (BLOWS/FT) SAMPLE	USCS	PROFILE	DESCRIPTION
0	MW02	0–2						sm/ml		CLAYEY SANDY SILT, DARK BROWN (7.5 yr 3/2), DRY, 20% FINE SAND
	GG1880	2–4[a]						sm		GRADES TO VERY FINE SAND, PINKISH YELLOW (7.5 yr 6/8) LOOSE
5	MW02	4–6						cl		SILTY CLAY, VERY STIFF, OLIVE BROWN (2.5 yr 3/4)
	MW02	6–8						sm/ml		SILTY CLAYEY SAND, SATURATED, GRADES DOWN TO VERY FINE GRAINED SANDY SILT DARK BROWN (7.5 yr 3/2), CHANGES TO REDDISH GREY (10 r 6/1)
	GG1881	8–10[a]	34.2	12.3				ml/cl		SANDY SILT TO SILTY CLAY, MOTTLED REDDISH YELLOW, DRY TO SLIGHTLY MOIST, SLIGHTLY PLASTIC
10										
15	GG1881	13.5–15.5[a]	(GRAIN SIZE)		14.8			cl		SILTY CLAY, REDDISH GREY, MOIST MED. STIFFF SLIGHTLY PLASTIC
	MW02	16.5–18.5						cl		SILTY CLAY, REDDISH GREY (10 r 6/1), MOIST
20										TOTAL DEPTH 18.3 FEET SAMPLING DEPTH 18.5 FEET LIMESTONE, GREY CONTAINING PYRITIZED BRACOPODS
25										
30										
35										

NOTE:

a – Geotechnical sample

Screen: B & K schedule 40, 2 inch threaded PVC, 0.01 inch from 8 to 18 feet.
Sand Sump: B & K Schedule 80 2 inch threaded PVC from 18 to 16 feet.
Riser: B & K schedule 40, 2 inch threaded PVC, approximately 8 feet, (including stick up.)
Bentonite: 1/4 inch bentonite pellets from 2 to 3.8 feet in depth.
Filter Sand: 40/80 mesh silica sand, tremied through augers from 3.8 to 18.3 feet in depth.
Grout: Portland cement with 3% bentonite from 0 to 2 feet.
Well Protection: Locking steel well protector and concrete apron with (3) 3 foot guard posts.
Static Water Level: 10.72 feet from top of riser. 10/21/89

PROJECT NO. 409658
CLIENT: PLUM BROOK

ACAD\GENERAL\BORELOG\409658-2

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APPENDIX E

APPENDIX D

BORING NO. MW05

COORDINATES N 625309.03 E 1950936.35

FIELD ENGINEER J. SHIREMAN DATE BEGAN 10/16/89
EDITED BY D. BURTON DATE FINISHED 10/17/89
CHECKED BY ______ GROUND SURFACE EL. 632.38

DEPTH IN FEET	LABORATORY TEST DATA: SAMPLE NO.	SAMPLE DEPTH	ATTERBERG LIMITS: LIQUID LIMIT (%)	PLASTICITY INDEX (%)	MOISTURE CONTENT (%)	USCS	DESCRIPTION
0	GG-1873	0-2*	(GRAIN	SIZE)		sp	SAND VERY FINE GRAINED, DRY, LOOSE, WELL ROUNDED, POORLY GRADED, REDDISH YELLOW (7.5 yr 6/8) MOIST AT 2 1/2 FT.
	GG-1874	2-4*			26.0	cl	CLAY/ SILTY CLAY STIFF CONTAINS UP TO 15% SILT
5	GG-1875	4-6*	26.8	7.4		ml	CLAYEY SANDY SILT
						cl	CLAY, SLIGHTLY PLASTIC, MOIST TO WET
	GG-1876	6-8*	(GRAIN	SIZE)		sm	SILTY SAND, VERY FINE GRAINED, LOOSE TO MED. DENSE, DRY
	GG-1877	8-10*	26.9	8.6		cl	CLAY, VERY PLASTIC, WET MED. STIFF TO STIFF, GREY (N 5/0)
10							CLAY, REDDISH GREY, MED. STIFF WET
15	MW-05	14-16				cl	CLAY, VERY PLASTIC, SATURATED TO VERY WET, REDDISH GREY
20	GG1878	19-21*			14.0	cl	CLAY WITH ABOUT 20% COARSE SAND TO SMALL GRAVEL GRAVEL IS VERY ANGULAR
25							
30							
35							

TOTAL BORING DEPTH 21 FEET
TOTAL SAMPLE DEPTH 21 FEET

NOTE:

* — Geotechnical sample

Screen: B & K schedule 40, 2 inch threaded PVC, 0.01 inch from 8.5 to 18.5 feet.
Sand Sump: B & K Schedule 80 2 inch threaded PVC from 18.5 to 20.5 feet.
Riser: B & K schedule 40, 2 inch threaded PVC, approximately 11.8 feet. (including stick up.)
Bentonite: 1/4 inch bentonite pellets from 4.5 to 6.5 feet in depth.
Filter Sand: 40/60 mesh silica sand, tremied through augers from 6.5 to 21 feet in depth.
Grout: Portland cement with 3% bentonite from 0 to 4.5 feet.
Well Protection: Locking steel well protector and concrete apron with (3) 3 foot guard posts.
Static Water Level: 15.78 feet from top of riser, 10/21/88

PROJECT NO. 409858
CLIENT: PLUM BROOK

ACAD\GENERAL\BORELOG\409858-5

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APPENDIX D

APPENDIX E

BORING NO. MW06

COORDINATES N 628604.10 E 1950228.42

FIELD ENGINEER J. SHIREMAN   DATE BEGAN 10/17/89
EDITED BY D. BURTON   DATE FINISHED 10/17/89
CHECKED BY ______   GROUND SURFACE EL. 628.90

LABORATORY TEST DATA

SAMPLE NO.	SAMPLE DEPTH	ATTERBERG LIMITS: LIQUID LIMIT (%)	ATTERBERG LIMITS: PLASTICITY INDEX (%)	MOISTURE CONTENT (%)
GG1883	0–2*			14.4
GG1884	2–4*	(GRAIN	SIZE)	
GG1885	4–6*	(GRAIN	SIZE)	
GG1886	6–8*	28.3	9.6	
GG1887	8–10*			22.6
GG1888	13.5–15.5*	28.9	9.2	

DEPTH IN FEET · WELL SUMMARY/BACKFILL · PENETRATION RESISTANCE (BLOWS/FT) SAMPLE · USCS · PROFILE

DESCRIPTION

TWO FEET OF CONCRETE ROADWAY

(USCS: sp) SAND, FINE GRAINED LOOSE TO MED. DENSE, POORLY GRADED, COLOR CHANGE AT 1.2 FEET FROM BROWNISH YELLOW (10 yr 6/8) TO OLIVE BROWN (2.5 yr 4/4)

(USCS: cl) CLAY, VERY PLASTIC DARK GREY (N 4/0) TO GREY, DRY TO SLIGHTLY MOIST, VERY LITTLE TO NO SILT. CLAY, VERY TO SLIGHTLY PLASTIC, MED. STIFF CONTAINS UP TO 1 % SAND GRADES TO SILTY CLAY AT 9 FEET

TOTAL SAMPLING DEPTH 15.5 FEET

TOTAL BORING DEPTH 18.5 FEET, AUGER REFUSAL

NOTE:

* – Geotechnical sample

Screen: B & K schedule 40, 2 inch threaded PVC, 0.01 inch slotted from 8 to 16 feet.
Sand Sump: B & K Schedule 80 2 inch threaded PVC from 16 to 18 feet.
Riser: B & K schedule 40, 2 inch threaded PVC, approximately 7.4 feet. (including stick up.)
Bentonite: 1/4 inch bentonite pellets from 4.4 to 2.4 feet in depth.
Filter Sand: 40/60 mesh silica sand, tremied through augers from 18.4 to 4.4 feet in depth.
Grout: Portland cement with 3% bentonite from 0 to 2.4 feet.
Well Protection: Locking steel well protector and concrete apron with (3) 3 feet guard posts.
Static Water Level: 13.46 feet from top of riser

PROJECT NO. 409658
CLIENT: PLUM BROOK

ACAD\GENERAL\BORELOG\409658-6

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APPENDIX D
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SLUG TEST ANALYSIS DESCRIPTION

The method for analysis was taken from Hvorslev, 1951, Time Lag and Soil Permeability in Ground Water Observation, U.S. Army Corps of Engineers, Bulletin No. 36, 50 pp.

The data for depth to water vs. time for each slug test was converted to a head ratio vs. time where the head ratio can be calculated by the following formula:

$$\frac{H_t - H_g}{H_i - H_g}$$

Where H_t is depth to water at a certain time, t,; H_i is the lowest water level obtained for the test; and H_g is static water level before the test started. The head ratio was plotted on a logrithmic scale vs. time on a straight arithmetic scale.

From the plots, two points were selected and read to obtain the corresponding head ratio values. The head ratio value was converted back into an actual head level (depth to water value) for each time, t, and t_2. These values were used in the equation:

$$K = \frac{r_2}{2(L_1 - L_2)\,(t_2 - t_1)} \text{ X ln } \frac{L_1 - L_2}{R} \text{ X ln } \frac{(H_1 - H_g)}{(H_2 - H_g)}$$

where:

r = radius of the well
$L_1 - L_2$ = screen length
H_g = static water level
R = effective well radius

to obtain K.

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01/18/90 F1

This was done for each well test. The geometric mean was calculated from the K values obtained from each well. It has been especially shown that the geometric mean is a more statistically reliable average than the normal average for K.

Real Time	Elapsed Time	HEAD	Head Ratio	Head Ratio	Line
13:00:00	2.68	7.96	0.060975	-1.21484	
12:55:00	2.59	7.96	0.060975	-1.21484	
12:50:00	2.51	7.96	0.060975	-1.21484	
12:45:00	2.43	7.96	0.060975	-1.21484	
12:40:00	2.34	7.96	0.060975	-1.21484	
12:35:00	2.26	7.96	0.060975	-1.21484	
12:30:00	2.18	7.95	0.065040	-1.18681	
12:25:00	2.09	7.95	0.065040	-1.18681	
12:20:00	2.01	7.94	0.069105	-1.16048	
12:15:00	1.93	7.94	0.069105	-1.16048	
12:10:00	1.84	7.94	0.069105	-1.16048	
12:05:00	1.76	7.93	0.073170	-1.13566	
12:00:00	1.68	7.93	0.073170	-1.13566	
11:55:00	1.59	7.92	0.077235	-1.11218	
11:50:00	1.51	7.92	0.077235	-1.11218	
11:45:00	1.43	7.91	0.081300	-1.08990	
11:40:00	1.34	7.91	0.081300	-1.08990	
11:35:00	1.26	7.9	0.085365	-1.06871	
11:30:00	1.18	7.89	0.089430	-1.04851	
11:25:00	1.09	7.88	0.093495	-1.02920	
11:20:00	1.01	7.87	0.097560	-1.01072	
11:15:00	0.93	7.86	0.101626	-0.99299	
11:10:00	0.84	7.85	0.105691	-0.97596	
11:05:00	0.76	7.83	0.113821	-0.94377	
11:00:00	0.68	7.81	0.121951	-0.91381	
10:55:00	0.59	7.79	0.130081	-0.88578	
10:50:00	0.51	7.77	0.138211	-0.85945	
10:47:26	0.47	7.75	0.146341	-0.83463	
10:46:26	0.45	7.74	0.150406	-0.82273	
10:45:26	0.43	7.74	0.150406	-0.82273	
10:44:26	0.42	7.73	0.154471	-0.81115	
10:43:26	0.40	7.72	0.158536	-0.79987	
10:42:26	0.38	7.72	0.158536	-0.79987	
0:41:26	0.37	7.71	0.162601	-0.78887	
0:40:26	0.35	7.7	0.166666	-0.77815	
0:39:26	0.33	7.69	0.170731	-0.76768	
0:38:26	0.32	7.68	0.174796	-0.75746	
0:37:26	0.30	7.67	0.178861	-0.74748	
0:36:26	0.28	7.66	0.182926	-0.73772	
0:35:26	0.27	7.65	0.186991	-0.72817	
0:34:26	0.25	7.64	0.191056	-0.71883	
0:33:26	0.23	7.63	0.195121	-0.70969	
0:32:26	0.22	7.62	0.199186	-0.70073	
0:31:26	0.20	7.6	0.207317	-0.68336	
0:30:26	0.18	7.59	0.211382	-0.67493	
:29:26	0.17	7.57	0.219512	-0.65854	
:28:26	0.15	7.55	0.227642	-0.64274	
:27:26	0.13	7.53	0.235772	-0.62750	
:26:26	0.12	7.51	0.243902	-0.61278	
:25:26	0.10	7.47	0.260162	-0.58475	
:24:26	0.08	7.43	0.276422	-0.55842	
:23:26	0.07	7.37	0.300813	-0.52170	
:22:26	0.05	7.27	0.341463	-0.46665	
:21:56	0.04	7.2	0.369918	-0.43189	
:21:26	0.03	7.07	0.422764	-0.37390	
:20:56	0.03	6.88	0.5	-0.30102	
:20:26	0.02	6.59	0.617886	-0.20909	
:19:56	0.01	6.2	0.776422	-0.10990	
:19:51	0.01	6.13	0.804878	-0.09426	

L = 8.000

Regression Output:

Constant	-0.595783
Std Err of Y Est	0.0153099
R Squared	0.9728488
No. of Observations	26
Degrees of Freedom	24

X Coefficient(s)	-0.48564
Std Err of Coef.	0.016561

To = 0.8891172

K = 0.2494469 ft/day
8.800E-05 cm/sec

V = 0.0178176 ft/day

10:19:46	0.01	6.05	0.837398	-0.07706
10:19:41	0.00	5.97	0.869918	-0.06052
10:19:36	0.00	5.88	0.906504	-0.04263
10:19:31	0.00	5.77	0.951219	-0.02171
10:19:26	0.00	5.65	1	0

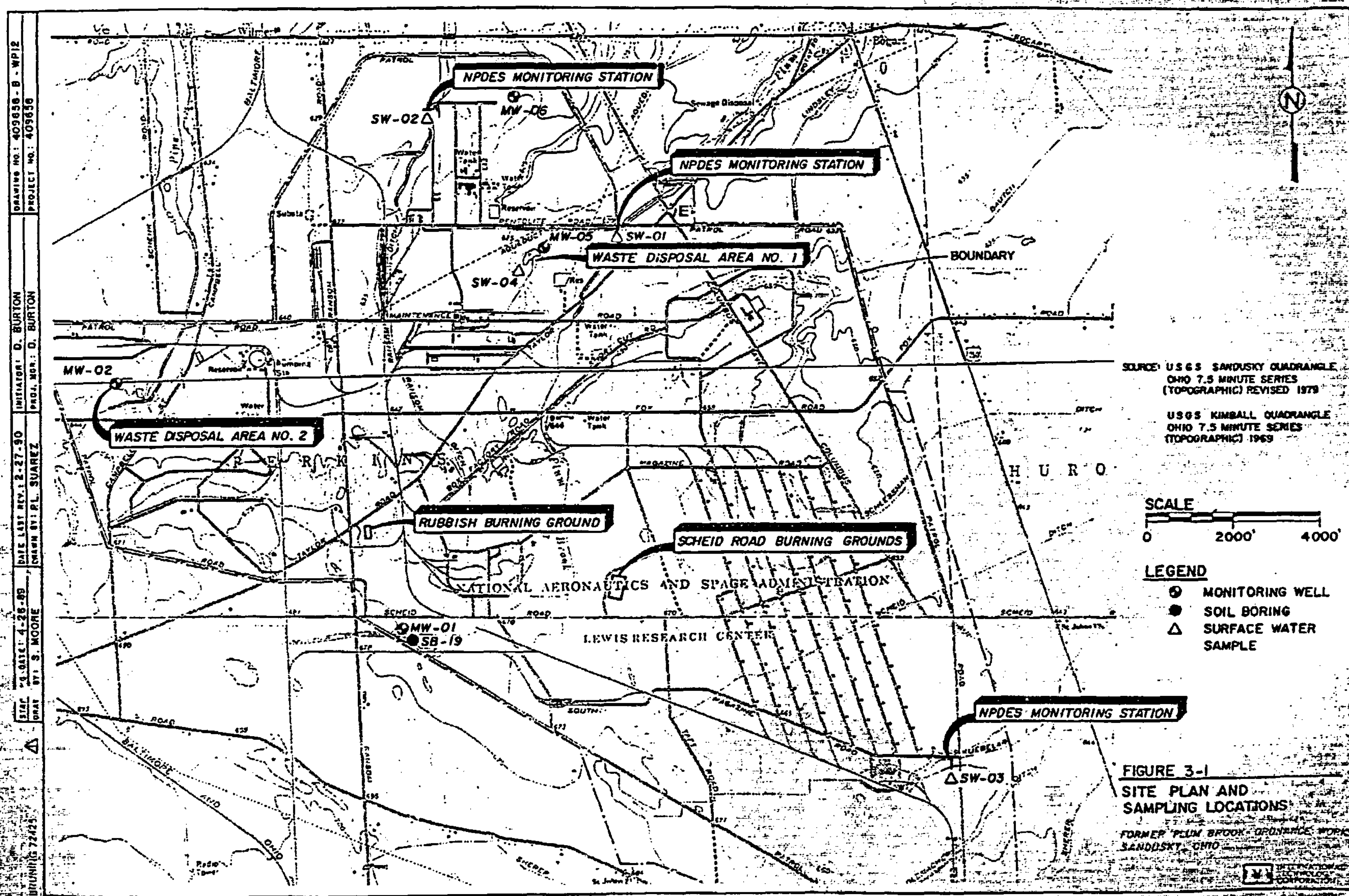

FIGURE 3-1
SITE PLAN AND SAMPLING LOCATIONS
FORMER PLUM BROOK ORDNANCE WORKS
SANDUSKY, OHIO

APPENDIX A

SECTION 4

1990 Closure Assessment for Tanks 21, 22, and 23

(Ebasco Environmental, May 1990)

CLOSURE ASSESSMENT FOR TANKS 21, 22, AND 23
AT PLUM BROOK STATION
SANDUSKY, OHIO

FOR
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
CLEVELAND, OHIO

PREPARED BY:

EBASCO ENVIRONMENTAL
5000 BRADENTON AVENUE, SUITE 200
DUBLIN, OHIO 43017

MAY 1990

APPENDIX B-1

UST Site Closure Assessment for Tanks 21, 22 and 23, EBASCO Environmental, 1990

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1.0 Introduction

On December 28, 1989 the permanent closure by removal of three (3) underground storage tanks (USTs) was performed at the NASA Plum Brook Station near Sandusky, Ohio. The tanks removed were Tank 21, Tank 22, and Tank 23. These tanks were located adjacent to the southern side of Building 1131, which is in the Reactor Facility area. Figure 1 shows the location of the Reactor Area within the boundaries of the Plum Brook Station. The tanks were adjacent to one another, lying in a north-south direction. Figure 2 shows the locations of the removed tanks relative to Building 1131. Tank 21 and Tank 22 were 7900 gallon fuel oil tanks which were not in use prior to their removal. Tank 23 was a 500 gallon waste oil tank which had been in use until the time of removal. These tanks were installed in 1961 and were constructed of steel.

Mr. Edwin Maglott of the State Fire Marshall's Office and Ms. Pamela Doerner of the Ohio Environmental Protection Agency were on site to oversee the removal of the USTs. Representatives of NASA Plum Brook Station, Warner Osborn Pardee and Turner Construction were also on site to monitor the removal of the USTs.

2.0 Tank Removal

The tops of the tanks were approximately six feet below grade. The soil from the surface to a depth of approximately eight feet was removed and placed in containment areas. These areas consisted of two roll off boxes and an area located approximately 100 yards east of the tank pit which was covered with plastic sheeting and bounded by hay bails. All soil excavation and tank removals were performed by Independence Excavating of Cleveland, Ohio, who was retained as a subcontractor to Turner Construction Company of Cleveland, Ohio.

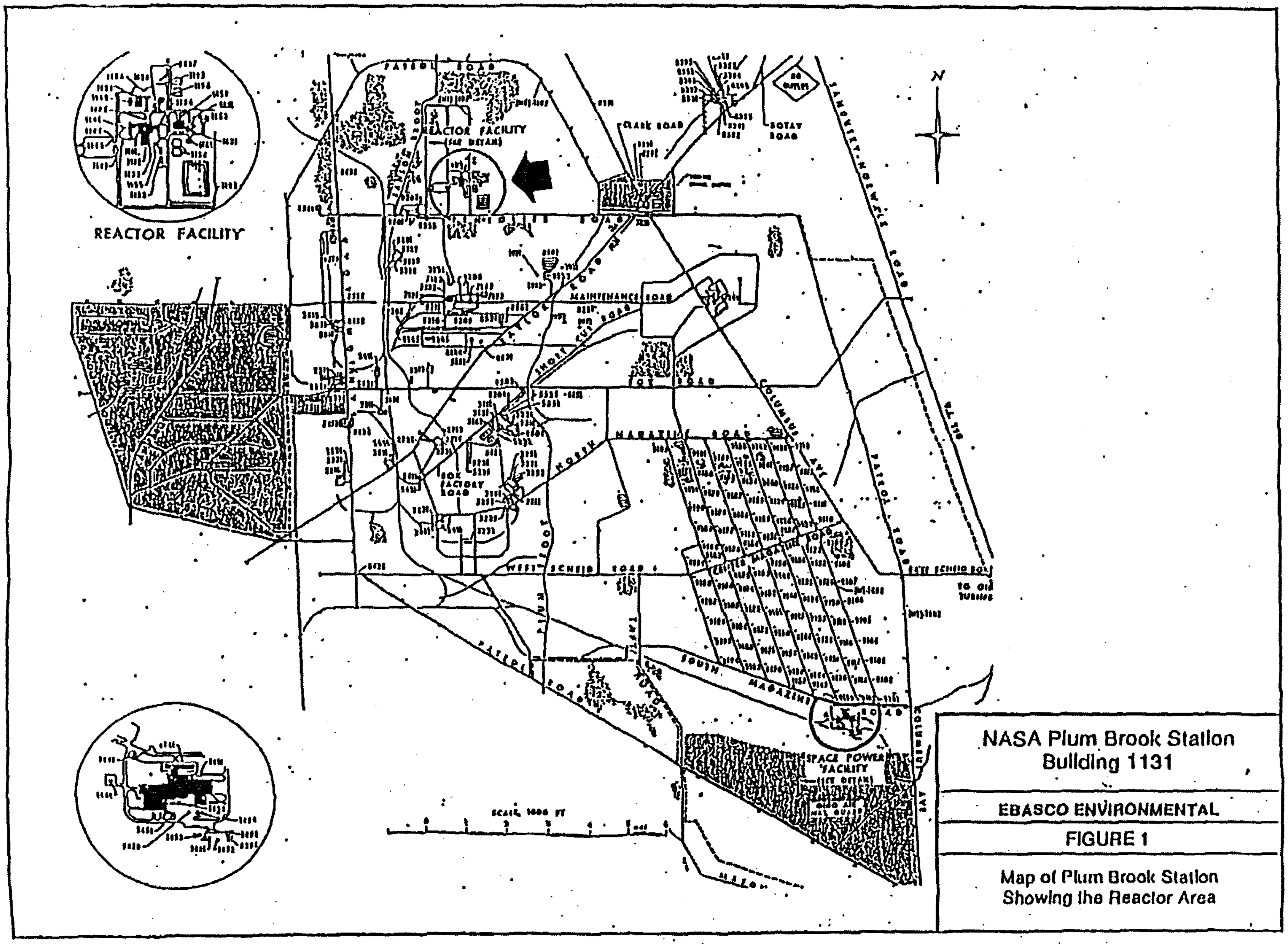
The three (3) USTs were cleaned prior to their removal. Before Tank No. 23 was cleaned, approximately 250 gallons of waste oil was removed and placed in 55 gallon drums. The cleaning of the USTs was performed by Clean Harbors of Cleveland, Ohio.

The three USTs were removed after the tank cleaning was completed. The pit appeared to contain a water-oil mixture after the tanks were removed. Two concrete slabs ran in an east-west direction beneath the tanks. These two concrete slabs were removed after the USTs were removed.

3.0 Sampling and Analysis

A total of eleven (11) soil samples were taken for this assessment. Eight (8) samples of the soils underlying the tanks were taken to detect the presence of any past or ongoing leaks. Three (3) samples of the tank cover soil were taken to determine if there had been appreciable surface spillage, overfilling or piping failures. An alphanumeric sample identification number encoded each sample's site location (Plum Brook Station), the building location (Building 1131), the sample medium (soil sample), and the sample number. Each sample was numbered sequentially, with the six samples taken from the pit bottom being samples PBS-1131-SS-1 through SS-6. Samples SS-7, SS-8 and SS-9 were taken from soil excavated prior to the removal of the USTs. Samples SS-10 and SS-11 were taken from the pit bottom after an additional 3-4 feet of soil was removed. Figure 2 shows the locations of the soil samples taken from the excavated area. The locations are shown relative to the locations of the three removed tanks.

The first set of samples (SS-1 through SS-6) was taken after the three (3) USTs and the concrete slabs were removed. Because the pit bottom soil was very unconsolidated after the removal of the tanks and concrete slabs direct sampling of the pit bottom was not possible. The soil samples

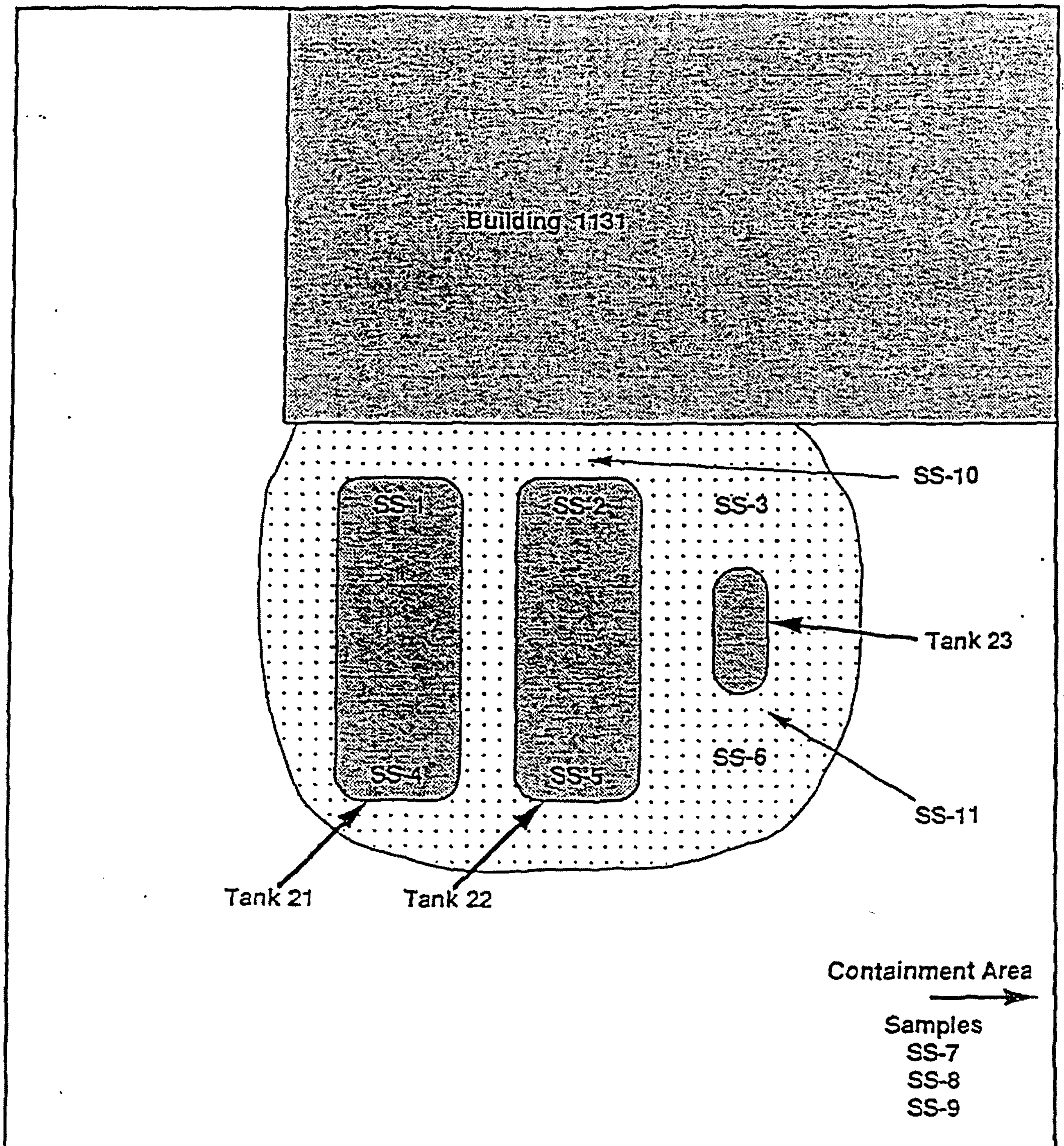


NASA Plum Brook Station
Building 1131

EBASCO ENVIRONMENTAL

FIGURE 1

Map of Plum Brook Station
Showing the Reactor Area



Buildings

Excavated Tank Pit

Locations of Excavated Tanks

SS-4 Soil Sample Locations

North

Not to Scale

NASA Plum Brook Station
Building 1131

EBASCO ENVIRONMENTAL

FIGURE 2

Locations of Removed Underground Storage Tanks and Soil Sampling Points were taken using the backhoe bucket to remove soil from the appropriate area of the pit bottom. Samples SS-1 through SS-6 were taken in this manner. Samples SS-1 through SS-6 were analyzed for Total Petroleum Hydrocarbons (TPH) (EPA Method # 418.1), volatile organics (EPA Method # 524.2), EP Toxicity for lead (EPA Method # 200.7), and flashpoint (American Society for Testing Materials Method # D-93).

As the samples were taken from the pit bottom, they were screened with an HNu photoionization detector to determine if there were non-methane volatile organics emanating from the soil samples. Table 1 shows the HNu readings for the samples taken from the pit bottom.

Table 1

HNu Readings for Samples SS-1 through SS-6

Sample I.D. Number	HNu Reading (ppm)
PBS-1131-SS-1	Not Taken
PBS-1131-SS-2	2.0
PBS-1131-SS-3	0.6
PBS-1131-SS-4	0.6
PBS-1131-SS-5	3.0
PBS-1131-SS-6	1.8
Background Range	0.0-0.1

Although there is not a direct correlation between HNu readings and the laboratory analytical results with regard to the degree of contamination, the HNu is useful in that it gives an indication as to whether volatile contamination is present in the soil sample.

Samples SS-7, SS-8 and SS-9 were taken from the soil excavated prior to the removal of the USTs. These samples were taken from the containment area east of Building 1131. Samples SS-7 through SS-9 were analyzed for TPH, volatile organics, EP Toxicity for lead, and flashpoint. HNu readings for samples SS-7, SS-8 and SS-9 were measured at background levels. This soil had been excavated on the previous day and therefore some volatilization of this soil may have already occurred.

Due to the apparent contamination, indicated by both the HNu readings and visual inspection of the tank, it was determined that additional soil would be removed before the excavation was backfilled. However, no additional soil was removed on December 28th, due to a lack of sufficient containment capacity. On December 29th additional containment areas were set up. Approximately 3-4 feet of additional soil was removed from the pit bottom. The depth of the excavation was approximately 13 feet after the additional excavation was completed. The soil at this depth was a consistent, well consolidated gray clay.

Two samples (SS-10 and SS-11) were taken from the pit bottom after the additional soil was removed Figure 2 shows the sample locations. Sample SS-10 was taken along the northern side of the pit were it appeared that the excavated soils had been discolored, possibly due to contamination from the excavated USTs. Sample SS-11 was taken along the eastern side of the pit beneath the previous location of the waste oil tank. Both samples had background readings when screened with the HNu. Both samples were analyzed for TPH and volatile organics.

4.0 Laboratory Results

All eleven of the soil samples were analyzed for TPH and volatile organics. Samples PBS-1131-SS-1 through SS-9 were analyzed for flashpoint and EP Toxicity for lead. Appendix A contains the complete set of laboratory data. The extracted lead in each of the samples was below the detection limit of 500 micrograms per liter. The flashpoint of all of the samples exceeded 200° F. The TPH concentrations for the eleven soil samples are listed in Table 2.

Table 2

Total Petroleum Hydrocarbons Concentrations for Samples SS-1 through SS-11

Sample I.D. Number	TPH Concentration (mg/kg)
PBS-1131-SS-1	1980
PBS-1131-SS-2	293
PBS-1131-SS-3	190
PBS-1131-SS-4	U
PBS-1131-SS-5	3050
PBS-1131-SS-6	762
PBS-1131-SS-7	801
PBS-1131-SS-8	3570
PBS-1131-SS-9	1590
PBS-1131-SS-10	114
PBS-1131-SS-11	U

U: below detection limits

The concentrations of TPH in the excavated cover soil (SS-7, SS-8 and SS-9) and the pit bottom soil indicate that contamination of the surrounding soils has occurred. High concentrations of total petroleum hydrocarbons (801, 3570, 1590 ppm) were found in the soil which covered the tanks (SS-7, SS-8, SS-9). This would seem to indicate that at least a portion of the soil contamination was due to piping failures, overfilling and/or surface spills, and not leakage from the tanks themselves. Samples taken from the pit bottom (SS-1 through SS-6) also showed elevated levels of total petroleum hydrocarbons, although no petroleum hydrocarbons were detected in sample SS-4. Samples SS-10 and SS-11, which were taken after additional soil was removed from the tank pit, did not show elevated levels of TPH.

Volatile organics also were detected in the soil samples. These volatiles included both possible petroleum degradation products and other compounds such as chlorinated organics which could have been found in the waste oil tank. Table 3 lists the concentrations for the organic compounds which were detected in the soil samples. Thirty-six organics were detected in various samples and the concentrations ranged as high as 13,388 ug/kg for naphthalene in SS-8. Concentrations were also in the thousands of parts per billion for 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, 1,1-dichloroethane, and total xylenes. The majority of the remaining chemicals were detected at concentrations in the hundreds of parts per billion. Most of these contaminants were detected in lower concentrations or not at all in the two soil samples which were taken after the additional soil was removed (SS-10, SS-11), although 1,1-dichloroethane, 1,2-dichloroethane, and chloroethane were detected in much higher concetrations in samples SS-10 and SS-11. Therefore, vertical contaminant migration may be limited to a few chlorinated organics.

TABLE 3	Soil Sample Concentrations for Samples Taken at the NASA Plum Brook Station										
Page 1 of 2	Building 1131 (Reactor Facility) Underground Storage Tank Removals										

Samples SS-1 through SS-6 were taken from the pit bottom, SS-7, SS-8, and SS-9 were taken from the excavated soils, and samples SS-10 and SS-11 were taken from the pit bottom after approximately 4 feet of additional soil was removed

Concentrations of TPH are in mg/kg and volatile concentrations are in micrograms/kg

	1131-SS-1	1131-SS-2	1131-SS-3	1131-SS-4	1131-SS-5	1131-SS-6	1131-SS-7	1131-SS-8	1131-SS-9	1131-SS-10	1131-SS-11
Total Petroleum Hydrocarbons (TPH) (mg/kg)	1980	293	190	u	3050	762	801	3570	1590	114	u

Volatile Organics (ug/kg)	1131-SS-1	1131-SS-2	1131-SS-3	1131-SS-4	1131-SS-5	1131-SS-6	1131-SS-7	1131-SS-8	1131-SS-9	1131-SS-10	1131-SS-11
Dichlorodiflouromethane	u	J 36	u	u	u	u	J 24	J 36	u	u	61
Chloromethane	u	u	u	u	u	u	u	u	u	u	u
Vinyl Chloride	u	u	u	u	u	u	u	u	u	u	u
Bromomethane	u	u	u	u	u	u	u	u	u	u	u
Chloroethane	u	u	u	u	u	u	u	u	u	990	105
Trichlorofluoromethane	u	J 120	u	u	u	u	J 112	u	u	u	20
1,1 Dichloroethene	u	u	u	u	u	u	u	u	u	u	u
Methylene Chloride	u	446	u	u	503	u	426	205	u	25	109
trans-1,2-Dichloroethene	u	u	u	u	u	u	u	u	u	u	17
1,1 Dichloroethane	482	4483	u	u	u	u	u	u	u	6120	673
cis-1,2 Dichloroethene	u	u	u	u	u	u	u	u	u	u	165
2,2 Dichloropropane	u	u	u	u	u	u	u	u	u	u	u
Chloroform	u	u	u	u	u	u	u	u	u	J 1	u
Bromochloromethane	u	u	u	u	u	u	u	u	u	u	u
1,1,1-Trichloroethane	197	423	891	u	u	u	u	u	J 123	u	u
1,1 Dichloropropene	u	u	u	u	u	u	u	u	u	u	u
Carbon Tetrachloride	u	u	J 91	u	u	u	u	u	u	u	u
1,2 Dichloroethane	u	u	u	u	u	u	u	u	u	178	u
Benzene	u	J 28	u	J 32	J 16	u	J 25	J 25	u	J 2	u
Trichloroethene	589	577	u	u	836	u	846	u	1019	u	997
1,2 Dichloropropane	u	u	u	u	u	u	u	u	u	u	u
Bromodichloromethane	u	u	u	J 23	u	u	u	u	u	u	u

u	Undetected
J	Below quantitation limits; Estimated Value

TABLE 3 Continued — Page 2 of 2

Soil Sample Concentrations for Samples Taken at the NASA Plum Brook Station
Building 1131 (Reactor Facility) Underground Storage Tank Removals

Volatile Organics (ug/kg)	1131-SS-1	1131-SS-2	1131-SS-3	1131-SS-4	1131-SS-5	1131-SS-6	1131-SS-7	1131-SS-8	1131-SS-9	1131-SS-10	1131-SS-11
Dibromomethane	u	u	u	u	u	u	u	u	u	u	u
Toluene	u	J 26	u	J 17	J 23	u	J 27	J 41	u	J 2	6
1,1,2-Trichloroethane	u	u	u	143	u	u	u	u	u	u	u
1,3 Dichloropropane	u	u	u	u	u	u	u	u	u	u	u
Tetrachloroethene	u	677	1043	u	u	u	u	u	u	u	u
Dibromochloromethane	u	u	u	u	u	u	u	u	u	u	u
1,2-Dibromomethane-EDB	u	u	u	u	u	u	u	u	u	u	u
Chlorobenzene	u	u	u	u	u	u	u	u	u	u	u
Ethylbenzene	311	431	u	1093	329	u	548	543	140	11	11
1,1,1,2-Tetrachloroethane	u	u	u	u	u	u	J 41	375	u	J 2	u
m & p -Xylenes	430	240	u	739	566	u	647	1115	J 38	19	4
o-Xylene	204	J 80	u	413	170	u	424	703	u	14	J 1
Styrene	u	u	u	u	u	u	u	u	u	u	u
1,1,2,2-Tetrachloroethane	u	u	u	194	u	463	231	283	u	5	12
Isopropylbenzene	J 84	u	u	u	128	u	176	380	u	10	u
Bromoform	u	u	u	u	u	u	u	u	u	u	u
1,2,3- Trichloropropane	u	u	u	u	u	u	u	u	u	9	u
n-Propylbenzene	235	J 71	u	u	289	u	369	612	u	12	u
Bromobenzene	u	u	u	u	u	u	u	u	u	u	u
1,3,5 Trimethylbenzene	1775	692	269	528	1685	166	2953	4365	178	106	u
4-Chlorotoluene	u	u	u	u	u	u	u	u	u	u	u
2-Chlorotoluene	u	u	u	u	u	u	u	u	u	u	u
tert-Butylbenzene	288	183	240	129	422	u	645	618	u	23	15
1,2,4 Trimethylbenzene	2470	1000	598	1122	2348	270	3909	4413	204	115	u
sec-Butylbenzene	290	125	J 67	u	430	u	682	858	u	11	u
p-Isopropyltoluene	639	337	u	u	806	u	1503	1854	u	27	u
1,3 Dichlorobenzene	u	u	u	u	u	u	u	u	u	J 2	u
1,4 Dichlorobenzene	u	u	u	u	u	u	u	u	u	J 2	u
n-Butylbenzene	u	u	u	u	u	u	u	u	u	u	u
1,2 Dichlorobenzene	u	u	u	u	u	u	u	J 31	u	u	u
Dibromo-3-Chloropropane	u	u	u	u	u	u	u	u	u	u	u
1,2,4 Trichlorobenzene	575	185	218	u	u	u	u	u	193	3	u
Hexachlorobutadiene	404	J 82	u	u	u	u	u	u	u	u	u
Naphthalene	4550	3070	3523	4935	6332	1743	7801	13388	1255	548	223
1,2,3 Trichlorobenzene	1025	143	490	385	J 45	178	J 115	198	u	5	6

u Undetected

J Below quantitation limits; Estimated Value

5.0 Discussion and Recommendations

The results of the laboratory analyses indicated that contamination of the surrounding soils has occurred. High concentrations of total petroleum hydrocarbons (TPH) were found in the majority of the soil samples, and elevated concentrations of volatile organic compounds were found in all of the soil samples. The tanks were visually inspected by the EBASCO engineer after their removal and were found to be in good condition structurally. There were no apparent holes or cracks in the tanks and there was very little visible corrosion. This would indicate that the cause of the leakage was from piping failures or overfilling. The concentrations of organics and TPH found in the soil samples were among the highest encountered at any of the tank areas sampled at Plum Brook Station.

At present, no state or federal standards are available for TPH and organic compounds in soils. Guidelines from the Ohio EPA concerning soil remediation levels have not been promulgated because of a delay in the release of similar federal standards. Although there are no soil standards at this time, representatives of both the State Fire Marshall's Bureau of Underground Storage Tank Regulation (BUSTR) and the Ohio EPA have indicated that acceptable levels of TPH in soil range from 50 - 100 mg/kg. Concentrations of TPH exceeded 700 mg/kg in 6 of the 11 samples. The analyses also indicated that numerous chlorinated organic compounds were present in the surrounding soil.

Because of the degree of contamination encountered in the soil samples taken, and also the apparent visible contamination of the tank pit bottom, additional investigation of the area surrounding this tank area is warranted. This area has been included under the scope of work for the UST Corrective Actions Remedial Investigation / Feasibility Study of the previously assessed tank areas at Plum Brook Station, being performed under Task Order 028 of NASA/Ebasco Contract Number NASW-4301.

APPENDIX A

SECTION 5

1991 Underground Storage Tank Study

(Ebasco Environmental, November 1991)

NASA PLUM BROOK STATION

UNDERGROUND STORAGE TANK
CORRECTIVE ACTIONS REMEDIAL INVESTIGATION/FEASIBILITY STUDY

- PHASE I REPORT -
November 1991

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1.0 INTRODUCTION

This report summarizes the work performed during the first phase of an underground storage tank (UST) Corrective Actions Remedial Investigation / Feasibility Study (RI/FS) at the NASA Plum Brook Station (PBS). The projected scope of the overall investigation was detailed in the PBS UST Corrective Actions RI/FS Work Plan developed by NASA and Ebasco Environmental (August, 1990 - Final Draft).

1.1 Objectives

The USTs at PBS have been the subject of study since new UST regulations went into effect in 1988. The ultimate objective of the federally and state-mandated UST corrective actions requirements is the cleanup of contaminated soil and ground water associated with leaking USTs. The purpose of the overall Corrective Actions RI/FS project of which the current investigation is an initial element, is to: characterize the nature and extent of any contamination in the soil, ground or surface water which has resulted from leaking UST systems at four (4) separate areas at PBS; evaluate the currently available remedial alternatives for addressing this contamination; and develop a Corrective Actions Plan for the UST sites for managing the associated risks to human health and the environment.

The primary objectives of the current investigation were to compile all the currently available data from the previous and current investigations for each of the four (4) Tank Areas, determine the contaminants present at each Tank Area (and consequently, the contaminants not present), conclude which detected contaminants were logically and physically linked to the reported contents of the former USTs and identify the pathways by which the residual contamination present may spread. A secondary objective of the investigation was to document either the presence or absence of contaminants at each Tank Area so that a more efficient, targeted analytical program could be designed for any future characterization work that may be required.

1.2 Project Background

To comply with the 1988 regulations, twenty (20) USTs at the NASA Lewis Research Center (LeRC) and nineteen (19) USTs at PBS were identified as requiring study under a UST Compliance Program. The tanks were designated for study based on information contained in LeRC and PBS UST inventory listings. In the fall of 1989, three more tanks at LeRC were located, identified, and scheduled for removal. All forty-two tanks contained petroleum products, hazardous spent solvents or unknown products.

A UST Compliance Program was designed by Ebasco Environmental and NASA to assure that the LeRC (which administratively includes PBS) was in compliance with the applicable state and federal regulatory requirements for USTs. As part of implementing this program, the fourteen (14) tanks at PBS were removed, and UST Closure Assessments were conducted by Ebasco. The locations of these former tank areas are shown in Figure 1-1. Table 1-1 summarizes the principal events of the PBS UST project history. Sampling and monitoring performed during the closure assessments indicated that the tanks had been leaking or that spills had apparently occurred. As a result, a 3-phase Corrective Actions Remedial Investigation / Feasibility Study (RI/FS) for the PBS was developed to characterize the nature and extent of any contamination, and to evaluate the currently available remedial alternatives for addressing the contamination. Phase I was the preliminary characterization effort aimed at describing current conditions at the tank areas. Phase II of the plan was the Remedial Investigation, and Phase III was the Feasibility Study.

Previously, the tank areas were assessed during tank closure activities, and during an initial field program which included limited soil excavation, soil sampling, ground water monitoring well installation, and soil gas surveys. The additional characterization activities performed in this study focus on determining the full nature of the residual contamination, and the potential for off-site migration of contaminants.

1.3 Facility Background Information

The Plum Brook Station is located approximately 4 miles south of Sandusky, Ohio, and covers approximately 6500 acres. Approximately 160 structures, many of them storage facilities, are located at the Plum Brook Station (Environmental Resources Document for NASA Lewis Research Center, May 1983). Much of the facilities at PBS are inactive currently. Activities associated with the four primary areas of investigation during the Phase 1 study are discussed as follows. Building 7131 at the Garage and Maintenance area continues to be used for vehicle and equipment maintenance, and is currently staffed with two to three employees. The remaining buildings in the Garage and Maintenance area, Buildings 7122 and 7121, are not staffed and are not in active use. During the Phase 1 investigation, operations were taking place at the Space Power Facility (SPF) and are expected to continue on an intermittent basis during the near future as various projects are undertaken at the SPF. The pump station, Building 8133, is staffed by two employees currently. The reactor area is inactive currently and no staff is assigned to the area. In total there are approximately 100 people working at the Plum Brook Station, most of whom are not regularly in the four Phase 1 areas of concern.

Acreage within the boundary of the site is primarily unused open space comprised of woodland, brushland and grassland. Approximately 23% of the site is associated with facilities and site operations (Environmental Resources Document for NASA Lewis Research Center, 1990).

The land immediately surrounding the site is used as a rural residential area with homes along the adjacent roadways. Farm fields and open fields with some wooded tracts account for the remainder of the immediate surrounding properties.

There are 130 ground water well beyond the Plum Brook Station boundary which are within a four mile radius of the site. None of these ground water wells are within 3/4 of a mile of any of the tank areas included in the Phase 1 investigation.

The Plum Brook Station is underlain by lucustrine glacial deposits and consolidated sedimentary rock. The lucustrine deposits are composed of clays and silts. These deposits were settled out of glacial lakes. The lake sediments are approximately 5 to 20 feet thick. Lucustrine deposits are poorly drained (Environmental Resources Document for NASA Lewis Research Center, May 1983).

The bedrock of the area is consolidated sedimentary rock. The regional dip of the strata is easterly, and younger rocks crop out progressively from west to east. The bedrock is limestone in the western part of the facility and shale in the eastern portion. The limestone formations have considerable variation in physical and chemical structure; nevertheless, the limestone has high porosity and makes excellent aquifers. The shale material has little porosity, except for fractures near the surface (Environmental Resources Document for NASA Lewis Research Center, May 1983).

1.4 Previous Investigations

Nineteen (19) USTs at PBS were identified as requiring study under a UST Compliance Program developed by Ebasco in 1989. From late June through December of 1989, fourteen (14) USTs were removed from the PBS in accordance with this program. Table 1-2 identifies the tanks, indicates the areas from which they were removed, and notes the type of material reported to have been stored in each tank given the best available records.

The removal of the USTs included the performance of a closure assessment as required by regulation. In addition, an initial remediation effort was conducted at the Garage and Maintenance Area (Building No. 7132), and soil gas surveys were performed at three of the four tank areas as indicated in Table 1-1. The results of each of these prior investigations is included in the appropriate subsections of Section 3.0.

TABLE 1-1
Summary of PBS UST Activities and Related Events

DATE	ACTIVITY/EVENT
1988, May	New Ohio State UST Regulations Promulgated - O.A.C. 1301:7-7-28 [Ohio Fire Code Article 28, Flammable and Combustible Liquids]
1988, December 22	New Federal UST Regulations Promulgated - 40 CFR Part 280 [Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks]
1989, June 13	NASA Meets with Ohio State Fire Marshal's Office, Bureau of Underground Storage Tank Regulation (BUSTR) to Discuss Compliance with State and Federal UST Regulations
1989, June	NASA Receives Permit from BUSTR to Remove Three USTs at the PBS
1989, June 28 - July 5	Underground Storage Tanks 7132-1 (#33), 7132-2 (#34), 7132-3 (#35) are Removed from the Garage and Maintenance Area - Closure assessment (including soil, ground water and surface water sampling and analysis) performed
1989, July	UST Compliance Program Developed for PBS - Program outlined the UST removal and/or replacement options available to NASA to comply with the new regulations over a 3-year period
1989, August	Monitoring wells installed at the Garage and Maintenance Area
1989, August	Closure Assessment Report for PBS USTs #33, #34 and #35 is Finalized
1989, September	Underground Storage Tanks 7121-1 (#28), 7121-2 (#29), 7121-3 (#30), 7121-4 (#31), 7131-1 (#32) are Removed from the Garage and Maintenance Area - Closure assessment (including soil sampling and analysis) performed

TABLE 1-1 (continued)

DATE	ACTIVITY/EVENT
1989, September	Underground Storage Tank 8133-1 (#39) is Removed from the Pump Station Area - Closure assessment (including soil sampling and analysis) performed
1989, September	Underground Storage Tanks 1411-1 (#24) and 1411-2 (#25) are Removed from the Space Power Facility - Closure assessment (including soil sampling and analysis) performed
1989, September	Preliminary Remediation Effort Undertaken at the Garage and Maintenance Area - 1,320 cubic yards of soil removed
1989, October	BUSTR Directs Further Removal of Soil from the Tank Pit at the Garage and Maintenance Area - 18 additional inches of soil is removed
1989, October 18 - 25	Soil Gas Surveys are Conducted at the Garage and Maintenance Area, the Pump Station Area and the Space Power Facility Area
1989, December	Closure Assessment Report for PBS USTs #24, #25, #28, #29, #30, #31, #32 and #39 is Finalized
1989, December	Underground Storage Tanks 1131-1 (#21), 1131-2 (#22) and 1131-3 (#23) are Removed from the Reactor Building Area - Closure assessment (including soil sampling and analysis) performed
1990, January	Revised NASA UST Compliance Program is Finalized
1990, May	Regulatory Jurisdiction for the PBS USTs is Turned Over to the OEPA Northwest District Office by BUSTR Because of Evidence of Hazardous Waste Contamination From Some of the USTs Removed

TABLE 1-1 (continued)

DATE	ACTIVITY/EVENT
1990, May	Closure Assessment Report for PBS USTs #21, #22 and #23 is Finalized
1990, June 12	Ebasco Submits Draft Work Plan for the PBS UST Corrective Actions RI/FS to NASA for Review
1990, August 9	Ebasco Submits Final Work Plan for the PBS UST Corrective Actions RI/FS to NASA
1990, September 25	NASA Submits Work Plan for the PBS UST Corrective Actions RI/FS to the Ohio EPA for Review and Concurrence
1990, October 5	Ebasco Begins Work on the First Phase of the Corrective Actions RI/FS Project to Characterize the Current Conditions at the Former UST Areas - Monitoring wells installed at all areas - Soil, ground water and sediment samples analyzed

TABLE 1-2

PBS USTs Removed During the 1989 Calendar Year

Location	No. of Tanks	Capacity (Gallons)	Contents
Garage and Maintenance Area:			
Building 7121	1	3,000	waste oil and solvents
	3	700	acetone, TCE, and TCA, respectively
Building 7131	1	1,500	waste oil
Building 7132	3	9,000	gasoline
Space Power Facility:			
Building 1411	2	1,000	waste oil
Pump Station:			
Building 8133	1	750	gasoline/diesel
Reactor Area:			
Building 1131	2	7,900	gasoline/diesel and fuel
	1	500	waste oil and solvents

3.3.3 Conclusions for Pump Station Area

The former gasoline tank at the Pump Station was found to contain holes and be leaking when it was removed. Visible contamination was present in the tank pit and significantly elevated BTEX concentrations were measured in the tank pit soil samples taken during the removal operation. The subsequent soil gas survey identified very low concentrations of the target fuel compounds in a set of sample locations west of Building No. 8133 along a line from the former UST location toward the North-North-East (NNE). A sample location east of the Building next to the electrical gear at the northeast corner showed evidence of an isolated spill or leak of fuel product not related to the former UST or of contaminant migration under the Building. No target solvent compounds were detected by the soil gas analyses. The most recent sampling indicated trace concentrations of TPH in all soil samples taken at this area. The source of the TPH is currently not clear, as a TPH concentration twice the value found in the samples closest to Building No. 8133 was measured at the boring location anticipated to be a background sample.

No soil or ground water contamination by volatile or semivolatile organic compounds, pesticides or PCBs was found in the samples taken during the current investigation. No inorganics were highlighted as problematic or potentially problematic based on this sampling. The trace levels of semivolatile contamination found in the one Pump Station sediment sample taken would not appear to be associated with the former UST, as trace PAH concentrations were also detected in the background soil boring.

Transport and migration of any residual contamination from the former UST would appear to be linked to ground water movement. Preferential migration may be along the buried raw or potable water lines to the west and northwest of the Building or along and under the Building itself. The media along these preferential migration routes may have become secondary sources of low level TPH contamination.

3.4 Reactor Area

The Reactor Area consists of a number of buildings, roads, tunnels, open areas, structures. Figure 3-1 shows the location of the Reactor Area at the Plum Brook Station. On December 28, 1989, the permanent closure by removal of three (3) USTs was performed.

The USTs were lying adjacent to each other in a north-south direction, south of Building No. 1311. Two (2) of the tanks, 1311-1 (#21) and 1311-2 (#22) were 7,900 gallon steel fuel oil tanks that were not in use at the time of their removal. Tank 1311-3 (#23) was a 500 gallon steel waste oil tank which was in use until its removal. All three tanks were installed in 1961.

3.4.1 Previous Investigations and Results

3.4.1.1 UST Closure Assessment

A UST closure assessment was performed as part of the tank removal operation. The study consisted of a visual inspection of the tanks during and after removal, environmental sampling, and air monitoring. Mr. Edwin Maglott of the State Fire Marshall's Office, and Ms. Pamela Doerner of the Ohio EPA, along with the Ebasco field representative, were onsite to oversee the removal of the USTs, and to inspect the tanks. After the tanks were removed, they were visually inspected and found to be in good condition structurally. There were no apparent holes or cracks in the tanks, and there was very little visible corrosion.

Environmental sampling consisted of the collection of eleven (11) soil samples. Soil samples were screened with an HNu photoionization meter to gain an indication of whether volatile organic compounds were present in the samples. Three (3) samples were taken from the tank cover soil to determine if there had been appreciable surface spillage, overfilling or piping failures. Six (6) samples were taken from the soil underlying the tanks, to detect the presence of any past or ongoing leaks.

Soil samples 1131-SS-1 through 1131-SS-6 were collected from beneath the tanks as shown in Figure 3-35 and were analyzed for TPH, VOCs, EP Toxicity lead, and ignitability. Samples 1131-SS-7, 1131-SS-8 and 1131-SS-9 were taken from the cover soil prior to the removal of the USTs. These samples were taken from the soil containment area which was set up east of Building No. 1131. The cover soil samples were analyzed for TPH, VOCs, EP Toxicity lead, and ignitability.

Due to the apparent contamination, indicated by both the HNu readings and visual inspection of the pit, it was determined that additional soil would be removed before the tank pit was backfilled. However, no additional soil was removed on December 28th, due to a lack of sufficient soil containment capacity. On December 29th, additional containment areas were set up. Approximately 3 to 4 feet of additional soil was removed from the pit bottom. The depth of the excavation was approximately 13 feet after the additional excavation was completed. The soil at this depth was a hard, homogeneous grey clay.

Two additional samples (1131-SS-10 and 1131-SS-11) were taken from the pit bottom after the additional soil was removed. Figure 3-35 shows the sample locations. Sample 1131-SS-10 was taken along the northern side of the pit where it appeared that the excavated soils had been discolored, possibly due to contamination from the excavated USTs. Sample 1131-SS-11 was taken along the eastern side of the pit beneath the previous location of the waste oil tank. Both samples had background readings when screened with the HNu. Both samples were analyzed for TPH and VOCs. The results of these analyses are summarized in Table 3-15.

Samples 1131-SS-1 through 1131-SS-9 had lead concentrations below the detection limit, and Flashpoints above 200°F. The concentrations of TPH in the excavated cover soil and the pit bottom indicated that contamination of the surrounding soils has occurred. As high concentrations of TPH were found in the soil which covered the tanks, it would seem that at least a portion of the soil contamination was due to piping failures, overfilling or surface spills. Five of the samples from the pit bottom also showed elevated levels of TPH. Samples 1131-SS-10 and 1131-SS-11, taken after an additional 3-4 feet of soil was removed, did not show elevated levels of TPH.

Volatile organics were also detected in the soil samples. They included both possible petroleum degradation products and other compounds such as chlorinated organics which could have been found in the waste oil tank. Thirty-seven (37) organics were detected in various samples and the concentrations ranged as high as 13,388 ug/kg for naphthalene in 1131-SS-8. Ten VOCs were detected at ppm levels.

3.4.1.2 Soil Gas Survey

No soil gas survey was conducted at this location.

3.4.2 Current Investigation and Results

The field activities at the Reactor Area associated with the current investigation were conducted on the following dates:

Soil Sampling: 12/4/90, 12/13/90, 12/14/90 and 12/17/90
Ground Water Sampling: 1/15/91 and 1/16/91
Ground Water Level Measurements: 1/9/91, 5/9/91

The results of these sampling and analysis activities, are presented below.

3.4.2.1 Soil Sampling and Analyses

Six soil borings were completed around the Reactor Area. These borings were completed to depths ranging from 10' to 22'. PBS-RA-01 and PBS-RA-06 were planned to be background locations, while the remaining locations, PBS-RA-02 through PBS-RA-05 had been selected to characterize the contaminated area.

All of the soil borings in the Reactor Area were completed as ground water monitoring wells. These locations are shown on Figure 3-36.

3.4.2.1.1 Physical and General Stratigraphic Characteristics

Based on the six boreholes made at the Reactor Area as part of the current investigation, the overburden material at the Reactor Area has an average thickness greater than 22 feet. Figure 3-37 presents the generalized stratigraphic section for the Reactor Area showing the types of soils and the order of occurrence of the soil units encountered. The surface soil in this area is brown fine sand, with a mean thickness of 6 to 7 feet. In some places, this unit is underlain by grey fine sand which varies in thickness from 2.5 to more than 14 ft. The grey fine sand is followed by grey sandy-clayey silt, which has a maximum thickness of 4 feet and overlies the grey silty clay. At PBS-RA-01, the brown fine sand is underlain by grey sandy-clayey silt with a thickness of 8 feet. This unit was followed by grey clayey silt. The bedrock was not encountered by any boring at this area. The overburden does not appear, to the extent that it has been investigated, to be a water bearing unit. The monitoring wells exhibit low yield as was seen during well the development effort. Following the purging of about 6 gallons of water, the wells were unable to sustain enough water to continue purging.

3.4.2.1.2 Nature and Extent of Contamination

The samples collected from the boreholes at the Reactor Area were composited over the total depth of the boring except for the volatiles samples which were ranging from 4 to 10 feet below the ground surface. The complete results of the chemical analyses of these samples are presented in Table A-4 in Appendix A. A summary of the detected organic compounds is presented in Table 3-16. Excluding the probable laboratory contaminants, four (4) different volatile organic compounds were detected in this set of samples. These four volatiles (1,2-Dichloroethene (Total) at 120 ppb, 1,1,1-Trichloroethane at 22 ppb, Trichloroethene at 760 ppb, and Tetrachloroethene - 19 ppb) were all detected only in one of the six samples, PBS-RA-SB-05. This sample was taken approximately 70 feet east of the former UST location. The distribution of the organics detected in the soils at this Tank Area is presented in Figure 3-38. Table 3-16 and Figure 3-38 also indicate that five or six non-lab contaminant semivolatile organic compounds belonging to the PAH family also were reported by the laboratory for the two samples just south of the Building. As is noted, the laboratory reported estimated concentrations for these compounds at levels associated with 20% to 65% of the sample detection limit. Consequently, the listed semivolatiles may practically be considered not detected. TPH was detected at 3 of the 6 sampling locations. The highest measured value of 159 ppm, was associated with the sampling location due west of Building No. 1131 next to the roadway. The other two concentrations, for the two soil samples taken south of Building No. 1131, were approximately at the detection limit. Using the inorganics comparison methodology and criteria described earlier, no inorganics are indicated to be of concern in the soils at the Reactor Area. Two inorganics (Calcium and Magnesium) were detected at levels exceeding their calculated UCLs indicating signicant difference from background, but these inorganics are not generally of concern with respect to toxic health hazard.

3.4.2.2 Ground Water Sampling and Analysis

3.4.2.2.1 *Nature and Extent of Contamination*

Two ground water samples were taken at the Reactor Area as part of the current investigation, one from a well expected to be heavily contaminated (PBS-RA-04) and one from a well expected to be clean (PBS-RA-01). The complete results of the chemical analyses of these samples are presented in Table B-4 in Appendix B. A summary of the detected organic compounds is presented in Table 3-16. As can be seen, no volatile or semivolatile organics, PCBs, or TPH were detected in either of these two samples. A very trace amount (0.097 ppb) of the insecticide Beta-BHC was detected in the presumed background well (see Figure 3-39). Because insecticides were not stored in the USTs, the presence of the Beta-BHC in ground water is not associated with the former USTs.

3.4.2.2.2 Ground Water Flow

Figures 3-40 and 3-41 present the local ground water elevation contours developed from the January 9, 1991 and May 9, 1991 ground water level measurements, respectively. The ground water elevation contours for this area reflect the presence of the underground tunnel which connects Building Nos. 1134, 1131 and 1152 in this area. A dewatering operation is taking place at this tunnel in which ground water draining into the area around the tunnel is collected and pumped out. The dewatering in this area has a pronounced local effect on ground water elevations and flow direction. The dewatering of the tunnel dominates the local ground water flow pattern in the surrounding area, including the former location of the USTs. This local effect diminishes with distance from the dewatering point, and the overall site ground water level contours shown in Figure 3-15 become more representative. In the area of the excavated tanks the ground water table during the Phase I investigation was above the level were the removed tanks had been located.

Taking the maximum theoretical hydraulic conductivity for the various soil units observed to be present at this Tank Area, the maximum horizontal ground water flow velocities associated with the January and May 1991 were calculated to be 72 and 58 feet per year, respectively. These calculated velocities are roughly a factor of 30 to 50 higher than the velocities calculated for the other areas. This calculation also highlighted the relative steepness of the gradients in this area.

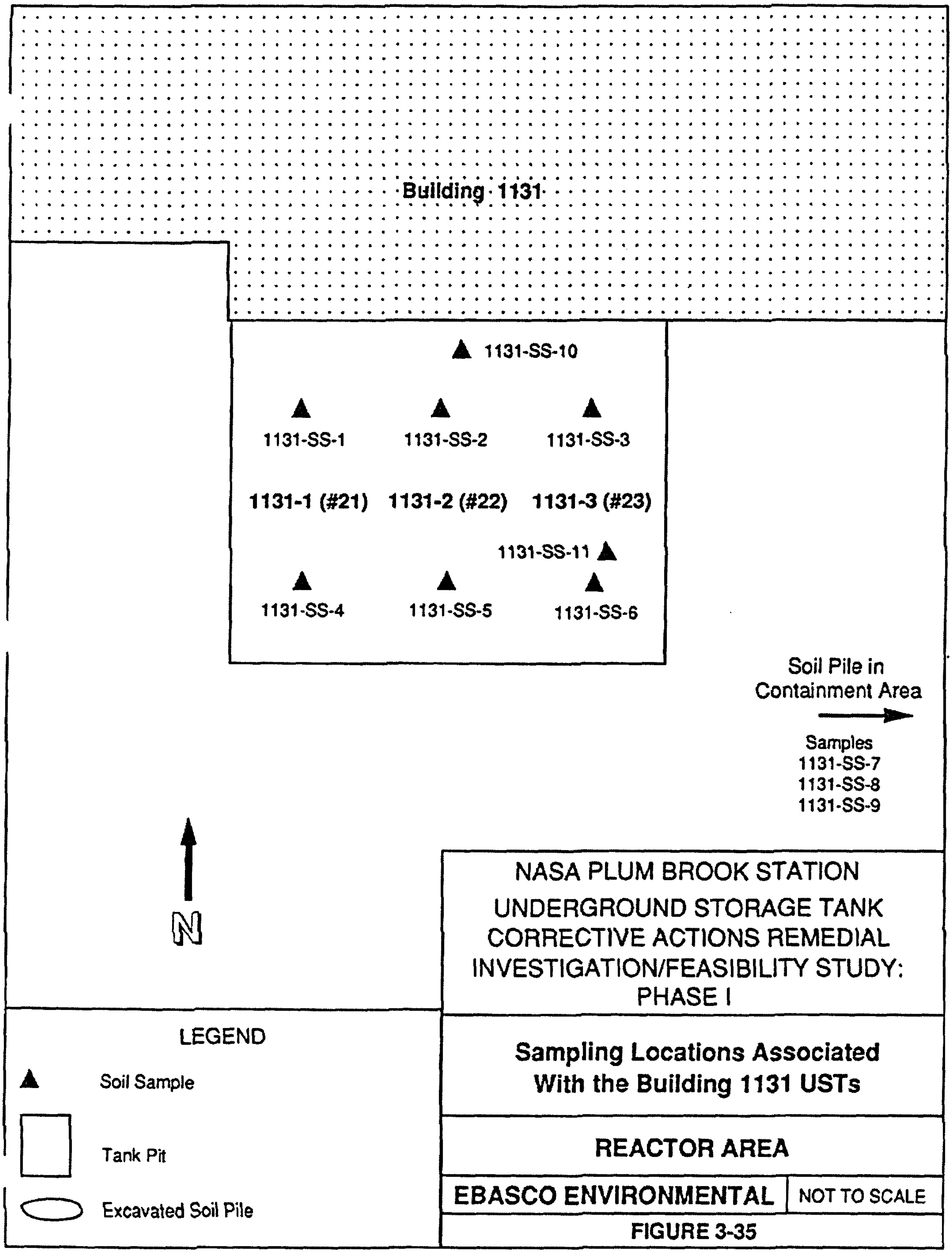
3.4.2.3 Sediment Sampling and Analysis

No sediment sampling or analysis was performed at the Reactor Area as part of the current investigation.

3.4.3 Conclusions for Reactor Area

Although the USTs removed at the Reactor Area appeared to be in good condition structurally, with no holes or cracks, initial soil sampling identified significantly elevated levels of a variety of fuel products and solvent compounds in the soil beneath and surrounding the tanks. The most recent sampling confirmed the presence of solvents in the soils from the sampling locations next to the south side of Building No. 1131. Trace or low levels of TPH were found in the three soil samples taken adjacent to the south or west sides of the Building. Trace levels of a number of semivolatile PAH compounds were also found in the samples closest to the former UST location. It is not clear at this time that the source of the PAHs is the former USTs, given the low concentrations of these compounds reported by the laboratory. No inorganics were highlighted to be of possible concern based on the current investigation. No PCBs were detected in any soil or ground water sample and a trace level of an insecticide was detected in the intended "background" location ground water sample for this Tank Area.

Transport and migration of contamination from the former UST locations at the Reactor Area would appear to be dictated by the movement of ground water and the apparent tunnel dewatering operation. This activity, as reflected in the local ground water level contours constructed for this Tank Area, would appear to be drawing the contamination away from the former UST locations toward the northwest. As the collected ground water is not treated before being discharged into Pentolite Ditch, any contaminated ground water collected at the tunnel would be transported directly to the surface water and sediments in the Ditch.



NASA PLUM BROOK STATION

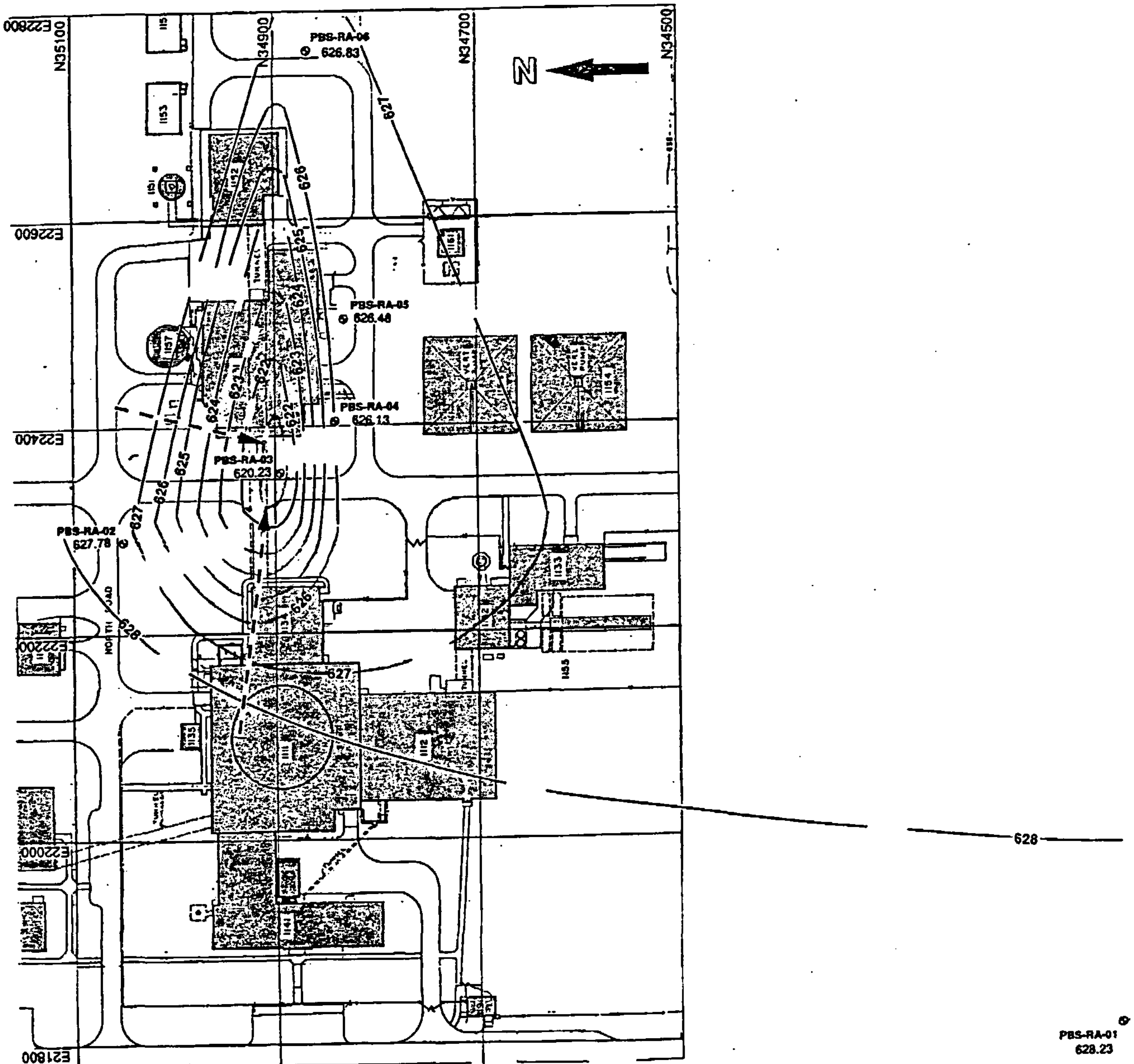
UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATION/FEASIBILITY STUDY: PHASE I

Sampling Locations Associated With the Building 1131 USTs

REACTOR AREA

EBASCO ENVIRONMENTAL | NOT TO SCALE

FIGURE 3-35



LEGEND

	PBS-RA-01 628.23	Ground Water Monitoring Well Ground Water Elevation
	628	Ground Water Elevation Contour
		Direction of Ground Water Flow

NASA PLUM BROOK STATION

UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATIONS/FEASIBILITY STUDY: PHASE I

Ground Water Elevation Contours for 05/09/91

REACTOR AREA

EBASCO ENVIRONMENTAL	SCALE: 1"=100'
FROM NASA DWG. NO. PF-65156	**FIGURE 3-41**

Soil Unit	Range of Unit Thickness at the Tank Area
Brown Fine Sand	6' - 8'
* Grey Fine Sand	2.5' - >14'
* Grey Sandy Clayey Silt	1.5' - 8'
* Grey Clayey Silt	>1.5'
Grey Silty Clay	

OVERBURDEN

* Unit not encountered at all borehole locations

NOTE Bedrock was not reached at this Tank Area; Drilling was completed in the first confining layer encountered

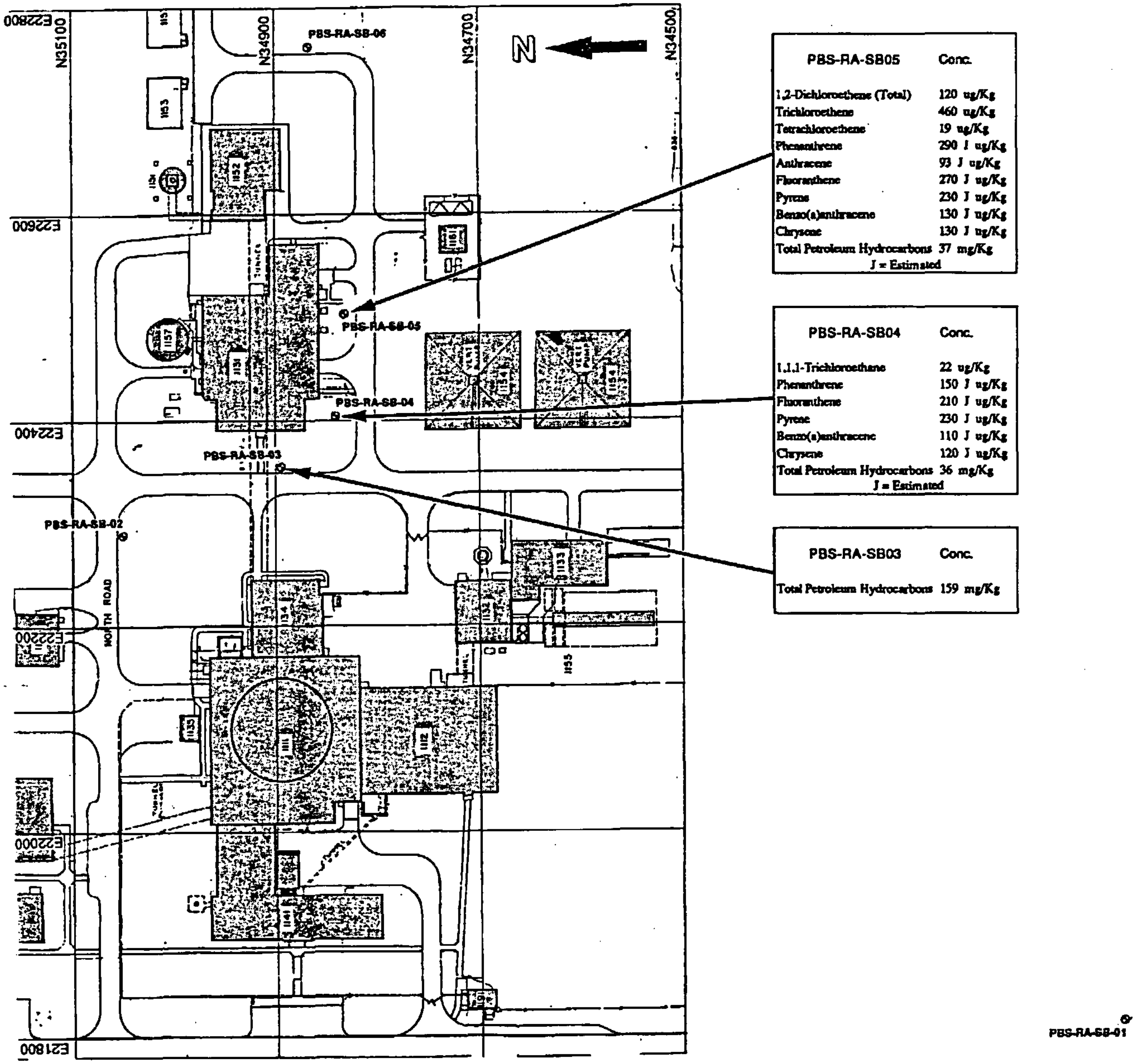
NASA PLUM BROOK STATION
UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATION/FEASIBILITY STUDY: PHASE I

Generalized Stratigraphic Section

REACTOR AREA

EBASCO ENVIRONMENTAL | NOT TO SCALE

FIGURE 3-37



PBS-RA-SB05	Conc.
1,2-Dichloroethene (Total)	120 ug/Kg
Trichloroethene	460 ug/Kg
Tetrachloroethene	19 ug/Kg
Phenanthrene	290 J ug/Kg
Anthracene	93 J ug/Kg
Fluoranthene	270 J ug/Kg
Pyrene	230 J ug/Kg
Benzo(a)anthracene	130 J ug/Kg
Chrysene	130 J ug/Kg
Total Petroleum Hydrocarbons	37 mg/Kg

J = Estimated

PBS-RA-SB04	Conc.
1,1,1-Trichloroethane	22 ug/Kg
Phenanthrene	150 J ug/Kg
Fluoranthene	210 J ug/Kg
Pyrene	230 J ug/Kg
Benzo(a)anthracene	110 J ug/Kg
Chrysene	120 J ug/Kg
Total Petroleum Hydrocarbons	36 mg/Kg

J = Estimated

PBS-RA-SB03	Conc.
Total Petroleum Hydrocarbons	159 mg/Kg

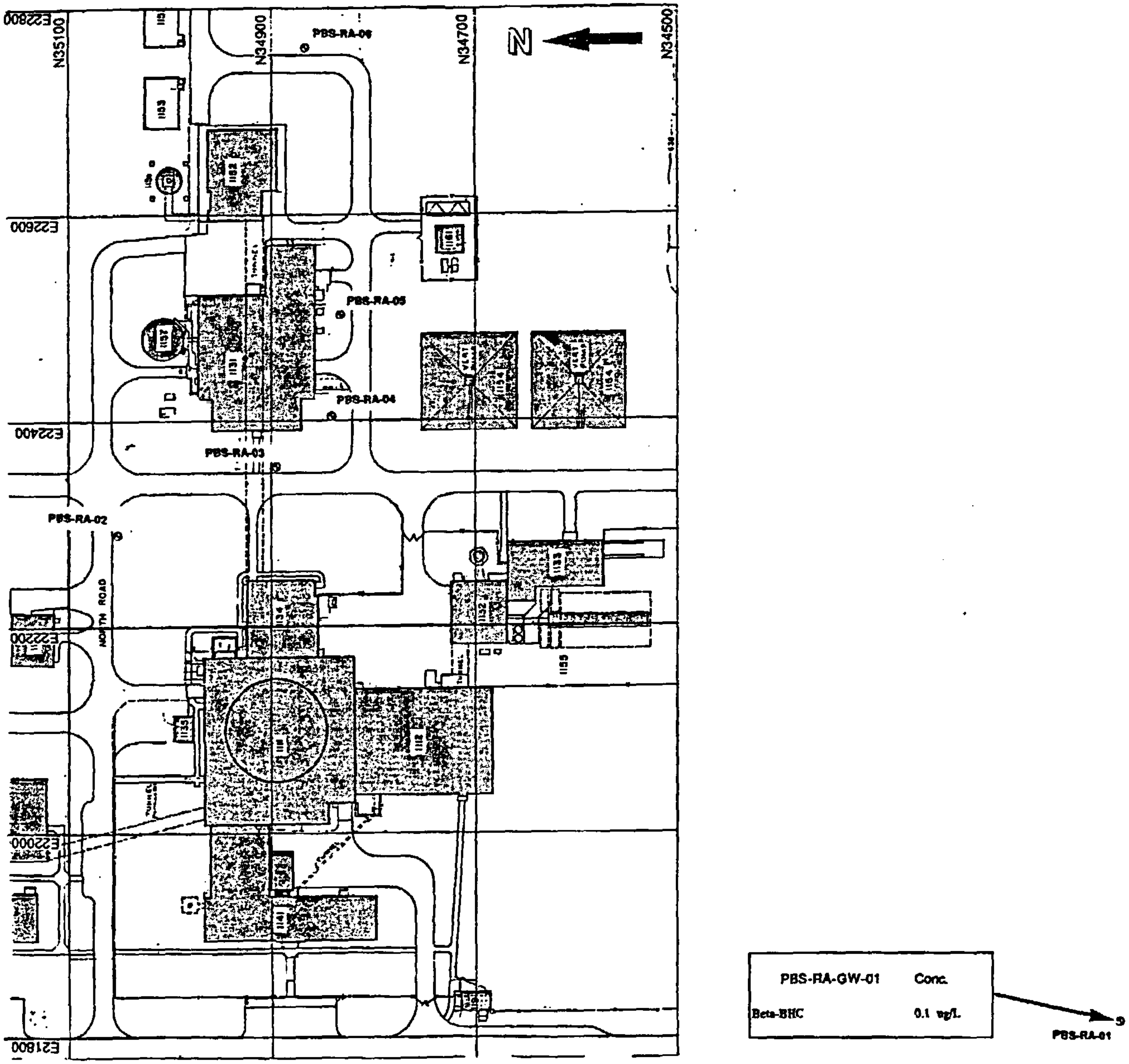
NASA PLUM BROOK STATION
UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATIONS/FEASIBILITY STUDY: PHASE I

Organic Contaminant Concentrations in Soil

REACTOR AREA

EBASCO ENVIRONMENTAL | SCALE: 1"=100'

FROM NASA DWG. NO. PF-65156 | FIGURE 3-38



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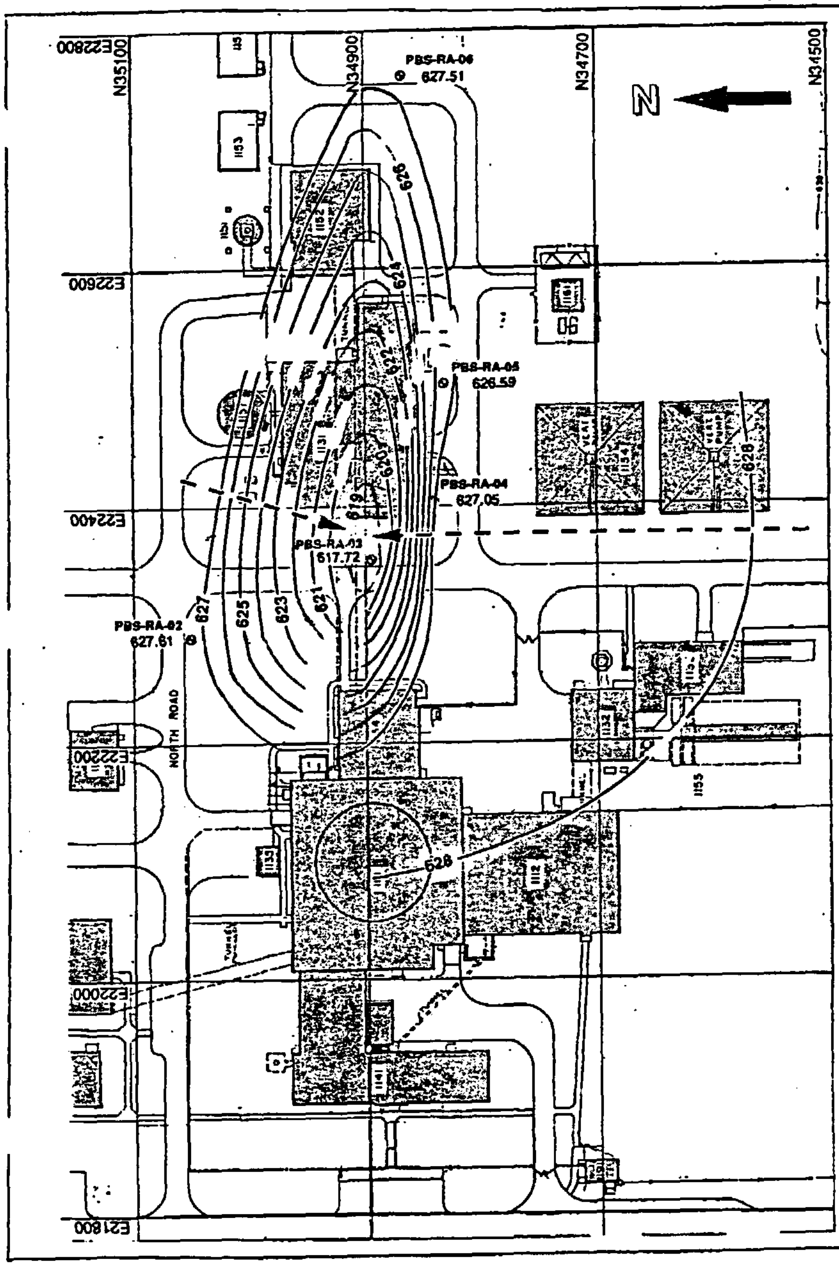
UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATIONS/FEASIBILITY STUDY: PHASE I

Organic Contaminant Concentrations in Ground Water

REACTOR AREA

EBASCO ENVIRONMENTAL	SCALE: 1"=100'
FROM NASA DWG. NO. PF-65164	FIGURE 3-39



PBS-RA-01
628.88

LEGEND

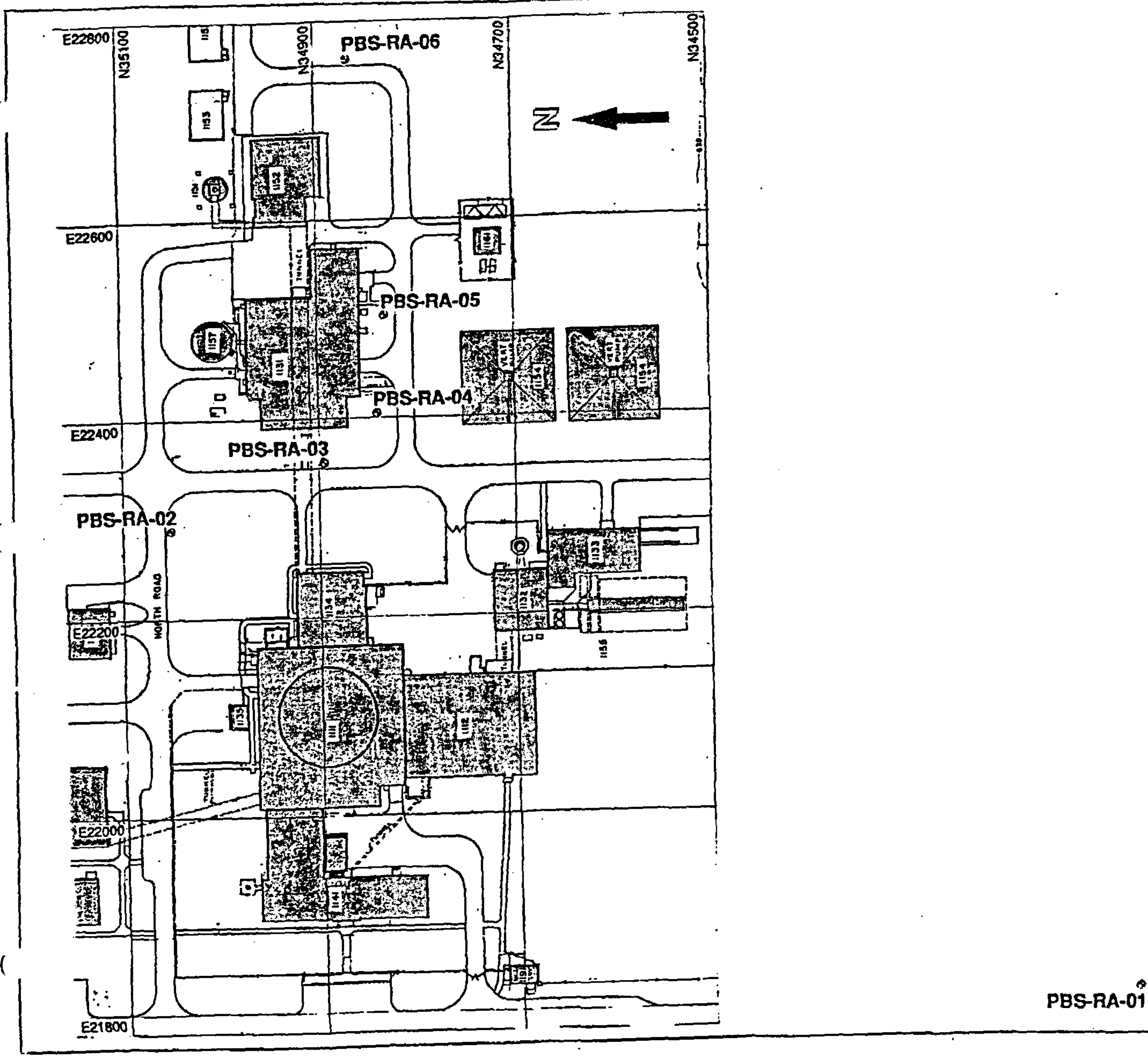
PBS-RA-01 628.88		Ground Water Monitoring Well Ground Water Elevation
	628	Ground Water Elevation Contour
		Direction of Ground Water Flow

NASA PLUM BROOK STATION
UNDERGROUND STORAGE TANK CORRECTIVE ACTIONS REMEDIAL INVESTIGATIONS/FEASIBILITY STUDY: PHASE I

Ground Water Elevation Contours for 01/10/91

REACTOR AREA

EBASCO ENVIRONMENTAL	SCALE: 1"=100'
FROM NASA DWG. NO. PF-85156	FIGURE 3-40



LEGEND

Ground Water Monitoring Well Location

NASA PLUM BROOK STATION
UNDERGROUND STORAGE TANK
CORRECTIVE ACTIONS REMEDIAL
INVESTIGATION/FEASIBILITY STUDY:
PHASE I

Locations of Soil Borings and Ground Water Monitoring Wells

REACTOR AREA

EBASCO ENVIRONMENTAL	SCALE: 1"=100'
FROM NASA DWG. NO. PF-65156	FIGURE 3-36

APPENDIX A

SECTION 6

1993 Preliminary Site Investigation, USTs

(Morrison Knudson Ferguson Group 1993)

PRELIMINARY SITE INVESTIGATION REPORT

100% SUBMITTAL

PHASE I

REMEDIATION OF CONTAMINATED
UNDERGROUND STORAGE TANK SITES

TASK ORDER 6105-004

PLUM BROOK STATION
6100 COLUMBUS AVENUE
SANDUSKY, OHIO 44870

JANUARY 28, 1993

PREPARED BY:

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INTRODUCTION

NASA requested Morrison Knudsen (MK) to submit a report to characterize the Underground Storage Tank (UST) sites at the Plum Brook Station (PBS) in Sandusky, Ohio. The report will prioritize, characterize and determine appropriate regulatory guidance, discuss potential remediation techniques, and provide a sampling and analysis plan for each site.

The UST sites at PBS consisted of the Garage and Maintenance Area (Buildings 7132, 7121, and 7131), the Space Power Facility (SPF) (Building 1411), the Pump Station (Building 8133), and the Reactor Area (Building 1131) (Figure 1). The associated buildings and USTs, tank composition and contents, and site comments are listed in Table 1.

Upon review of the data available, it would be beneficial to separate the Garage and Maintenance Area into two sites. One site would be the Building 7132 Area, which consisted of four petroleum USTs, 7132-1(33), 7132-2(34), 7132-3(35), and 7132-4(36) and has a history with the Bureau of Underground Storage Tank Regulations (BUSTR) for the UST removals. This site could be closed under the new BUSTR regulations. The second site would be the Building 7121 and 7131 areas which consisted of USTs 7121-1(28), 7121-2(29), 7121-3(30), 7121-4(31), and 7131-1(32). These sites have a history of volatile organic compound (VOC) contamination and should follow the Resource Conservation and Recovery Act (RCRA) guidance for closure.

Each of the UST sites have had a history of UST removal and soil sampling. The Building 7132 Area and the Pump Station (Building 8133) sites have petroleum contamination; the levels are shown in Table 2. The Building 7121 and 7131 Area, SPF (Building 1411), and the Reactor Area (Building 1131) have contamination from VOC in addition to petroleum; the levels are shown in Table 3.

SITE PRIORITIZATION

Each site has been prioritized according to potential environmental hazards. The sites are listed in order from most critical to least critical, with the rationale for prioritization following.

1. Building 7121 and 7131 Area - (RCRA)
2. Reactor Area (Building 1131) - (RCRA)
3. Space Power Facility (Building 1411) - (RCRA)
4. Building 7132 Area - (BUSTR)
5. Pump Station (Building 8133) - (BUSTR)

The USTs associated with Building 7121 and 7131 were 7121-1(28) which contained waste oil and solvents (VOC), 7121-2(29) which contained acetone (VOC), 7121-3(30) which contained trichloroethene (TCE) (VOC), 7121-4(31) which contained 1,1,1-trichloroethane (TCA) (VOC), and 7131-1(32) which contained waste oil and solvents (VOC). Building 7121 and 7131 Area is the most critical because past studies have shown VOC contamination throughout the soils and groundwater of the site. These results indicate that contamination from the USTs has spread beyond the UST site. This site had the highest levels of contamination in the soils and groundwater and the furthest spread of contamination across the site. This UST site should be remediated to prevent the potential migration of contamination through the soils and groundwater.

The USTs associated with the Reactor Area (Building 1131) were 1131-1(21) which contained fuel oil, 1131-2(22) which contained fuel oil, and 1131-3(23) which contained waste oil and solvents. This area has VOC contamination in the soils but no contamination has been found in the groundwater. This site is listed as priority #2 because soil contamination exists outside the UST excavation area. Footer tiles, associated with an underground utility tunnel west of Building 1131, collect and discharge water to a sump in the basement of Building 1131. The sump discharges water to a ditch, eventually discharging to Plum Brook. This water collection may affect the local groundwater flow direction, drawing contamination from the excavation area through the soil to the footer tiles. The site should be remediated to prevent the further migration of contamination through the soils.

The USTs associated with the SPF (Building 1411) were 1411-1(24) which contained waste oil and solvents, and 1411-2(25) which contained fuel oil. This area had levels of VOC found in the UST cavity soils after excavation. This site is listed as priority #3 because less VOC contamination was detected than in the priority #2 site (Reactor Area) and no contamination was detected in the groundwater.

The USTs associated with Building 7132, near the Garage and Maintenance area, were 7132-1(33) which contained gasoline, 7132-2(34) which contained gasoline, 7132-3(35) which contained diesel fuel, and 7132-4(36) which contained diesel fuel. This area had soil sample results indicating the presence of benzene. This site is listed as priority #4 because a groundwater sample from near the UST excavation indicated benzene contamination. The soils in the contaminated area should be resampled and the groundwater should be sampled. The site should be categorized according to the BUSTR regulations. Levels in the area may be low enough to allow closure of the site.

The UST associated with the Pump Station Area (Building 8133) was 8133-1(39) which contained gasoline. This area is listed as priority #5. Total Petroleum Hydrocarbons (TPH) levels were found in the UST cavity soil after excavation. No contamination was found in the groundwater. The site does not appear to be a threat to the environment. The site should be categorized according to the BUSTR regulations. Levels in the area may be low enough to allow closure of the site.

UST SITE CHARACTERIZATIONS

Building 7121 and 7131 Areas (Priority #1)

There were four USTs located east of Building 7121 (Figure 2). They were UST 7121-1 which contained waste oil and solvents (VOC), 7121-2 which contained acetone (VOC), 7121-3 which contained TCE (VOC), and 7121-4 which contained TCA (VOC). USTs 7121-2, 7121-3, and 7121-4 were in a common excavation, while UST 7121-1 was located east of the common excavation. UST 7131-1 contained waste oil and solvents (VOC) and was located north of Building 7131. All of these USTs were removed in September of 1989. The closure report indicated levels of VOC in the soils, so the sites were placed under the Ohio Environmental Protection Agency (OEPA) jurisdiction. Ebasco was contracted by NASA to complete a site assessment to define areas of contamination.

Soils

The excavated soils from around USTs 7121-2, 7121-3, and 7121-4 had results indicating the presence of VOC contamination. The contaminated excavated soil was removed from the site. Two soil samples were taken from the north and south sidewalls of the UST excavation. These two UST excavation samples detected the presence of VOC contamination. No depth was given for the sample areas so it is not known at what depth this contamination may exist.

The analytical data from the UST 7121-1 excavation indicated the presence of VOC contamination. The depths from which the excavation samples were obtained were not presented in the Ebasco assessment report, so it cannot be determined at what depth the contamination occurs.

Four soil borings were installed east of Building 7121. Analytical results of the four borings, (PBS-GM-SB01, PBS-GM-SB05, PBS-GM-SB06, and PBS-GM-SB07) indicated VOC contamination present in the soils. The depths at which contamination occurred cannot be determined as the soil boring samples were composited over the entire length of each boring. Thus, contamination could have been from the surface or deeper within the soils.

Underground storage tank 7131-1, north of Building 7131 had soil sample results from its excavation which showed the presence of TPH and VOC contamination. Depth of the samples are not known.

Two soil borings, (PBS-GM-SB02 and PBS-GM-SB03) were completed north of Building 7131. The analytical results of the soil samples obtained from PBS-GM-SB02 indicated TPH and VOC contamination. The analytical results of soil samples from PBS-GM-SB03 indicated no VOC were present. The depths at which contamination occurred cannot be determined as the soil boring samples were composited over the entire length of each boring. Thus, contamination could have been from the surface or deeper within the soils.

A soil gas study was conducted around the entire area. The sampling methods produced results from the 0-4 foot soil interval. Levels of benzene, toluene, xylene (BTX), and TCA (VOC) were detected in the samples around USTs 7121-2, 7121-3, and 7121-4. No contamination was found in the samples collected from the area around UST 7131-1.

Groundwater

Six borings were completed as monitoring wells. Groundwater samples were collected from two wells, PBS-GM-02 and PBS-GM-06. The analytical results for both wells indicated the presence of VOC. PBS-GM-06 was near an outside door of Building 7121 where surface spillage could have occurred contaminating soils and groundwater in the immediate area. The other wells in the area should be tested to determine the extent of groundwater contamination over the entire area.

Closure of the 7121 and 7131 Areas

The UST excavation areas near Buildings 7121 and 7131 had VOC contamination. The USTs 7121-1 and 7131-1, containing waste oils and solvents (VOC), were in service until their removal in 1989. This area should follow the RCRA Closure Guidance.

It cannot be determined from existing data whether the contamination is restricted to the surface soils or exists at a deeper depth. There is not enough groundwater analytical data in the area to show spread of contamination through this medium. Before remedial technologies for this area can be determined, the full spread of possible contamination in the groundwater and soils should be identified.

It is recommended that the existing groundwater monitoring wells be sampled and analyzed for VOC and that additional borings and wells be installed on the site. The additional monitoring wells will also give the opportunity for further soil testing to determine depth of contamination. It is also recommended that soil permeability and transmissivity parameters be tested for, in field or laboratory tests, to determine groundwater flow and soil vapor transport. This information will be necessary for the remedial technology selection.

Reactor Area (Building 1131) (Priority #2)

The Reactor Area (Building 1131) contained three USTs, 1131-1 which contained fuel oil, 1131-2 which contained fuel oil, and 1131-3 which contained waste oil and solvents. These USTs were located in a common excavation adjacent to the south side of Building 1131 (Figure 3). The USTs were removed in December of 1989.

Soils

Soil samples were collected during the UST removals. These samples revealed levels of TPH and VOC. Additional soil was removed from the excavation and two additional samples were collected from the bottom of the excavation. The additional soil samples indicated no TPH results but they did detect VOC.

Six soil borings were placed around the site and were completed as monitoring wells. The borings (PBS-RA-01 through PBS-RA-06) were sampled. The laboratory analysis for these borings detected semi-volatile organic compounds and VOC present in the soils. The soils for each boring were composited over the entire length of the boring so specific depths of contamination cannot be determined.

Groundwater

Two groundwater samples were collected from monitoring wells PBS-RA-01 and PBS-RA-04 which were installed around the site. No VOC or TPH contamination was detected in the groundwater samples.

Closure of the Reactor Area (Building 1131)

Review of the soil and groundwater data in the area revealed the presence of VOC in the soils. UST 1131-3 was in service until removal. Because of these facts, this site cannot be closed under the BUSTR regulations and should be closed under RCRA guidance. Further soil sampling is recommended in the area to determine the horizontal and vertical extent of contamination.

It is recommended that the existing groundwater monitoring wells be sampled and analyzed for VOC and that additional borings and wells be installed on the site. The additional monitoring wells will also give the opportunity for further soil testing to determine depth of contamination. This information will be necessary for the remedial technology selection.

Space Power Facility (Building 1411) (Priority #3)

The two SPF USTs 1411-1 and 1411-2 were located in a common excavation adjacent to the south foundation of Building 1411 (Figure 4). The USTs were removed in September of 1989. UST 1411-1 had contained waste oil and solvents and UST 1411-2 had contained fuel oil.

Soils

During the UST removal, the UST excavation was advanced to 12 feet in depth, where shale bedrock was encountered. Analytical results of the soil samples collected from the excavation during the UST removal indicated the presence of TPH and VOC.

A soil gas survey was completed in the SPF area in October of 1989. The survey tested the soil gas for the 0-4 foot interval. Results of this survey showed the presence of BTX outside the excavation area and one occurrence of VOC, isolated from the excavation, on the southeast side of the building.

Six soil borings (PBS-SP-SB-01 through PBS-SP-SB-06) were completed at the SPF. Analytical results of soil samples indicated the presence of VOC contamination in PBS-SP-SB-06 at the edge of the UST excavation. Levels of TPH were found in PBS-SP-SB-01, PBS-SP-SB-04, and PBS-SP-SB-06.

Groundwater

Two of the groundwater monitoring wells (PBS-SP-06 and PBS-SP-01) were sampled. Groundwater samples from the wells were analyzed for VOC, semi-volatiles, pesticides, PCBs, and TPH. There was no contamination detected in the groundwater samples.

Closure of the Space Power Facility (Building 1411)

Review of the soil and groundwater analytical data show that VOC were found in the UST excavation. In addition, UST 1411-2 contained waste oil and solvents and was in service until its removal in 1989. Because of the above facts, the area should be closed under RCRA guidance.

The soil gas survey, soil borings, and the monitoring well samples indicated BTX in the soil gas, VOC and TPH in the soil and no indication of contamination in the groundwater samples.

Four soil borings are recommended upgradient and downgradient of the UST excavation and existing monitor wells should be resampled. Soil and groundwater should be analyzed for VOC in order to comply with RCRA closure guidance.

Building 7132 USTs (Priority #4)

Three petroleum USTs were removed from a common excavation in the Building 7132 area in July of 1989 (Figure 5). The USTs were 7132-1 which contained gasoline, 7132-2 which contained gasoline, and 7132-3 which contained diesel fuel. A fourth UST, 7132-4 which contained diesel fuel, was located south of Building 7132.

Soils

During the removal of USTs 7132-1, 7132-2, and 7132-3 visibly contaminated soil was observed. Soil samples were collected and the laboratory analytical results detected benzene, toluene, ethylbenzene, and xylenes (BTEX); therefore, additional soil was removed from the excavation. Analytical results of soil samples collected after the additional excavation showed the contaminated soils had been removed. One sampling location in the excavation had a benzene concentration of 0.420 ppm. The range of permissible benzene concentrations for soils under the new BUSTR regulations is 0.006 ppm to 0.500 ppm. Categorization of the area is required under the new BUSTR regulations.

UST 7132-4, south of Building 7132, contained diesel fuel and was removed in July of 1990. There was no contamination found in this excavation.

As part of the Ebasco work, a soil gas survey was conducted around the entire site. Two samples west of the site indicated low levels of benzene and one sample east of the site indicated dichlorethene. The soil gas survey methods described in the Ebasco report show that the samples were most likely obtained from the 0-4 foot soil depth and were most likely indicative of surface contamination.

During the Ebasco work a soil boring/monitoring well (PBS-GM -04) was completed west of the site. The soils from the boring were analyzed for VOC and TPH. The only result for the soil was a TPH level of 129 ppm. The permissible level for TPH in soils according to BUSTR is 380 ppm or less.

Groundwater

Four monitoring wells 7132-GW-1, 7132-GW-2, 7132-GW-3, and 7132-GW-4 were placed around the Building 7132 Area in August of 1989. All groundwater tested from the wells was free of contamination except for monitoring well 7132-GW-1 which had a result of 0.058 ppm benzene.

Closure of Building 7132 USTs

Review of the soil and groundwater data for the Building 7132 Area show that the site can be closed under the BUSTR regulations. According to the new BUSTR regulations, the site must be categorized. In order to close this site under BUSTR regulations it is recommended that a water sample be collected from monitoring well PBS-GM-04 and that three soil samples are collected from the area surrounding the site.

Pump Station Area (Building 8133) (Priority #5)

The UST 8133-1 was located on the west side of Building 8133 (Figure 6). The UST was a 250 gallon steel gasoline tank that was removed in September of 1989. At the time of removal, the UST was out of service.

Soils

The soils sampled from the walls of the UST excavation were tested for BTEX and TPH. Results of the samples were below BUSTR action levels.

Fourteen soil gas survey samples were collected around the site. Low BTEX results were indicated in five of the samples.

Four soil borings (PBS-PS-01, PBS-PS-02, PBS-PS-03, PBS-PS-04) were placed around the site. Three borings were completed as monitoring wells. Levels of TPH were found in all four borings. VOC were found in PBS-PS-04 and PBS-PS-01. Neither of these borings, however, were in the immediate vicinity of the UST area, and therefore are likely to be unrelated to the USTs.

Groundwater

Groundwater samples were collected from PBS-PS-02 and PBS-PS-04. There was no contamination found in the water samples.

Closure of Pump Station Area (Building 8133)

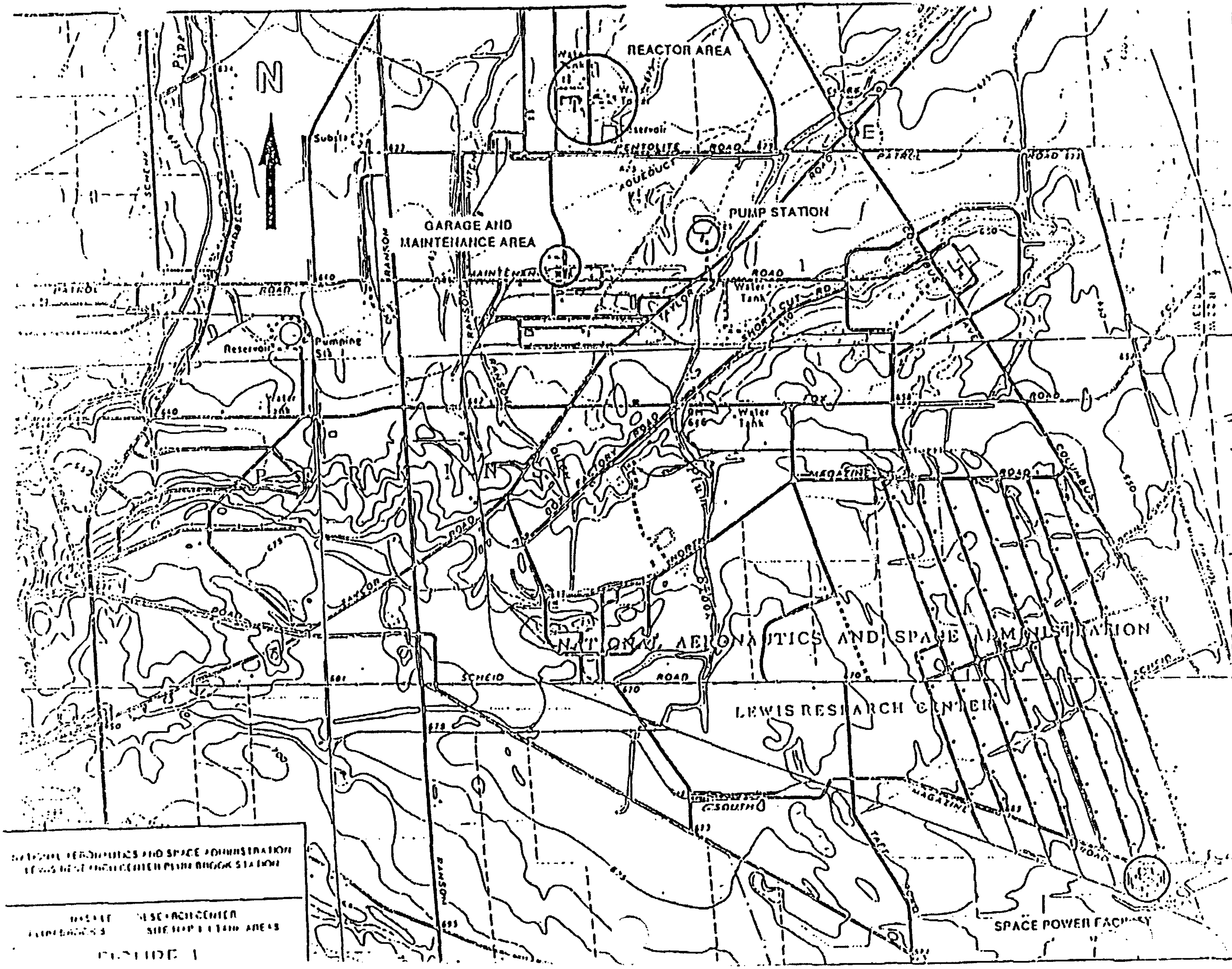
The Pump Station Area can be closed in accordance with the new BUSTR regulations. The site should be categorized according to the BUSTR regulations. Three soil samples should be collected from the surrounding area and existing monitor wells should be resampled to prove clean closure.

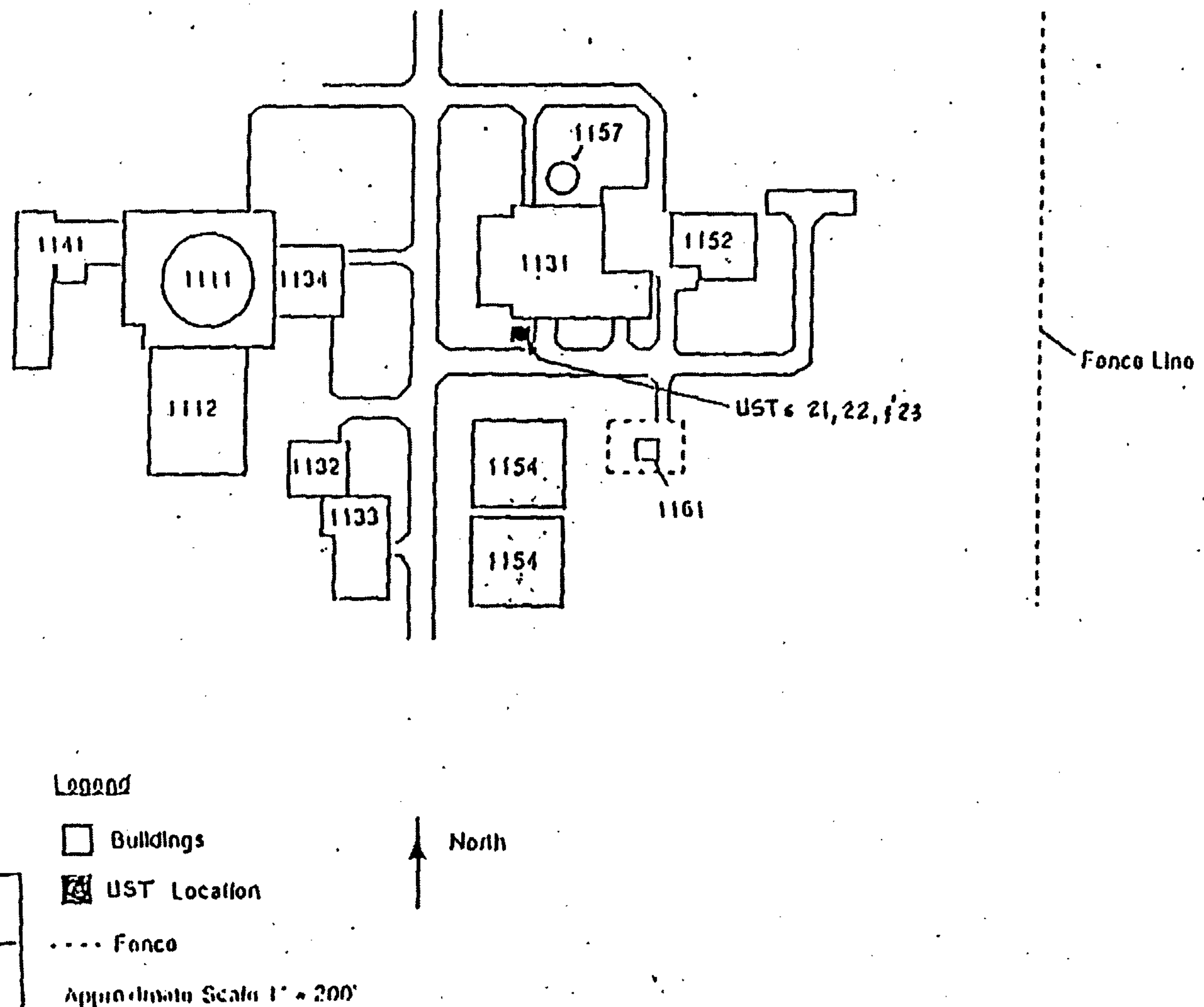
REVIEW OF EXISTING MATERIAL

A review of the Ebasco report submitted in November of 1991 revealed that much of the data collected during the study may be incomplete. The soil gas survey samples were collected in a manner which would have produced results from the 0-4 foot interval of soil. The manner in which the probes were advanced may have resulted in readings being produced from surface sediments which were transported down to the sampling level during installation of the probes. The asphalt in the parking lot at Building 7132 may have contributed to the contamination concentrations detected in the soil gas survey.

The soil samples collected from borings give an indication of the type of contamination in the area, but since samples were not consistently collected over the same depths and samples were composited, specific depth of contamination cannot be determined.

FIGURES


N
REACTOR AREA
PUMP STATION
GARAGE AND
MAINTENANCE AREA
PENTOLITE ROAD
PATROL ROAD
TAYLOR ROAD
SHORT CUT RD
FOX ROAD
MAGAZINE ROAD
COLUMBUS
SCHEID ROAD
SOUTH
RANSOM
Reservoir
Pumping Sta
Water Tank
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER
SPACE POWER FACILITY


1157
1141
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1152
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1133
1154
1154
1161
USTs 21, 22, & 23
Fence Line
Legend
Buildings
UST Location
Fence
North
Approximate Scale 1" = 200'

FIGURE 3

TABLES

SUMMARY OF DETECTED SOIL CONTAMINATION AT SITES FOR BUSTR CLOSURE

Soils Sampled from UST Excavation (Building 7132)

Sample Location	Benzene ug/kg	Toluene ug/kg	Ethylbenzene ug/kg	Xylene ug/kg	TPH mg/kg
7132-SS-1	BDL	1.10	BDL	0.35	166.0
7132-SS-2	420.0	8.90	0.79	4.00	132.0
7132-SS-3	3.0	0.85	BDL	0.27	159.0
7132-SS-4	3.0	3.80	0.59	2.70	190.0
7132-SS-5	BDL	1.60	BDL	BDL	121.0
7132-SS-6	BDL	1.10	BDL	BDL	118.0
7132-PI-1	BDL	1.20	BDL	1.70	79.0
7132-PI-2	0.95	9.50	2.30	5.60	BDL
7132-PI-3	0.46	7.70	BDL	BDL	BDL
7132-PI-4	0.60	3.00	0.37	0.94	BDL
7132-PI-5	1.30	0.64	BDL	BDL	81.0
7132-PI-6	0.30	1.80	BDL	BDL	BDL
BUSTR Action Level	335.0	900.0	14,000.0	67,000.0	904.0

Groundwater Samples (Building 7132)

Monitoring Well	Benzene ug/kg	Toluene ug/kg	Ethylbenzene ug/kg	Xylene ug/kg	TPH mg/kg
7132-GW-1	58.0	1.6	0.4	6.1	BDL
7132-GW-2	BDL	0.18	BDL	BDL	BDL
7132-GW-3	BDL	BDL	BDL	BDL	BDL
7132-GW-4	BDL	BDL	BDL	BDL	BDL
BUSTR Action Level	5.0	100.0	700.0	10,000.0	

Soil Samples from UST Excavation (Building 8133)

Sample Location	Benzene ug/kg	Toluene ug/kg	Ethylbenzene ug/kg	Xylene ug/kg	TPH mg/kg
8133-SS-3	0.19	0.77	0.27	0.94	BDL
BUSTR Action Level	350.0	900.0	14,000.0	67,000.0	904.0

BDL - Below Detection Levels

TABLE 3

SUMMARY OF DETECTED SOIL CONTAMINATION AT RCRA CLOSURE SITES (EBASCO 1991)
.SOILS SAMPLED FROM UST EXCAVATION

COMPOUND	USEPA MAXIMUM CONTAMINANT LEVEL ug/kg	BLDG.7121 7121-1 ug/kg	BLDG.7121 7121-2,3,4 ug/kg	BLDG.7131 7131-1 ug/kg	BLDG.1411 1411-1,2 ug/kg	BLDG.1131 1131-1,2,3 ug/kg
Chloroethane	6.9	10.0	34.0	ND (1)	ND	ND
Trichloroflouromethane	1.8	28.0	4.0	17.0	93.0	120.0
1,1 Dichloroethane	1.2	44.0	13.0	ND	22.0	ND
Methylene Chloride	2.4	249.0	4.0	70.0	164.0	503.0
Trans1,2Dichloroethane	2.0	2.0	ND	ND	17.0	17.0
1,1Dichloroethane	0.53	1214.0	70.0	ND	228.0	6120.0
Chloroform	0.35	1.0	ND	ND	ND	1.0
1,1,1Trichloroethane	3.0	7770.0	610.0	23.0	1254.0	891.0
Carbon Tetrachloride	3.4	431.0	94.0	2.0	213.0	91.0
1,2Dichloroethane	0.53	96.0	3.0	370.0	5.0	178.0
Benzene	1.0	14.0	ND	ND	11.0	32.0
Trichloroethene	2.6	21142.0	200.0	728.0	1432.0	1019.0
Toluene	.60	1101.0	2.0	1.0	16.0	41.0
1,1,2Trichloroethane	3.2	212.0	1.0	ND	11.0	143.0
Tetrachloroethene	1.7	10048.0	8.0	17.0	342.0	1043.0
Ethylbenzene	0.50	411.0	1.0	2.0	45.0	1093.0
Xylenes	0.50	395.0	2.0	2.0	43.0	115.0
1,1,2,2Tetrachloroethane	1.0	4.0	ND	ND	ND	463.0
Isopropylbenzene	1.0	10.0	ND	ND	31.0	380.0
Tert-Butylbenzene	2.0	40.0	ND	ND	70.0	645.0
1,2,4Trimethylbenzene	2.0	479.0	ND	349.0	541.0	4413.0
Sec-Butylbenzene	2.0	8.0	ND	ND	37.0	ND
p-Isopropyltoluene	1.0	22.0	ND	ND	74.0	1854.0
Naphthalene	250.0	268.0	ND	159.0	1094.0	13388.0
1,2,3Trichlorobenzene	3.0	55.0	ND	18.0	40.0	1025.0

(1) ND - Not Detected

REACTOR AREA
TASK ORDER 6105-006

The Reactor Area contained three (3) USTs. Two (2) contained fuel oil and one (1) contained waste oil and solvents. The USTs were removed in December 1989 with the waste oil/solvent tank in service until removal.

In April 1993, four (4) borings were drilled at the Reactor Area and labeled B-1 through B-4 (Figure 2). B-1 was also converted into a monitoring well. Auger refusal depths are indicated in Table 2.

Three (3) samples were collected from each boring. The soil samples were analyzed for:

- TPH (Method 418.1)
- BTEX (Method 8020)
- Volatiles (Method 8240)
- Polynuclear Aromatic Hydrocarbons (Method 8100)

A summary of the results are attached.

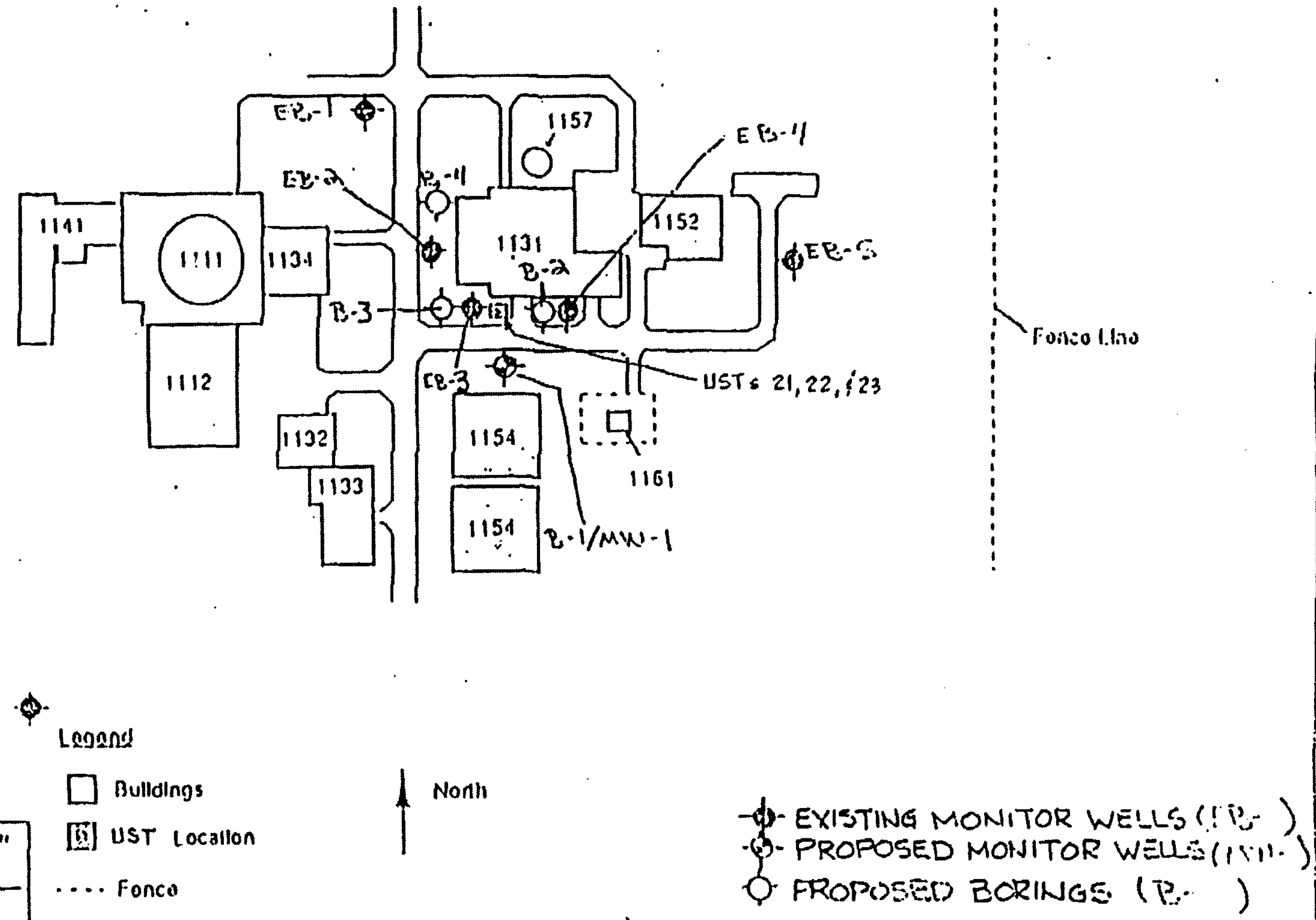
Boring B-1/MW-1 was developed into a monitoring well. This well was sampled along with six (6) other wells previously installed. A sump area inside of the Reactor Building was also sampled. The sump collects water from the building foundation drain system. All of the groundwater was analyzed for:

- Volatiles (Method 8240)
- Polynuclear Aromatic Hydrocarbons (Method 8100)

The sump was resampled because the original sample bottle was broken at the laboratory.

TABLE 2

LOCATION NO.	BORING NO.	BORING DEPTH (FEET)
MKB-55	B-1/MW-1	16
MKB-56	B-2	16
MKB-57	B-3	16
MKB-58	B-4	14



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LEWIS RESEARCH CENTER PLUM BROOK STATION

REACTOR FACILITY

FIGURE 2

TPH AND BTEX RESULTS FOR SOIL

REACTOR AREA
TASK NO. 6105-006

BORING NUMBER	SAMPLE DEPTH	TPH (418.1) (mg/kg)[1]	BENZENE (ug/kg)[2]	TOLUENE (ug/kg)	ETHYLBENZENE (ug/kg)	M&P XYLENES (ug/kg)	O XYLENE (ug/kg)
B1	2'-4'	17	< 2	< 2	< 2	< 2	< 2
B1	4'-6'	26	< 2	< 2	< 2	< 2	< 2
B1	14'-16'	19	< 2	< 2	< 2	< 2	< 2
B2	2'-4'	12	< 2	< 2	< 2	< 2	< 2
B2	4'-6'	< 10	< 2	< 2	< 2	< 2	< 2
B2[D][3]	4'-6'	< 10	< 2	< 2	< 2	< 2	< 2
B2	6'-8'	< 10	< 2	< 2	< 2	< 2	< 2
B3	2'-4'	10	< 2	< 2	< 2	< 2	< 2
B3	4'-6'	< 10	< 2	< 2	< 2	< 2	< 2
B3	6'-8'	10	< 2	3.14	< 2	< 2	< 2
B4	2'-4'	< 10	< 2	2.77	< 2	< 2	< 2
B4	4'-6'	< 10	< 2	2.86	< 2	< 2	< 2
B4	6'-8'	19	< 2	2.26	< 2	< 2	< 2

(1) mg/kg = parts per million
(2) ug/kg = parts per billion
(3) D = Duplicate Sample

GAS CHROMATOGRAPHY/MASS SPECTROMETRY FOR VOLATILE ORGANICS IN SOIL

REACTOR AREA
TASK NO. 6105-006

BORING NUMBER	SAMPLE DEPTH	COMPOUND	RESULT (ug/kg)[1]	PQL (ug/kg)[2]
B1	2'-4'	---	---[3]	---
B1	4'-6'	---	---	---
B1	14'-16'	---	---	---
B2	2'-4'	---	---	---
B2	4'-6'	---	---	---
B2 D[4]	4'-6'	---	---	---
B2	6'-8'	1,1,1-TRICHLOROETHANE	23.0	5
B3	2'-4'	---	---	---
B3	4'-6'	---	---	---
B3	6'-8'	---	---	---
B4	2'-4'	---	---	---
B4	4'-6'	---	---	---
B4	6'-8'	---	---	---

(1) ug/kg = ppb
(2) PQL = Practical Quantification Limit
(3) --- = Compound/Concentrations Below PQL
(4) D = Duplicate Sample

POLYNUCLEAR AROI IC HYDROCARBONS IN SOIL

REACTOR AREA
TASK NO. 6105-006

BORING NUMBER	SAMPLE DEPTH	COMPOUND	RESULT (mg/kg)[1]	PQL (mg/kg)[2]
B1	2'-4'	PHENANTHRENE	0.121	< 0.1
B1	2'-4'	PYRENE	0.177	< 0.1
B1	4'-6'	CHRYSENE	0.118	< 0.1
B1	4'-6'	FLUORANTHENE	0.304	< 0.1
B1	4'-6'	PYRENE	0.343	< 0.1
B1	14'-16'	PYRENE	0.151	< 0.1
B2	2'-4'	FLUORANTHENE	0.105	< 0.1
B2	2'-4'	PYRENE	0.185	< 0.1
B2	4'-6'	ACENAPHTHENE	0.141	< 0.1
B2[D(3)]	4'-6'	ACENAPHTHENE	0.132	< 0.1
B2	6'-8'	---	---[4]	---
B3	2'-4'	ACENAPHTHENE	0.159	< 0.1
B3	2'-4'	ACENAPHTHYLENE	0.103	< 0.1
B3	2'-4'	ANTHRACENE	0.378	< 0.1
B3	2'-4'	BENZO (a) ANTHRACENE	1.28	< 0.1
B3	2'-4'	BENZO (a) PYRENE	1.45	< 0.1
B3	2'-4'	BENZO (b) FLUOROANTHENE	1.16	< 0.1
B3	2'-4'	BENZO (k) FLUOROANTHENE	1.02	< 0.1
B3	2'-4'	BENZO (ghi) PERYLENE	0.635	< 0.1
B3	2'-4'	CHRYSENE	1.26	< 0.1

POLYNUCLEAR AROMATIC HYDROCARBONS IN SOIL

REACTOR AREA
TASK NO. 6105-006

BORING NUMBER	SAMPLE DEPTH	COMPOUND	RESULT (mg/kg)[1]	PQL (mg/kg)[2]
B3	2'-4'	DIBENZO (a,h) ANTHRACENE	0.277	< 0.1
B3	2'-4'	FLUORANTHENE	2.48	< 0.1
B3	2'-4'	INDENO (1,2,3-cd) PYRENE	0.775	< 0.1
B3	2'-4'	PHENANTHRENE	1.16	< 0.1
B3	2'-4'	PYRENE	0.220	< 0.1
B3	4'-6'	ACENAPHTHENE	0.124	< 0.1
B3	6'-8'	PYRENE	0.185	< 0.1
B4	2'-4'	PYRENE	0.106	< 0.1
B4	4'-6'	---	---[4]	---
B4	6'-8'	PYRENE	0.152	< 0.1

(1) mg/kg = ppm
(2) PQL = Practical Quantification Limit
(3) D = Duplicate Sample
(4) --- = Compound/Concentrations Below PQL

GAS CHROMATOGRAPHY/MASS SPECTROMETRY FOR VOLATILE ORGANICS IN WATER

REACTOR AREA
TASK NO. 6105-006

MONITOR WELL	COMPOUND	RESULT (ug/L)[1]	PQL (ug/L)[2]
MW1[3]	---	---[4]	---
MW1A[5]	---	---	---
EB1[6]	DICHLORODIFLUORO-METHANE[7]	1.03	1
EB2	---	---	---
EB3	1,1,1-TRICHLOROETHANE	2.90	1
EB4	CIS-1,2-DICHLOROETHENE	51.9	1
EB4	TRANS-1,2-DICHLOROETHENE	1.93	1
EB4	TETRACHLOROETHENE	1.85	1
EB4	TRICHLOROETHENE	483	1
EB5	---	---	---
EB6	DICHLORODIFLUORO-METHANE[8]	1.70[4]	1
SUMP 2[9]	CHLOROETHANE	3.56	2
SUMP 2	1,1-DICHLOROETHANE	9.36	1
SUMP 2	1,1,1-TRICHLOROETHANE	10.8	1
SUMP 2	TRICHLOROETHENE	1.43	1

(1) ug/L = ppb

(2) PQL = Practical Quantification Limit

(3) MW1 = MK/NASA Installed Well

(4) --- = Concentrations Below PQL

(5) MW1A = Duplicate Sample of MW1

(6) EB1 = Ebasco Installed Well

(7) The method blank contained 0.384 ug/L of Dichlorodifluoromethane. The approximately equivalent concentration, taking into account dilution factors, is amplified to 0.384 ug/L. This is considered to be a significant contribution to the reported value.

(8) The method blank contained 0.903 ug/L of Dichlorodifluoromethane. The approximately equivalent concentration, taking into account dilution factors, is 0.903 ug/L. This is considered to be a significant contribution to the reported value.

(9) A sump in Building 1131 was sampled twice, the lab accidentally destroying the first sample. Sump 2 is the second sample.

POLYNUCLEAR AROMATIC HYDROCARBONS IN WATER

REACTOR AREA
TASK NO. 6105-006

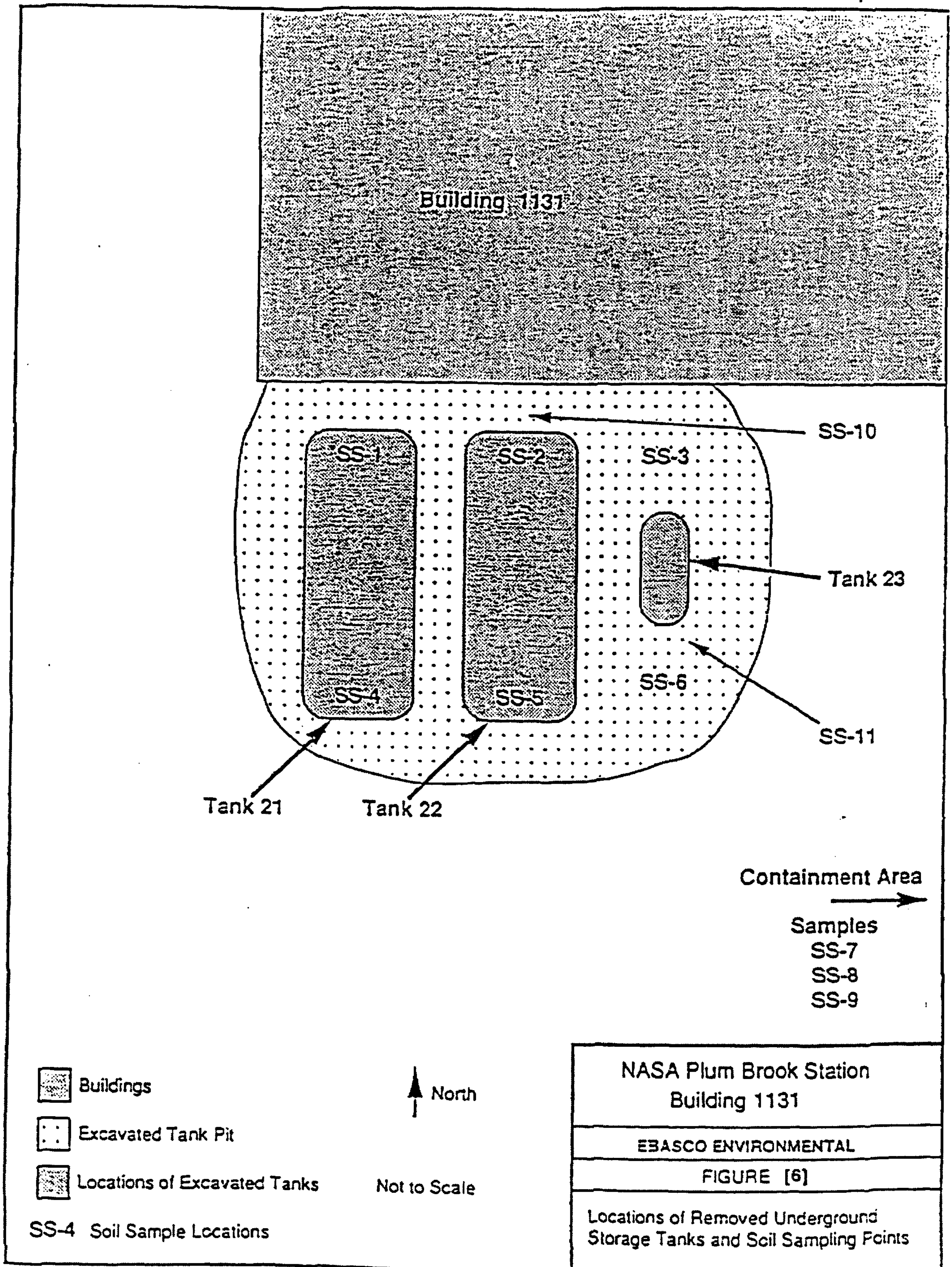
MONITOR WELL	COMPOUND	RESULT (ug/L)[1]	PQL (ug/L)[2]
MW1[3]	---	---[4]	---
MW1A[5]	BENZO (a) ANTHRACENE	1.30	< 1.0
EB1[6]	BENZO (b) FLUOROANTHENE	4.02	< 1.0
EB2	---	---	---
EB3	BENZO (a) PYRENE	1.94	< 1.0
EB3	PHENANTHRENE	1.05	< 1.0
EB4	---	---	---
EB5	BENZO (a) PYRENE	9.20	< 1.0
EB6	---	---	---
SUMP	ACENAPHTHENE	163	< 1.0
SUMP	ACENAPHTHYLENE	414	< 1.0
SUMP	ANTHRACENE	215	< 1.0
SUMP	BENZO (a) ANTHRACENE	4.82	< 1.0
SUMP	CHRYSENE	17.6	< 1.0
SUMP	DIBENZO (a,h) ANTHRACENE	18.1	< 1.0

POLYNUCLEAR AROMATIC HYDROCARBONS IN WATER

REACTOR AREA
TASK NO. 6105-006

MONITOR WELL	COMPOUND	RESULT (ug/L)[1]	PQL (ug/L)[2]
SUMP	FLUORANTHENE	71.8	< 1.0
SUMP	FLUORENE	690	< 1.0
SUMP	PYRENE	32.9	< 1.0

(1) ug/L = ppb
(2) PQL = Practical Quantification Limit
(3) MW1 = MK/NASA Installed Well
(4) --- = Compound/Concentrations Below PQL
(5) MW1A = Duplicate Sample of MW1
(6) EB1 = Ebasco Installed Well



NASA Plum Brook Station
Building 1131

EBASCO ENVIRONMENTAL

FIGURE [6]

Locations of Removed Underground Storage Tanks and Soil Sampling Points

APPENDIX A

SECTION 7

1995 Closure Work Plan for Reactor Area

(URS, September 1995)

REACTOR AREA
NASA PLUM BROOK STATION
SANDUSKY, OHIO

CLOSURE WORK PLAN
TASK ORDER 7059-004

SEPTEMBER 1995

PREPARED FOR:

NASA LEWIS RESEARCH CENTER
21000 BROOKPARK ROAD
CLEVELAND, OHIO 44135

PREPARED BY:

URS CONSULTANTS
23355 MERCANTILE ROAD
CLEVELAND, OHIO 44122

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3.0 THE REACTOR AREA

3.1 SITE-SPECIFIC CONDITIONS

As mentioned previously in this report, the Plum Brook Facility is very extensive in size, approximately 6,400 acres. Physical conditions change considerably across the facility. The following is a site-specific description of the northern boundary of Plum Brook Station which includes the Reactor Area (RA) complex. Figure 3-1 shows the Reactor Area and the location of the former UST pit adjacent to the south wall of Building 1131.

Building 1131 is currently used for storage of equipment. A battery backup system for high voltage switching gear is also housed in this building.

The area of study is the former UST area, containing 3 USTs, located adjacent to the south wall of Building 1131. Building 1131, titled Reactor Service Equipment Building in PBS records, was constructed in 1959 with a total floor area of 26,975 square feet. Its purpose was to house equipment such as the water treatment operations, the boiler/heating system for the reactor, large air compressors, emergency generators, and other equipment from various locations at PBS. A control room for a now demolished cooling tower and a small radiological laboratory were also housed in this building.

A dewatering sump located in the basement is used to collect water from floor drains and tunnel dewatering. The sump is situated north of the "Cold Pipe Tunnel", along the interior wall in the northwest quadrant of the basement. The sump receives groundwater from footer drains for the Building 1131 tunnel and is reported to receive inflow from the floor drains. Sump water is pumped to the Reactor Effluent Metering Station at Building 1192, located approximately 900 feet south of Building 1131. This building also receives sump discharges from 6 or 8 other sumps within the general Reactor area. Facility personnel estimate the combined flow to be approximately 200 to 250 gallons per hour. The major contributor to the combined flow is a sump, 25 feet deep, located at Building 1111, which is estimated to yield approximately 180 gallons per hour. Therefore, the sump serving the Building 1131 tunnel is estimated to produce approximately 5 to 10 gallons per hour.

The combined sump water is discharged to Pentolite Ditch and subsequently flows eastward along the south side of Pentolite Road for a distance of approximately 2500 feet to Plum Brook. Collected water is discharged into Pentolite Ditch. The reactor sump discharge is under a group outfall permit for Plum Brook (#003).

Pentolite Ditch has a channel width of approximately 6 feet, a typical flow depth of 6 to 8 inches, and low flow velocities. It flows year round. Most, if not all, of the flow is from the sump discharges. Plum Brook has a channel width of 12 to 15 feet, a typical flow depth of 3 feet, and a drainage area of approximately 1960 acres at the property boundary.

Building 1131 is connected to Building 1111 by means of an underground tunnel on the west side. Building 1131 has numerous floor drains leading to a collection sump in the basement. The only utility that traverses the south side of the building, where the USTs were located, is a buried power line from substation/Building 1161. Building 1131 is predominately sheet metal sided, with brick on the west side where the control rooms are located.

3.1.1 Topography

The RA complex is located on relatively flat land characterized by topography that slopes gently north and east toward Lake Erie. The ground surface has an average slope of less than six percent. The surficial deposits and landforms were produced by glacial processes. The approximate elevation at the RA complex is 630 feet mean sea level (MSL).

3.1.2 Surficial Geology/Soil Conditions

Sixteen soil borings in the vicinity of the RA complex have identified surface soil to be predominantly a fine sand and grey mottled clayey silt. The overburden at the Reactor Area has an average thickness greater than 22 feet. Brown fine sand was found near the surface to a depth of 8 feet in all boreholes in the UST area. This brown fine sand was found in some areas to be underlain by 2-14 feet of grey fine sand, 1.5-8 feet of grey sandy clayey silt, >1.5 feet of grey clayey silt and grey silty clay. The soil is consistent with that identified in mapping by the Ohio Department of Natural Resources (ODNR) as the Arkport-Galen association which occurs in the northern and western portions of PBS. Bedrock was not reached at this UST area, although the boreholes were drilled to a depth of auger refusal at 10-22 feet.

3.1.3 Bedrock Geology

Bedrock was not encountered in any of the borings at the RA complex. Bedrock in this area may be the Ohio Shale or Devonian Columbus and Delaware limestone. To the south of the site, at the Garage and Maintenance Area (GMA), soil borings at a depth of 27-29 feet encountered the Ohio Shale. The Ohio shale has also been encountered at shallow depths of 6-8 feet in the Space Power Facility (SPF) and in the GMA at PBS. It is likely that shale will be encountered at depths of greater than 29 feet, being that the general dip of the shale bedrock is to the north. A well which will be drilled in the bedrock at the RA will help to define the bedrock in the area.

According to a groundwater zone map developed by the ODNR the underlying shale bedrock can supply domestic wells. Limited groundwater flow (<3gpm) may be obtained from thin, discontinuous sand and gravel deposits interbedded in fine sandy clay seams. The ODNR map also indicates the Devonian Columbus and Delaware limestone and dolomite aquifer occurs in the area at depths of less than 100 feet.

The zone map indicates the RA complex is in an area where bedrock yields of 5 to 25 gallons per minute may be developed. Development of cavernous porosity within this zone is highly erratic as indicated by a well located just outside of the Plum Brook Station boundary, which had a yield of 8 gpm in the same aquifer.

3.1.4 Surficial Groundwater

In the area of the excavated USTs, the groundwater table during the Phase I investigation was above the level where the removed USTs had been located. Figures 3-2 and 3-3 present the surficial groundwater aquifer elevation contours developed from the January 9, 1991 and May 9, 1991 groundwater level measurements, respectively. The groundwater flow direction indicated for both the January and May measurements was inward toward the buildings. The groundwater elevation contours for this area reflect the presence of the underground tunnel that connects Building Nos. 1134, 1131, and 1152 in this area. A dewatering operation is taking place at this tunnel in which groundwater draining into the area around the tunnel is collected and pumped out. The dewatering in this area has a pronounced local effect on groundwater elevations and flow direction. The dewatering of the tunnel dominates the local groundwater flow pattern in the surrounding area, including the former location of the USTs. This local effect diminishes with distance from the dewatering point.

A regional groundwater elevation study under the Corrective Actions Remedial Investigations/Feasibility Study (RI/FS) Phase I indicates groundwater flow contours show the flow to be in a northwesterly direction (Figure 3-4). At the northernmost point of PBS, the regional flow at the RA complex appears to head in a northeasterly direction. After placement of the additional wells, more information will be available to determine the regional flow direction in the area.

Taking the maximum theoretical hydraulic conductivity for the various soil units observed at this UST area, the maximum horizontal groundwater flow velocities in the soils are 72 and 58 feet per year, calculated based on the January and May 1991 water elevation measurements, respectively. These calculated velocities are roughly a factor of 30 to 50 higher than the velocities calculated for the other areas. This calculation also highlighted the relative steepness of the gradients in this area. The slug test will offer more information regarding the hydraulic conductivities.

3.2 PAST WASTE MANAGEMENT ACTIVITIES

Figure 3-5 shows the area of waste and fuel management operations at the RA complex. Three USTs were located in a common excavation adjacent to the south side of the RA complex (Building 1131). Two of the USTs were 7,900 gallon steel fuel oil USTs (#21 and #22) and the third (UST #23) was a 500 gallon steel waste oil and solvent UST. All three USTs were installed in 1961. The three USTs were removed on December 28, 1989. USTs #21 and #22 were not in service at the time of removal and were empty; UST #23 was in service at the time of its removal. USTs #21 and #22, used to store gasoline and diesel fuel, were removed and closed under BUSTR regulations. Since these USTs were never regulated as a waste management unit by RCRA and not known to ever have contained any waste oils, waste solvents, or other RCRA waste, they are not part of the RCRA closure of the RA complex.

The USTs did not have secondary containment or release detection systems. The intention was to close the site according to the Ohio State Fire Marshall BUSTR Regulations. There were no formally established target cleanup levels other than those presented in BUSTR guidance.

It is estimated the maximum hazardous waste inventory in UST #23 is 250 gallons. Waste oil and solvents were allowed to accumulate in the UST until it was approximately half full. Contents of the UST was disposed of once a year. There are no manifests which document routine disposal of the UST contents. It is estimated the throughput of hazardous wastes over the life of the waste oil and solvent UST is 8400 gallons. Manifests from the shipment of hazardous waste solvents from the reactor area closure are included in Appendix D.

Records listing the identities and quantities of waste solvents stored in UST #23 could not be found, but discussions with facility personnel provided the following information: acetone, carbon tetrachloride, methylene chloride, 1,1,1-trichloroethane, and tetrachloroethene were known to have been used and are likely to have been placed in the UST.

Table 3-1 is a list of chemical solvents which are known to have been managed at UST #23. Table 3-2 shows the additional chemicals that were found at the site during past investigations and are potentially associated with UST #23 as either chemicals that were used or degradation products thereof. The combination of Tables 3-1 and 3-2 constitutes the list of the potential chemicals of concern for site closure.

3.3 PREVIOUS SITE INVESTIGATIONS

During the past six years there have been a number of environmental investigations at Plum Brook Station that provide site-specific background information for the RA complex.

3.3.1 Underground Storage Tank Removals

On December 28, 1989, the permanent removal of USTs #21, #22, and #23 was performed at the RA complex. These USTs were located adjacent to the southern side of Building 1131. The USTs were adjacent to one another, lying in a north-south direction. These USTs were installed in 1961 and were constructed of steel. Mr. Edwin Maglott of the State Fire Marshal's Office and Ms. Pamela Doerner of the Ohio Environmental Protection Agency were on site to oversee the removal of the USTs. Representatives of NASA Plum Brook Station, Warner/ Osborn/ Pardee and Turner Construction were also on site to monitor the removal of the USTs.

The tops of the USTs were approximately 6 feet below grade. The soil from the surface to a depth of approximately 13 feet was removed and placed in containment areas. These areas consisted of roll off boxes and in an area located approximately 100 yards east of the UST pit which was covered with plastic sheeting and bounded by hay bales. All soil excavation and UST removals were performed by Independence Excavating of Cleveland, Ohio, who was retained as a subcontractor to Turner Construction Company of Cleveland, Ohio.

The three USTs were cleaned prior to their removal. Before UST #23 was cleaned, approximately 250 gallons of waste oil was removed and placed in 55-gallon drums. The cleaning of the USTs was performed by Clean Harbors of Cleveland, Ohio. No as-built or engineering drawings were available for the USTs. A scaled drawing of the UST layout was obtained and is included in Appendix C.

Partial cleanup of the site has occurred in the form of UST removal and disposal of excavated soil. All waste residues from the USTs were removed and transported offsite for disposal. It is estimated that the following quantities of wastes were generated during the UST removal on December 28, 1989:

- Three USTs were cleaned prior to their removal by Clean Harbors of Cleveland, Ohio. Before UST #23 was cleaned, 250 gallons of liquid pumpable wastes were removed and drummed, and 190 gallons of rinseate was generated from the cleaning and drummed. A total of 400 gallons of waste was drummed and shipped by Clean Harbors of Kingston, Inc. and disposed of at Clean Harbors of Braintree, Inc. on February 19, 1990. A Uniform Hazardous Waste Manifest is included in Appendix D.

- From March 23 through March 28, 1990, soil generated from the removal of the UST, and solid residue within the UST #23 was transported by Myers Chemical Transport and disposed of at Envirosafe Landfill in Oregon, Ohio. Uniform Hazardous Waste Manifests which document soil disposal are included in Appendix D. A total of 468 tons of soil was disposed of at Envirosafe.

- The underground storage USTs and ancillary piping were removed, cleaned, and transported offsite for disposal. Site personnel have stated that the storage USTs were cut open and rendered useless prior to removal from the site and disposal as scrap steel. There is no available documentation as to the final disposition of the USTs nor their ancillary piping.

- All excavations were backfilled with clean sand from a borrow pit within PBS.

In regard to health and safety during the 1989 UST removal, NASA requires a site-specific health and safety plan from each contractor that performs work on site. The health and safety plan was reviewed by NASA Health and Safety personnel. During this removal, work was performed in accordance with OSHA 29CFR 1910.120. These regulations include site worker 40-hour training, environmental monitoring for organic vapors and explosive environment, and personal protection with respect to clothing and decontamination.

3.3.2 UST Closure Assessment, EBASCO Environmental, 1990

As part of the UST removal, an UST Site Closure Assessment for USTs #21, #22, and #23 was completed by EBASCO Environmental in December, 1989, and a report was generated dated May, 1990 that included soil sampling and analyses. A complete copy of the report including figures and laboratory data may be found in Appendices B-1 and B-2. A total of eleven soil samples from beneath the UST, the sidewalls of the excavation pit, and from excavated soils were collected from the UST cavity at the time of UST removal in order to determine if a release of UST contents had occurred during the active life of the UST. Two concrete slabs that ran an east-west direction beneath the USTs were removed after the USTs were removed. Soil samples were labelled PBS-1131-SS-1 through PBS-1131-SS-11. Soil samples SS-1 through SS-6 were taken from the pit excavation after the 3 USTs and the concrete slabs were removed. Soil samples SS-7 through SS-9 were taken from the excavated soils from above the USTs.

The closure assessment indicated that varying degrees of contamination were present. During the original excavation of the soils, the pit appeared to contain a water-oil mixture after the USTs were removed. An Hnu photoionization detector was used to determine if there were volatile organics emanating from the soil samples. The Hnu readings and visual contamination was the rationale for excavating an additional 3-4 feet beneath the concrete slabs. Soil samples SS-10 and SS-11 were taken from the bottom of the pit after the additional 3-4 feet of soil was removed.

The eleven soil samples were collected and analyzed for Volatile Organic Compounds (VOCs) (EPA method 524.2), EP Toxicity for lead (EPA method 200.7), Flash point (ASTM method D-93) and Total Petroleum Hydrocarbons (TPH) (EPA method 418.1). The samples were analyzed for EP toxicity because that was the accepted leachate test when the samples were analyzed. No groundwater samples were taken at the time.

A summary of chemicals identified in the soil listed with their highest detected concentrations is shown in Table 3-3. There were detectable levels of TPH in the area of UST #23. Eleven samples were analyzed for TPH and concentrations ranged from a low of 114 ppm to a high of 3570 ppm. Lead leachate concentrations were below the detection limits in all of the samples and a flashpoint

>200° F was measured in each of the samples indicating the soils are not considered hazardous by virtue of their toxicity characteristic or ignitability.

3.3.3 Soil and Groundwater Sampling and Analyses, EBASCO Environmental, 1991

In November 1991, Phase I of a Corrective Action RI/FS was completed by EBASCO Environmental. A copy of the report including figures, well logs, data, etc. may be found in Appendices B-3 and B-4. During Phase I field investigation, six soil borings with depths ranging from 10-22 feet were completed and were finished as groundwater monitoring wells. Soil borings were labelled PBS-RA-SB-01 through PBS-RA-SB-06. Samples for volatile organics analysis were collected as discrete samples. All others were composited and collected over the depth of the borings and analyzed. The field activities involved in the Phase I field investigation included soil borings and sampling, well installation, and groundwater sampling. Two of the six monitoring wells were sampled; PBS-RA-GW-04 because it was presumed to be contaminated and PBS-RA-GW-01 because it was expected to be clean and used as background.

All of the field samples, duplicates and field blanks, were analyzed for the target compound list (TCL) volatiles, semivolatiles, pesticides/PCBs and target analyte list (TAL) metals and cyanide and total petroleum hydrocarbons (TPH). The TCL/TAL analyses were completed following USEPA contract laboratory protocols. The TPH analysis was performed in accordance with EPA method 418.1. Methods for the additional sample analysis were not specifically stated, however they are believed to be consistent with SW-846 methodology. Four VOCs (1,2-dichloroethane, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene) were detected in this set of soil samples. Methylene chloride, acetone, carbon disulfide, and bis(2-ethylhexyl)phthalate were also detected and were referred to as probable laboratory contaminants. Additional semivolatile compounds were also found in the soil samples. TPH was found in the soil samples up to a concentration of 159 mg/kg (SB03 0'-22' composite). Table 3-4 is a summary of maximum detected chemical contaminants in soil samples.

Groundwater wells range in depth from 10 to 22 feet. All screens used were 304 stainless steel .01" slot, and ranged in length from five to fifteen feet. Well #PBS-RA-GW-01 was drilled to a depth of 16 feet and the bottom 10 feet was screened. Well #PBS-RA-GW-02 was drilled to a depth of 18 feet and was screened across the bottom 10 feet. Well #PBS-RA-GW-03 was drilled to a depth of 22 feet and a 15 feet screen was utilized. Well #s PBS-RA-GW-04 through PBS-RA-GW-06 were each drilled to a depth of 10 feet and screened in the bottom five feet of the well. Copies of well logs and a geologic cross-section may be found included in the full report in Appendix B-3.

The groundwater samples indicated the presence of a pesticide endosulfan sulfate at 1.00 ug\L in PBS-RA-GW-04, 0.580 ug/L in PBS-RA-GW-01, and the analyte was also found in the associated blank. Beta-BHC, a chlorinated insecticide, was found at a concentration of 0.097 ug/L in PBS-RA-GW-01, which was expected to be clean. The result is an extremely low concentration and it is unknown whether the analytical procedure was performed using dual column confirmation, therefore indicating the potential for a false positive. Beta-BHC was never utilized in the area of the UST #23. The groundwater assessment for the Phase I was inadequate for determining rate and extent.

3.3.4 Soil and Groundwater Sampling and Analysis, Morrison Knudsen Corporation, 1993

In April 1993, MK performed Site Assessments of the UST areas. A copy of the report, Preliminary Site Investigation, Phase I, can be found in Appendix B-5. The laboratory data are included in Appendix B-6. As part of the investigation, soil, groundwater and sediment samples were collected in and around the RA complex.

Four borings were drilled at the reactor area and labelled B-1 through B-4. B-1 through B-3 were drilled to a depth of 16 feet, and B-4 to 14 feet. B-1 was also converted into a monitoring well, MW-1. Three samples were collected from each boring. Samples were collected at depths of 2-4', 4-6', 6-8' or 14-16'. The soil samples were analyzed for TPH (Method 418.1), BTEX (Method 8020), Volatiles (Method 8240) and Polynuclear Aromatic Hydrocarbons (Method 8100). Well MW-1 was sampled along with six other previously installed monitoring wells.

During this investigation MK renamed the existing monitoring wells: PBS-RA-GW-01 was renamed EB-6 and PBS-RA-GW-02 through PBS-RA-GW-06 were renamed EB-1 through EB-5 respectively.

A sump area inside of the Building 1131 was also sampled. The sump collects water from the building foundation drain system and building floor drains. All of the groundwater samples were analyzed for volatiles (Method 8240) and polynuclear aromatic hydrocarbons (Method 8100).

Table 3-5 is a summary of chemicals detected in the soil during this round of sampling. Analytical results for the groundwater are found in Table 3-6.

3.3.5 Facility Wide Site Inspection, Morrison Knudsen Corporation, 1993

Water and sediment samples were collected in Plum Brook approximately 500 feet downstream from Pentolite Road on July 20, 1993, as part of a facility wide Site Inspection by MK. These samples were collected at a period of extreme low flow (approximately 100,000 gpd). The samples found no detectable hazardous waste constituents.

3.3.6 Decontamination and Cleaning of Cold Drains and of Sump, Morrison Knudsen Corporation, 1994

On August 8, 1994, Matt Construction Services, Inc. under contract to MK, mobilized equipment to clean the drains and associated piping in the Service Equipment Building #1131, rooms 13,15,18,20,21,25,26, and 27. A high pressure sewer cleaning unit was used to vacuum material from the drains at the point of entry to the sump. Air movement was audible in some of the drains, which showed that gross debris had been removed by the vacuuming process.

Cleaning of the drains continued on August 9, 1994. Alternate drains were temporarily plugged in order to increase the strength of the vacuum to effectively remove material in the drains. After all drains were audibly clear of debris, water was introduced under high pressure. Each drain location was flushed for three to five minutes and a sample of water collected at the point of entry to the sump. When the water exhibited no debris, odor, or sheen the drain was considered clean.

Air monitoring was performed on August 9, 1994, by MK for 1,1,1-trichloroethane using Drager gas measurement detector tubes. Areas around the drains as well as in the sump showed levels to be below detection levels (50 parts per million). Aries Environmental of Pittsburgh, Pennsylvania performed personnel monitoring using detector badges on the same date. 1,1,1- Trichloroethane was not detected in the sample.

On August 10, 1994, the sump cleaning was completed. The majority of liquid and sludge removed from the drains and sump was transferred from the vacuum tanker to a storage tank (approximately 2,000 gallons). Three drums of sludge and water were containerized in 55-gallon drums.

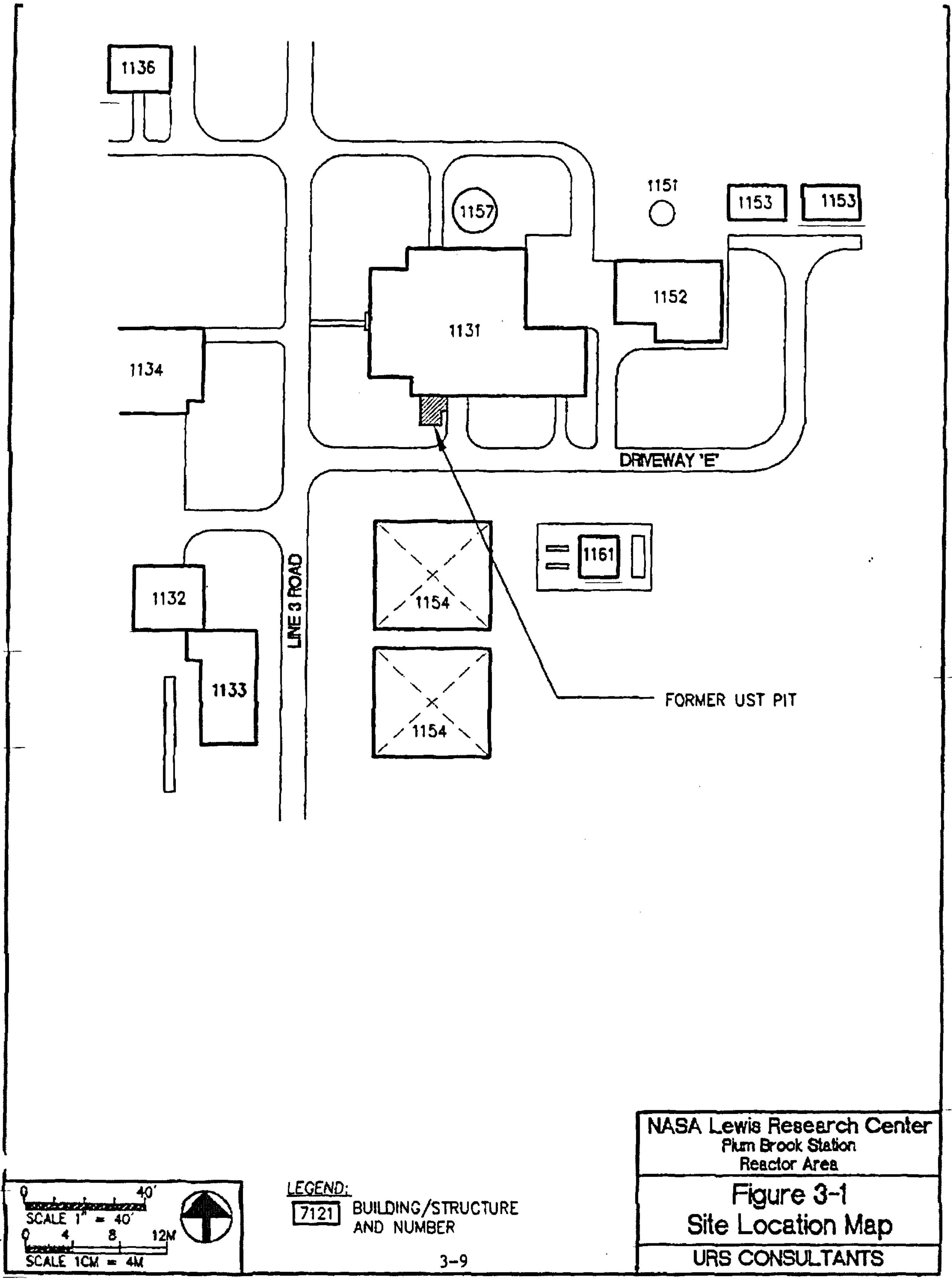
In addition, four 55-gallon drums of plastic, personnel protective equipment (PPE), and trash were generated during the cleaning process. Samples of wastewater from the drums and holding tank were submitted to B.E.C. Laboratories in Twinsburg, Ohio for analysis. Copies of the analyses, and drawings of the drains are in Appendix B-7.

Temporary plugs were placed in the drains after cleaning to prevent further contamination of the drains and sump. Equipment used in the cleaning process was screened for radiation contamination by NASA personnel after completion of the project. No radiation levels were found to exist above background levels. With the approval of NASA Office of Environmental Programs, seven drums of sludge, trash and PPE were disposed of at Laidlaw Environmental Services (TS), Inc. on November 9, 1994, under manifest number 94011, and 2,410 gallons of water was disposed of on November 10,1994 at Chem Met Services, Inc. under manifest document number 94012. Uniform Hazardous Waste Manifests from disposal of the sludge are found in Appendix D.

3.3.7 Summary of Previous Site Investigations at RA

Based on soil and groundwater sample analyses of the previous site investigations, it is apparent that soil contamination and groundwater contamination exists at the site as a result of waste and fuel management operations at the RA complex. Ohio EPA has commented on the above mentioned investigations used in a previous submittal (NASA Plum Brook Station, Closure Work Plan Reactor Area, May 20, 1994). After review and discussions with OEPA, NASA agrees that the RA complex has not been adequately characterized for extent and that much of the analytical data used to support the risk assessment may not have the required validation.

NASA intends to define the full vertical and horizontal extent of soil and groundwater contamination at the Reactor Area. The following Sampling and Analysis Plan details how NASA intends to fully determine the extent of contamination. The results of the previous investigations will be used as qualitative information to direct a more efficient site characterization.

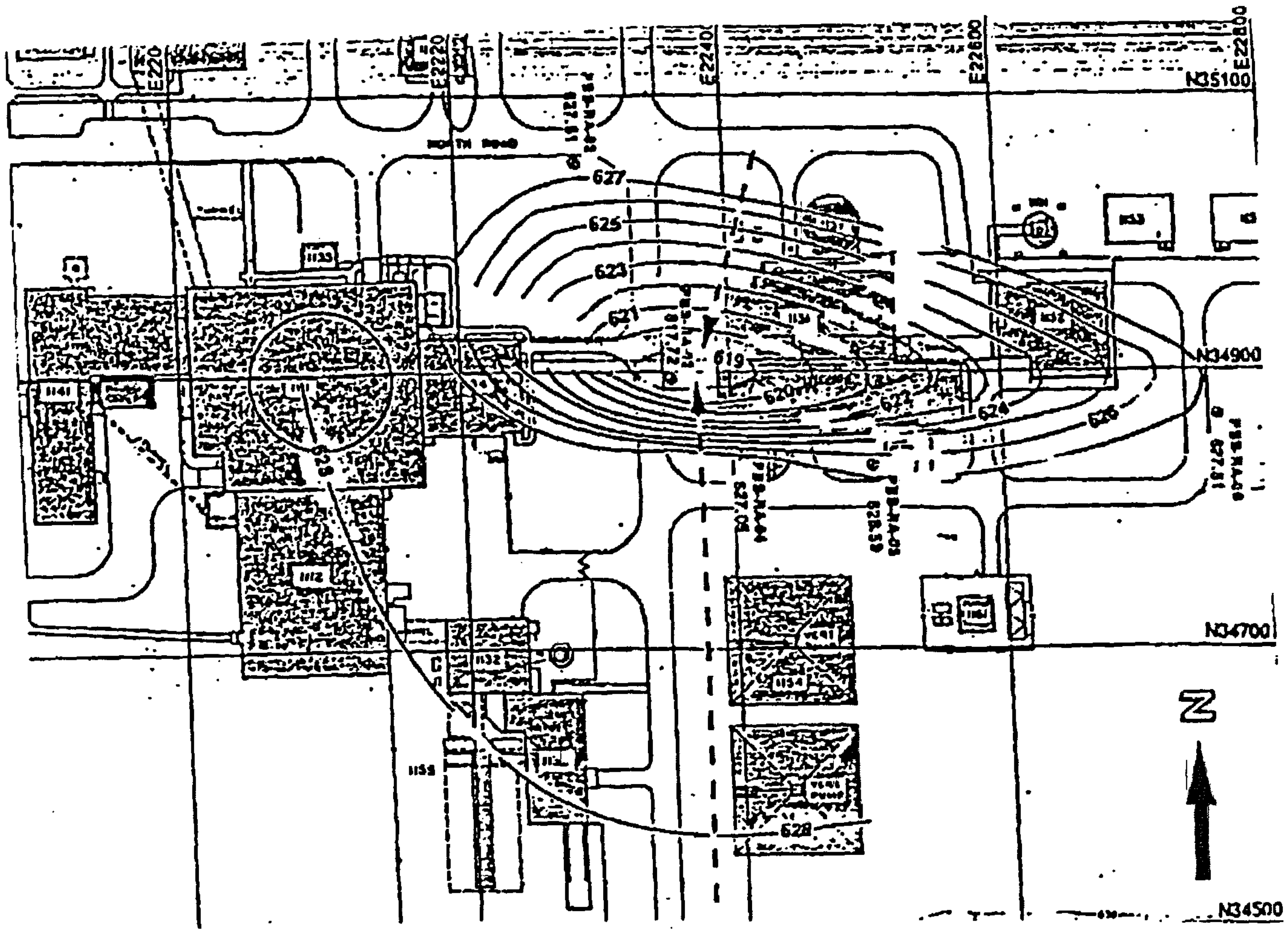


LEGEND:
7121 BUILDING/STRUCTURE AND NUMBER

NASA Lewis Research Center
Plum Brook Station
Reactor Area

Figure 3-1
Site Location Map

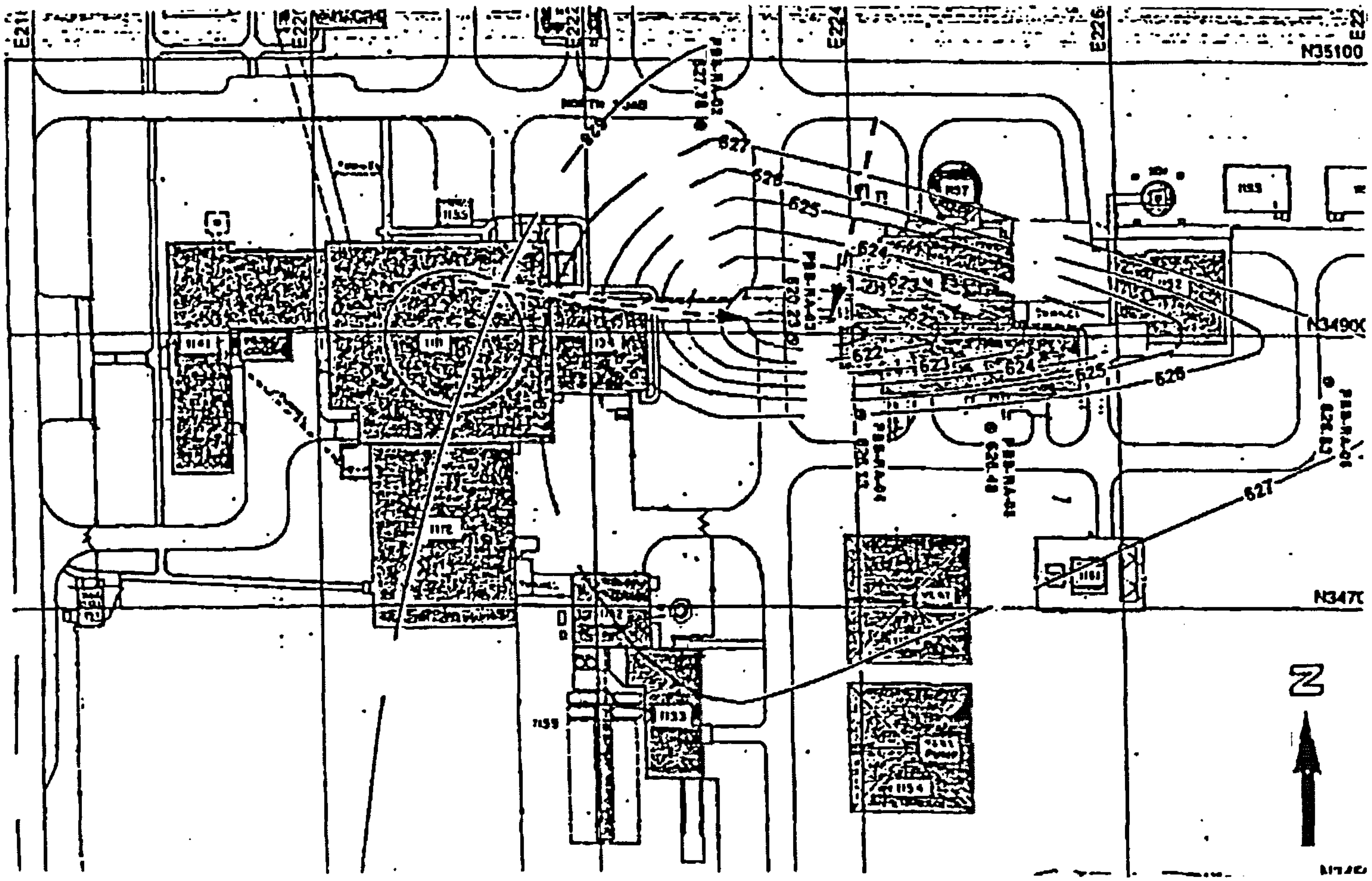
URS CONSULTANTS



NASA Lewis Research Center
Plum Brook Station
Reactor Area

Figure 3-2
Groundwater Contour Map - January 1991

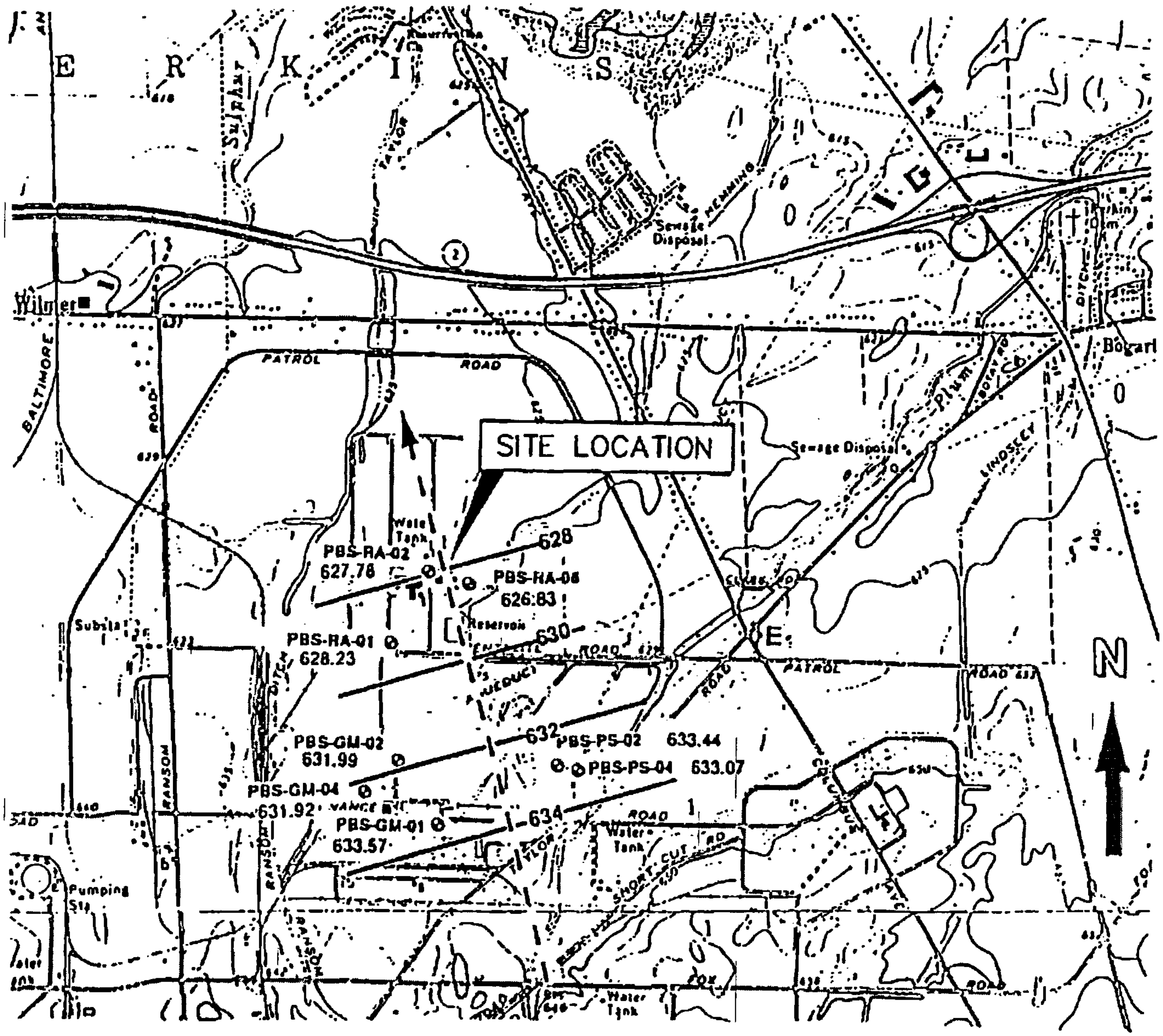
URS CONSULTANTS



NASA Lewis Research Center
Plum Brook Station
Reactor Area

Figure 3-3
Groundwater Contour
Map - May 1991

URS CONSULTANTS



LEGEND

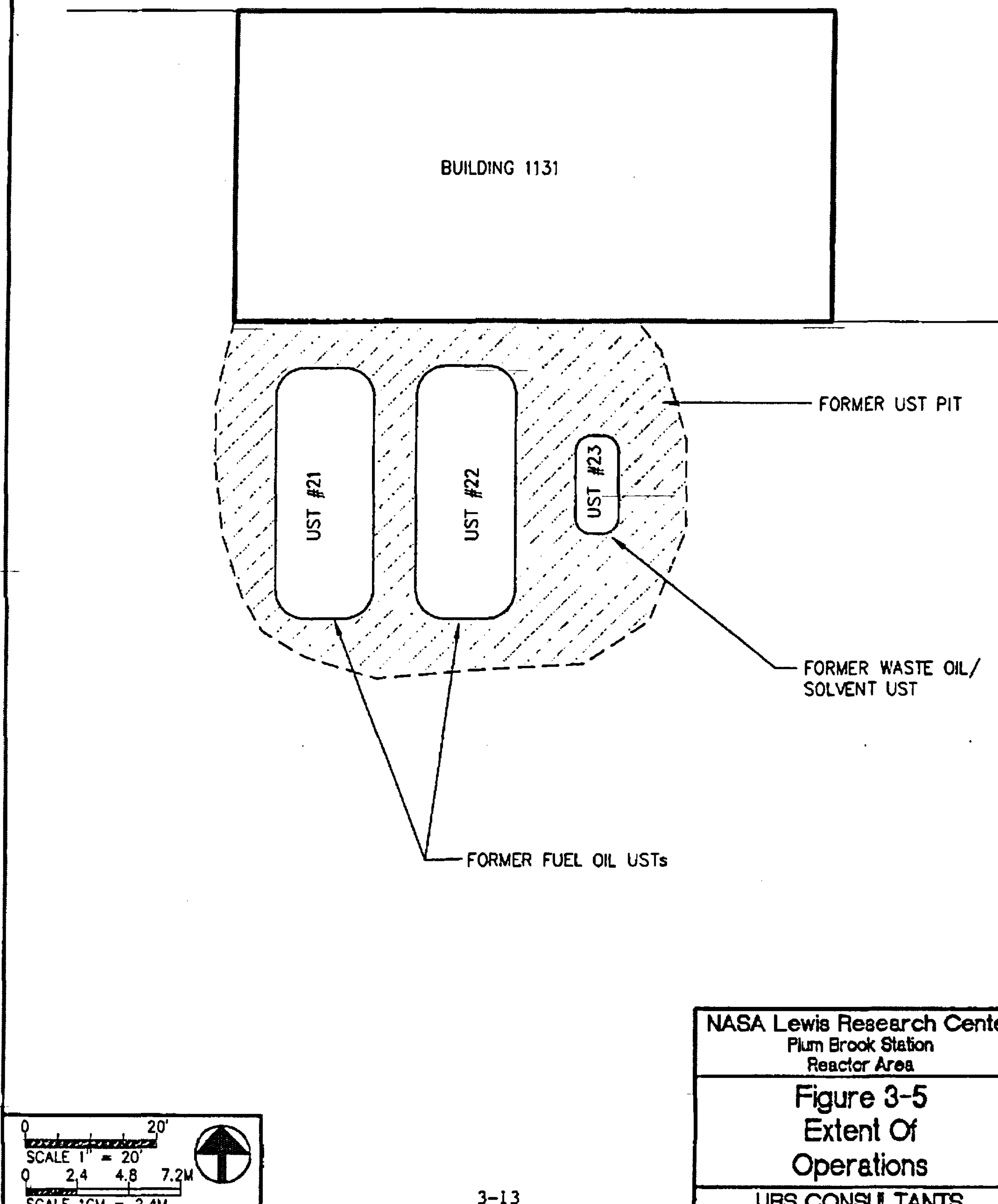
Symbol	Description
PBS-GM-01 633.57	Ground Water Monitoring Well Ground Water Elevation
634.0	Ground Water Elevation Contour
— — — ▶	Direction of Ground Water Flow

NASA Lewis Research Center
Plum Brook Station
Reactor Area

Figure 3-4
Regional Groundwater
Contour Map - May 1991

URS CONSULTANTS

M: \d7253900\C\REACTOR\FIG3-4



NASA Lewis Research Center
Plum Brook Station
Reactor Area

Figure 3-5
Extent Of
Operations

URS CONSULTANTS

Table 3-1

Chemicals Managed at UST #23
Reactor Area, Plum Brook Station

CHEMICAL	HAZARDOUS WASTE CODE
acetone	F003
carbon tetrachloride	F001,F002
methylene chloride	F001,F002
1,1,1-trichloroethane	F001,F002
tetrachloroethene	F001,F002

Table 3-2
Chemicals Potentially Managed at UST#23 - Reactor Area, Plum Brook Station

CHEMICAL
1,1-dichloroethane
cis-1,2-dichloroethene
trans-1,2-dichloroethene
1,2-dichlorobenzene
bromodichloromethane
1,2-dichloroethane
tert-butylbenzene
sec-butylbenzene
p-isopropyltoluene
1,3-dichlorobenzene
1,4-dichlorobenzene
dichlorodifluoromethane
chloroethane
naphthalene
trichloroethene
1,2,4-trimethylbenzene
1,3,5-trimethylbenzene
toluene
n-propylbenzene
chloroform
hexachlorobutadiene
isopropylbenzene
1,1,2-trichloroethane
1,1,1,2-tetrachloroethane
1,1,2,2-tetrachloroethane
1,2,3-trichloropropane
trichlorofluoromethane
1,2,4-trichlorobenzene
1,2,3-trichlorobenzene
xylenes

Table 3-3

Maximum Concentrations of Analytes in Soil, EBASCO Environmental, 1990
Reactor Area, Plum Brook Station

CHEMICAL	MAXIMUM CONCENTRATION IN SOIL (ug/kg)	SAMPLE LOCATION
dichlorodifluoromethane	61	SS-11
chloroethane	990	SS-10
trichlorofluoromethane	120 J	SS-2
methylene chloride	503	SS-5
trans-1,2-dichloroethene	17	SS-11
1,1-dichloroethane	6120	SS-10
cis-1,2-dichloroethene	165	SS-11
chloroform	1 J	SS-10
1,1,1-trichloroethane	891	SS-3
carbon tetrachloride	91 J	SS-3
1,2-dichloroethane	178	SS-10
benzene	32 J	SS-4
trichloroethene	1019	SS-9
bromodichloromethane	23 J	SS-4
toluene	41	SS-8
1,1,2-trichloroethane	143	SS-4
tetrachloroethene	1043	SS-3
ethylbenzene	1093	SS-4
1,1,1,2-tetrachloroethane	375	SS-8
m & p- xylenes	1115	SS-8
o-xylene	703	SS-8
1,1,2,2-tetrachloroethane	463	SS-6
isopropylbenzene	380	SS-8
1,2,3-trichloropropane	9	SS-10
n-propylbenzene	612	SS-8
1,3,5-trimethylbenzene	4365	SS-8

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Table 3-3 continued

Maximum Concentrations of Analytes in Soil, EBASCO Environmental, 1990 Reactor Area, Plum Brook Station

CHEMICAL	MAXIMUM CONCENTRATION IN SOIL (ug/kg)	SAMPLE LOCATION
tert-butylbenzene	645	SS-7
1,2,4-trimethylbenzene	4413	SS-8
sec-butylbenzene	858	SS-8
p-isopropyltoluene	1854	SS-8
1,3-dichlorobenzene	2 J	SS-10
1,4-dichlorobenzene	2 J	SS-10
1,2-dichlorobenzene	31 J	SS-8
1,2,4-trichlorobenzene	575	SS-1
hexachlorobutadiene	404	SS-1
naphthalene	13388	SS-8
1,2,3-trichlorobenzene	1025	SS-1

J Below Quantitation limits; Estimated Value

Table 3-4
Maximum Concentrations of Analytes in Soil, EBASCO Environmental, 1991
Reactor Area, Plum Brook Station

CHEMICAL	MAXIMUM CONCENTRATION DETECTED IN SOILS (ug/kg)	SAMPLE LOCATION
methylene chloride*	95	SB03 6'-8'
acetone*	320 BE	SB03 6'-8'
carbon disulfide*	31	SB03 6'-8'
1,2-dichloroethene	120	SB05 4'-6'
1,1,1-trichloroethane	22	SB04 4'-6'
trichloroethene	760 E	SB05 4'-6'
tetrachloroethene	19	SB05 4'-6'
SEMI-VOLATILE COMPOUNDS		
phenanthrene	290 J	SB05 COMP.0'-10'
anthracene	93 J	SB05 COMP.0'-10'
fluoranthene	270 J	SB05 COMP.0'-10'
pyrene	230 J	SBO4,SB05 COMP. 0'-10'
benzo(a)anthracene	130 J	SB05 COMP. 0'-10'
chrysene	130 J	SB05 COMP. 0'-10'
bis(2-ethylhexyl)phthalate*	590	SB01 COMP. 0'-16'
PESTICIDE/PCBs		
endosulfan sulfate	16 B	SB06 COMP. 0'-10'

* Probable Laboratory Contaminant
J Estimated, value below the Quantitation Limit
E Concentration exceeds calibration range of GC/MS Instrument
B Analyte Found in Associated Blank

Table 3-5

Maximum Concentrations of Analytes in Soil, Morrison Knudsen Corporation, 1993 Reactor Area, Plum Brook Station

CHEMICAL	MAXIMUM CONCENTRATION (mg/kg)	SAMPLE LOCATION
1,1,1-trichloroethane	0.023	B2 6'-8'
toluene	0.003	B3 6'-8'
phenanthrene	1.16	B3 2'-4'
pyrene	0.343	B1 4'-6'
chrysene	1.26	B3 2'-4'
acenaphthene	0.159	B3 2'-4'
anthracene	0.378	B3 2'-4'
benzo(a)anthracene	1.28	B3 2'-4'
benzo(a)pyrene	1.45	B3 2'-4'
benzo(b)fluoroanthene	1.16	B3 2'-4'
benzo(k)fluoroanthene	1.02	B3 2'-4'
benzo(ghi)perylene	0.635	B3 2'-4'
dibenzo(a,h)anthracene	0.277	B3 2'-4'
fluoranthene	2.48	B3 2'-4'
indeno(1,2,3-cd)pyrene	0.775	B3 2'-4'
acenaphthylene	0.103	B3 2'-4'

Table 3-6

Maximum Concentrations of Analytes in Groundwater, Morrison Knudsen Corporation, 1993 Reactor Area, Plum Brook Station

CHEMICAL	MAXIMUM CONCENTRATION IN GROUNDWATER (ug/l)	SAMPLE LOCATION
dichlorodifluoromethane	1.70	GW-01 (1)
1,1,1-trichloroethane	2.90	GW-04
cis-1,2-dichloroethene	51.9	GW-05
trans-1,2-dichloroethene	1.93	GW-05
tetrachloroethene	1.85	GW-05
trichloroethene	483	GW-05
benzo(a)anthracene	1.30	MW1A (dup. sample of MW-1)
benzo(b)fluoranthene	4.02	GW-02
benzo(a)pyrene	9.20	GW-06
phenanthrene	1.05	GW-04
acenaphthene	414	SUMP
anthracene	215	SUMP
chrysene	17.6	SUMP
dibenz (a,h) anthracene	18.1	SUMP
chloroethane	3.56	SUMP2(2)
1,1-dichloroethane	9.36	SUMP2
1,1,1-trichloroethane	10.8	SUMP2
trichloroethene	1.43	SUMP2
fluoranthene	71.8	SUMP
fluorene	690	SUMP
pyrene	32.9	SUMP

(1) The method blank contained 0.903 ug/L of dichlorodifluoromethane. The approximately equivalent concentration, taking into account dilution factors, is 0.903 ug/L. This is considered to be a significant contribution to the reported value.

(2) A sump in Building 1131 was sampled twice, the lab accidentally destroying the first sample. Sump 2 is the second sample.

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APPENDIX A

SECTION 8

1997 Records Review Report

(Dames & Moore, April 1997a)

DAMES & MOORE

A DAMES & MOORE GROUP COMPANY

RECORDS REVIEW REPORT
PLUM BROOK ORDNANCE WORKS
SANDUSKY, OHIO

APRIL 1997

235 PEACHTREE STREET, N.E.
NORTH TOWER, SUITE 2000
ATLANTA, GEORGIA 30303-1405

Job No. 04715-052-009

2.0 SITE HISTORY

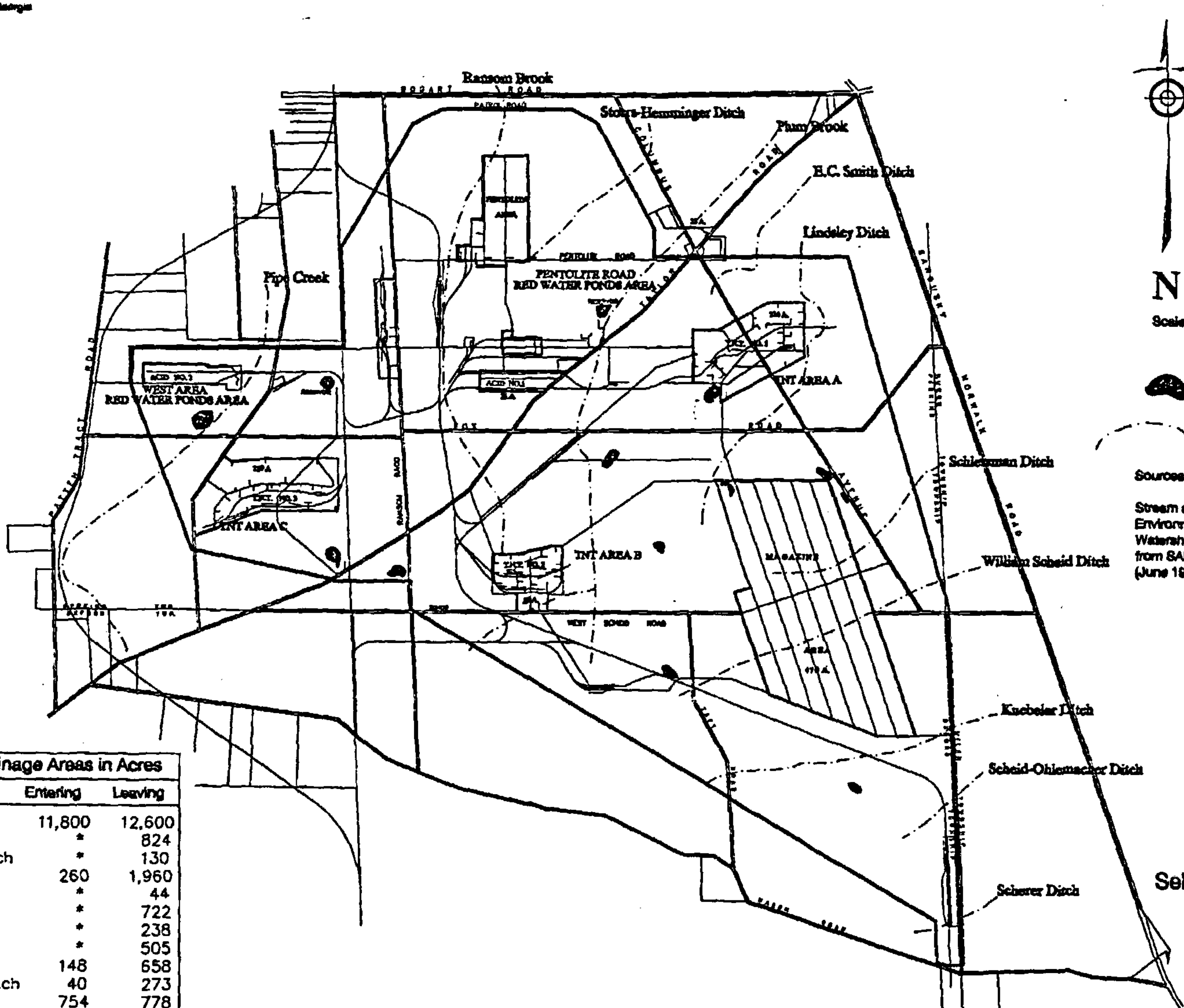
2.1 HISTORICAL POLLUTION REPORTS

SAIC requested information from the Ohio Department of Natural Resources (ODNR) as part of their PA. This information was reviewed by Dames & Moore. The ODNR provided information from their pollution reports and records regarding pollution of Plum Brook, Erie County, Ohio, by the former Trojan Powder Company (TPC) which operated the PBOW under contract to the U.S. Army. The locations of Plum Brook and other surface water features at the former PBOW are illustrated on Figure 2-1.

The information provided in the ODNR report was limited. However, it did document two early-1940s era court cases in which fish kills and damage of the Wyandotte marsh were alleged against the TPC. A "Report of Activities of Stream Pollution Engineering Section" for the month of October 1942 documented attempts by the state agency to investigate complaints and concerns regarding pollution of Plum Brook and Sandusky Bay by the PBOW (Unknown author, Stream Pollution Engineering Section, 1942).

Another "Report of Stream Pollution Section" report for the month March 1945 documented a heavy fish filling in the east end of Sandusky Bay. The water was reportedly a red-brown in the entire east end of the bay, including the swamps from Plum Brook to the entrance to the Cedar Point property on Route 2. Plum Brook and a small creek to the west were reportedly the principal feeders of this pollution. The author reported that the color in Plum Brook and the bay had greatly increased during the 2 months prior to March 1945. The author further reported that during the previous year (ever since improved waste treatment had been implemented at the PBOW), a decided decrease in the color and turbidity of the water in Plum Brook had been observed. The author referenced a newspaper article that stated the PBOW had stepped up production of TNT and another "new explosive" (Unknown author, Stream Pollution Section, 1945).

Government Services Division; Atlanta, Georgia
H:\CAD\COE-PLUM\PLOT\FIG2_1.DWG



Stream	Drainage Areas in Acres Entering	Leaving
Pipe Creek	11,800	12,600
Ransom Brook	*	824
Storrs–Hemminger Ditch	*	130
Plum Brook	260	1,960
E.C. Smith Ditch	*	44
Lindsley Ditch	*	722
Schlessman Ditch	*	238
William Scheid Ditch	*	505
Kuebeler Ditch	148	658
Scheid–Ohlemacher Ditch	40	273
Scherer Ditch	754	778

* Stream originates within station boundaries

N

Scale: 1" = 2800'

Pond or Reservoir

Surface Water Drainage Feature

Sources:

Stream and ditch locations and names from NASA Environmental Resources Document (August 1990). Watershed areas and locations of ponds and reservoirs from SAIC Plum Brook Station Preliminary Assessment (June 1991).

Figure 2-1
Selected Surface Water Features
at Plum Brook Station

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE
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The report for August 1945 stated that although the arsenal had ceased operations, the TNT-contaminated surface water (presumably based upon color) had continued flowing into the east end of Sandusky Bay from Plum Brook as of August 31, 1945 (Gallagher, Stream Pollution Section, 1945).

2.2 PREVIOUS ENVIRONMENTAL INVESTIGATIONS

Several environmental investigations have been completed at the PBS. The investigations which focused on DoD-related activities and potential AOCs are summarized herein.

2.2.1 1983 OEPA Preliminary Assessment

This document was not provided to Dames & Moore for review. The MK Site Inspection (SI) (MK, 1994) stated that the Ohio Environmental Protection Agency (OEPA) conducted a PA of the PBS in 1983. The areas of interest were a 1981 spill of polychlorinated biphenyls (PCBs) and the Red Water Ponds.

2.2.2 Information from Ohio National Guard, 1980s

In the 1980s, the OHARNG conducted an Environmental Assessment (EA) of the western portion of the PBS. As part of the assessment, the OHARNG assembled information regarding past investigations of the WARWP. A NASA study included collection and identification of macroinvertebrates, vertebrates, and fish from the ponds. In 1985, the OHARNG collected and analyzed sediment samples for TNT, DNT and metals. Low levels of the explosive compounds were found in some of the samples and some metals were reported above the levels found in samples from Lake Erie. The EA also describes a Battelle study in which one soil sample was collected from the spoils area at the WARWP (neither TNT nor pentaerythritol tetranitrate [PETN] were detected; 2,4-DNT and 2,6-DNT were detected in small amounts); and one red water sample and one sediment sample were collected (no contaminants were indicated by analysis). The EA also presents information related to water quality studies of Pipe Creek conducted in 1986 and 1987 which provided no indication of contamination in Pipe Creek, both upstream and downstream of the WARWP.

2.2.3 1989 Contamination Evaluation by IT Corporation, 1989

Under contract to the CEORN, IT conducted a Contamination Evaluation at the PBS in 1989. The report documenting the project was finalized in 1991. The investigation consisted of a records review and evaluation, visual site inspections, and field investigations of the PRRWP (referred to as "Waste Disposal Area #1), WARWP (referred to as "Waste Disposal Area #2), Snake Road Burn Ground (referred to as "Scheid Road Burning Grounds"), and the Taylor Road Burn Ground (referred to as "Rubbish Burning Grounds"). Four groundwater monitoring wells were installed and sampled, and surface water samples from four on-site streams were collected and sampled. Twenty-one soil samples were also collected and analyzed. Samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), nitroaromatic compounds, nitrates, sulfates, pH, and metals. Some soil samples were also tested for geotechnical characteristics.

IT's investigation indicated no soil or groundwater contamination from VOCs at any of the locations investigated, limited soil and groundwater contamination from SVOCs at the PRRWP and Snake Road Burn Grounds, elevated metals, sulfates, and nitrates in soils at the PRRWP, and elevated metals in groundwater at the WARWP.

2.2.4 1992 Investigation of Burn Grounds at Snake Road by H^+GCL

In 1992, H^+GCL conducted an investigation of the Snake Road Burn Ground and the adjacent burn grounds used by NASA (referred to as "Disposal Area Three.") The area that was investigated included three burn areas referred to by H^+GCL as "a fire training pit, an Army burnable dump, and a burnable dump used under NASA operations." The fire training pit was located on the west side of Snake Road. The Army burnable dump and the NASA burnable dump were located on the east side of Snake Road. According to the H+GCL report, the Army burnable dump was used from 1941 to 1963 for destruction of explosives during decommissioning of the PBOW (H+GCL, 1992). The purpose of the investigation was to characterize possible groundwater and surface water contamination due to the use of this area as an uncontrolled burn ground. H+GCL installed soil borings and groundwater monitoring wells in the area, including one background monitoring well. Based upon the results of the investigation, H+GCL recommended no further site characterization or remediation of the area.

2.2.5 1994 Site Investigation by Morrison Knudsen Corporation

In 1994, MK completed a SI of the PBS for NASA in order to perform a Hazard Ranking for the site. The MK investigation included records review, installation and sampling of groundwater monitoring wells, surface water sampling, sediment sampling, and surface soil sampling.

The results of the MK investigation identified limited contamination in multiple areas of the site, some of which were previously used for DoD activities. However, the Hazard Ranking Score for the site was below Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) action levels.

6.0 AOC 5 - WASTE WATER SETTLING BASINS IN THE PENTOLITE AREA

6.1 INTRODUCTION

The former Pentolite Area is located north of Pentolite Road at what is now the location of the NASA reactor. The Pentolite Area was used for production of potential from March 1943 through the PBOW shut-down date in August 1945 (TPC, August 1945). The area contained three pentolite lines with a designated capacity of 7,000 pounds per 24 hours. Two basins received waste water generated during the pentolite production. The volume of waste water, specific treatment details, and sludge disposal details were not found in the documents reviewed.

The PA (SAIC, 1991) states that the waste water probably contained significant concentrations of pentaerythritol (PE), PETN, acetone, and TNT. The waste water basins were removed during construction of the Plum Brook Reactor Facility (PBRF). The soils in the entire Pentolite Area was moved and the surface was filled and regraded to meet reactor site specifications. It is likely that any basin-contaminated substrata were removed or dispersed during PBRF construction (SAIC, 1991).

6.2 DESCRIPTION OF THE PENTOLITE WASTE WATER SETTLING BASINS

Two waste water settling basins were formerly located within the Pentolite Area at the location shown on Figure 6-1. Figure 6-2, derived from historical Plan No. R-42, "Unit Layout Map, Pentolite Area" (E.B. Badger & Sons Co., no date) shows the layout of the waste basins, which consisted of two adjacent basins, each measuring approximately 100 feet wide by 140 feet long. The PA (SAIC, 1991) stated that the basins were constructed with precast 15 by 9 foot 9 inch blocks of concrete with asphaltic-filled expansion joints. The concrete was placed on 4 to 6 inches of gravel or #4 stone. The construction details are shown on Figure 6-3.

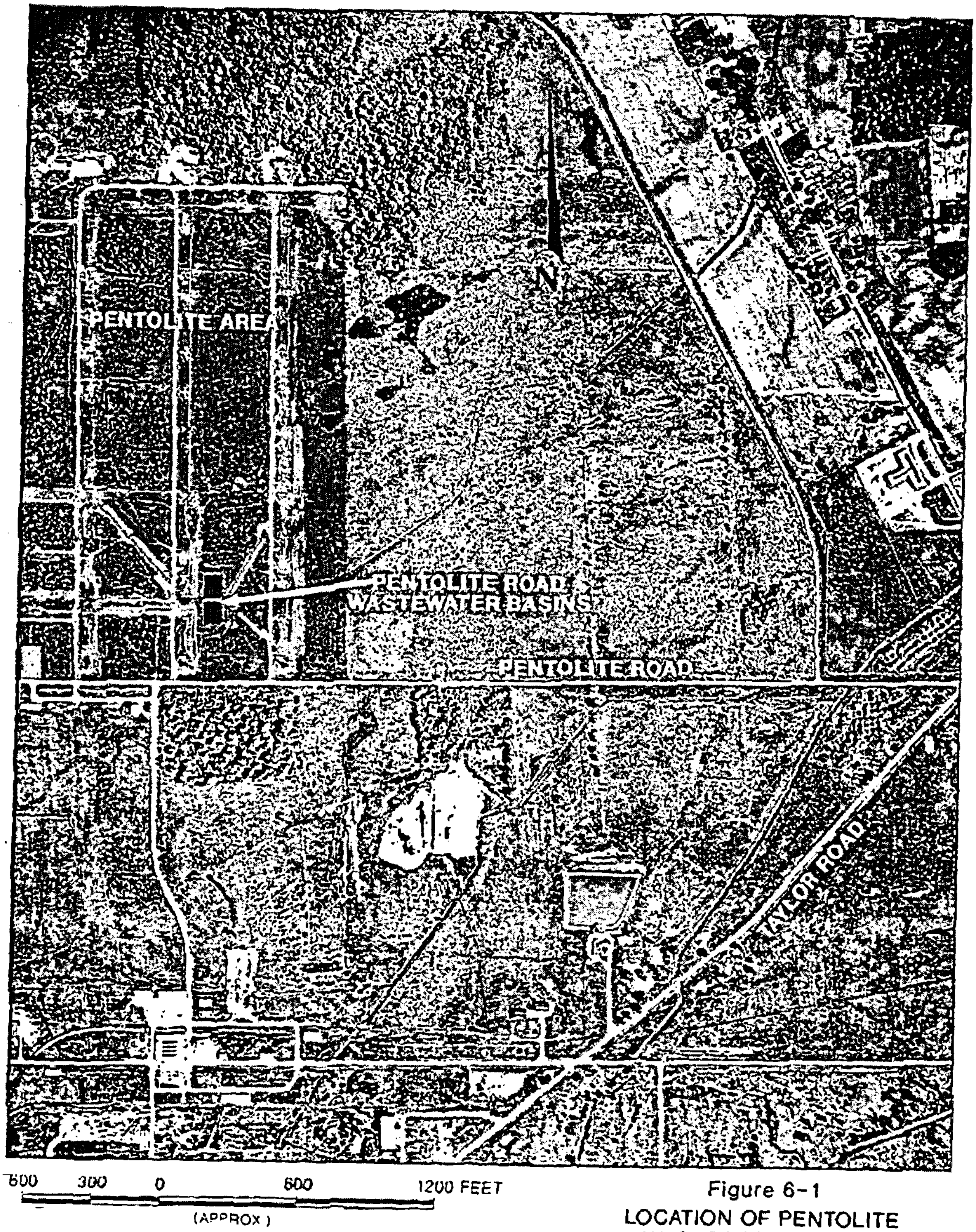

Figure 6-1
LOCATION OF PENTOLITE
WASTE WATER BASINS

Plum Brook Ordnance Works
Sandusky, Ohio

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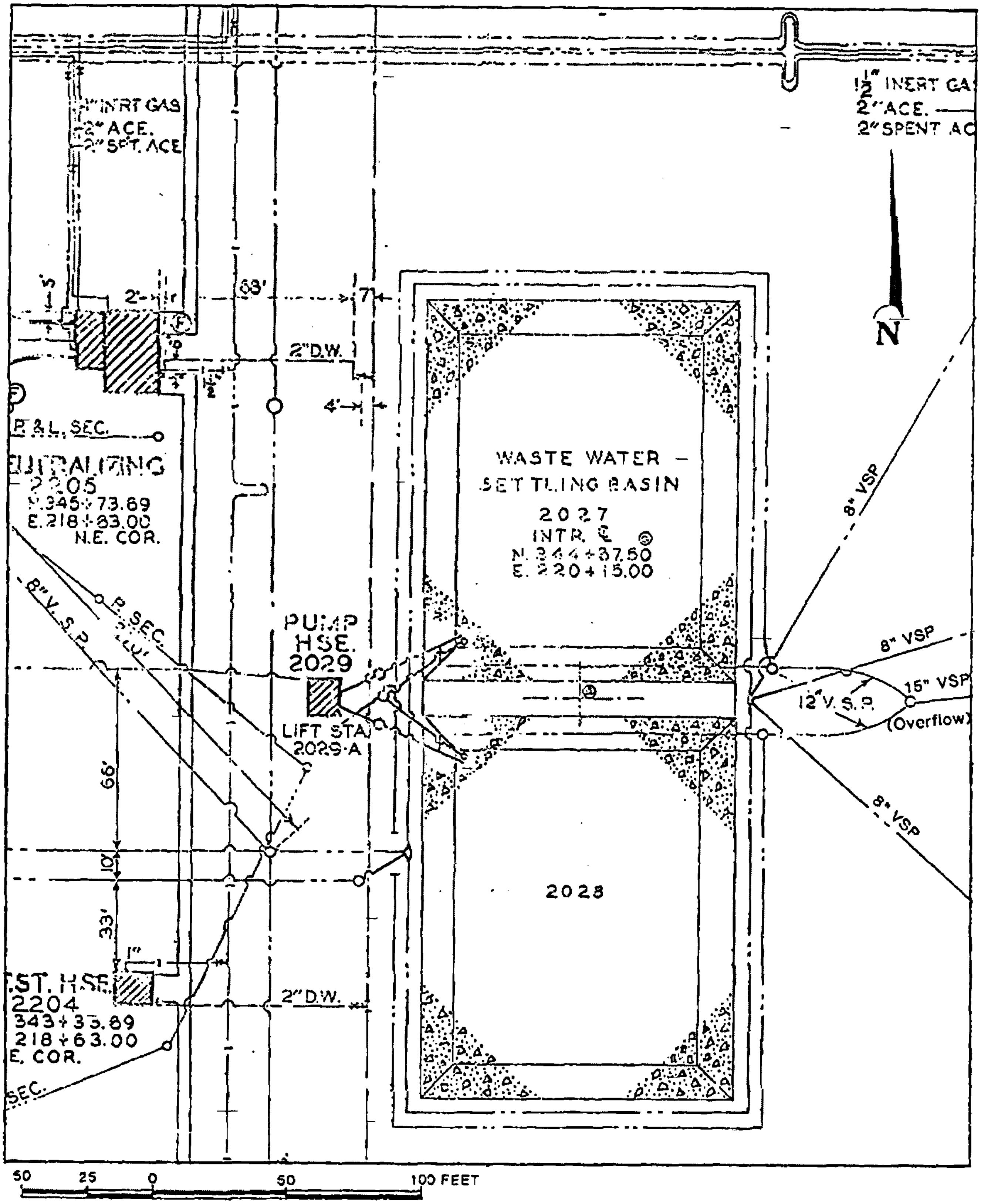

KEY:

VSP Vitreous Sewer Pipe

BASE: Plan No. R-42, "Unit Layout Map, Pentolite Area", E.B. Badger & Sons (no date)

Figure 6-2
LAYOUT OF
PENTOLITE WASTE WATER BASINS

Plum Brook Ordnance Works
Sandusky, Ohio

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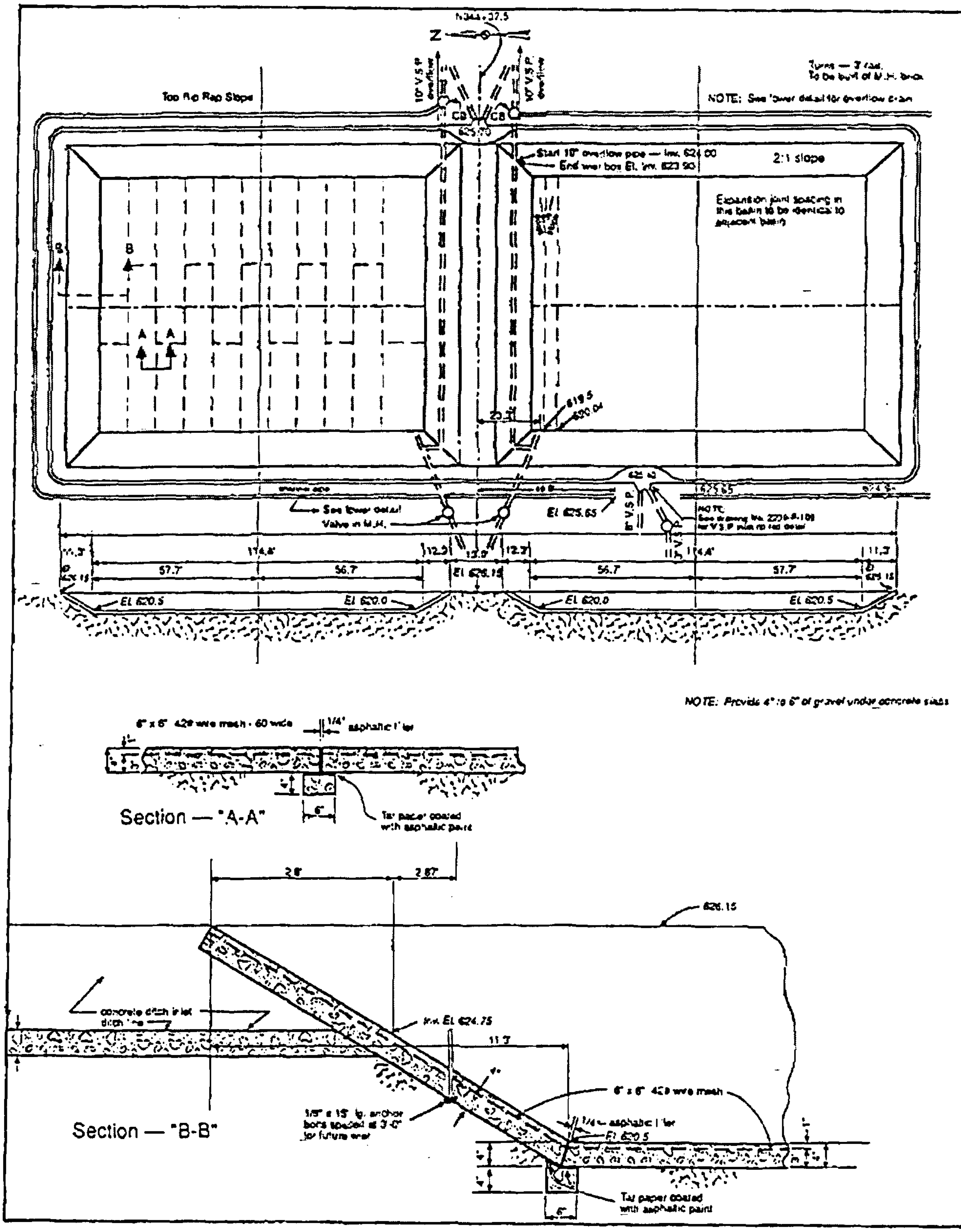

REFERENCE: SAIC 1991 PBS Preliminary Assessment

Figure 6-3

CONSTRUCTION DETAILS OF
PENTOLITE WASTE WATER BASINS
Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE

6.3 REMOVAL OF THE BASINS

Review of historical documents obtained from NASA indicates that in 1956 the National Advisory Committee for Aeronautics (NACA) was granted permission to use and occupy the Pentolite Area. The "Permit to Other Federal Government Department or Agency to Use Property on Plum Brook Ordnance Works, Ohio" (U.S. Department of the Army, 1956), states that decontamination of this area was to be accomplished by the Army "to a degree which in the opinion of the installation commander leaves no significant hazard remaining which will prevent the use of the area for non-military purposes or endanger the lives of individuals or the public ..."

A subsequent memo (Everett and Campbell, 1958) states that the "Pentolite Area of approximately 117.3 acres was decontaminated, demolished, and cleared for use as the site of the Lewis Laboratory Reactor Facility." The Pentolite Area was apparently chosen as the site of the reactor due to the "cleanliness" of the area.

The "Shut Down and Decontamination Procedures for Plum Brook Ordnance Works, Sandusky, Ohio," (Dykema and Lee, March 1944) state that the stand-by and storage procedures for the Pentolite settling basins shall consist of draining and flushing the limestone bed and basin with high pressure hoses, removing the limestone while it is wet, and then inspecting the basin for evidence of accumulated explosives. The "Special Instructions for Decontamination of Pentolite Area" contained in the referenced document state that all PETN would be processed. All buildings were to be considered as contaminated and burned at the burn grounds. No mention was included in this document nor in the "Decontamination Procedures" (War Department, 1945) regarding decontamination procedures for the surrounding soils in the Pentolite Area.

No environmental investigations have been performed at the former location of the Pentolite Road Waste Water Settling Basins.

APPENDIX A

SECTION 9

1997 Site-wide Groundwater Investigation

(Dames & Moore, April 1997b)

SITEWIDE GROUNDWATER

INVESTIGATION

FINAL REPORT

FOR

PLUM BROOK ORDNANCE WORKS

PLUM BROOK STATION/NASA

SANDUSKY, OHIO

Prepared for:

U.S. Army Corps of Engineers

Nashville District/Huntington District

Prepared by:

Dames & Moore, Inc.
Atlanta, Georgia

APRIL 1997

G:\WP\C\COE\PLUM BRO.OK\GROUND WTR\GND.ALL

EXECUTIVE SUMMARY

The former Plum Brook Ordnance Works (PBOW), an approximately 9,000 acre site located in Sandusky, Ohio, was used as an explosives manufacturing facility during World War II. The site is now owned by the National Aeronautics and Space Administration (NASA) and is operated as the NASA Lewis Research Center, Plum Brook Station (PBS). Under provisions of the Department of Defense (DoD) Defense Environmental Restoration Program - Formerly Used Defense Sites, the U.S. Army Corps of Engineers (USACE), Nashville District (CEORN) conducted a Sitewide Groundwater Investigation of the overburden and bedrock hydrostratigraphic units at the former PBOW.

The objectives of the Sitewide Groundwater Investigation were to evaluate groundwater occurrence and flow conditions in the overburden and bedrock aquifers; to assess the groundwater quality in the overburden aquifer at the former Red Water Ponds and TNT manufacturing areas with respect to the primary chemicals of concern from the former manufacturing operations - nitroaromatics and metals; to investigate on a sitewide basis the baseline groundwater quality of the bedrock aquifer; and to evaluate whether additional investigation of the groundwater in either or both aquifers is warranted.

Groundwater Flow

Groundwater at the site occurs in two hydrostratigraphic units: the unconsolidated overburden materials and the consolidated bedrock. The overburden is composed of glacial outwash materials, and varies in thickness from a few feet to over 40 feet. The bedrock consist of both limestone and shale.

Contouring of water level measurements made in the site wells indicates that, generally, groundwater flow in both hydrostratigraphic units is to the north, eventually toward Lake Erie, as would be expected for this site. On the western side of the site, the groundwater contours for the overburden indicate that flow is to the northwest. In the bedrock, contours indicate that flow in the western portion of the site is to the northeast, from the area of TNT Area C and the West Area Red Water Ponds toward the Pentolite Road Red Water Ponds and the Reactor Area.

In the overburden it is likely that the vertical component of groundwater flow is much more significant than the horizontal flow characterized by the contours. Because of the shallow bedrock and the thin veneer of overlying glacial materials, the dominant direction of groundwater flow in the overburden over most of the site is probably not horizontal but is vertically downward from the overburden into the bedrock. This flow pattern, if accurate, would facilitate migration of contaminants from the overburden soils and groundwater into the bedrock aquifer.

The presence of groundwater in the overburden hydrostratigraphic unit at the site is apparently very seasonal. During the early winter when groundwater samples were collected for this investigation, several of the overburden monitoring wells were dry. However, in the early spring after abundant winter precipitation, groundwater was *present in all of the previously dry wells.*

Groundwater Quality

The results of the groundwater quality investigation indicate that significant levels of explosives residues are present in the groundwater in the overburden aquifer in the immediate vicinity of both former Red Water Ponds areas. With increasing distance from the ponds, even in the downgradient direction of horizontal flow, levels of explosives residues decrease in the overburden aquifer.

At the Pentolite Road Red Water Ponds, significant levels of explosives residues were detected in three overburden wells located within or adjacent to the perimeter of the former ponds. The most elevated concentrations were detected for 1,3,5-trinitrobenzene (TNB), 1,3-dinitrobenzene (DNB), and 2,4-dinitrotoluene (DNT).

Explosives residues were not detected in overburden well IT-MW5 which is located a short distance downgradient of the ponds. Thus, the chemical data for this investigation supports the conclusion of the groundwater flow investigation with regard to the predominance of vertical flow in the overburden hydrostratigraphic unit. Even after 50 years, nitroaromatics at concentrations comparable to those present in the wells within the ponds have not migrated horizontally the short distance to well IT-MW5.

At the West Area Red Water Ponds, explosives residues were also detected in two of the overburden wells but at concentrations considerably lower than were detected in the overburden wells installed within the pond perimeter at the Pentolite Road Red Water Ponds. However, the concentrations of explosives residues detected in a sample of reddish-tinted groundwater from a test pit excavated on the north bank of the west pond were significantly higher than concentrations detected at the Pentolite Road Red Water Ponds. Again, the presence of red water and high explosives residues concentrations in the immediate vicinity of the pond supports the conclusion of the groundwater flow assessment that the dominant direction of groundwater flow in the overburden is apparently vertically downward.

Low levels of explosives residues were detected in one of the five overburden wells in TNT Area A and in one of the two overburden wells at TNT Area B. No nitroaromatics were detected in the two overburden wells sampled at TNT Area C.

Nitroaromatics were also detected at low levels in several of the bedrock wells: one well at the Pentolite Road Red Water Ponds, two wells at the West Area Red Water Ponds, one well at TNT Area C, the well installed at the central toluene tanks, and the background well.

Nitrate concentrations were elevated in the three wells in which high concentrations of nitroaromatics were detected at the Pentolite Road Red Water Ponds. Nitrates were also detected at elevated concentrations in both of the overburden wells in which explosives residues were detected at the West Area Red Water Ponds. However, concentrations were not as elevated as those at the Pentolite Road Red Water Ponds.

Several volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) were detected in the bedrock aquifer, generally hydrocarbons and associated compounds. The highest concentrations were present in the two bedrock wells installed in the north central portion of the site, well BED-MW16 which is located near the central set of toluene storage tanks, and well BED-MW15 which is downgradient from the Pentolite Road Red Water Ponds and the central toluene storage tanks. Benzene concentrations in seven of the nine bedrock wells equaled or exceeded the regulatory action level.

Eleven metals were detected in the groundwater samples: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, nickel, thallium, and zinc.

The highest metals concentrations were reported at the Pentolite Road Red Water Ponds in the same three overburden wells that had the highest nitroaromatics concentrations. The metals detected at excessively high concentrations in these wells were copper, manganese, and nickel. These same three metals were also detected at high concentrations in the overburden wells that contained explosives residues at the West Area Red Water Ponds.

Zinc was detected in samples collected throughout the site. Most of the other seven metals, antimony, arsenic, beryllium, cadmium, chromium, lead, and thallium, were detected in a few limited areas. They were frequently detected only in the unfiltered samples indicating that the reported concentrations may be related to particulate matter in the samples.

Groundwater at the site is not used for potable water. However, for evaluation purposes, metals concentrations were compared to the applicable regulatory action levels. Copper, manganese, nickel, and thallium were detected in one or more wells at concentrations exceeding their respective regulatory action levels.

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LIST OF ACRONYMS

AL	Action Level
ASI	Analytical Services, Inc.
ATV	All terrain vehicle
BDL	below detection limit
BTEX	benzene, ethylbenzene, toluene, xylenes
CEORN	U.S. Army Corps of Engineers, Nashville District
COD	chemical oxygen demand
CRREL	Cold Regions Research and Engineering Laboratories
DNB	dinitrobenzene
DNT	dinitrotoluene
DoD	Department of Defense
EPA	U.S. Environmental Protection Agency
gpm	gallons per minute
HMX	cyclotetramethylene tetranitramine
ID	inside diameter
IT	IT Corporation
MCL	Maximum Contaminant Level
MDL	method detection limit
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
MRD	Missouri River Division
msl	mean sea level
NASA	National Aeronautics and Space Administration
NB	nitrobenzene
NPDES	National Pollutant Discharge Elimination System
NT	nitrotoluene

OD	outside diameter
OEPA	Ohio Environmental Protection Agency
ORD	Ohio River Division
PBOW	Plum Brook Ordnance Works
PBRF	Plum Brook Reactor Facility
PBS	Plum Brook Station
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PQL	practical quantitation limit
PVC	Polyvinyl Chloride
QC	Quality Control
RDX	cyclotrimethylene trinitramine
SAIC	Science Applications International Corporation
SCS	Soil Conservation Service
SMCL	Secondary Maximum Contaminant Level
SVOC	semivolatile organic compound
TNB	trinitrobenzene
TNT	trinitrotoluene
ug/L	micrograms per liter
umhos/cm	microhoms per centimeter
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
V-J	Victory Over Japan
VOC	volatile organic compound

1.0 INTRODUCTION

The former Plum Brook Ordnance Works (PBOW), an approximately 9,000 acre site located in Sandusky, Ohio, was used as an explosives manufacturing facility during World War II. The site is now owned by the National Aeronautics and Space Administration (NASA) and is operated as the NASA Lewis Research Center, Plum Brook Station (PBS). The site location is illustrated on Figure 1-1. Under provisions of the Department of Defense (DoD) Defense Environmental Restoration Program - Formerly Used Defense Sites, the U.S. Army Corps of Engineers (USACE), Nashville District (CEORN) conducted a Sitewide Groundwater Investigation at the former PBOW.

1.1 SITE BACKGROUND

1.1.1 *Site Location*

The PBS is a 6,453.5-acre research facility located in Erie County, Ohio 4.7 miles south of Sandusky and 59 miles west of Cleveland. Although primarily in Perkins (T6N, R23W) and Oxford (T5N, R23W) Townships, the eastern edge of PBS extends into Huron and Milan Townships. The site is bounded on the north by Bogart Road, on the south by Mason Road, on the east by U.S. Highway 250, and on the west by County Road 43. State Route 4 is also located to the west. The PBS is served internally by a 62.5-mile paved road system and a currently unused 15.7-mile rail system.

The geographic coordinates for the extreme boundaries of PBS are:

Northern Boundary Latitude: 41° 23' 39"
Southern Boundary Latitude: 41° 20' 04"
Eastern Boundary Longitude: 82° 38' 39"
Western Boundary Longitude: 82° 43' 12"

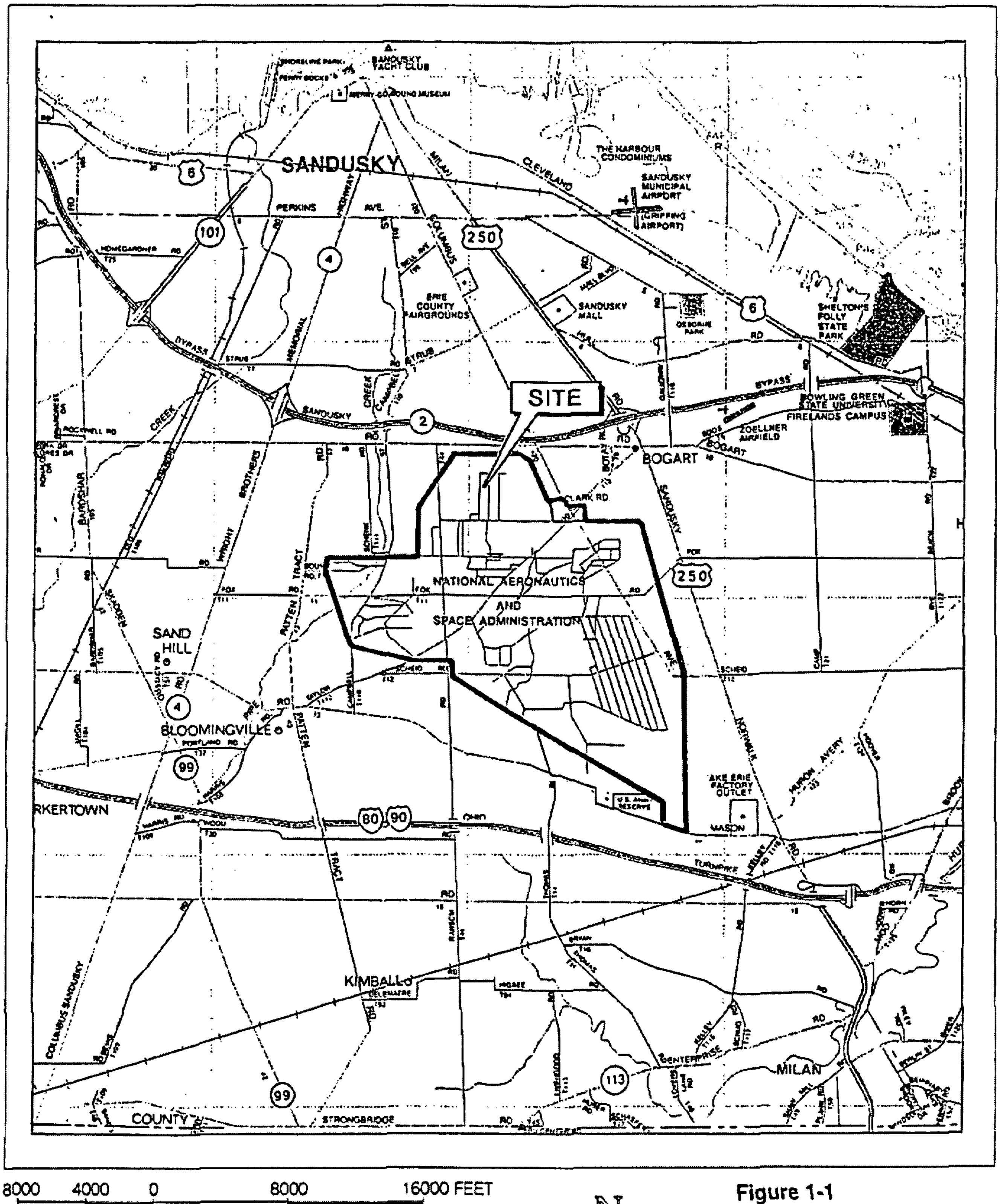

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Figure 1-1

SITE LOCATION MAP

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE

1.1.2 Site History

The original PBOW site consisted of 9,071.06 acres of primarily agricultural land which were acquired by DoD for construction of an explosives manufacturing plant. From 1941 to 1945, the Trojan Powder Company manufactured trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite at the PBOW. Production of explosives ceased 2 weeks after Victory Over Japan (V-J) Day. During the 4-year operating period, over one billion pounds of explosives were manufactured.

After manufacturing activities ceased in 1945, the U.S. Army conducted decontamination and decommissioning of many of the structures used to manufacture ordnance. Decontamination of TNT, acid, and pentolite manufacturing lines was performed until the end of 1945. Typical decontamination procedures consisted of moving all structures, equipment, and manufacturing debris to a burning ground, where everything was burned. In their 1994 Site Inspection Report, MK Ferguson estimated that 65 percent of the decontamination of the PBOW was completed by the end of 1945 (MK Ferguson, 1994).

The magazine area of the PBOW was renamed the Plum Brook Depot and was used for ammunition storage. Otherwise, virtually the entire site was mothballed from 1946 to 1954 when the Plum Brook Reactor Facility (PBRF) was constructed on a 500 acre parcel in the northern part of the site. NASA acquired the entire site on March 15, 1963. Many of the remaining original structures from the PBOW were removed by NASA soon after it acquired the property.

NASA uses the site to conduct space research as a satellite operation of the NASA Lewis Research Center in Cleveland, Ohio. Throughout the 1960's and early 1970's a variety of test and research facilities were constructed and operated. NASA also operated the PBRF from 1963 to 1973. In 1974, PBS was placed in standby condition.

On April 18, 1978, NASA declared 2,152.15 acres of land excess. Of this excess, 46.023 acres were conveyed to the Perkins Board of Education on June 2, 1978. This area is used as a bus transportation center. The General Services Administration retained the remaining acreage and currently has a use agreement with the Ohio National Guard for 604 acres of the land. In 1988, PBS began to emerge from standby status and started utilizing several of the research and test facilities again.

There are approximately 106 permanent structures and 99 munitions bunkers at the site, including a variety of structures that were a part of the original PBOW. Utilities are provided from off site, while sanitary waste discharge is processed on site. Ohio Edison Company provides the electrical power and the City of Sandusky provides the potable water supply. A PBS-owned water intake at Lake Erie supplies water for cooling, testing, and fire protection. PBS has five sanitary waste treatment systems, three of which are currently operating. The largest is a 110,000 gallon per day, high rate, trickling-filter, secondary treatment plant located on Taylor Road.

1.1.3 Environmental Investigation History

Hazardous waste disposal practices during the period of explosives manufacturing and DoD site control are unknown. Explosives manufacturing and/or handling at the site resulted in the operation of holding ponds ("red water ponds") for process waste water. Typical red water contains residues of the explosives manufacturing process and is acidic in nature. Out-of-specification explosives may have been burned or discarded on the site. Possible effects of these materials on soil, groundwater, and surface water at the site are unknown. Some of the remaining original structures (e.g., the power plants) and site features (e.g., the red water ponds) have not been remediated (USACE, 1994).

A number of environmental investigations have been conducted at the PBOW. In 1989, IT Corporation (IT) performed a limited investigation of areas of potential concern to the DoD. The field investigation activities included: collection of soil, surface water, sediment, and groundwater samples for geotechnical or chemical analysis and performance of one hydraulic conductivity test. MK Ferguson performed a preliminary sitewide environmental investigation for NASA in 1993 (report date 1994). Additional investigations have been performed by NASA (e.g., investigation of underground storage tanks) and other interested parties (the U.S Army Reserve conducted a limited investigation of the West Area Red Water Ponds).

Three additional environmental investigations have been performed at the PBS. Science Applications International Corporation (SAIC) completed a Preliminary Assessment of the PBS in 1991. Also in 1991, Ebasco Environmental performed an assessment of underground storage tanks. H+GCL characterized the Snake Road Burn Ground and the adjacent burn grounds used by NASA (referred to as "Disposal Area Three") in 1992.

1.2 PROJECT OBJECTIVES

Previous investigations at the PBS have included minimal assessment of the groundwater *quality in the overburden aquifer. None of the investigations addressed* groundwater quality in the bedrock aquifer. However, based on the limited investigations that have been performed, groundwater contamination of the overburden aquifer by nitroaromatics (explosives residues) is expected in the red water ponds areas and may be present in the overburden aquifer in other parts of the site (e.g., the former TNT manufacturing areas) and/or in the bedrock aquifer.

Nitroaromatics could be present in the site soils and groundwater as a direct results of manufacturing and disposal activities that occurred while the plant was in operation. Explosives residues in the soil could have migrated into the underlying groundwater. Possible human exposure to contamination could result through inhalation, ingestion, or absorption of contaminated groundwater. Disposal of contaminated waste water in artificially created surface water bodies during operation of the PBOW could have resulted in contamination of groundwater in the vicinity of those surface water bodies.

The objectives of the Sitewide Groundwater Investigation were to evaluate groundwater occurrence and flow conditions in the overburden and bedrock aquifers; to assess the groundwater quality in the overburden aquifer at the former Red Water Ponds and TNT manufacturing areas with respect to the primary chemicals of concern from the former manufacturing operations - nitroaromatics and metals; to investigation on a sitewide basis the baseline groundwater quality of the bedrock aquifer; and to evaluate whether additional investigation of the groundwater in either or both aquifers is warranted.

1.3 SCOPE OF WORK

The Sitewide Groundwater Investigation was performed as part of the Statement of Work for Delivery Order 0020 of Dames & Moore's Indefinite Delivery Order Contract DACA62-92-D-0015 with CEORN. This Statement of Work also included a Site Investigation of the TNT areas (reported separately) and a Focused Remedial Investigation of the Red Water Ponds areas (reported separately). The field work for all three investigations was performed concurrently. The primary tasks to be performed for the Sitewide Groundwater Investigation included:

- Performance of a fracture trace analysis of aerial photographs of the site to identify optimal locations for installation of groundwater monitoring wells in the bedrock;
- Installation of shallow groundwater monitoring wells completed in the unconsolidated overburden materials;
- Installation of deep groundwater monitoring wells completed in the consolidated bedrock;
- Assessment of the groundwater flow regime in both the overburden and bedrock hydrostratigraphic units based on water level measurement made in the newly installed wells and well installed during previous investigations;
- Collection of groundwater samples from the newly installed wells and from selected wells installed during previous investigations for laboratory analysis and evaluation of groundwater quality, including baseline groundwater quality in the bedrock aquifer; and
- Preparation of the Sitewide Groundwater Investigation Report presenting the results of the investigation.

The original Statement of Work included in Delivery Order 0020 was modified by mutual agreement between Dames & Moore and CEORN at meetings conducted at the PBS on August 29 to 31, 1994 and on September 19 through 22, 1994. The modifications, generally changes in the sampling locations based on review of historical documents and access limitations identified when sample locations were staked in the field, were incorporated into the Final Sampling and Analysis Plan (Dames & Moore, 1994).

Additional modifications were made during the course of the field investigation. The modification that related to the Sitewide Groundwater Investigation included:

- Deletion of the overburden groundwater monitoring well at TNT Area B due to the shallow depth to bedrock;
- Relocation of the bedrock groundwater monitoring well planned for TNT Area B to the West Area Red Water Ponds along the northern property boundary downgradient from the West Area Red Water Ponds;
- Relocation of one of the overburden wells within the Pentolite Road Red Water Ponds based on conditions observed during the field work;
- Addition of analysis of nitrates for all groundwater samples;
- Deletion of laboratory analysis for three dry overburden wells, one at the West Area Red Water Ponds and two at TNT Area C;
- Addition of analysis of a groundwater sample from one overburden well at the West Area Red Water Ponds that had been installed as part of a previous investigation;
- Addition of analysis of one water sample collected from a pit excavated on the north side of the west pond for explosives residues; and
- Addition of Diesel Range Hydrocarbons analysis of an oily substance present in the bedrock monitoring well installed near the toluene tanks in the central portion of the site to try to identify the substance.

All modifications to the field investigation were approved by representatives of CEORN during the course of the field work.

1.4 REPORT ORGANIZATION

The Sitewide Groundwater Investigation Report is organized in seven sections preceded by an Executive Summary.

This section, Section 1.0, presents the project background, the Sitewide Groundwater Investigation objectives, the Scope of Work, and the report organization.

Section 2.0 describes the PBOW environmental setting.

Section 3.0 provides a general history and descriptions of the red water ponds areas and the TNT manufacturing areas.

Section 4.0 outlines the investigation methods and activities.

Section 5.0 describes the groundwater flow conditions at the site.

Section 6.0 discusses the groundwater quality assessment.

Section 7.0 provides conclusions.

References are provided after Section 7.0. The tables and figures are included in the text after the page on which they are first mentioned.

Nine appendices are included in this report.

Appendix A includes a copy of the NASA Drilling and Excavation Permit.

Appendix B provides the Boring Logs for the overburden and bedrock groundwater monitoring wells.

Appendix C contains the Monitoring Well Construction Diagrams.

Appendix D provides the sieve analysis results.

Appendix E contains the well development documentation.

Appendix F includes the well survey documentation.

Appendix G provides the Groundwater Sampling Records.

Appendix H provides Dames & Moore's Data Quality Assessment of the analytical laboratory data.

Appendix I provides the laboratory reports.

Appendix J includes the fracture trace analysis.

2.0 ENVIRONMENTAL SETTING

This section describes the environmental setting at PBS.

2.1 PHYSIOGRAPHY AND TOPOGRAPHY

The PBS is located within the Eastern Lake section of the Central Lowland Province near the southwestern shore of Lake Erie (U.S. Department of Agriculture, Soil Conservation Service [SCS], 1971). The region is characterized by lake plains, outwash plains, and till plains with occasional small hills produced during the retreat of the Wisconsin ice sheet. Approximately two-thirds of Erie County was once covered by a glacial lake that produced features such as beach ridges and wave-cut cliffs.

The area was originally a flat lake bottom resulting from glacial melt waters. Across PBS, the topography is relatively flat with a gentle NNE slope towards Lake Erie. Elevations at the site range from 675 feet above mean sea level (msl) at the southwest edge of the site to 625 feet msl in the northern portion of the property at Bogart Road (U.S. Geological Survey [USGS] Topographic Quadrangles Sandusky and Kimball, Ohio; 1969). The land surface has an average slope of less than 1 percent with steeper areas having approximately 2 percent slope.

2.2 LAND USE

Prior to acquisition of the site for construction of the PBOW, the area was largely agricultural. During construction of the PBOW, most of the forested areas were cleared. Today, second generation forests have returned to large portions of the site that are not used by NASA. Other undeveloped areas of the site are maintained in open fields. The surrounding area is mostly agricultural and residential.

2.3 CLIMATE

The climate for the Sandusky area is continental, but strongly influenced by Lake Erie. Predominately westerly winds parallel the shoreline of Lake Erie. In a 1956 study by the National Advisory Committee for Aeronautics, the wind direction at PBS was from the southwest approximately 55 percent of the time throughout the year (SAIC, 1991). The frequency of northerly and northeasterly winds increases during the spring and summer.

The average annual precipitation for the city of Sandusky from 1961 to 1990 is 34.05 *inches (Midwestern Climate Center, 1997). The mean monthly precipitation at the* U.S. Weather Bureau Station for Sandusky for that 30 year period ranged from a low of 1.65 inches for February to a high of 3.70 inches for July. The monthly average precipitation for all months for the period 1961 to 1990 is provided on Table 2-1. This table also lists the extreme total high and low monthly precipitation for the period 1936 to 1996 and the year the extreme occurred. Finally, Table 2-1 lists the mean snowfall for the period 1961 to 1990.

Average annual temperatures for Sandusky for the 30 year period 1961 to 1990 ranged from 32.2° F in January to 82.3° F in August. The average this period was 32.2° F. Summers are moderately warm and humid, with temperatures occasionally *exceeding 90° F. The monthly average maximum, minimum, and mean temperatures* for all months for the period 1961 to 1990 are provided on Table 2-2. This table also lists the extreme mean high and low monthly temperatures for the period 1936 to 1996 and the year the extreme occurred. Winters are cold and cloudy, with sub-zero temperatures an average of 5 days per winter. The temperature usually first falls to freezing in October and the last freezing temperature normally occurs in April. Weather changes often occur every few days as fronts pass through the region.

TABLE 2-1

PRECIPITATION DATA FOR SANDUSKY, OHIO

Month	Mean *(inches)*	Extreme High *(inches)*	Year of Extreme *High*	Extreme Low *(inches)*	Year of Extreme *Low*	Mean Snowfall *(inches)*
January	1.73	6.58	1937	0.19	1961	8.0
February	1.65	4.53	1950	0.02	1987	7.0
March	2.60	5.44	1985	0.74	1958	3.6
April	2.95	7.19	1961	0.75	1946	0.6
May	3.44	9.04	1943	0.70	1988	0.0
June	3.85	12.51	1937	0.68	1988	0.0
July	3.70	12.60	1966	0.80	1944	0.0
August	3.41	9.93	1975	0.40	1996	0.0
September	3.12	7.72	1950	0.91	1963	0.0
October	2.18	4.91	1954	0.03	1963	0.0
November	2.80	6.53	1982	0.23	1976	0.3
December	2.62	6.44	1990	0.65	1943	6.1
Annual	34.05	50.50	1950	18.29	1963	24.8

Source: Midwestern Climate Service, 1997

TABLE 2-2

TEMPERATURE DATA FOR SANDUSKY, OHIO

Month	Average Monthly Temperature			Mean Extreme High Temperature (°F)	Year of Extreme High	Mean Extreme Low Temperature (°F)	Year of Extreme Low
	Maximum (°F)	Minimum (°F)	Mean (°F)				
January	32.2	17.5	24.8	37.2	1950	11.9	1977
February	34.3	19.2	26.7	37.1	1954	14.9	1978
March	44.4	28.8	36.7	49.2	1945	26.7	1960
April	56.6	39.3	48.0	56.5	1955	42.1	1975
May	68.1	50.5	59.3	66.5	1962	53.8	1967
June	78.0	60.1	69.1	74.9	1949	64.1	1972
July	82.4	64.8	73.6	79.1	1949	70.7	1992
August	80.6	62.9	71.7	77.8	1947	67.3	1992
September	74.1	56.1	65.1	70.2	1961	59.9	1975
October	62.2	44.5	53.4	62.0	1947	47.6	1988
November	49.9	35.3	42.6	47.4	1975	34.9	1976
December	37.2	25.7	30.5	39.7	1982	17.2	1989
Annual	58.3	41.9	50.1	54.2	1949	45.6	1982

Source: Midwestern Climate Service, 1997

G:\WP\C\COE\PLUM-BRO OK\2-2TBL.WPD

2.4 SOILS

Most of the soils of Erie County were formed from either glacial till or glacial melt-water deposits. The dominant soil material was deposited by glacial till, outwash, and lacustrine deposits. Glacial till is material laid down directly from glaciers with minimum water action. Typically, it consists of particles of different sizes, and many pebbles in glacial till have sharp corners, indicating that they have not been rounded or worked by water. Outwash materials were deposited by running water from melting glaciers. The size of the particles that make up the outwash material varies according to the speed of the water in which particles were carried. Outwash deposits generally consist of layers of particles of similar size, such as sand and gravel. Lacustrine deposits, material settled from still, ponded glacial melt water, contain only the finer particles such as very fine sand, silt, and clay because the coarser material dropped out as outwash. Other soils formed from more recent deposits of alluvium or the weathering of parent rock (SCS Soil Survey of Erie County, Ohio).

Within the PBS, the soil origins are listed as lacustrine (Erie Planning Commission Report on Land Capability, 1967). The glacial drift is less than 20 feet on average and bedrock is exposed in many places (Ohio Department of Natural Resources, Division of Geological Survey; Drift Thickness of Erie County, Ohio; Open File Map 209).

The General Soil Map of Erie County, Ohio (SCS, 1970) identified four soil associations at the PBS site: Arkport-Galen, Prout, Del Rey-Lenawee, and Lewisburg. The Arkport-Galen and Prout soil associations make up the majority of soils at PBS. The Arkport-Galen soils are present in the western, central, and northern portions of the site. The Prout soils occur in the southeastern portion of PBS. The Del Rey-Lenawee soils are listed for the extreme southeast corner of PBS and Lewisburg soils are listed for the southwestern edge of PBS.

The Arkport-Galen association is characterized by deep, nearly level to moderately sloping, well-drained to moderately-well-drained soils that have a subsoil of loamy fine sand and fine sand. The Arkport soils are gently to moderately sloping, and well drained, formed in fine sand deposited by wind and water at the edge of a glacial lake. The permeability of the Arkport soils is estimated to be approximately 12 inches/hour.

The Galen soils are mostly level and moderately well-drained, formed as small sandy deposits on outwash plains and deltas. Galen soils have a fine sand or sandy loam surface layers, a subsurface of fine sand which is underlain by silt or clay. Runoff is slow, permeability is rapid, and the available moisture capacity is low. The permeability of the Galen soils is estimated to be between 6 and 12 inches/hour. The Arkport-Galen association is made up of about 40 percent Arkport soils, 30 percent Galen soils, and 30 percent minor soils.

Prout soils are moderately-deep to deep, nearly level to gently sloping, somewhat poorly drained soils that have a subsoil of heavy silt loam to silty clay loam. Prout soils are commonly underlain by shale bedrock. They are somewhat poorly drained, with slow runoff and permeability. The permeability of the Prout soils is estimated to be between 0.2 and 0.6 inches/hour. Prout soils commonly occur in uplands such as the sides of stream valleys and shale outcrop ridges.

Del Rey-Lenawee soils generally lie on old lake beds and are deep, nearly level, somewhat poorly-drained to very poorly-drained soils that have a subsoil of silty clay to clay loam. The Lewisburg association are moderately deep to deep, nearly level in depressions, and are narrow strips along natural drainageways. Runoff is slow, and permeability is moderately slow.

The thickness of soils at PBS ranges from approximately 5 feet or less for most of the site to approximately 20 feet for the extreme northern portion of the site (Erie Planning Commission Report on Land Capability, 1967).

2.5 BEDROCK GEOLOGY

The bedrock formations of northwestern Ohio consist of Devonian and Silurian carbonates (limestones and dolomites) and clastics (sandstones and shales). The regional dip is to the southeast, with younger rocks outcropping to the east. The Silurian and Devonian formations unconformably overlie sedimentary sequences of Ordovician and Cambrian Age, which in turn unconformably overlie the Pre-Cambrian crystalline Grenville basement (Ohio Department of Natural Resources, Division of

Geology, Generalized Column of Bedrock Units in Ohio, 1990). A generalized stratigraphic section of the Silurian and Devonian strata which underlie the site was presented by SAIC in their Preliminary Assessment and is reproduced in Figure 2-1 of this report.

At PBS, four Devonian formations crop out beneath the glacial drift cover. From oldest to youngest, these formations are the Delaware Limestone, the Plum Brook Shale, the Prout Limestone, and the Huron Shale. The formations dip to the southeast with a regional dip angle of approximately 35 feet per mile (Campbell, 1955). Structurally, these formations are located on the eastern limb of the Findlay Arch (Campbell, 1955). Figure 2-2 shows the estimated outcrop areas of each of the four formations beneath the PBS site.

The Delaware Limestone conformably overlies the Columbus Limestone, and is approximately 75 feet thick. The contact between the two formations occurs to the northwest of PBS. The Delaware Limestone crops out beneath the extreme northwestern corner of PBS. It is described as a massive to thin-bedded brown to gray fossiliferous limestone and dolomite. According to the PBS Preliminary Assessment (SAIC, 1991), karst topography occurs selectively in some of the Silurian and Devonian carbonates in the northern and western sections of Erie County. Subsequently, cavernous porosity occurs in some areas of the underlying carbonates.

The Plum Brook Shale unconformably overlies the Delaware Limestone and crops out underneath most of the northwest portion of the site. It is approximately 35 feet thick, and is described as a blue, soft, fossiliferous shale containing thin layers of dark, hard, fossiliferous limestone.

The Prout Limestone is a 15 foot thick limestone which conformably overlies the Plum Brook Shale. The Prout Limestone crops out as a thin (1000 to 2000 foot wide) northeast striking band across the middle of PBS. It is described as a dark-gray to bluish-gray to blue, very hard, silicious, fossiliferous limestone or dolomitic mudstone.

The Huron Shale is the lower member of the Ohio Shale and crops out under much of the southern and eastern portions of PBS. It is described as a grayish-black, dense,

Age	Formation/Group	Depth to Top (ft)	Thickness (ft) a	Hydrologic Unit b	Rock Description
DEVONIAN	Ohio Shale	c	300	Zone 3	Shale : *black, thin-bedded with bituminous and carbonaceous material.*
	Prout Limestone/ Plum Brook Shale	Surface	210		Shale : *light grey, calcareous.*
	Delaware Limestone	40	50	Zone 1 and Zone 2	Limestone : *buff, earthy, foss. interbedded with brown crystalline dolomite.*
	Columbus Limestone	90	110		Limestone : *brown to grey, fine crystalline, foss. with tan to buff-grey, partly sandy dolomite at base.*
	Lucas Dolomite	200	70		Dolomite : *brown, crystalline, porous, chert.*
SILURIAN	Amherstburg Dolomite	270	20		Dolomite : *tan to grey, microcrystalline, sl. argillaceous.*
	Bass Island Dolomite	290	30		
	Salina	320	590'		Dolomite : *anhydrite and shale sequence. Interbedded and intercalated. Dolomite is tan to brown and mostly tight. Scattered shale laminae. Few scattered oil stains. Some dolomite is shaly. few massive beds of dolomite and anhydrite.*

a. Depth to formation, formation thickness, and lithology based on deep borehole located at N 288+68, E 155+54.

b. Refer to Figure 5. for areal distribution of Zones 1, 2, and 3.

c. The Ohio shale was not encountered in the deep borehole, it outcrops in the southeasternmost *portion of Plum Brook Station.*

Figure 2-1

GENERALIZED STRATIGRAPHIC SECTION OF SILURIAN AND DEVONIAN STRATA UNDERLYING PLUM BROOK STATION

Plum Brook Ordnance Works

Sandusky, Ohio

REFERENCE: Reproduced from SAIC Preliminary Assessment, 1991

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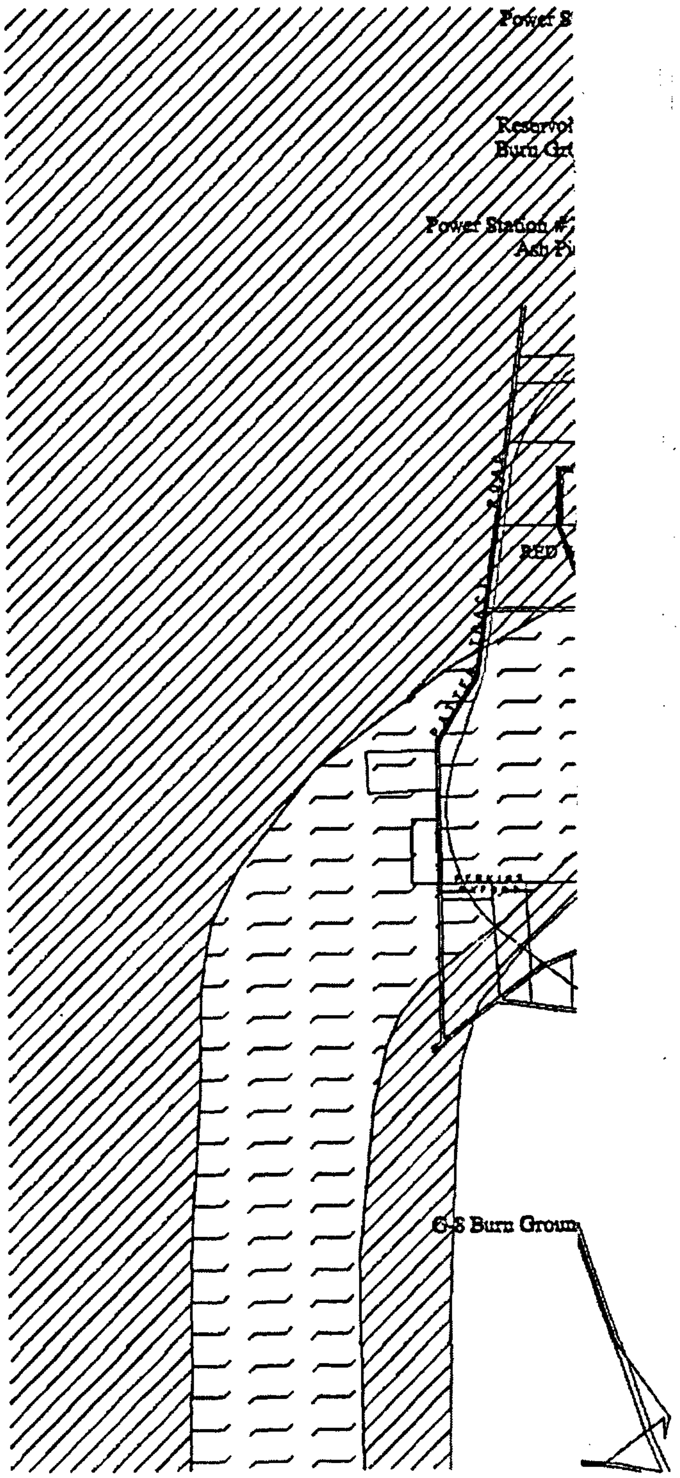

1° 17'

N

Scale: 1" = 2800'

- Ohio (Huron) Shale
- Prout Limestone
- Plum Brook Shale
- Delaware Limestone

Source: Geologic contact and bedrock unit information is from a portion of the "Bedrock Geology" map of the "Comprehensive Planning Study" included in the "Land Capability Report" by the Erie Planning Commission, 1967

Figure 2-2
Bedrock Units at NASA Plum Brook Station

Plum Brook Ordnance Works
Sandusky, Ohio

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Government Services Division; Atlanta, Georgia
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platy to fissile shale containing large pyrite/carbonate concretions (1 to 6 feet in diameter). It is up to 300 feet thick. The glacial drift cover over the Huron Shale is generally thinner than over the other formations, in many places the shale is within several feet of the surface.

2.6 SURFACE WATER

PBS lies in the eastern region of the Pickeral Creek-Pipe Creek Basin, which, in turn, lies within the St. Lawrence River drainage basin (Ohio Department of Natural Resources Availability of Underground Water, Pickeral Creek -Pipe Creek Area, 1962 and Ground Water Pollution Potential of Erie County, Ohio; 1994). The Huron River Basin lies approximately 3.5 miles east of PBS. Sandusky Bay and Lake Erie are the largest surface water bodies within a 15 mile radius of PBS, approximately 4.5 miles north of the site.

Eleven streams pass through or originate within PBS and are a part of four drainage areas: (1) Sawmill Creek (southern PBS), (2) Plum Brook (central PBS), (3) Pipe Creek (western PBS) and (4) Storrs-Hemminger Ditch (USGS Topographic Quadrangles Sandusky and Kimball, Ohio; 1969 and SAIC, 1991). All streams flow north or northeasterly into Sandusky Bay. The locations of these streams and other selected surface water features are illustrated on Figure 2-3.

Although Sawmill Creek does not pass through PBS itself, several ditches cross the southern portion of PBS, flow easterly and feed into Sawmill Creek. The ditches, listed in order from north to south, are Schlessman Ditch, W. Scheid Ditch, Kuebelar Ditch, Scheid-Olemacher Ditch and Scherer Ditch. Lindsley and E.C. Smith Ditches flow north along the northern portion of PBS into Plum Brook just north of PBS. Ransom Ditch (northern PBS) flows northward into Pipe Creek. Additionally, ditches totalling 380,000 lineal feet are within PBS (SAIC, 1991). Numerous ponds lie within and around PBS. Seventeen isolated ponds and reservoirs and one former red water pond are located on PBS. The ponds are probably fed from shallow groundwater, and the pond water levels remain high even during dry months. (SAIC, 1991)

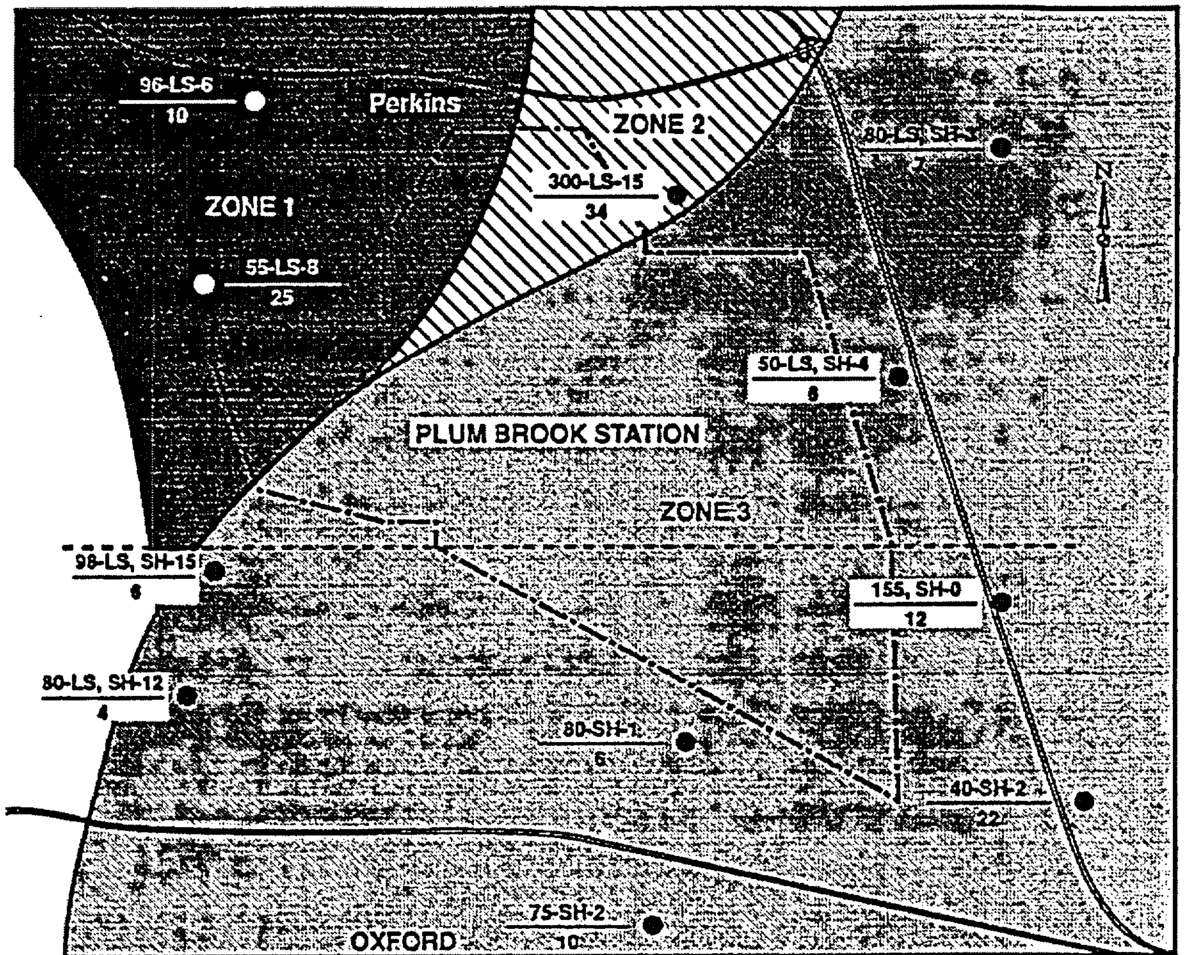
2.7 GROUNDWATER USE

Two aquifer systems are utilized for drinking water in the area surrounding PBS: a carbonate aquifer cropping out in the western portion of Erie County and a shale aquifer cropping out in the eastern portion. PBS covers the transition of the two aquifer systems. Both aquifer systems are overlain by a veneer (generally less than 20 feet) of glacial drift that is considered a poor source of ground water except in areas of sand and gravel lenses (Ground Water Pollution Potential of Erie County, Ohio; 1994).

The carbonate aquifer is subdivided into two zones by the Ohio Department of Natural Resources based on their areas of usage and yields. The shale aquifer and overlying discontinuous sand and gravel deposits are designated as zone three. Figure 2-4. reproduced from SAIC's Preliminary Assessment, illustrates the three zones. Zone one occurs in the north and northwestern portion of PBS and includes wells with yields of 100 to 500 gallons per minute (gpm) developed in cavernous limestone and dolomite, generally obtained from depths of around 100 feet. Zone two occurs in the north portion of PBS and includes wells with yields of 15 gpm or less developed in a deeper carbonate aquifer at an approximate depth of 300 feet. Zone three occurs over all of the eastern and southern portions of PBS and includes wells with yields that seldom exceed 3 gpm.

Yields from zone one are high in the karst terrain of western Erie County. From west to east in zone one yields decrease as evidenced by a well just west of PBS that has a yield of 8 gpm. Additionally, the carbonate aquifer beneath the shale aquifer will yield larger quantities of water than the shale aquifer, but the quality is considered likely to be poor due to high mineral content (Ohio Department of Natural Resources, Availability of Underground Water, Pickeral Creek - Pipe Creek Area, 1962).

According to SAIC (1991), 179 permitted private drinking water wells, listed at the Erie County Health Department, were within a 4-mile radius of PBS. Permits are not required for agricultural use.



LEGEND

ZONE 1 — AREAS IN WHICH YIELDS OF 100 TO 500 GALLONS PER MINUTE MAY BE DEVELOPED.

Yields of more than 500 gallons per minute have been developed at depths of less than 200 feet in cavernous limestone and dolomite. Domestic supplies are generally obtained at depths of around 100 feet.

Hydrogen sulfide, in varying amounts, may be encountered in the bedrock.

ZONE 2 — AREAS IN WHICH YIELDS OF 5 TO 25 GALLONS PER MINUTE MAY BE DEVELOPED.

Yields of 15, or less, gallons per minute are developed from wells drilled into the limestone. Hydrogen sulfide may be present in varying amounts.

ZONE 3 — AREAS IN WHICH YIELDS SELDOM EXCEED 3 GALLONS PER MINUTE

Limited quantities of ground water are obtained from thin, discontinuous sand and gravel deposits interbedded in fine, sandy clay or from the underlying shale. Drilling deeper than 30 feet into the shale is not recommended. Occasional gas or salt noted in the eastern half of the county.

Larger yields may be obtained in western Huron and Oxford townships and southeastern Perkins Township. Wells may encounter water-bearing limestone beneath as much as 80 feet of impervious shale.

Depth (ft)

75-SH-2
10

● Existing Domestic Wells

Water-bearing formation

Yield (gpm)

Depth to bedrock (ft.)

SCALE

1 0 1 mile

Figure 2-4

REGIONAL WATER-BEARING ZONES IN THE BEDROCK AQUIFERS (Modified from Walker, 1986)

Plum Brook Ordnance Works

Sandusky, Ohio

REFERENCE: Reproduced from SAIC Preliminary Assessment, 1991

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Residences to the north and east of PBS are served by city, county and rural water departments. Residences south and west of PBS are supplied by wells and cisterns (SAIC, 1991). According to SAIC (1991) the nearest recorded well is at 6115 Schenk Road; however a closer well was observed at 1810 Schenk Road. Additionally, two other wells are considered public drinking water supplies (used by 25 or more people for 60 days or more a year): Woussickett Golf Course clubhouse (6311 Mason Road) and Stanley's Tavern (4408 Mason Road), (SAIC, 1991).

Prior to the construction of a sewage treatment facility by Bellevue in 1971, the carbonate aquifer was contaminated by the injection of waste water through privately and municipally owned wells (Ground Water Pollution Potential of Erie County, Ohio, 1994). Samples of potable wells in the Bellevue-Castille area in 1961 contained alkyl benzene sulfonate (indicative of household detergents), ammonium nitrogen, as well as higher concentrations of nitrogen compounds than the adjacent limestone areas (Ohio Department of Natural Resources Availability of Underground Water, Pickeral Creek - Pipe Creek Area, 1962).

2.8 SURFACE WATER USE

Surface water intakes within 15 miles of PBS include Lake Erie, Huron River, and reservoirs fed by tributaries of the west branch of Huron River or the west branch itself.

The Erie County Health Department does not permit the use of surface water for private drinking water supply and no surface water within PBS is used as a drinking water supply (SAIC, 1991). It is unknown if surface waters are used for livestock in the local area. Crop irrigation is not common in Ohio (SAIC, 1991). Lake Erie and Sandusky Bay are a resource for recreational sports including fishing, swimming, and boating.

6.0 GROUNDWATER QUALITY

Groundwater samples were collected from 16 wells completed in the overburden hydrostratigraphic unit and nine wells completed in the bedrock. Samples from all 25 wells were analyzed for explosives residues, nitrates, and total and dissolved concentrations of 14 metals, the 13 priority pollutant metals plus manganese. Samples from the nine bedrock wells were also analyzed for VOCs and SVOCs. The analysis of the laboratory results and data evaluation, including the establishment of a PQL for explosives residues compounds, were previously discussed in Section 4.0. Copies of the laboratory reports, which list explosives residues concentrations detected above the MDL but below the PQL, are included in Appendix I.

The analytical results for explosives residues, nitrates, metals, VOCs, and SVOCs are discussed in Sections 6.1, 6.2, 6.3, 6.4, and 6.5, respectively. Measurements of pH, specific conductance, and temperature were gathered during sample collection. These measurements are discussed in Section 6.6. A summary of the groundwater quality is provided in Section 6.7.

6.1 EXPLOSIVES RESIDUES

Explosives residues were detected at concentrations above the PQL in eight of the 16 overburden wells and six of the nine bedrock wells. Nitroaromatics concentrations above the PQL are listed in Table 6-1 and illustrated on Figure 6-1.

By far the highest concentrations of explosives residues were detected in the groundwater in the overburden hydrostratigraphic unit at the two former red water ponds areas. Nine nitroaromatics, 2,4,6-TNT, 1,3,5-TNB, 2,4-DNT, 2,6-DNT, 4-Am-2-NT, 3,4-DNT, 4-Am-DNT, 2-Am-DNT, and 1,3-DNB, were each detected in at least one well at each of the former red water ponds areas. Concentrations of 1,3,5-TNB, 2,4-DNT, 4-Am-2-NT, and 1,3-DNB at the Pentolite Road Red Water Ponds were significantly higher than at the West Area Red Water Ponds. Concentrations of the other five compounds were comparable in both areas.

6.1.1 Pentolite Road Red Water Ponds

The highest concentrations of explosives residues detected were in samples collected from the Pentolite Road Red Water Ponds wells DM-MW7 and DM-MW8. Explosives residues were also detected in one of the two other overburden wells, DM-MW9, and in one of the two bedrock wells, Reactor Well 2.

Seven explosives residues were detected in well DM-MW7. Of these, three were present at much higher concentrations than the others. 1,3,5-TNB, 1,3-DNB, and 2,4-DNT were reported at concentrations of 5,700 µg/L, 3,000 µg/L, and 980 µg/L, respectively. These three nitroaromatics are among the compounds removed from TNT in the washing process that generates the "red water." 4-Am-2-NT, a product plant mediated biotransformation of 2,4-DNT was present at a concentration of 66 µg/L. The other three nitroaromatics, 2,4,6-TNT, 2,6-DNT, and 3,4-DNT were each present at concentrations of 30 µg/L or less.

Groundwater monitoring well DM-MW7 was installed coincident with soil boring PR-S4 in the southern portion of the western pond. Soil samples were collected from the upper 10 feet of the boring. Relatively low levels of explosives residues were detected. However, red water was noted in the split spoon samples retrieved as the boring was advanced below 10 feet.

Significant levels of nitroaromatics were also detected in well DM-MW8, which was installed in soil boring PR-S14. The purge and sample water bailed from well DM-MW8 during the sampling process was red. The highest levels of explosives residues detected in the soils at the Pentolite Road Red Water Ponds were present in this boring. As with well DM-MW7, the nitroaromatics reported at the highest levels were 1,3,5-TNB, 1,3-DNB, and 2,4-DNT. The concentrations were 1,300 µg/L, 790 µg/L, and 440 µg/L, respectively. 2,4,6-TNT, which was detected at very high levels in the soil samples collected from 3 to 10 feet in the boring for this well, was detected in the groundwater sample at a concentration of 64 µg/L. Two other components of red water, 2,6-DNT and 3,4-DNT, were detected at concentrations of 33 µg/L and 41 µg/L, respectively. Also, three biotransformation products were detected. 4-Am-2-NT was detected at a concentration of 37 μg/L. 4-Am-DNT and 2-Am-DNT, microbially mediated biotransformation products of TNT, were also detected.

Only two nitroaromatics were detected in the sample collected from overburden well DM-MW9. 1,3-DNB and 2,4-DNT were detected at concentrations of 49 μg/L and 9.5 μg/L, respectively. This well is located on the eastern boundary of the Pentolite Road Red Water Ponds and, based on a 1956 aerial photograph, is just outside the pond perimeter. However, as stated in Section 5, it is possible that the pond configuration was larger during plant operation and that this location was at one time within the pond area.

No explosives residues were detected in the sample collected from overburden well IT-MW5, which is located on the downgradient side of the Pentolite Road Red Water Ponds.

No explosives residues were detected in the sample collected from bedrock well BED-MW15, which is located downgradient of the former pond area. However, low levels of two nitroaromatics were detected in Reactor Well 2 which is also located on the north, or downgradient, side of the former pond area. 3-NT and 3,4-DNT were detected at concentrations of 23 μg/L and 13 μg/L, respectively.

6.1.2 West Area Red Water Ponds

Explosives residues were detected at concentrations above the PQL in two of the three overburden wells and both of the bedrock wells at the former West Area Red Water Ponds. Nitroaromatics were also detected in a groundwater sample collected from a test pit excavated on the north side of the western pond.

The nitroaromatics concentrations detected in the groundwater in the overburden at the West Area Red Water Ponds were significantly lower than those detected in the samples from wells DM-MW7 and DM-MW8 at the Pentolite Road Red Water Ponds. However, in both areas the highest concentrations were detected for 1,3,5-TNB, 1,3-DNB, and 2,4-DNT. 1,3,5-TNB was detected in wells DM-MW2 and IT-MW2, at concentrations of 560 μg/L (average of two duplicate samples) and 390 μg/L, respectively. 1,3-DNB and 2,4-DNT were detected at slightly lower levels in each well. 2,4,6-TNT was detected only in the sample collected from well DM-MW2 at a concentration of 30 μg/L (average of two duplicate samples). Biotransformation products were present in both wells.

No explosives residues were detected in the sample collected from the third overburden well MK-MW11.

It is noteworthy that the highest concentrations of explosives residues in a groundwater sample from the West Area Red Water Ponds were reported in a sample of water retrieved from the bottom of a test pit excavated on the north side of the west pond. NASA excavated a pit where soil boring WA-S16 had been installed approximately 5 feet from the north bank of the west pond. Total depth of the pit was estimated as approximately 10 feet. Red water collected in the bottom of the pit immediately following excavation. A sample of the water was collected for laboratory analysis. Nine of the 14 explosives residues analytes were detected in this sample, some at significant concentrations noted on Table 6-1. 1,3,5-TNB was present at a concentration of 20,000 μg/L and 1,3-DNB was present at a concentration of 7,200 μg/L. Other components of red water that were also present in this sample were: 2,4-DNT at a concentration of 9,200 μg/L; 2,6-DNT at a concentration of 850 μg/L; 3,4-DNT at a concentration of 1,500 μg/L; and 4-NT at a concentration of 110 μg/L. Four biotransformation products were also present in this sample: 4-Am-2-NT at a concentration of 190 μg/L; 2-Am-4-NT at a concentration of 22 μg/L; 4-Am-DNT at a concentration of 370 μg/L; and 2-Am-DNT at a concentration of 63 μg/L. These nitroaromatics concentrations are significantly higher than the concentration detected in the groundwater monitoring wells at the West Area Red Water Ponds and indicate that red water contamination is present in the immediate vicinity of the west pond at concentrations comparable to those observed at the Pentolite Road Red Water Ponds.

QC sample DM-MW22 was a duplicate of sample DM-MW2. Six nitroaromatics were detected in each of the duplicate samples at comparable concentrations. 3,4-DNT was detected at a concentration of 75 μg/L in one sample, but was not detected in the other sample.

Low levels of nitroaromatics were detected in each of the bedrock wells at the West Area Red Water Ponds. Only one compound was detected per well. 2-Am-4-NT, a biotransformation product of DNT was detected at a concentration of 11 μg/L in well BED-MW14 which was installed near overburden well IT-MW2. 3-NT was reported at a concentration of 8.1 μg/L in well BED-MW19 which is located along the northern property boundary.

6.1.3 TNT Area A

Explosives residues were detected at concentrations above the PQL in two of the five overburden wells. No explosives residues were detected in either of the two bedrock wells installed in TNT Area A.

The sample from well DM-MW10 contained four explosives residues. The average concentrations detected in the two duplicate samples were: 10.0 μg/L of 2,4,6-TNT, 10.5 μg/L of 2,4-DNT, 8.3 μg/L of 4-Am-DNT, and 30 μg/L of 2-Am-DNT. This well is located immediately downgradient of the Wash House for manufacturing line 3. Two of these same compounds, 2,4,6-TNT and 2-Am-DNT were also detected in a soil sample from boring TNTA-S5 which was installed closest to the location of Well DM-MW10. The presence of two biodegradation products in this sample, 4-Am-DNT and 2-Am-DNT, indicates that natural degradation of the nitroaromatics is occurring in this area.

3-NT was the only explosives residue detected in overburden well MK-MW23. It was present at a concentration of 13 μg/L. This well is located northwest of the Wash House for line 1. Well MK-MW23 had been installed and sampled for explosives residues by MK Ferguson in their 1993 investigation. No explosives residues were detected in that investigation. However, the analytical laboratory method for detecting low levels of explosives residues has been refined since 1993.

No explosives residues were detected above the PQL in the three other overburden wells, DM-MW11, MK-MW22, or MK-MW24, in TNT Area A or in either of the two bedrock wells, BED-MW17 and BED-MW18. Explosives residues were also not detected in wells MK-MW22 or MK-MW24 in the 1993 MK Ferguson investigation.

QC sample DM-MW23 was a duplicate of sample DM-MW10. The same four explosives residues compounds were found in both samples at very consistent concentrations. Additionally, QC sample BED-MW21 was a duplicate of sample BED-MW18. No explosives residues compounds were detected at concentrations above the PQL in either sample.

6.1.4 TNT Area B

Explosives residues were detected at concentrations above the PQL in overburden well MK-MW17, the well which is installed on the downgradient side of TNT Area B east of the Waste Water Settling Basins. 2,4,6-TNT and 3-NT were detected at concentrations of 6.5 μg/L and 5.3 μg/L, respectively. No explosives residues were detected in the sample from well MK-MW16 which is located on the upgradient side of TNT Area B.

The presence of explosives residues in the groundwater in the overburden at TNT Area B is not surprising. Explosives residues are ubiquitous in the thin soil layer overlying bedrock in this area and the groundwater is very shallow. Therefore, migration of explosives residues into the groundwater in the overburden would be expected.

No explosives residues were detected in either of these two wells during the 1993 MK Ferguson investigation.

6.1.5 TNT Area C

No explosives residues were detected at concentrations above the PQL in either of the two overburden wells sampled at TNT Area C in December 1994. 3-NT was detected at a concentration of 11 μg/L in bedrock well BED-MW13.

6.1.6 Other Areas

Two bedrock wells were installed at locations away from the TNT manufacturing areas and red water ponds areas.

Well BED-MW16 was installed near the central set of toluene storage tanks on the east side of Taylor Road. Four explosives residues were detected in this well. 1,3,5-TNB, 3-NT, 2,4,6-TNT, and 2,6-DNT, were detected at concentrations of 22 μg/L, 18 μg/L, 7.8 μg/L, and 7.0 μg/L, respectively.

The background bedrock well was installed on the south side of the site west of Taft Road in an area thought to be uninfluenced by PBOW operations. However, the highest single concentration of explosives residues in the bedrock aquifer was detected in this well. 3-NT was reported at a concentration of 53 μg/L. No other nitroaromatics were detected in the sample collected from this well.

6.2 NITRATES

Nitrate levels are considered significant at the former PBOW when they exceed the EPA established Maximum Contaminant Level (MCL) of 10 milligrams per liter (mg/L). As the nitrate data on Table 6-2 indicates, nitrate concentrations exceeded 10 mg/L in only five of the 25 wells samples. In all cases, the elevated nitrate levels correspond to elevated levels of explosives residues.

The highest nitrate levels were detected in the three Pentolite Road Red Water Ponds overburden wells in which high levels of explosives residues were detected. In wells

TABLE 6-2

NITRATE CONCENTRATIONS IN GROUNDWATER

	Sample ID	Nitrates (mg/L)
West Area Red Water Ponds Overburden Wells	DM-MW2	15
	IT-MW2	12
	MK-MW11	0.2
Pentolite Road Red Water Ponds Overburden Wells	DM-MW7	80
	DM-MW8	650
	DM-MW9	50
	IT-MW5	0.1
TNT Area A Overburden Wells	DM-MW10	0.3
	DM-MW11	0.2
	MK-MW22	0.3
	MK-MW23	0.3
	MK-MW24	0.5
TNT Area B Overburden Wells	MK-MW16	0.2
	MK-MW17	0.2
TNT Area C Overburden Wells	DM-MW5	0.2
	DM-MW6	1.4
Bedrock Wells	BED-MW13	BDL
	BED-MW14	3.3
	BED-MW15	0.5
	BED-MW16	BDL
	BED-MW17	0.2

BDL = Below Detection Limit

mg/L = milligrams per liter or ppm

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

TABLE 6-2
(Continued)

	Sample ID	Nitrates (mg/L)
Bedrock Wells (Continued)	BED-MW18	0.2
	BED-MW19	0.2
	BED-MW20	0.2
	Reactor Well 2	0.2
QC Samples	BED-MW21	0.4
	DM-MW22	16
	DM-MW23	0.3
	Drill Water	0.3

QC sample BED-MW21 is a duplicate of BED-MW18.
QC sample DM-MW22 is a duplicate of DM-MW2.
QC sample DM-MW23 is a duplicate of DM-MW10.

BDL = Below Detection Limit

mg/L = milligrams per liter or ppm

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

TABLE 6-1
EXPLOSIVES RESIDUES CONCENTRATIONS
GROUNDWATER MONITORING WELLS

	Sample ID	2,4,6-TNT	1,3,5-TNB	NB	2,4-DNT	2,6-DNT	4-Am-2-NT	3,4-DNT	4-Am-DNT	2-Am-DNT	2-NT	3-NT	4-NT	2-Am-4-NT	1,3-DNB
West Area Red Water Ponds	DM-MW2	34	550		320	12		75		5.7					470
	IT-MW02		390		340	24	14		5.1						340
	MK-MW11														
	WA-S16-P*		20,000		9,200	850	190	1,500	370	63			110	22	7,200
Pentolite Road Red Water Ponds	DM-MW07	30	5,700		980	17	66	11							3,000
	DM-MW08	64	1,300		440	33	37	41	10	11					790
	DM-MW09				9.5										49
	IT-MW05														
TNT Area A Overburden Wells	DM-MW10	10			11				8.7	31					
	DM-MW11														
	MK-MW22														
	MK-MW23											13			
	MK-MW24														
TNT Area B Overburden Wells	MK-MW16														
	MK-MW17	6.5										5.3			

Concentrations are listed in $\mu g/L$ or ppb.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

All samples listed in the Sample ID column (column 2) were analyzed for all 14 nitroaromatic compounds listed across the top row of the table. Only concentrations above the Practical Quantitation Limit (PQL) are listed on the table. Concentrations corresponding to the blank boxes were either below the laboratory detection limit (BDL) or above BDL but less than the PQL.

QC sample DM-MW22 is duplicate of DM-MW2.
QC sample DM-MW23 is duplicate of DM-MW10.
* Sample WA-S16-P at the West Area Red Water Ponds was a sample of groundwater collected from a test pit excavated on the north bank of the west pond.

TABLE 6-1
(Continued)

	Sample ID	2,4,6-TNT	1,3,5-TNB	NB	2,4-DNT	2,6-DNT	4-Am-2-NT	3,4-DNT	4-Am-DNT	2-Am-DNT	2-NT	3-NT	4-NT	2-Am-4-NT	1,3-DNB
TNT Area C Overburden Wells	DM-MW05														
	DM-MW06														
Bedrock Wells	BED-MW13											11			
	BED-MW14													11	
	BED-MW15														
	BED-MW16	7.8	22			7.0						18			
	BED-MW17														
	BED-MW18														
	BED-MW19											8.1			
	BED-MW20											53			
	Reactor Well 2							13				23			
QA Samples	DM-MW21														
	DM-MW22	26	570		250	10				5.2					400
	DM-MW23	10			10				7.9	29					
	Drill Water		13												

Concentrations are listed in µg/L or ppb.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

All samples listed in the Sample ID column (column 2) were analyzed for all 14 nitroaromatic compounds listed across the top row of the table. Only concentrations above the Practical Quantitation Limit (PQL) are listed on the table. Concentrations corresponding to the blank boxes were either below the laboratory detection limit (BDL) or above BDL but less than the PQL.

QC sample BED-MW21 is a duplicate of BED-MW18.
QC sample DM-MW22 is a duplicate of DM-MW2.
QC sample DM-MW23 is a duplicate of DM-MW10.

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DM-MW7, DM-MW8, and DM-MW9, the nitrate concentrations were 80 mg/L, 650 mg/L, and 50 mg/L, respectively.

Nitrates were present at levels above the MCL in two of the three overburden wells at the West Area Red Water Ponds. Concentrations in wells DM-MW2 and IT-MW2 were 15 mg/L and 12 mg/L, respectively. Elevated levels of nitroaromatics were present in both of these wells.

The nitrate concentrations in duplicate samples DM-MW10 and DM-MW23 were both 0.3 mg/L. Additionally, the nitrate concentrations in duplicate samples BED-MW18 and BED-MW21 of 0.2 mg/L and 0.4 mg/L, respectively, compare favorably.

6.3 METALS

Groundwater samples from all wells were analyzed for total (unfiltered) and dissolved (filtered) concentrations of 14 metals, the 13 priority pollutant metals and manganese. The reported concentrations are listed on Table 6-3 and are illustrated on Figure 6-2.

Mercury, selenium, and silver were not detected in any of the groundwater samples. Concentrations of the 11 metals that were detected are discussed below.

6.3.1 Antimony

Antimony was detected in eight wells, three completed in the overburden and five completed in bedrock. In seven of the eight wells, antimony was detected only in the filtered sample. As stated in Section 4, antimony was detected in the filtered equipment blank sample. It is probable that the antimony concentrations in the filtered samples are related to the sample collection process and are not representative of groundwater conditions at the site.

The three overburden wells in which antimony was detected are located in the former TNT manufacturing areas. Antimony was reported in one overburden well in each

TABLE 6-3

METALS CONCENTRATIONS
GROUNDWATER MONITORING WELLS

	Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
West Area Red Water Ponds Overburden Wells	DM-MW2-U					14	38	10	1,600		63				88
	DM-MW2-F						20		1,000		60				
	IT-MW2-U						140		2,300		120				34
	IT-MW2-F						130		2,500		130				
	MK-MW11-U								160						30
	MK-MW11-F								180						
Pentolite Road Red Water Ponds Overburden Wells	DM-MW7-U					36	1,400		12,000		2,000			0.9	94
	DM-MW7-F					21	1,100		10,000		1,800			0.7	44
	DM-MW8-U					52	1,600		8,000		2,500				62
	DM-MW8-F					38	1,400		7,000		2,100				50
	DM-MW9-U						770		1,800		1,500				60
	DM-MW9-F						760		1,800		1,600				70
	IT-MW5-U								100						27
	IT-MW5-F								100						
TNT Area A Overburden Wells	DM-MW10-U							7	980						110

Concentrations are listed in µg/L or ppb.

All samples listed in the Sample ID Column (column 2) were analyzed for all 14 metals listed across the top row of the table. Only concentrations above the detection limit are listed on the table. Concentrations corresponding to the blank boxes were below the laboratory detection limit.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

Sample DM-MW2 is a duplicate of QC sample DM-MW22.
Sample DM-MW10 is a duplicate of QC sample DM-MW23.

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TABLE 6-3
(Continued)

	Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
TNT Area A Overburden Wells (Continued)	DM-MW10-F								960						
	DM-MW11-U		10			29	21	14	1,300		46				74
	DM-MW11-F	5							710						
	MK-MW22-U								280						20
	MK-MW22-F								190						
	MK-MW23-U								460		47				63
	MK-MW23-F								240		30				20
	MK-MW24-U								310						21
	MK-MW24-F								220						
TNT Area B Overburden Wells	MK-MW16-U			2			35	6	14,000		150			2.3	160
	MK-MW16-F			2					17,000		180			2.6	140
	MK-MW17-U		13		2		37	9	2,200		320			0.9	250
	MK-MW17-F	2							2,300		320				200
TNT Area C Overburden Wells	DM-MW5-U							13	570						52
	DM-MW5-F	8							460						
	DM-MW6-U							5	1,400		29				34
	DM-MW6-F								1,600		20				

Concentrations are listed in µg/L or ppb.

All samples listed in the Sample ID Column (column 2) were analyzed for all 14 metals listed across the top row of the table. Only concentrations above the detection limit are listed on the table. Concentrations corresponding to the blank boxes were below the laboratory detection limit.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

Sample DM-MW10 is a duplicate of QC sample DM-MW23.

[illegible]

TABLE 6-3
(Continued)

	Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
Bedrock Wells	BED-MW13-U														23
	BED-MW13-F	14													
	BED-MW14-U													0.5	28
	BED-MW14-F														
	BED-MW15-U						40							0.6	22
	BED-MW15-F	16													
	BED-MW16-U	3							280						30
	BED-MW16-F														34
	BED-MW17-U		18												
	BED-MW17-F	7	15												
	BED-MW18-U						38		89						20
	BED-MW18-F								80						
	BED-MW19-U						22							0.6	24
	BED-MW19-F	8													
	BED-MW20-U						54		140						24
	BED-MW20-F								140						
	Reactor Well 2-U						20	9.6	470		70				90
	Reactor Well 2-F						20		120						

Concentrations are listed in µg/L or ppb.

All samples listed in the Sample ID Column (column 2) were analyzed for all 14 metals listed across the top row of the table. Only concentrations above the detection limit are listed on the table. Concentrations corresponding to the blank boxes were below the laboratory detection limit.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

Sample BED-MW18 is a duplicate of QC sample BED-MW21.

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TABLE 6-3
(Continued)

	Sample ID	Antimony	Arsenic	Beryllium	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Thallium	Zinc
QC Samples	BED-MW21-U						38		90						27
	BED-MW21-F								80						20
	DM-MW22-U						32	4	1,800		47			0.5	63
	DM-MW22-F						20		970		60				
	DM-MW23-U							7	880						34
	DM-MW23-F								830						
	Drill Water-U						20	3.1							110
	Drill Water-F	10													240

QC sample BED-MW21 is a duplicate of BED-MW-18.
QC sample DM-MW22 is a duplicate of DM-MW2.
QC sample DM-MW23 is a duplicate of DM-MW10.

Concentrations are listed in µg/L or ppb.

All samples listed in the Sample ID Column (column 2) were analyzed for all 14 metals listed across the top row of the table. Only concentrations above the detection limit are listed on the table. Concentrations corresponding to the blank boxes were below the laboratory detection limit.

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

G:\WP\QC\CONFLUM BRG.OK\GROUND WTR\TAB6-3 area. In TNT Area A, antimony was detected in the filtered sample from overburden well DM-MW11 at a concentration of 5 μg/L. In TNT Area B, antimony was detected only in the filtered sample collected from well MK-MW17 at a concentration of 2 μg/L. In overburden well DM-MW5, located in TNT Area C, the antimony concentration in the filtered sample was 8 μg/L.

Antimony was detected in five bedrock wells. In four wells, BED-MW13, BED-MW15, BED-MW17, and BED-MW19, the antimony concentrations were 14 μg/L, 18 μg/L, 7 μg/L, and 8 μg/L, respectively, in the filtered samples. Wells BED-MW13 and BED-MW17 are located at TNT Areas C and A, respectively. Wells BED-MW15 and BED-MW19 are located at the Pentolite Road Red Water Ponds and West Area Red Water Ponds, respectively. Only in well BED-MW16, located near the central toluene storage tanks, was antimony detected in the unfiltered sample at a concentration of 3 μg/L.

In five of the eight wells in which antimony was detected, DM-MW5, BED-MW13, BED-MW15, BED-MW17, and BED-MW19, the antimony concentration exceeded the MCL of 6 μg/L. However, all of these results are for suspect filtered samples. The only antimony result for an unfiltered sample, in well BED-MW16, was below the MCL.

6.3.2 Arsenic

Arsenic was detected in three wells, two completed in the overburden and one in bedrock. All three wells are located in former TNT areas. Arsenic was detected in overburden well DM-MW11, located at TNT Area A, and overburden well MK-MW17, located at TNT Area B. Concentrations were 10 μg/L and 13 μg/L, respectively. In both cases, arsenic was detected only in the unfiltered samples. Based on the fact that arsenic was not detected in the filtered samples in either overburden well, it appears that the arsenic in the samples from the overburden wells are related to particulate matter in the samples.

In bedrock well BED-MW17, located in TNT Area A, arsenic was detected in both the unfiltered and filtered samples at concentrations of 18 μg/L and 15 μg/L, respectively.

Because arsenic was detected in both the filtered and unfiltered samples, it is likely that arsenic is present in the bedrock aquifer in this area in the dissolved phase.

All arsenic concentrations are below the MCL of 50 μg/L.

6.3.3 Beryllium

Beryllium was detected in only one groundwater sample, collected from well MK-MW16 in TNT Area B. The concentrations in both the unfiltered and filtered samples *were 2 μg/L.* This concentration is below the MCL of 4 μg/L.

Because beryllium was detected in both the filtered and unfiltered samples, it is likely that it is present in the dissolved phase in well MK-MW16. Additionally, because beryllium was detected in several of the soil samples collected from TNT Area B, it is probably naturally occurring.

6.3.4 Cadmium

Cadmium was detected only in the unfiltered sample from well MK-MW17, located at former TNT Area B. The concentration of 2 μg/L is below the MCL of 5 μg/L.

As cadmium was not detected in the filtered sample from well MK-MW17, it is possible that its presence is related to particulate matter suspended in the groundwater.

6.3.5 Chromium

Chromium was detected in four overburden wells, two located at the Pentolite Road Red Water Ponds, one at the West Area Red Water Ponds, and one at former TNT Area A. Chromium was not detected in any of the bedrock wells.

The highest chromium concentrations were reported for overburden wells DM-MW7 and DM-MW8 at the Pentolite Road Red Water Ponds. These are the two wells in which the highest nitroaromatics concentrations were detected. Chromium was detected in both the filtered and unfiltered samples. In both cases, the concentration in the unfiltered sample was about 50 percent higher than in the filtered samples. The concentrations in the unfiltered samples were 36 µg/L and 52 µg/L, respectively for wells DM-MW7 and DM-MW8. The corresponding concentrations in the filtered samples were 21 µg/L and 38 µg/L, respectively. Therefore, it is likely that some of the chromium in the unfiltered samples is related to particulate matter, but chromium does appear to be present in the dissolved phase in the groundwater in this area.

In the other two wells in which chromium was detected, well DM-MW11 at TNT Area A and well DM-MW2 at the West Area Red Water Ponds, chromium was detected only in the unfiltered samples. The concentrations in wells DM-MW11 and DM-MW2 were 29 µg/L and 14 µg/L, respectively. As chromium was not detected in the filtered samples from either well, it is likely that the concentrations in the unfiltered samples are related to presence of particulate matter. This is supported by the fact that chromium was not reported in the duplicate unfiltered sample from well DM-MW2.

All chromium concentrations detected are below the MCL of 100 µg/L.

6.3.6 Copper

Copper was detected in eight overburden wells and five bedrock wells. By far the highest concentrations of copper were detected in the overburden wells at the two red water ponds areas. The highest copper concentrations were in the wells with the highest levels of explosives residues.

Copper was detected in three of the four overburden wells, DM-MW7, DM-MW8, and DM-MW9 at the Pentolite Road Red Water Ponds and in two of the three overburden wells, DM-MW2 and IT-MW2, at the West Area Red Water Ponds.

The highest concentrations, 1,400 µg/L and 1,600 µg/L, were detected in the Pentolite Road Red Water Ponds wells DM-MW7 and DM-MW8, respectively. As noted above for chromium, these are the two wells in which red water has been observed. Much lower levels of explosives residues from red water were detected in well DM-MW9. The copper levels in the sample from this well, 770 µg/L in the unfiltered sample and 760 µg/L in the filtered sample, were half the levels detected in wells DM-MW7 and DM-MW8. Copper was not detected in overburden well IT-MW5. Also, no explosives residues were detected in well IT-MW5.

Copper concentrations at the West Area Red Water Ponds were significantly lower than at the Pentolite Road Red Water Ponds. This same pattern was observed for the explosives residues. The concentrations in well IT-MW2,140 µg/L and 130 µg/L in the unfiltered and filtered samples, respectively, were an order of magnitude higher than in well DM-MW2. In well DM-MW2 the concentrations in the unfiltered and filtered samples were 38 µg/L and 20 µg/L, respectively.

Copper was present in both the filtered and unfiltered samples from each of the five red water ponds areas overburden wells where it was detected. The concentrations in the unfiltered samples were slightly higher than in the filtered samples in all cases. This indicates that copper is probably present in the groundwater in these areas in the dissolved phase.

In the TNT areas, copper was present in only three of nine overburden wells. In each well, it was detected only in the unfiltered samples. Concentrations in wells DM-MW11, MK-MW16, and MK-MW17 were 21 µg/L, 35 µg/L, and 37 µg/L, respectively. As copper was not detected in the filtered samples, it is likely that the concentrations in the unfiltered samples are related to presence of particulate matter.

Copper was detected in five of the nine bedrock wells. In four of the five cases, it was detected in the unfiltered samples only indicating that it is likely not present in the dissolved phase. The concentrations in the unfiltered samples from wells BED-MW15, BED-MW18, BED-MW19, and BED-MW20 were 40 µg/L, 36 µg/L, 22 µg/L, and 54 µg/L, respectively. Copper was detected in both the filtered and unfiltered samples from Reactor Well 2 at concentrations of 20 µg/L.

The concentrations in all samples from overburden wells DM-MW7 and DM-MW8 were above the MCL of 1,300 μg/L. All other copper concentrations were below the MCL and the Secondary Maximum Contaminant Level (SMCL) of 1,000 μg/L.

6.3.7 Lead

Lead was detected at relatively low levels in about a third of the wells (eight of 25).

Interestingly, lead was not detected in any samples collected from the Pentolite Road Red Water Ponds overburden wells. At the West Area Red Water Ponds, lead was detected in only one groundwater sample. The concentration in the unfiltered sample collected from well DM-MW2 was 7 μg/L (average of two duplicate samples). No lead was present in either of the corresponding duplicate filtered samples.

Lead was detected in six of the nine samples collected from overburden wells in the former TNT areas. In each case, lead was detected only in the unfiltered sample. In wells DM-MW10 and DM-MW11 in TNT Area A, the concentrations were 7 μg/L and 14 μg/L, respectively. At TNT Area B, lead was detected in the unfiltered samples from wells MK-MW16 and MK-MW17 at concentrations of 6 μg/L and 9 μg/L, respectively. In wells DM-MW5 and DM-MW6 in TNT Area C, the concentrations were 13 μg/L and 5 μg/L, respectively.

Reactor Well 2, located north of the Pentolite Road Red Water Ponds, was the only bedrock well in which lead was detected. The concentration in the unfiltered samples was 9.6 μg/L.

Lead was only detected in unfiltered samples indicating it is probably related to particulate matter in the sample and is not dissolved in the groundwater. In any event, all reported lead concentrations are below the lead Action Level (AL) of 15 μg/L.

6.3.8 Manganese

Manganese was detected in all of the filtered and unfiltered groundwater samples collected from overburden wells. The highest concentrations were reported in TNT Area B in well MK-MW16. In this well, the concentrations in the unfiltered and filtered samples were 14,000 µg/L and 17,000 µg/L, respectively. In well MK-MW17, the concentrations were much lower, 2,200 µg/L and 2,300 µg/L, respectively, for the unfiltered and filtered samples.

Manganese concentrations were also very elevated in the samples from the Pentolite Road Red Water Ponds area. The highest concentrations, 12,000 µg/L in the unfiltered sample and 10,000 µg/L in the filtered sample, were reported in well DM-MW7. The manganese levels in well DM-MW8, 8,000 µg/L in the unfiltered sample and 7,000 µg/L in the filtered sample, were not substantially lower. Concentrations in well DM-MW9 were 1,800 µg/L in both the filtered and unfiltered samples. Nitroaromatics were detected in each of these three wells. The manganese concentrations of 100 µg/L in both the unfiltered and filtered samples from well IT-MW5 were an order of magnitude lower than those in wells DM-MW8 and DM-MW9 and two orders of magnitude lower than in well DM-MW7.

At the West Areas Red Water Ponds, manganese was detected at relatively high concentrations in two of the three overburden well samples. In wells IT-MW2 and MK-MW11, the manganese concentration in the filtered sample was slightly higher than in the unfiltered sample. Manganese levels were an order of magnitude lower in well MK-MW11, the well located north of the West Area Red Water Ponds along Patrol Road. In the two wells in or immediately adjacent to the ponds area, wells DM-MW2 and IT-MW2, the manganese concentrations were all 1,000 µg/L or more.

Manganese was also detected in both groundwater samples collected from overburden wells in TNT Area C. In each case, manganese was reported in both the filtered and unfiltered samples. The manganese concentration in the unfiltered sample from well DM-MW5 of 570 µg/L was higher than the concentration of 460 µg/L in the filtered sample. Conversely, the concentration in the filtered sample from well DM-MW6 of

1,600 μg/L was higher in the filtered sample than the concentration of 1,400 μg/L in the unfiltered sample.

In TNT Area A, manganese concentrations ranged from a low of 190 μg/L in the filtered sample from well MK-MW22 to a high of 1,300 μg/L in the sample collected from overburden well DM-MW11.

Manganese concentrations in the soils at the PBS were sampled in connection with the TNT Site Investigation and the Red Water Ponds Focused Remedial Investigation. The results of the analysis showed elevated levels of manganese in the soils in the investigation areas in relation to concentrations in soils collected from background areas. Elevated manganese levels are also apparent in the groundwater. No statistical relationship was established between the presence of explosives residues and manganese. However, the elevated manganese levels do appear to be coincident with elevated concentrations of other metals and explosives residues, particularly at the two red water ponds areas. At the former red water ponds areas, the samples in which the highest manganese concentrations were reported are also the samples containing elevated concentrations of copper, nickel, and zinc and explosives residues.

Manganese was not as ubiquitous in the bedrock groundwater. It was detected in only four of the nine wells. Concentrations in the unfiltered samples ranged from a low of 89.5 μg/L (average of two duplicate samples) in the sample collected from bedrock well BED-MW18 to a high of 470 in Reactor Well 2. In the filtered samples, concentrations ranged from 80 μg/L in well BED-MW18 to 140 μg/L in the background well BED-MW20.

Manganese values in all samples in which it was detected exceeded the SMCL of 50 μg/L. In some samples, particularly in TNT Area B and the Pentolite Road Red Water Ponds, the concentrations exceeded the SMCL by three orders of magnitude.

6.3.9 Nickel

Nickel was detected in ten of the fifteen overburden wells but in only one of the nine bedrock wells. By far the highest nickel concentrations were detected in the overburden wells at the Pentolite Road Red Water Ponds. Again, as with copper and manganese, the highest concentrations were in the wells with the highest levels of explosives residues. In overburden wells DM-MW7, DM-MW8, and DM-MW9, nickel concentrations ranged from 1,500 µg/L to 2,500 µg/L. All of these values exceed the MCL of 100 µg/L by an order of magnitude. Concentrations in the unfiltered samples from well DM-MW7 and DM-MW8 slightly exceeded the concentrations in the filtered samples. However, in well DM-MW9, the concentration of 1,600 µg/L in the filtered sample slightly exceeded the concentration of 1,500 µg/L in the unfiltered sample. Nickel was not detected in overburden well IT-MW5. Also, no explosives residues were detected in well IT-MW5.

Nickel concentrations at the West Area Red Water Ponds were significantly lower than at the Pentolite Road Red Water Ponds. Nickel was detected only in the two overburden wells installed immediately adjacent to the ponds area, wells IT-MW2 and DM-MW2. Concentrations in well IT-MW2 (120 µg/L for the unfiltered sample and 130 µg/L for the filtered sample) were about double concentrations in well DM-MW2 (55 µg/L for the unfiltered sample and 60 µg/L for the filtered sample averaged for two duplicate samples). In both wells, the concentration in the filtered samples was slightly higher than in the unfiltered samples. Also, the explosives residues concentrations in well IT-MW2 were an order of magnitude higher than in well DM-MW2. No nickel or explosives residues were reported in well MK-MW11.

In the TNT areas, nickel was present in five of nine overburden wells. In TNT Area A, nickel was detected at a concentrations of 47 µg/L and 30 µg/L in the unfiltered and filtered samples from well MK-MW23 and in the unfiltered sample from well DM-MW11 at a concentration of 46 µg/L. In TNT Area B, the nickel concentrations in the filtered samples were equal to or greater than the concentrations in the unfiltered samples. In well MK-MW16, the nickel concentrations in the unfiltered and filtered samples were 150 µg/L and 180 µg/L, respectively. Concentrations in the both samples from well MK-MW17 were 320 µg/L. Nickel was detected in only one of the two wells at TNT Area C. The concentrations were 29 μg/L and 20 μg/L in the unfiltered and filtered samples, respectively, from well DM-MW6.

Nickel was detected in only one bedrock well. In the unfiltered sample from Reactor Well 2 the nickel concentration was 70 μg/L. It was not reported in the corresponding filtered sample.

The nickel concentrations in both wells at TNT Area B, in all three wells where it was detected at the Pentolite Road Red Water Ponds, and in well IT-MW2 at the West Area Red Water Ponds were above the MCL of 100 μg/L.

6.3.10 Thallium

Thallium was detected in three of the overburden well groundwater samples and three of the bedrock well samples. The highest concentrations, in well MK-MW16 in TNT Area B, were 2.6 μg/L in the filtered sample and 2.3 μg/L in the unfiltered sample. Both of these concentrations are above the MCL of 2 μg/L. In well MK-MW17, also located in TNT Area B, thallium was only detected in the unfiltered sample at a concentration of 0.9 μg/L.

Thallium was also detected at low levels in overburden well DM-MW7 at the Pentolite Road Red Water Ponds. Concentrations of 0.9 μg/L and 0.7 μg/L were reported in the unfiltered and filtered samples, respectively. In overburden well DM-MW2 at the West Area Red Water Ponds, thallium was detected at a concentration of 0.5 μg/L in one of two duplicate unfiltered samples. Thallium was not detected in the other duplicate unfiltered sample, in either of the duplicate filtered samples, or in any of the samples from either of the other overburden wells.

In the bedrock aquifer, thallium was detected in the unfiltered samples from three wells. The concentrations in wells BED-MW14 and BED-MW19, both at the West Area Red Water Ponds, were 0.5 μg/L and 0.6 μg/L, respectively. In well BED-MW15, located at the Pentolite Road Red Water Ponds, thallium was detected at a concentration of 0.6 μg/L in the unfiltered sample.

6.3.11 Zinc

Zinc was detected in all of the unfiltered samples collected from the overburden wells. In both wells in TNT Area B and in three of the four wells at the Pentolite Road Red Water Ponds, zinc was also detected in the filtered samples. On a sitewide basis, in the overburden wells, zinc concentrations in the unfiltered samples ranged from 20 µg/L in well MK-MW22 in TNT Area A to 250 µg/L in well MK-MW17 near the Waste Water Settling Basins in TNT Area B. In the filtered samples, concentrations ranged from 44 µg/L in well DM-MW7 at the Pentolite Road Red Water Ponds to 200 µg/L in well MK-MW17.

Zinc was also detected in the unfiltered samples from eight of the nine bedrock wells. It was only detected in the filtered sample from one well, BED-MW16. In this well, the concentration in the filtered sample, 34 µg/L, was slightly higher than the concentration in the unfiltered sample of 30 µg/L. Values in the filtered samples in the bedrock aquifer ranged from 20 µg/L in well BED-MW18 to 90 µg/L in the sample from *Reactor Well 2*.

Zinc values were all well below the SMCL of 5,000 µg/L.

6.4 VOCs

VOCs were analyzed only for the samples collected from the nine bedrock wells. Concentrations are listed on Table 6-4 and illustrated on Figure 6-3. Seven VOCs, acetone, benzene, 2-butanone, carbon disulfide, ethylbenzene, toluene, and xylenes, were detected in the bedrock wells. As is discussed below, low levels of three hydrocarbons were reported in the sample from the background well, BED-MW20. The other four VOCs were not detected in the background well.

QC sample BED-MW21 was a duplicate of sample BED-MW18. The same five VOCs, benzene, carbon disulfide, ethylbenzene, toluene, and xylenes, were detected in both samples at relatively similar concentrations.

TABLE 6-4

VOC AND SVOC CONCENTRATIONS IN BEDROCK WELLS

		VOCs							SVOCs		
	Sample ID	Acetone	Benzene	2-Butanone	Carbon Disulfide	Ethyl-benzene	Toluene	Xylenes	2,4-Dimethyl-phenol	2-Methyl-naphthalene	Naphthalene
Bedrock Wells	BED-MW13		50			82	190	720	10	24	28
	BED-MW14					1.6	3	14			
	BED-MW15	660	830		1,500	180	540	1,300		70	60
	BED-MW16	550	2,000	150		230	730	1,400		160	90
	BED-MW17	150	33			98	160	420		20	21
	BED-MW18		14		160	79	72	350	19		17
	BED-MW19	59	5		26	3	5	26			
	BED-MW20		8				4	3			
	Reactor Well 2		1.8			1.2		8			
QC Samples	BED-MW21		16		90	120	93	520	17		15
	Drill Water										

VOCs = volatile organic compounds
SVOCs = semivolatile organic compounds

QC sample BED-MW21 is a duplicate of BED-MW18.

Concentrations are listed in µg/L or ppb.

The sample IDs used in this table are abbreviated. "BED" indicates a well completed in the bedrock. The well number is designated by MW (e.g., MW13).

All samples listed in the Sample ID column (column 2) were analyzed for all analytes on the VOC and SVOC method analysis lists. Only concentrations above the detection limit are listed on the table. Concentration corresponding to the blank boxes were below the laboratory limit.

6.4.1 BTEX Compounds

One or more of the hydrocarbon compounds benzene, ethylbenzene, toluene, and xylenes (BTEX) were detected in all of the bedrock wells, including the background well. Previous investigations have indicated that low levels of BTEX compounds are ubiquitous in the soil and groundwater at the site. Low levels of benzene, toluene, and xylenes were detected in the groundwater sample from the background well, BED-MW20. The total BTEX concentration in background well BED-MW20 was 11 μg/L. The benzene concentration of 8 μg/L in this well was above the MCL of 5 μg/L.

The highest hydrocarbon levels, 2,850 μg/L total BTEX and 4,360 μg/L total BTEX, respectively, were detected in wells BED-MW15 and BED-MW16. These wells are both located in the north central portion of the site. Well BED-MW16 is installed near the central toluene tanks. An oily liquid was present in well BED-MW16. Well BED-MW15 is located downgradient of well BED-MW16, on the north side of Pentolite Road. The benzene concentrations in wells BED-MW15 and BED-MW16 of 830 μg/L and 2,000 μg/L, respectively, were both significantly above the MCL of 5 μg/L.

The total BTEX concentration in well BED-MW13 was 1,042 μg/L. This well is located along what is called "the EPA Road." Previously, this area was used for vehicle testing which may account for the high BTEX levels. The benzene concentration in well BED-MW13 of 50 μg/L is an order of magnitude above the MCL.

Significant levels of BTEX constituents were also present in the two bedrock wells located in the vicinity of former TNT Area A. Total BTEX concentrations in wells BED-MW17 and BED-MW18 were 711 μg/L and 632 μg/L (average of two duplicate samples), respectively. In both wells, the benzene concentrations, 33 μg/L in well BED-MW17 and 14 μg/L in well BED-MW18, were above the MCL.

Lower levels of BTEX were detected in the two West Area Red Water Ponds bedrock wells, BED-MW14 and BED-MW19. Three of the four BTEX compounds (ethylbenzene, toluene, and xylenes) were detected in both wells. Benzene was detected only in well BED-MW19 at a concentration of 5 μg/L, equal to the MCL. The total BTEX concentration in well BED-MW19 was 39 µg/L. The total BTEX concentration in well BED-MW14 was only 18.6 µg/L.

Three of the four BTEX compounds, benzene, ethylbenzene, and xylenes, were detected in Reactor Well 2 at very low levels. The total BTEX concentration was 11 µg/L. This is the only bedrock well in which benzene was detected that the concentration was not above the MCL.

6.4.2 Acetone

Acetone was detected in four of the nine bedrock wells. It was not detected in the background bedrock well, BED-MW20. Acetone is a common solvent with a wide variety of common industrial uses. Acetone is also used in the manufacture of pentolite, one of the products of the PBOW.

The highest acetone concentration, 660 µg/L, was reported in Well BED-MW15. As discussed above, this is also one of the two wells with the highest levels of BTEX compounds.

The second highest concentration of acetone, 550 µg/L, was detected in the well with the highest BTEX concentration, well BED-MW16.

Acetone was also detected at somewhat lower levels in Wells BED-MW17, located at the former TNT Area A, and well BED-MW19, located north of Patrol Road north of the West Area Red Water Ponds. The concentrations in wells BED-MW17 and BED-MW19 were 150 µg/L and 59 µg/L, respectively.

6.4.3 2-Butanone

2-Butanone, or methyl ethyl ketone, was detected in only one well, BED-MW16. This well contained the highest concentration of BTEX compounds and an unidentified oily liquid. This compound is a common additive in fuels and may be related to the hydrocarbons detected in this well.

6.4.4 Carbon Disulfide

Carbon disulfide, a VOC often related to petroleum hydrocarbons, coal tars, and crude hydrocarbons, was detected in three wells. The highest concentration, 1,500 µg/L, was reported in well BED-MW15, one of the two wells north of the former toluene storage tanks.

Carbon disulfide was also detected at significantly lower concentrations in two other wells. The concentration in well BED-MW18 was 125 µg/L (average of two duplicate samples). In well BED-MW19, the reported concentration was 26 µg/L.

6.5 SVOCs

SVOCs were also analyzed only for the samples collected from the nine bedrock wells. Table 6-4 lists the concentrations detected in each well. Three SVOCs, 2,4-dimethylphenol, 2-methylnaphthalene, and naphthalene, were detected in the bedrock wells.

No SVOCs were detected in the sample from the bedrock background well BED-MW20.

QC sample BED-MW21 was a duplicate of sample BED-MW18. The same two SVOCs, 2,4-dimethylphenol and naphthalene, were detected in both samples at almost identical concentrations.

6.5.1 2,4-Dimethylphenol

2,4-dimethylphenol was detected in only two wells, BED-MW13 and BED-MW18. The reported concentrations were 10 μg/L and 18 μg/L (average of two duplicate samples), respectively. 2,4-dimethylphenol is a naturally occurring, substituted phenol derived from the cresol fraction of petroleum or coal tars. It is also an additive to lubricants and gasolines. Its presence corresponds with two wells where elevated levels of BTEX were detected.

6.5.2 2-Methylnaphthalene

2-methylnaphthalene, a polyaromatic hydrocarbon related to naphthalene, occurs in nature in association with coal, coal tars, and oil deposits. As a trace constituent of oils, it is also often found with petroleum hydrocarbons released into the environment by man. 2-methylnaphthalene was detected in four of the nine bedrock wells. Petroleum hydrocarbons were also detected in all four wells. The highest concentrations, 160 μg/L and 70 μg/L, were detected in wells BED-MW16 and BED-MW15, respectively. The highest BTEX concentrations were also present in these two wells. The other two wells in which 2-methylnaphthalene was detected, wells BED-MW13 and BED-MW17, contained the third and fourth highest concentrations of BTEX respectively.

6.5.3 Naphthalene

Naphthalene is the single most common constituent of coal tar and, like 2-methylnaphthalene, is found in association with naturally occurring oils and hydrocarbons. It is insoluble in water, but readily soluble in benzene, toluene, or carbon disulfide. It is a constituent of several additives for lubricants and motor fuels.

Naphthalene was detected in five of the nine bedrock wells, the five wells with the five highest total BTEX concentrations. The highest concentrations, 90 μg/L and 60 μg/L, were detected in wells BED-MW16 and BED-MW15, respectively. Not surprisingly, these are the two wells with the highest BTEX concentrations. The other three wells in which naphthalene was detected each contained a total BTEX concentration of 500 µg/L or more. The naphthalene concentrations in these five wells corresponded directly from highest to lowest with the total BTEX concentrations in each well.

6.6 pH AND CONDUCTIVITY

pH, specific conductance, and temperature measurements made during the sample collection in December 1994 are listed in Table 6-5.

The normal range of pH in groundwater is 6.0 to 8.5. The pH of all samples except two were within this range. The pH in well MK-MW17 in TNT Area B was 5.5, somewhat below the normal range. The pH in well MK-MW24 in TNT Area A was 5.9, only slightly below the normal range.

pH values in all of the other overburden wells ranged from 6.0 in several wells to 6.82 in two wells at the Pentolite Road Red Water Ponds. pH values in the bedrock well were slightly higher ranging from 6.0 in the background bedrock well and well BED-MW14 to 8.0 in wells BED-MW17 and BED-MW13 in TNT Areas A and C, respectively.

Specific conductance is the ability of a fluid like water to conduct a current. Values above 1,000 microhoms per centimeter (umhos/cm) are considered elevated. Specific conductance in all overburden wells except IT-MW5 (931 umhos/cm) and MK-MW22 (700 umhos/cm), and bedrock Reactor Well 2 (700 umhos/cm) were elevated. The highest specific conductance values measured were in the three overburden wells at the Pentolite Road Red Water ponds, wells DM-MW7, DM-MW8, and DM-MW9, which had high levels of explosives residues.

As is noted on Table 6-5, a hydrogen sulfide odor was obvious in a number of the bedrock wells. The source of the gas is not known, but was widespread in the bedrock wells. It correlated with high specific conductance measurements, although it was not noted in all wells with very elevated specific conductance values.

TABLE 6-5

GROUNDWATER SAMPLING FIELD MEASUREMENTS

	Well Identification	pH	Temperature (°F)	Conductivity (µmhos/cm)	Remarks
West Area Red Water Ponds	DM-MW2	6.5	48	>1990	
	IT-MW2	6.0	51	>1990	
	MK-MW11	6.7	54	1080	
	BED-MW14	6.0	47	1580	
	BED-MW19	7.0	50	>1990	
Pentolite Road Red Water Ponds	DM-MW7	6.75	52	18,060	
	DM-MW8	6.82	53	26,400	Water is red
	DM-MW9	6.82	53	11,520	
	IT-MW5	6.61	52	931	
	BED-15	7.5	50	>1990	
	Reactor Well 2	6.5	52	700	
TNT Area A	DM-MW10	6.75	48	1300	Water cloudy with fines
	DM-MW11	6.0	51	1570	Water cloudy with fines
	MK-MW22	6.5	51	700	Water mostly clear

µmhos/cm - microhoms per centimeter

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

TABLE 6-5
(Continued)

	Well Identification	pH	Temperature (°F)	Conductivity (μmhos/cm)	Remarks
TNT Area A	MK-MW23	6.5	54	1370	Water mostly clear
	MK-MW24	5.9	53	1294	Water mostly clear
	BED-MW17	8.0	50	>1990	Strong H_2S odor. Possible hazardous environment from CGI monitoring.
	BED-MW18	7.5	47	>1990	H_2S odor
TNT Area B	MK-MW16	6.0	49	1350	
	MK-MW17	5.5	43	1520	
TNT Area C	DM-MW5	6.5	49	1060	Water cloudy with fines
	DM-MW6	6.75	51	1470	Water cloudy with fines
	BED-MW13	8.0	51	>1990	Strong H_2S odor to H_2S bubbling into well as water draws down. Slight oil film.
Central Toluene Tanks	BED-MW16	---	---	---	Petroleum oil on water. Cloudy water with fines.
Background	BED-MW20	6.0	51	>1990	

μmhos/cm - microhoms per centimeter

The sample IDs used in this table are abbreviated. For overburden wells, the ID is composed of two parts: the investigation for which the well was installed (e.g., DM = Dames & Moore, MK = MK Ferguson, IT = IT Corporation); and the well number (e.g. MW10). Bedrock wells are designated by "BED" and the well number.

6.7 SUMMARY OF GROUNDWATER QUALITY

The results of the groundwater quality investigation indicate that significant levels of explosives residues are present in the groundwater in the overburden aquifer in immediate vicinity of both former Red Water Ponds areas. With increasing distance from the ponds, even in the downgradient direction of horizontal flow, levels of explosives residues decrease in the overburden aquifer.

6.7.1 Pentolite Road Red Water Ponds

Explosives residues were detected at concentrations above the PQL in three of the four overburden wells at the Pentolite Road Red Water Ponds, wells DM-MW7, DM-MW8, and DM-MW9. Each of these wells is located within or immediately adjacent to the boundary of (well DM-MW) the former ponds. Nine of the 14 nitroaromatics analytes were detected in these three wells. The highest concentrations were present in well DM-MW7 and DM-MW8 which are definitely located within the perimeter of the former ponds. The most elevated concentrations (in excess of 500 µg/L) were detected for 1,3,5-TNB, 1,3-DNB, and 2,4-DNT.

Explosives residues were not detected in well IT-MW5 which is located a short distance downgradient of the ponds. Thus, the chemical data for this investigation supports the conclusion of the groundwater flow investigation with regard to the predominance of vertical flow in the overburden hydrostratigraphic unit. Even after 50 years, nitroaromatics have not migrated horizontally the short distance to well IT-MW5.

Low levels of explosives residues were detected in one of the two bedrock wells installed downgradient from the Pentolite Road Red Water Ponds. 3,NT and 3,4-DNT were detected at concentrations of 23 µg/L and 13 µg/L, respectively, in Reactor Well 2.

Nitrate levels in these same three wells, DM-MW7, DM-MW8, and DM-MW9, were also elevated. In each well, the nitrate concentration exceeded the MCL of 10 mg/L.

Several VOCs and SVOCs were detected in the two bedrock, generally hydrocarbons and associated compounds. The benzene concentration in bedrock well BED-MW15 was two orders of magnitude above the MCL.

Eight metals (antimony, chromium, copper, lead, manganese, nickel, thallium, and zinc) were detected in the groundwater samples collected at the Pentolite Road Red Water Ponds.

Very elevated levels of copper, manganese, and nickel were detected in each of the three wells in which high explosives residues were detected, wells, DM-MW7, DM-MW8, and DM-MW9. Chromium and zinc were also detected in the overburden wells, but at concentrations consistent with those detected in other site wells. Thallium was detected only in well DM-MW7, coincidentally the well with the highest explosives residues concentrations.

The antimony concentration in the filtered sample from bedrock well BED-MW15 is suspect and was the only antimony concentration detected at the Pentolite Road Red Water Ponds. Lead was detected in the Reactor Well 2 sample at a concentration below the AL. Copper, manganese, nickel, thallium, and zinc were also detected in the bedrock aquifer in this area.

Copper concentrations were above the MCL in two of the three overburden wells, and above the SMCL in all three of the overburden wells in which it was detected. Manganese concentrations were above the SMCL, sometimes by several order of magnitude, in all of the wells in which it was detected. Nickel values exceeded the MCL in all three overburden wells in which it was detected.

6.7.2 West Area Red Water Ponds

Explosives residues were also detected in two of the overburden wells at the West Area Red Water Ponds. The explosives residues concentrations in the two overburden wells at the West Area Red Water Ponds were considerably lower than the concentrations detected in the overburden wells installed within the pond perimeter at the Pentolite Road Red Water Ponds. However, the concentrations of explosives residues detected in the sample of reddish-tinted groundwater from the pit excavated on the north bank of the west pond were significantly higher than any concentrations detected at the Pentolite Road Red Water Ponds. Again, the presence of red water and high explosives residues concentrations near the current pond boundary and probably within the boundary of the pond during operation of the PBOW, supports the conclusion of the groundwater flow assessment. The dominant direction of groundwater flow in the overburden is apparently vertically downward.

Low levels of nitroaromatics were also detected in both of the bedrock wells at the West Area Red Water Ponds.

Nitrates were detected at concentrations above the MCL in both of the overburden wells in which explosives residues were also detected. However, concentrations were not as elevated as those at the Pentolite Road Red Water Ponds.

VOCs and SVOCs were detected in both bedrock wells at the West Area Red Water Ponds. The compounds detected were generally hydrocarbons and associated compounds. The benzene concentration in well BED-MW19 was 5 μg/L, equal to the MCL.

Eight metals (antimony, chromium, copper, lead, manganese, nickel, thallium, and zinc) were detected in the groundwater samples collected from the West Area Red Water Ponds.

Copper, manganese, and nickel were detected at relatively high concentrations in the two wells in which explosives residues were also detected. Again, the concentrations were significantly lower than those detected in the Pentolite Road Red Water Ponds samples. Chromium, lead, and zinc were also detected in unfiltered samples collected from the West Area Red Water Ponds overburden wells.

Low levels of thallium and zinc were detected in the unfiltered sample from bedrock well BED-MW14 and low levels of copper, thallium, and zinc were detected in bedrock well BED-MW19 also only in the unfiltered sample.

The antimony concentration in the filtered sample from bedrock well BED-MW19 is suspect and was the only antimony concentration detected in the West Area Red Water Ponds.

Nickel concentrations in overburden well IT-MW2 exceeded the MCL. Manganese concentrations in all samples in which it was detected exceeded the SMCL.

6.7.3 TNT Area A

Groundwater samples were collected from five overburden and two bedrock wells located at TNT Area A. Explosives residues were detected in one of the overburden wells, DM-MW10, located downgradient from the Wash House for TNT manufacturing line 3. Several VOCs and SVOCs were detected in the bedrock aquifer, generally hydrocarbons and related compounds.

Seven priority pollutant metals, antimony, arsenic, chromium, copper, lead, nickel, and zinc, were present in the area groundwater. Groundwater at the site is not used for potable drinking water; however, it is noted that none of the concentrations of priority pollutant metals exceeded regulatory action levels. An eighth metal, manganese was detected in filtered and unfiltered samples from six of the seven groundwater monitoring wells at TNT Area A. All concentrations exceeded the SMCL.

6.7.4 TNT Area B

Groundwater samples were collected from two overburden wells located at TNT Area B. Explosives residues were detected in one of the two overburden wells, MK-MW17, located on the downgradient side of the area.

Nine priority pollutant metals, antimony, arsenic, beryllium, cadmium, copper, lead, nickel, thallium, and zinc, plus manganese were present in the area groundwater. Nickel, manganese, and thallium were detected in concentrations which exceed regulatory action levels. Manganese concentrations are two to three orders of magnitude over the SMCL.

6.7.5 TNT Area C

Groundwater samples were collected from two overburden wells and one bedrock well located at TNT Area C. One explosives residues compound was detected in the bedrock well, BED-MW13 located downgradient of the former TNT Area C. Several VOCs and SVOCs were detected in the bedrock aquifer, again generally hydrocarbons and related compounds.

Four priority pollutant metals, antimony, lead, nickel, and zinc, were present in the area groundwater. Antimony in the filtered samples from wells DM-MW5 and BED-MW13 exceeded the regulatory action level, but its presence in the samples is suspect. Manganese was detected in filtered and unfiltered samples from both overburden wells at TNT Area C. All concentrations exceeded the SMCL.

7.0 CONCLUSIONS

7.1 GROUNDWATER FLOW REGIME

The results of the groundwater investigation indicate that generally groundwater flow is to the north, eventually toward Lake Erie, as would be expected for this site. However, it is likely that with the shallow bedrock and thin veneer of overburden materials overlying the bedrock, the downward flow of groundwater from the overburden into the bedrock predominates over horizontal flow in the overburden. This flow pattern, if accurate, would facilitate migration of contaminants from the overburden soils and groundwater into the bedrock aquifer.

At the Pentolite Road Red Water Ponds, the direction of groundwater flow indicated by contouring water levels is from the southwest to the northeast. The direction of groundwater flow in the overburden at the West Area Red Water Ponds is from the southeast to the northwest. The investigation indicates that there is apparently not a significant hydrologic connection between the west pond and the groundwater in the overburden.

Groundwater in the overburden at TNT Area A generally flows south to north; however, on the western side of the site, there is a northwestern component to the flow direction. Contouring of groundwater levels at TNT Area B indicates a groundwater flow direction in the overburden from south to north. However, because of the very shallow bedrock in this area, the dominant direction of flow is probably vertical from the overburden to the bedrock. Groundwater flow in the overburden in the vicinity of TNT Area C is generally from southeast to northwest. However, the presence of groundwater in the overburden materials in this area, and the resulting groundwater flow pattern, is apparently seasonal.

In the bedrock, the direction of groundwater flow in generally from south to north. In the northwest portion of the site, the only part of the site underlain by limestone, the groundwater flow direction is east-northeast from the West Area Red Water Ponds toward the Reactor Area. In the northeast part of the site, groundwater flow in the bedrock is north-northwest.

The presence of groundwater in the overburden hydrostratigraphic unit at the site is apparently very seasonal. During the early winter when groundwater samples were collected for this investigation, several of the overburden monitoring wells were dry. However, after abundant winter precipitation, in early spring groundwater was present in all of the previously dry wells.

7.2 GROUNDWATER QUALITY

The results of the groundwater quality investigation indicate that significant levels of explosives residues are present in the groundwater in the overburden aquifer in immediate vicinity of both former Red Water Ponds areas. With increasing distance from the ponds, even in the downgradient direction of horizontal flow, levels of explosives residues decrease in the overburden aquifer. Low levels of explosives residues were detected in the overburden wells at two of the three TNT areas and in the bedrock wells.

Nitrates were also detected at elevated levels in some overburden wells at the two red water Ponds areas.

Several VOCs and SVOCs were detected in the bedrock wells. These were generally hydrocarbons and associated compounds. Benzene was reported at concentrations equal to or exceeding the MCL in seven of the nine bedrock wells sampled.

Eleven metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, nickel, thallium, and zinc) were detected in the groundwater. The highest concentrations were of copper, manganese, and nickel in the wells at the Red Water Ponds that also contained elevated levels of explosives residues and nitrates. Copper, nickel, manganese, and thallium were detected at concentrations above their regulatory action levels.

7.2.1 Pentolite Road Red Water Ponds

Four overburden wells and two bedrock wells were sampled at the Pentolite Road Red Water Ponds. Explosives residues were detected at concentrations above the PQL in three of the four overburden wells at the Pentolite Road Red Water Ponds, wells DM-MW7, DM-MW8, and DM-MW9. Each of these wells is located within or immediately adjacent to the boundary of (well DM-MW) the former ponds.

Explosives residues were not detected in well IT-MW5 which is located a short distance downgradient of the ponds. Thus, the chemical data for this investigation supports the conclusion of the groundwater flow investigation with regard to the predominance of vertical flow in the overburden hydrostratigraphic unit. Even after 50 years, nitroaromatics have not migrated horizontally in the overburden the short distance to well IT-MW5.

Low levels of explosives residues were detected in one of the two bedrock wells installed downgradient from the Pentolite Road Red Water Ponds.

Nitrate levels in wells DM-MW7, DM-MW8, and DM-MW9 were also elevated. In each well, the nitrate concentration exceeded the MCL of 10 mg/L.

Six VOCs and two SVOCs, generally hydrocarbons and associated compounds, were detected in the two bedrock wells. The benzene concentration in bedrock well BED-MW15 was two orders of magnitude above the MCL.

Eight metals (antimony, chromium, copper, lead, manganese, nickel, thallium, and zinc) were detected in the groundwater samples collected at the Pentolite Road Red Water Ponds.

Very elevated levels of copper, manganese, and nickel were detected in each of the three wells in which high explosives residues were detected, wells DM-MW7, DM-MW8, and DM-MW9.

Copper concentrations were above the MCL in two of the three overburden wells, and above the SMCL in all three of the overburden wells in which it was detected. Manganese concentrations were above the SMCL, sometimes by several orders of magnitude, in all of the wells in which it was detected. Nickel values exceeded the MCL in all three overburden wells in which it was detected.

7.2.2 West Area Red Water Ponds

Three overburden and two bedrock wells were sampled at the West Area Red Water Ponds. Explosives residues were also detected in two of the overburden wells at the West Area Red Water Ponds. The explosives residues concentrations in the two overburden wells at the West Area Red Water Ponds were considerably lower than the concentrations detected in the overburden wells installed within the pond perimeter at the Pentolite Road Red Water Ponds. However, the concentrations of explosives residues detected in the sample of reddish-tinted groundwater from the pit excavated on the north bank of the west pond were significantly higher than concentrations detected at the Pentolite Road Red Water Ponds. Again, the presence of red water and high explosives residues concentrations near the current pond boundary (and probably within the boundary of the pond during operation of the PBOW) supports the conclusion of the groundwater flow assessment. The dominant direction of groundwater flow in the overburden is apparently vertically downward.

Low levels of nitroaromatics were detected in both of the bedrock wells at the West Area Red Water Ponds.

Nitrates were detected at concentrations above the MCL in both of the overburden wells in which explosives residues were also detected. However, concentrations were not as elevated as those at the Pentolite Road Red Water Ponds.

Five VOCs were detected in bedrock wells at the West Area Red Water Ponds. The compounds detected were generally hydrocarbons and associated compounds. The benzene concentration in well BED-MW19 was 5 μg/L, equal to the MCL.

Eight metals (antimony, chromium, copper, lead, manganese, nickel, thallium, and zinc) were detected in the groundwater samples collected from the West Area Red Water Ponds.

Copper, manganese, and nickel were detected at relatively high concentrations in the two wells in which explosives residues were also detected. Again, the concentrations were significantly lower than those detected in the Pentolite Road Red Water Ponds samples.

Nickel concentrations in overburden well IT-MW2 exceeded the MCL. Manganese concentrations in all samples in which it was detected exceeded the SMCL.

7.2.3 TNT Area A

Groundwater samples were collected from five overburden and two bedrock wells located at TNT Area A. Explosives residues were detected in one of the overburden wells, DM-MW10, located downgradient from the Wash House for TNT manufacturing line 3.

Nitrate concentrations were all well below the MCL.

Six VOCs and two SVOCs were detected in the bedrock. The TNT Area A bedrock wells had the third and fourth highest concentrations of BTEX compounds. Benzene exceeded the MCL in both bedrock wells.

Eight metals (antimony, arsenic, chromium, copper, lead, manganese, nickel, and zinc) were present in the area groundwater. All manganese concentrations exceeded the SMCL.

7.2.4 TNT Area B

Groundwater samples were collected from two overburden wells located at TNT Area B. Explosives residues were detected in one of the two overburden wells, MK-MW17, located on the downgradient side of the area.

Nitrate concentrations were all well below the MCL.

Ten metals (antimony, arsenic, beryllium, cadmium, copper, lead, manganese, nickel, thallium, and zinc) were present in the area groundwater. Nickel, manganese, and thallium were detected in concentrations which exceed regulatory action levels. Manganese concentrations are two to three orders of magnitude over the SMCL.

7.2.5 TNT Area C

Groundwater samples were collected from two overburden wells and one bedrock well located at TNT Area C. One explosives residues compound was detected in the bedrock well, BED-MW13 located downgradient of the former TNT Area C.

Nitrate concentrations were all well below the MCL.

Four VOCs and two SVOCs, generally hydrocarbons and related compounds, were detected in the bedrock well. The benzene concentration exceeded the MCL.

Five metals (antimony, lead, manganese, nickel, and zinc) were present in the area groundwater. Antimony in the filtered samples from wells DM-MW5 and BED-MW13 exceeded the regulatory action level. All manganese concentrations exceeded the SMCL.

7.2.6 Other Areas

Low levels of explosives residues were detected in two additional wells installed in the bedrock, one at the central toluene storage tanks and the background well located in the southern portion of the site.

The highest levels of VOCs and SVOCs were detected in bedrock well BED-MW16 installed near the central set of toluene storage tanks. The benzene concentration was 2,000 μg/L, 400 times the MCL. An oily substance was present in this well. Analysis of the substance for Diesel Range Hydrocarbons did not provide any data useful in identifying it.

Low levels of hydrocarbons were also present in the background bedrock well. However, no SVOCs were detected in the sample collected from the background well.

7.3 LIMITATIONS

The observations, findings, and conclusions included in this report are professional opinions based upon performance of a Sitewide Groundwater Investigation for the former PBOW in Sandusky, Ohio. They are intended exclusively for the use of the Nashville and Huntington Districts of the USACE for the purposes outline herein. Any use or reuse of this document or the comments, findings, conclusions, and recommendations represented herein is at the sole risk of said user.

The observations and conclusions presented herein apply only to the investigation of the groundwater at the former PBOW; the site conditions existing at the time of the investigation; and the review of historical information that could reasonably and accurately be obtained during the course of the investigation and as specified in the Scope of Work for the Sitewide Groundwater Investigation. They cannot apply to subsequent changes in site conditions of which Dames & Moore is not aware and to conditions which were inaccurately portrayed to Dames & Moore by other parties.

-oOo-

Charles T. Allen, P.E.
Principal

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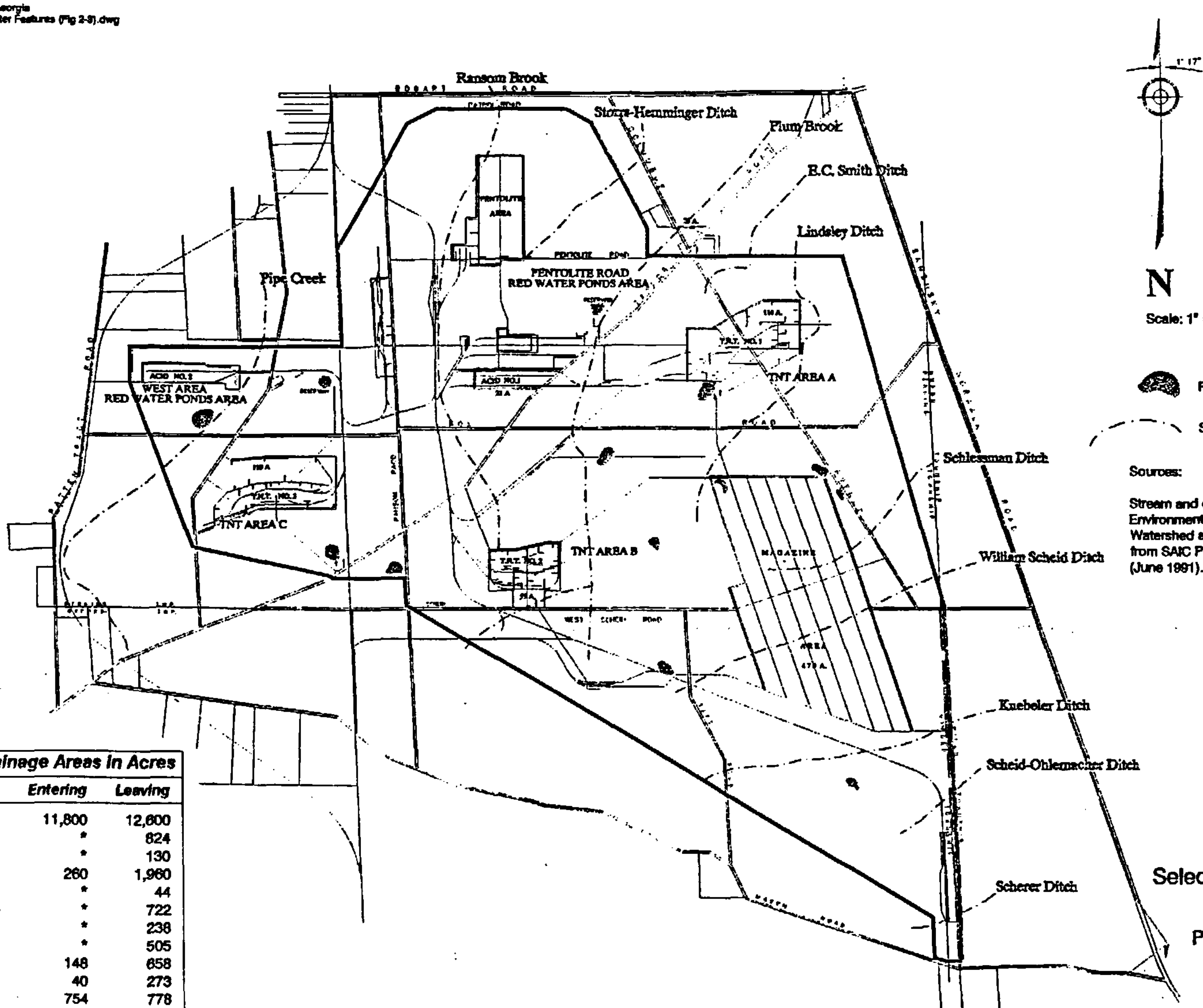

Pond or Reservoir

Surface Water Drainage Feature

Sources:

Stream and ditch locations and names from NASA Environmental Resources Document (August 1990). Watershed areas and locations of ponds and reservoirs from SAIC Plum Brook Station Preliminary Assessment (June 1991).

Stream	*Drainage Areas in Acres*	
	Entering	*Leaving*
Pipe Creek	11,800	12,600
Ransom Brook	*	824
Storrs-Hemminger Ditch	*	130
Plum Brook	260	1,960
E.C. Smith Ditch	*	44
Lindsley Ditch	*	722
Schlessman Ditch	*	238
William Scheid Ditch	*	505
Kuebeler Ditch	148	658
Scheid-Ohlemacher Ditch	40	273
Scherer Ditch	754	778

* Stream originates within station boundaries

Figure 2-3
Selected Surface Water Features
at Plum Brook Station

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE

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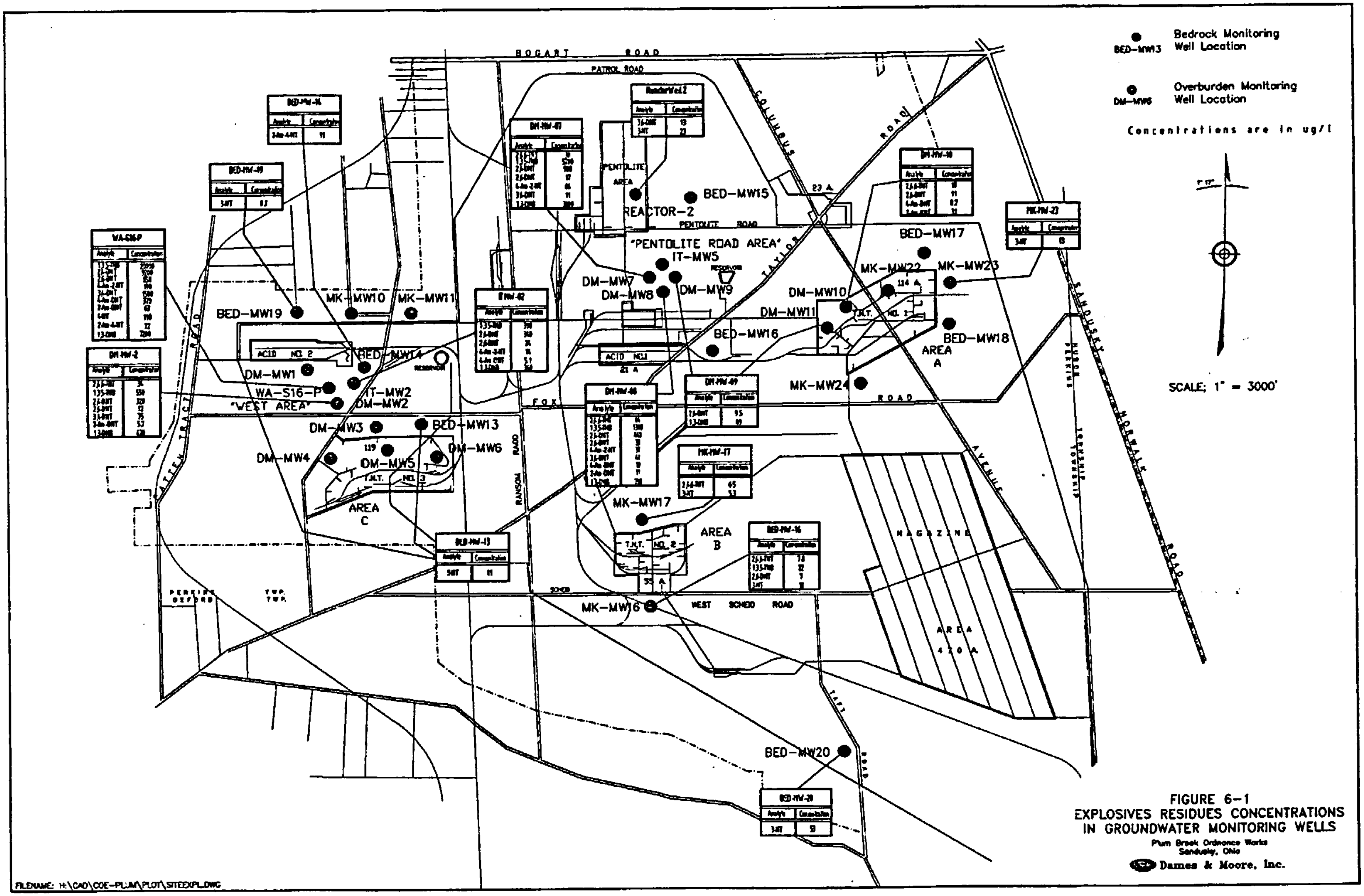

FIGURE 6-1
EXPLOSIVES RESIDUES CONCENTRATIONS
IN GROUNDWATER MONITORING WELLS
Plum Brook Ordnance Works
Sandusky, Ohio
Dames & Moore, Inc.

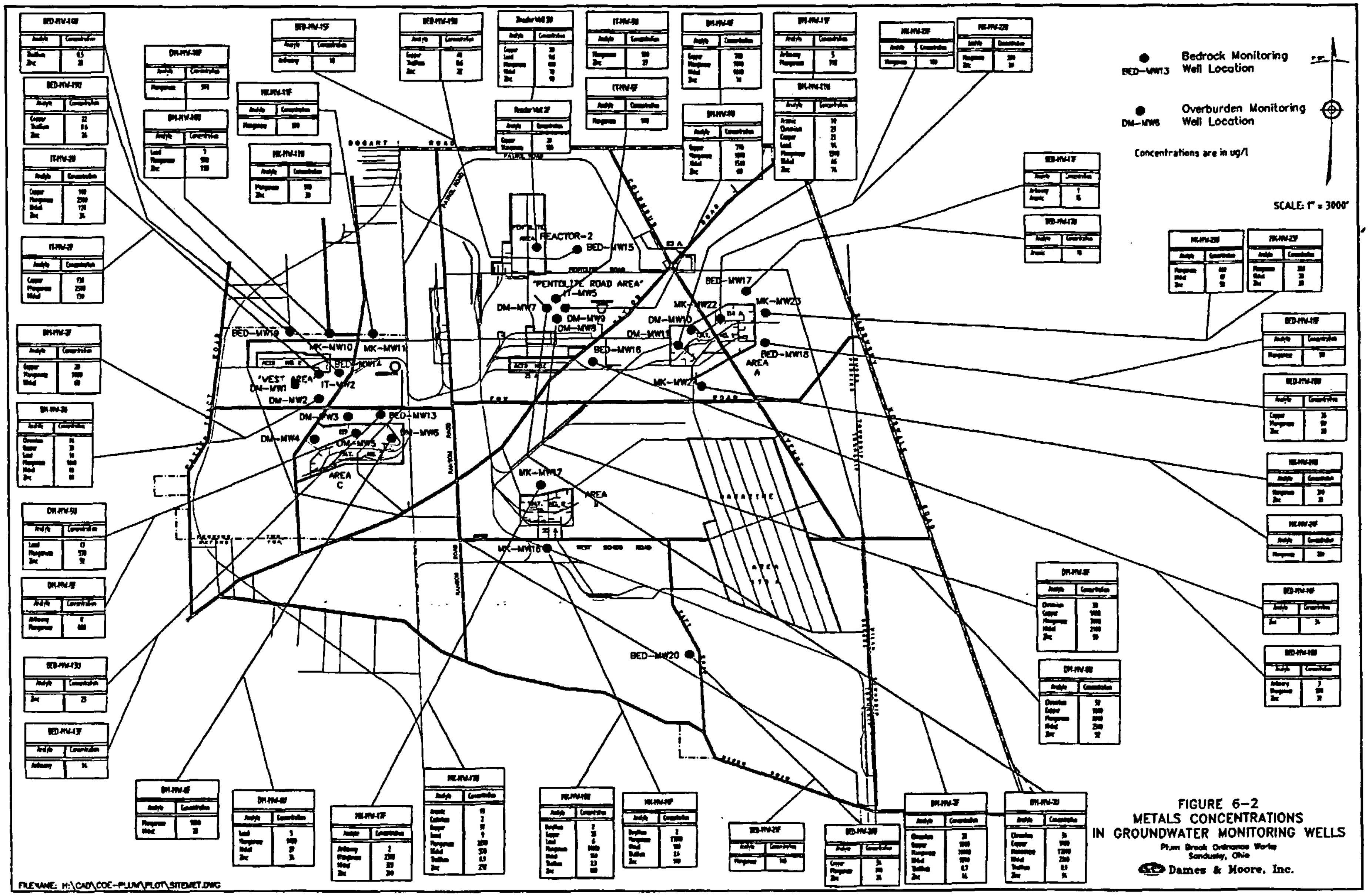

FIGURE 6-2
METALS CONCENTRATIONS
IN GROUNDWATER MONITORING WELLS
Plum Brook Ordnance Works
Sandusky, Ohio
Dames & Moore, Inc.

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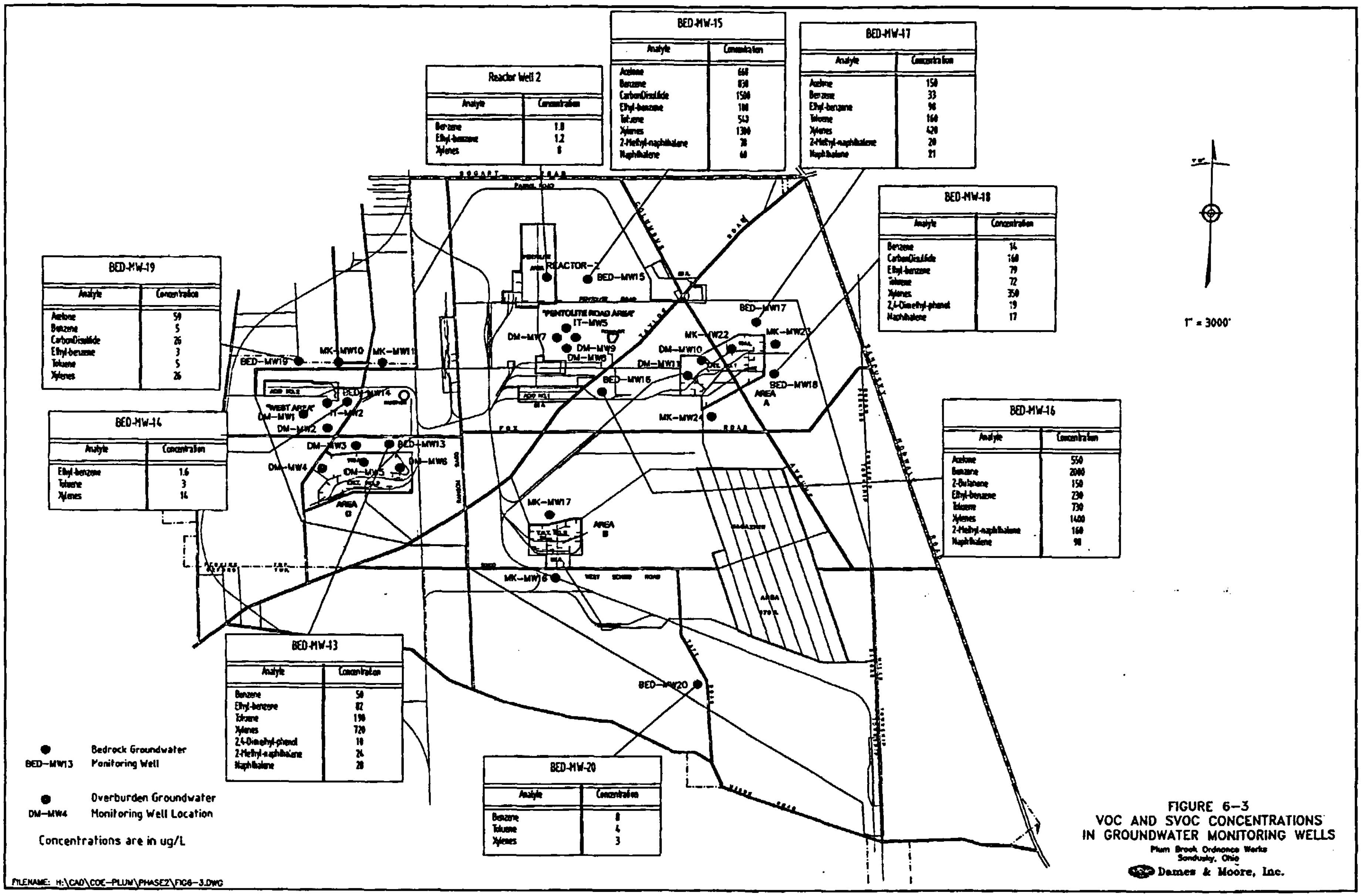


Reactor Well 2

Analyte	Concentration
Benzene	1.0
Ethyl-benzene	1.2
Xylenes	8

BED-MW-15

Analyte	Concentration
Acetone	660
Benzene	830
CarbonDisulfide	1500
Ethyl-benzene	100
Toluene	540
Xylenes	1300
2-Methyl-naphthalene	30
Naphthalene	60

BED-MW-17

Analyte	Concentration
Acetone	150
Benzene	33
Ethyl-benzene	90
Toluene	160
Xylenes	420
2-Methyl-naphthalene	20
Naphthalene	21

BED-MW-18

Analyte	Concentration
Benzene	14
CarbonDisulfide	160
Ethyl-benzene	79
Toluene	72
Xylenes	350
2,4-Dimethyl-phenol	19
Naphthalene	17

BED-MW-19

Analyte	Concentration
Acetone	59
Benzene	5
CarbonDisulfide	26
Ethyl-benzene	3
Toluene	5
Xylenes	26

BED-MW-14

Analyte	Concentration
Ethyl-benzene	1.6
Toluene	3
Xylenes	14

BED-MW-16

Analyte	Concentration
Acetone	550
Benzene	2000
2-Butanone	150
Ethyl-benzene	230
Toluene	730
Xylenes	1400
2-Methyl-naphthalene	160
Naphthalene	90

BED-MW-13

Analyte	Concentration
Benzene	50
Ethyl-benzene	82
Toluene	190
Xylenes	720
2,4-Dimethyl-phenol	10
2-Methyl-naphthalene	24
Naphthalene	20

BED-MW-20

Analyte	Concentration
Benzene	8
Toluene	4
Xylenes	3

FIGURE 6-3
VOC AND SVOC CONCENTRATIONS IN GROUNDWATER MONITORING WELLS
Plum Brook Ordnance Works
Sandusky, Ohio

Dames & Moore, Inc.

Volume II - Appendices

SITEWIDE GROUNDWATER INVESTIGATION FINAL REPORT

Plum Brook Ordnance Works
Plum Brook Station / NASA
Sandusky, Ohio

for

U.S. Army Corps of Engineers
Nashville District / Huntington District

April 1997

DAMES & MOORE, INC.

US Army Corps of Engineers

APPENDIX B

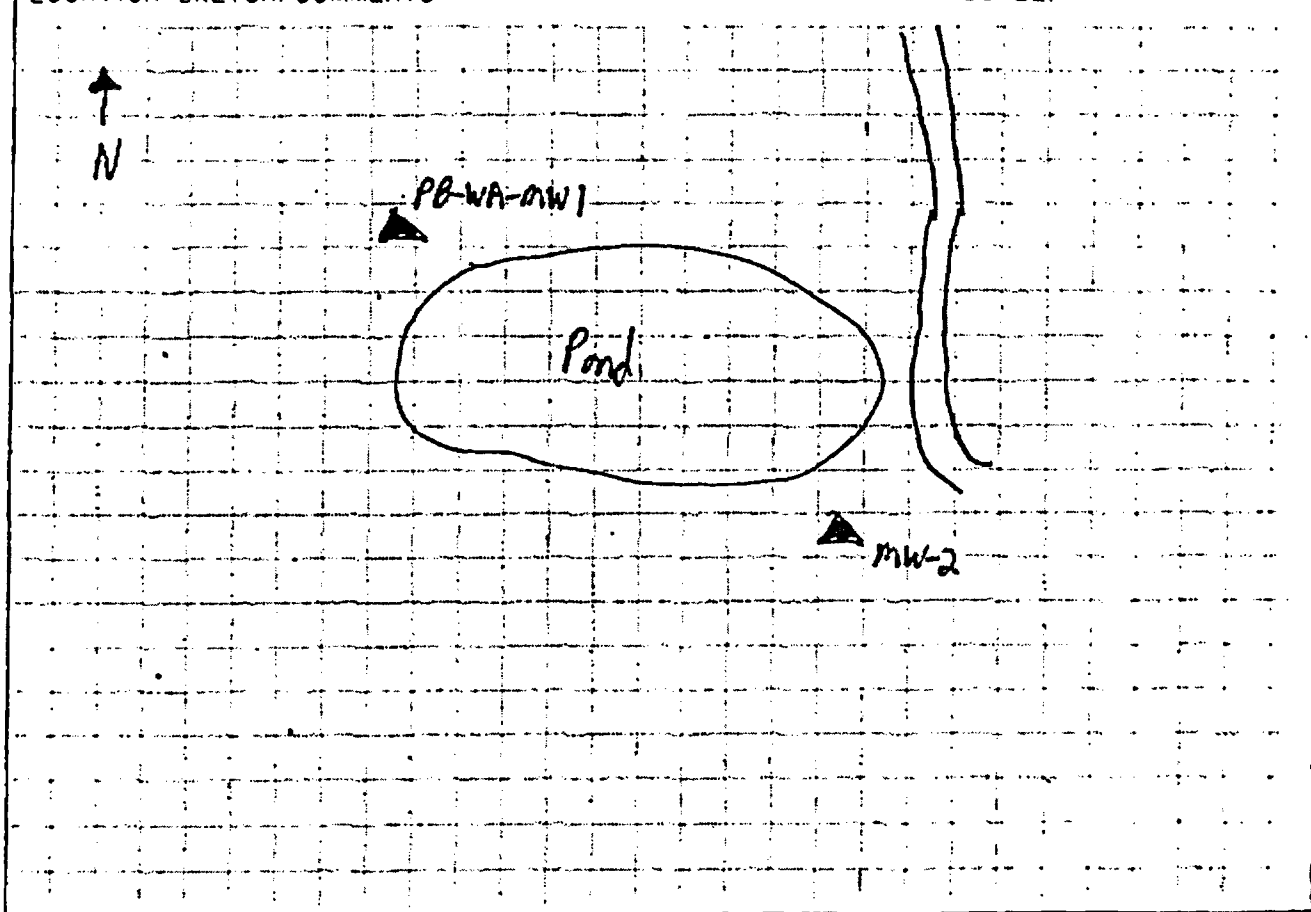
MONITORING WELL BORING LOGS

HTRW DRILLING LOG

HOLE NUMBER: PB-WA-MW1						
1. COMPANY NAME: Dames & Moore			2. DRILLING SUBCONTRACTOR: Belasco Drilling Services Inc.			SHEET 1 OF 4 SHEETS
3. PROJECT: Plum Brook Ordnance Works			4. LOCATION: Sandusky, Ohio			
5. NAME OF DRILLER: Darryl			6. MANUFACTURER'S DESIGNATION OF DRILL: D-50 Diesel			
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ∅ 5 ft long hollow stem auger; 24" split spoon; 140 lb drop hammer			8. HOLE LOCATION: West Area Pond			
			9. SURFACE ELEVATION:			
			10. DATE STARTED: 10-17-94		11. DATE COMPLETED: 10-18-94	
12. OVERBURDEN THICKNESS: 22.3 ft			15. DEPTH GROUNDWATER ENCOUNTERED: approx 17 feet			
13. DEPTH DRILLED INTO ROCK: 0			16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED:			
14. TOTAL DEPTH OF HOLE: 22.3 ft			17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A			
18. GEOTECHNICAL SAMPLES: None	DISTURBED: ---	UNDISTURBED:	19. TOTAL NUMBER OF CORE BOXES: N/A			
20. SAMPLES FOR CHEMICAL ANALYSIS: -	VOC: -	METALS:	OTHER (SPECIFY): Explosives	OTHER (SPECIFY):	OTHER (SPECIFY):	21. TOTAL CORE RECOVERY:
22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL: X	OTHER (SPECIFY):	23. SIGNATURE OF INSPECTOR: Doc Deatkerg		

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER / SHEET
Plum Brook Ordnance Works	Joe Deatherage	PB-WA-MW; Sheet 2 of 4 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–1	Dark brown well graded Sandy organic material; dry	Hnu=1 (Background)			Blow Count = 5, 11, 9, 7; Ran: 2.0; Rec: 2.0; Lost: 0
	1	Brownish yellow well graded Sand; dry				
	2	Yellowish red very Sandy clay; well graded; ~~dry~~ moist	Hnu=1 (Background)			Blow Count: 5, 9, 11, 15; Ran: 2.0; Rec: 1.4; Lost: 0.6
	3					
	4	Brownish yellow weathered Shale; moist, well graded	Hnu=1 (Background)			Blow Count: 6, 8, 7, 11; Ran: 2.0; Rec: 1.3; Lost: 0.7
	5					
	6	Brown to brownish Yellow Sandy weathered Shale; moist	Hnu=1 (Background)			Blow Count: 3, 9, 13, 14; Ran: 2.0; Rec: 1.9; Lost: 0.1
	7					
	8	Brownish yellow sandy weathered Shale; moist	Hnu=1 (Background)			Blow Count: 2, 3, 3, 4; Ran: 2.0; Rec: 2.0; Lost: 0
	9	Gray sandy clay; Soft; moist; wet traces in Spoon				
	10					

PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG

PB-WB-MW1

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Deathenage (signature) | SHEET 3 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10–11	Gray soft clay w/ weathered shale; moist w/ traces of wetness in spoon	Hnu=1 (Background)			Blow Count: 2,3,3,3 Run: 2.0 Rec: 1.8 Lost: 0.2
	12–13	Gray, soft, sandy clay w/ weathered shale; moist w/ traces of wetness.	Hnu=1 (Background)			Blow Count = 2,2,3,2 Run: 2.0 Rec: 2.0 Lost: 0
	14–15	Gray, soft sandy clay w/ weathered shale; moist with traces of wetness	Hnu=1 (Background)			Blow Count: 3,3,3,3 Run: 2.0 Rec: 1.9 Lost: 0.1
	16–17	Gray, very soft clay; moist to wet; high plasticity	Hnu=1 (Background)			Blow Count = 1,1,1,1 Run: 2.0 Rec: 2.0 Lost: 0
	18–20	Gray very soft clay: wet; high plasticity	Hnu=1 (Background)			Blow Count = 1,1,3,2 Run: 2.0 Rec: 2.0 Lost: 0

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER / SHEET
Plum Brook Ordnance Works	Joe Deatherage	PB-WA-MW; SHEET 4 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20		Hnu=1 (Background)			Blow Count: 0, 1, 6, 12 Run: 2.0 Rec: 1.5 Lost: 0.5
		Gray soft clay; moist to wet; high plasticity				
	21					
		Gray soft clay w/ weathered shale mix; moist to wet				
	22	Gray soft clay with limestone at base; moist to wet.	Hnu=1 (Background)			Blow Count = 7, 50 over 3" Run: 0.7 Rec: 0.4 Lost: 0.3
	23					*Refusal at 22.3'*
	24					

PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER: PB-WA-MW2 & PB-WA-S10

SHEET 1 OF 2 SHEETS

1. COMPANY NAME: Dames & Moore
2. DRILLING SUBCONTRACTOR: Belasco Drilling Services, Inc.
3. PROJECT: Plum Brook Ordnance Works
4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Darry
6. MANUFACTURER'S DESIGNATION OF DRILL: CME 45 ATV
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 2" split spoon; 140 lb drop hammer; stainless steel bowls & spoons
8. HOLE LOCATION: Red Water Pond area
9. SURFACE ELEVATION:
10. DATE STARTED: 10-27-94
11. DATE COMPLETED: 10-27-94
12. OVERBURDEN THICKNESS: 12.0 ft
15. DEPTH GROUNDWATER ENCOUNTERED: approx 1.5 ft
13. DEPTH DRILLED INTO ROCK: 0
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED:
14. TOTAL DEPTH OF HOLE: 12.0 ft
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A

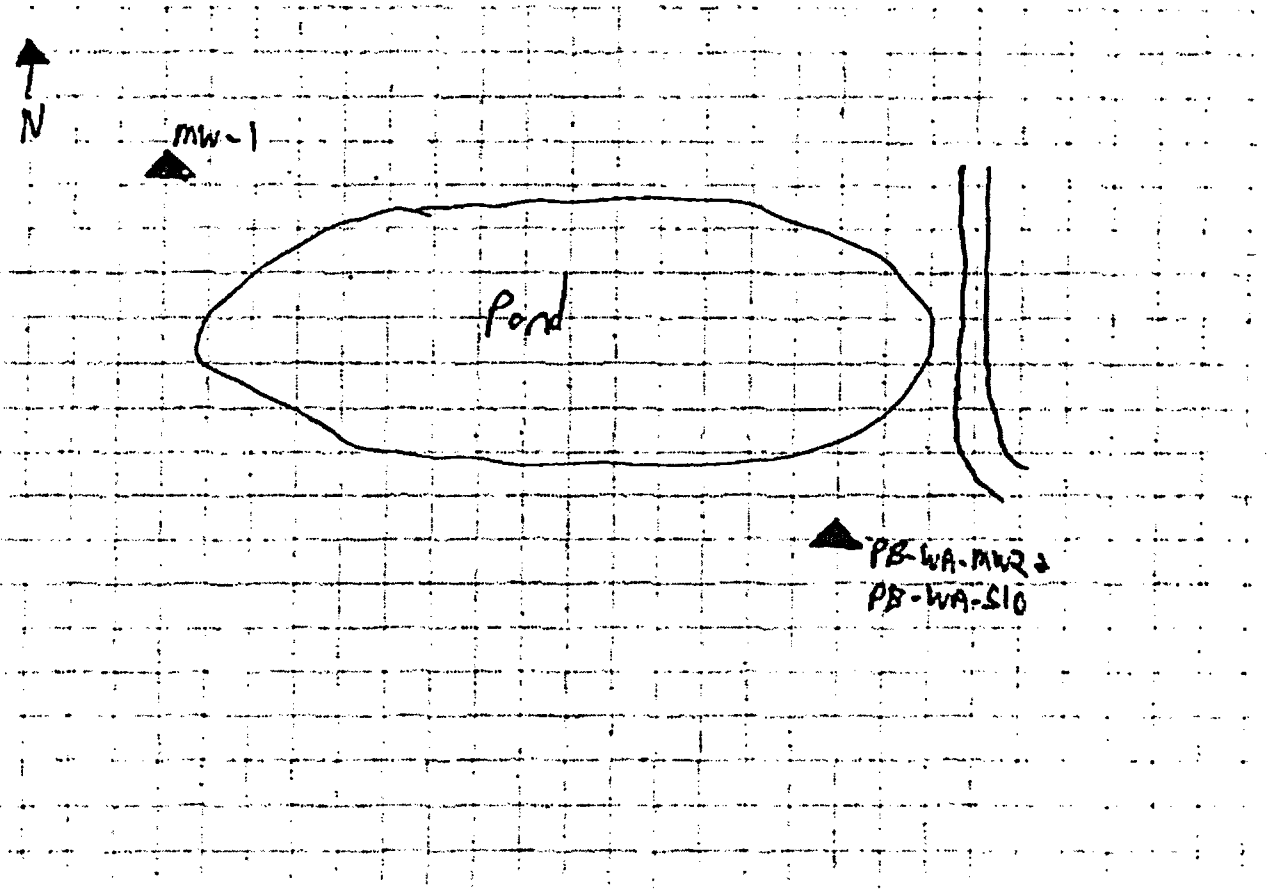
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deatherage

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER: PB-WA-MW 8 / PB-WA-S10

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Deatheras

SHEET 2 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Dark Brown Sandy organic material; Brown well graded sand w/ some clay mix; wet at 1.5ft	Hnu=2 (Background =0)			Blow Count =2,4,2,2 Run: 2.0 Rec: 1.6 Lost: 0.4
	1.0					
	2.0	Brown sandy, well graded, some clay mix and brownish yellow Flakes; wet	Hnu=2 (Background =0)			Blow Counts 1,1,1,1 Run: 2.0 Rec: 2.0 Lost: 0
	3.0				PB-WA-S10-3.0/5.0	
	4.0	Brown to gray sandy clay; wet. Gray clay; very soft; moderate plasticity; very moist	Hnu=2.0 (Background =0)			Blow Count=1,1,1,1 Run: 2.0 Rec: 2.0 Lost: 0
	5.0					
	6.0	Gray clay with brownish yellow mottlins; very soft; high plasticity; very moist	Hnu=5.0 (Background =0)		PB-WA-S10-8.0/10.0	Blow Count: 0,1,1,1 Run: 2.0 Rec: 2.0 Lost: 0
	7.0					
	8.0	Gray Clay; very soft; high plasticity; moist to wet. Brownish yellow mottlins	Hnu=5.0 (Background =0)			Blow Count: 1,2,6,7 Run: Rec: Lost:
	9.0					
	10.0					

PROJECT: Plum Brook Ordnance Works

HOLE NO.

HTRW DRILLING LOG

HOLE NUMBER: PB-WA-MW2 / PB-WA-S10

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Dentlerge | SHEET 3 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Gray Clay; very soft; high plasticity; wet; brownish yellow mottling	Hnu = 1 (Background)			Blow Counts 2,19,10,50 over 5"
		Weathered Shale; gray				Run: 1.9' Rec: 1.0' Lost: 0.9'
	11					
	12					Boring terminated at 12.0 ft due to auger refusal
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					

PROJECT: Plum Brook Ordnance Works | HOLE NO.

PB-PR-54

HTRW DRILLING LOG

HOLE NUMBER: PB-PR-MW7

1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: ~~Belasco~~ Belasco Drilling Services
SHEET 1 OF 4 SHEETS	
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: CME45 ATV
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 24" split spoon; 140 lb drop hammer; Stainless steel bowls & spoons	8. HOLE LOCATION: Pentalite Rd
	9. SURFACE ELEVATION: N/A
	10. DATE STARTED: 10-30-94
	11. DATE COMPLETED: 10-31-94
12. OVERBURDEN THICKNESS: 22.0ft	15. DEPTH GROUNDWATER ENCOUNTERED: 9/1/10x 10.5ft
13. DEPTH DRILLED INTO ROCK: 0.3ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED
14. TOTAL DEPTH OF HOLE: 22.3ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A

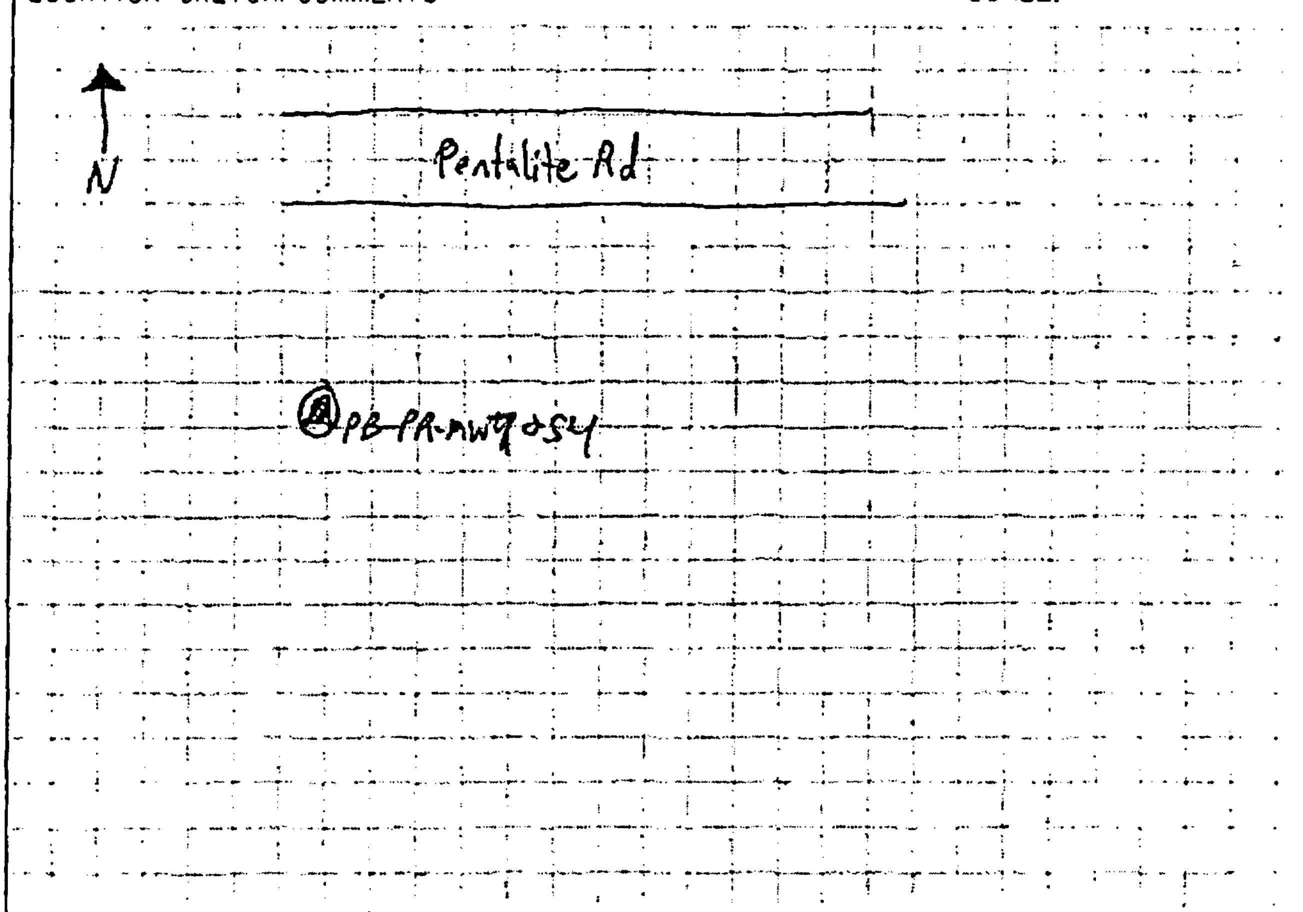
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Dentlurs

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NO.: PB-PR-MW9

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Deatherage / Ted Berty

SHEET 2 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–1		Hnu=18 (Backgrand =0)		PB-PR-S4-0.0/3.0	Blow Count: 1,2,3,4 Ran: 2.0 Rec: 1.2 Lost: 0.8
	1	Dark Brown Sandy organic material; dry				
	1.7	Brown to dark Brown Sandy organic material; dry				
	2	Brownish yellow well graded sand w/ silts, moist	Hnu=2 (Backgrand =0)			Blow Count: 3,3,3,4 Ran: 2.0 Rec: 2.0 Lost: 0
	3.2	Brown sandy clay w/ brownish yellow mottling; moist; moderate plasticity			PB-PR-S4-3.0/5.0	
	4	Brown Clay w/ brownish yellow sandy mottling; soft; moderate plasticity; moist to wet	Hnu=2 (Backgrand =0)			Blow Count: 1,1,1,4 Ran: 2.0 Rec: 2.0 Lost: 0
	6	Brown Sandy clay w/ brownish yellow mottling; moist to wet	Hnu=7 (Backgrand =0)		PB-PR-S4-5.0/10.0	Blow Count: 1,3,5,9 Ran: 2.0 Rec: 2.0 Lost: 0
	7.5	Gray clay w/ some brownish yellow mottling				
	8	Gray clay w/ some brownish yellow mottling; moist to wet; very soft; high plasticity	Hnu=3 (Backgrand =0)			Blow Count: 3,2,4,4 Ran: 2.0 Rec: 2.0 Lost: 0
	10					

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

PB-PR-MW-7 & B4

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works	Joe Deatherage / Ted Berry	3 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Gray clay; soft; high plasticity; wet with some red water noted; wet	Hnu= 0			Blow Count: 0, 2, 2, 5 Ran: 2.0 Rec: 1.6 Lost: 0.4
	11					
	12	Gray soft clay, high plasticity; wet w/ ~~water brown water~~ yellowish red water	Hnu=0			Blow Count: 2, 3, 4, 5 Ran: 2.0 Rec: 2.0 Lost: 0
	13					
	14	Gray very soft clay; high plasticity; wet w/ yellowish red water	Hnu=0			Blow Count: 2, 2, 3, 4 Ran: 2.0 Rec: 2.0 Lost: 0
	15					
	16	Gray clay, a bit more hard and tight; moderate plasticity; wet w/ brownish yellow water	Hnu=0			Blow Count: 4, 7, 10, 13 Ran: 2.0 Rec: 1.6 Lost: 0.4
	17					
	18	Gray clay; moderately hard; moderate plasticity; wet w/ brownish yellow water	Hnu=0			Blow Count: 3, 6, 14, 18 Ran: 2.0 Rec: 1.3 Lost: 0.7
	19					
	20					

HTRW DRILLING LOG

HOLE NUMBER: PB-PR-MW7-2SY

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works	Joe Detherage / Ted Bern	4 of 4 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20	Gray sandy clay; hard; low plasticity; moist soil, Wet spoon w/ brownish yellow water. Some shale fragments.	Hnu=0			Blow Count: 2, 12, 17, 20 Run: Rec: Lost:
	22	Weathered Shale; dry w/ wet spoon	Hnu=0			Blow Count: 19, 47, refusal Run: 1.0 Rec: 0.7 Lost: 0.3
		refusal at 22.3 ft				

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

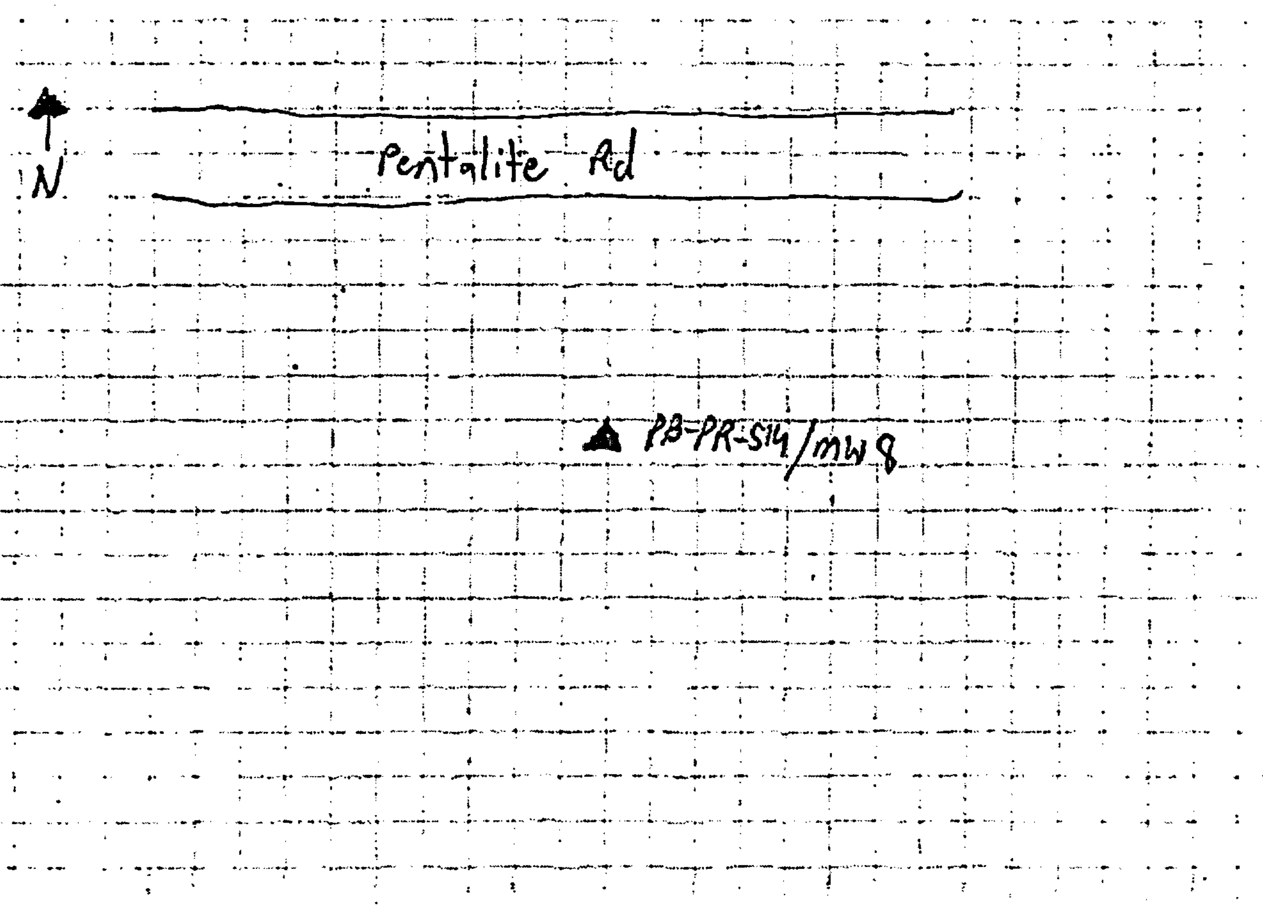
HOLE NUMBER	PB-PR-S14/MW8
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services, Inc.
SHEET 4 OF 4 SHEETS	
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	
6. MANUFACTURER'S DESIGNATION OF DRILL	D120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	24" split spoons; 140 lb drop hammer; stainless steel bowls & spoons
8. HOLE LOCATION	Pentalite Rd
9. SURFACE ELEVATION	
10. DATE STARTED	11-7-94
11. DATE COMPLETED	11-7-94
12. OVERBURDEN THICKNESS	27.5
15. DEPTH GROUNDWATER ENCOUNTERED	approx 7 Feet
13. DEPTH DRILLED INTO ROCK	0
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	
14. TOTAL DEPTH OF HOLE	27.5
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	N/A

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deallere

LOCATION SKETCH/COMMENTS SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Deatherage | HOLE NO.: PB-PR-S14/MW8 | SHEET 2 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–2	Dark brown sandy organic material; Brown well graded sand w/ brownish yellow flackes; slightly moist	Hnu=2 (Backgrnd)		PB-PR-S14-0.0/3.0	Blow Count: 2,2,8,10 Run: 2.0 Rec: 1.4 Lost: 0.6
	2–4	Brown well graded sand w/ some brownish yellow mottling; slightly moist	Hnu=0		PB-PR-S14-3.0/5.0	Blow Count: 7,10,7,8 Run: 2.0 Rec: 1.8 Lost: 0.2
	4–6	Dark brown sandy clay; stained; Brown sandy clay w/ some brownish yellow mottling; moist	Hnu=0			Blow Count: 2,3,5,5 Run: 2.0 Rec: 1.6 Lost: 0.4
	6–8	Brown clay w/ some sand; brownish yellow mottling; soft; moderate plasticity; wet; Dark Brown Stained layer	Hnu=3 (Backgrnd =1)		PB-PR-S14-5.0/10.0	Blow Count: 2,1,2,2 Run: 2.0 Rec: 1.6 Lost: 0.4
	8–10	Brown clay w/ sand; yellowish brown and reddish brown mottling; soft; moderate plasticity; wet	Hnu=4 (Backgrnd =0)			Blow Count: 1,2,3,4 Run: 2.0 Rec: 2.0 Lost: 0

PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works	Joe Dentherage	PB-PR-S14/MW8	3 of 4 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10–12	Brown to gray clay w/ some sand; brownish yellow & reddish brown mottling; wet	Hnu=0			Blow Count: 2,2,2,4 Run: 2.0 Rec: 2.0 Lost: 0
	12–14	Gray clay w/ reddish brown sand layers; soft; high plasticity; wet	Hnu=0			Blow Count: 1,2,4,4 Run: 2.0 Rec: 2.0 Lost: 0
	14–16	Gray clay w/ reddish brown sand layers; wet	Hnu=0			Blow Count: 1,2,3,3 Run: 2.0 Rec: 2.0 Lost: 0
	16–18	Gray clay w/ traces of shale; no mottling; moist to wet	Hnu=0			Blow Count: 2,2,7,8 Run: 2.0 Rec: 2.0 Lost: 0
	18–20	Gray soft weathered shale w/ traces of shale; moist	Hnu=0			Blow Count: 4,9,11,12 Run: 2.0 Rec: 2.0 Lost: 0

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

Hole No.: PB-PR-S14/MW8

Project: Plum Brook Ordnance Works | Inspector: Joe Deatherage | Sheet 4 of 4 sheets

Elev. (a)	Depth (b)	Description of Materials (c)	Field Screening Results (d)	Geotech Sample or Core Box No. (e)	Analytical Sample No. (f)	Remarks (g)
	20	Gray weathered shale; harder; moist	Hnu=0			Slow Count: 5, 12, 23, 38 Run: 2.0 Rec: 1.8 Lost: 0.2
	21					
	22	Gray weathered shale w/ traces of sand and shale; moist	Hnu=0			Blow Count: 12, 17, 24, 27 Run: 2.0 Rec: 2.0 Lost: 0
	23					
	24	Gray weathered shale moist	HNu 0			Blow Count: 5, 16, 21, 32 Run: 2.0 Rec: 2.0 Lost: 0
	25					
	26	Gray weathered shale large shale fragments present.	HNu 0			Blow Count: 11, 28, 50/5 Run: 1.4' Rec: 1.4' Lost: 0
	27					
	28					Well terminated at 27.5 ft

Project: Plum Brook Ordnance Works | Hole No.:

PB-PR-S19

HTRW DRILLING LOG

1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services, Inc.	HOLE NUMBER: PB-PR-MW19; SHEET 1 OF 3 SHEETS
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio	
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: CME 45 ATV	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 24" split spoon - 140 lb drop hammer - Stainless Steel bowls & spoons.	8. HOLE LOCATION: Pentalite Rd	
	9. SURFACE ELEVATION: N/A	
	10. DATE STARTED: 10-30-94	11. DATE COMPLETED: 11-1-94
12. OVERBURDEN THICKNESS: 19.0	15. DEPTH GROUNDWATER ENCOUNTERED: 9ft/4x 9ft	
13. DEPTH DRILLED INTO ROCK: N/A (0)	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	
14. TOTAL DEPTH OF HOLE: 19.0	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A	

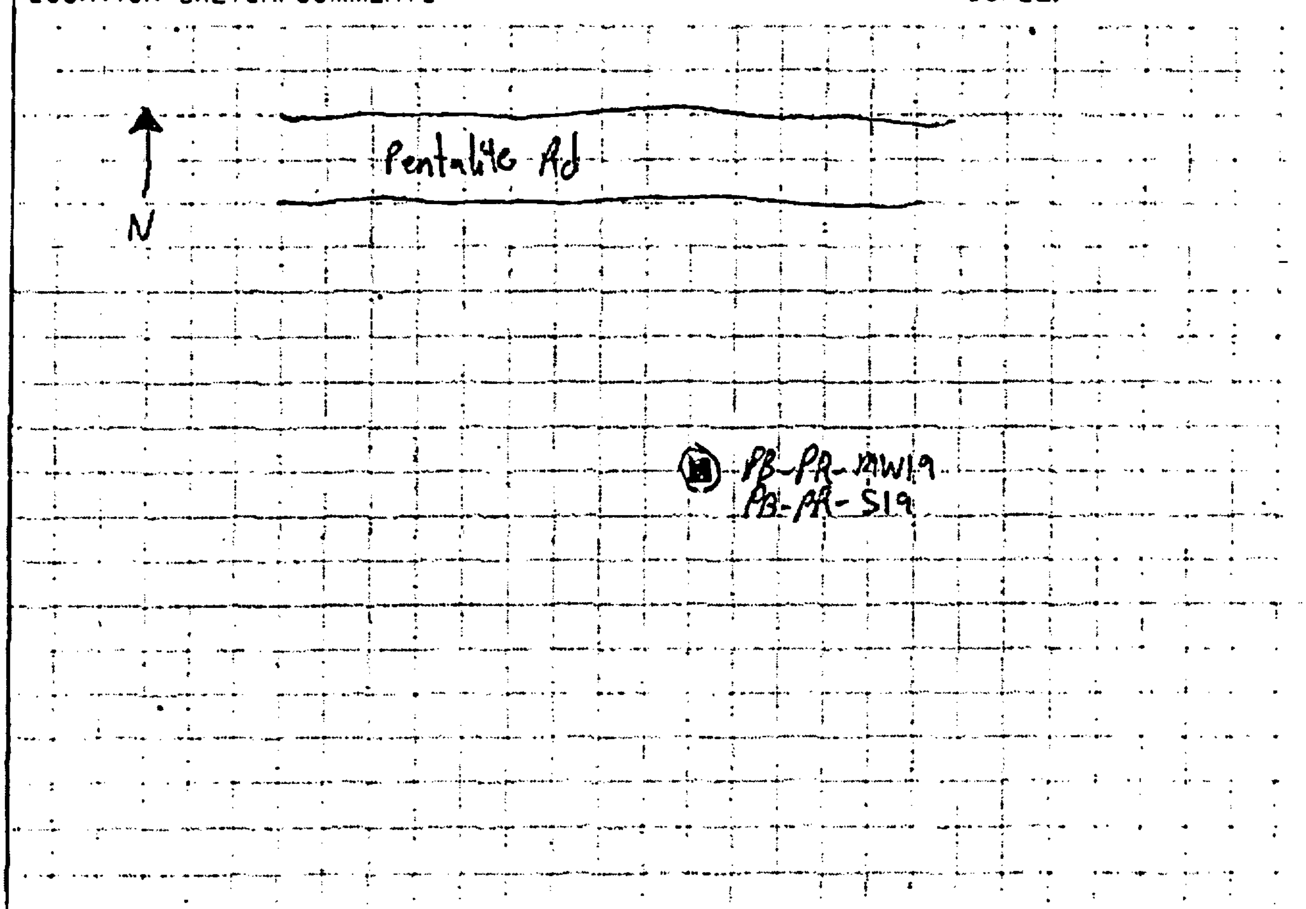
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
				Joe Diatkus

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

PB-PR-MW-9 (hole no.; a second, unclear annotation above it reads "PB-PA-319")

SHEET 2 OF 3 SHEETS

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Deatherage / Ted Berry

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–2	Dark Brown Sandy organic material; Brown to brownish yellow well graded sandy silty clay; slightly moist	Hnu=3 (Background =0)		PB-PR-S19-0.0/3.0	Blow Count: 1,2,5,5 Ran: 0.0 Rec: 1.8 Lost: 0.2
	2–4	Brown sandy clay with dark brown mottling; Brown sandy clay - no mottling	Hnu=10 (Background =0)		PB-PR-S19-3.0/5.0	Blow Count: 5,5,5,5 Ran: 2.0 Rec: 1.1 Last: 0.9
	4–6	Brown sandy clay w/ brownish yellow mottling and some dark brown streaks.	Hnu=2 (Background =0)			Blow Count: 2,3,3,3 Ran: 2.0 Rec: 2.0 Lost: 0
	6–8	Brown sandy clay w/ brownish yellow mottling and some pink streaks	Hnu=8 (Background =0)		PB-PR-S19-5.0/10.0	Blow Count: 2,3,4,5 Ran: Rec: Lost:
	8–10	Brown Sandy Clay w/ brownish yellow layers; moist to wet; Gray clay w/ brownish yellow sandy layers and reddish brown sandy layers; wet	Hnu=4 (Background =0)			Blow Count: 3,3,3,4 Ran: 2.0 Rec: 2.0 Last: 0

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PROJECT: Plum Brook Ordnance Works

HOLE NO.

HTRW DRILLING LOG

PB-PR-mw9

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works	Joe Denthorne	3 of 3 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10–12	Gray very soft clay; high plasticity; some sand traces; wet	Hnu=0			Blow Count: 0,2,2,3 Run: 2.0 Rec: 2.0 Lost: 0
	12–14	Gray very soft clay; high plasticity; no sand; wet	Hnu=0			Blow Count: 2,2,3,4 Run: 2.0 Rec: 1.7 Lost: 0.3
	14–16	Gray very soft clay: high plasticity; wetness on spoon	Hnu=0			Blow Count: 3,2,2,3 Run: 2.0 Rec: 1.7 Lost: 0.3
	16–18	Gray soft clay; high plasticity Gray clay, harder, with traces of shale; moist soil, wet spoon	Hnu=0			Blow Count: 6,10,15,15 Run: 2.0 Rec: 2.0 Lost: 0
	18–19	Gray clay; hard, with traces of shale; moist soil; a wet spoon	Hnu=0			Blow Count. 4,14,25,26 Run: 2.0 Rec: 1.0 Lost: 1.0
	19–20					Auger refusal at 19.0 ft.

PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

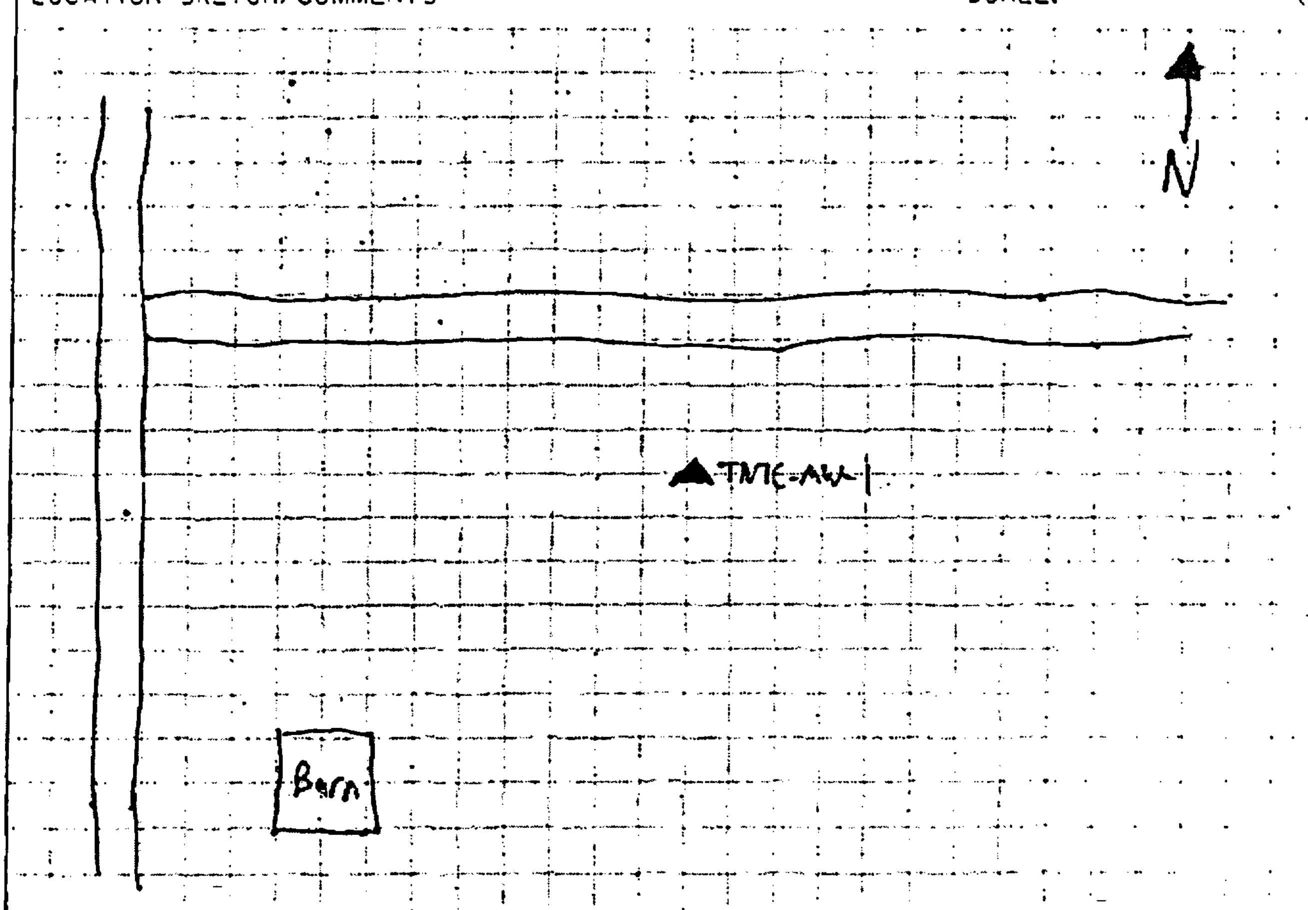
HOLE NUMBER: TNTC-MW03	SHEET 1 OF 3 SHEETS	
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services, Inc.	
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio	
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: D-50 diesel	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4 inch Ø hollow stem auger. 24" split spoon sampler. The augers are 5 ft in length. 140 lb drop hammer dropped 30 inches	8. HOLE LOCATION: TNT Area C	
	9. SURFACE ELEVATION:	
	10. DATE STARTED: 10-12-94	11. DATE COMPLETED: 10-12-94
12. OVERBURDEN THICKNESS: 14.5 ft	15. DEPTH GROUNDWATER ENCOUNTERED: Dry	
13. DEPTH DRILLED INTO ROCK: 0	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: Dry	
14. TOTAL DEPTH OF HOLE: 14.5 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): Dry	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
N/A			Explosives			NA

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deatherage

LOCATION SKETCH/COMMENTS SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

TMC-MW03

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works	Joe Deatherage	2 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	~~GEOTECH SAMPLE OR CORE BOX NO.~~ Blow Count (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	1	Dark Brown, well graded sandy material; dry. Shale encountered at 2 ft. ~~9 inches~~ recovery. 0.75 ft	0 (Background) Hnu	6, 10, 11, 11		
	2	8 tenths foot recovery. Light Brown to Brown shale; Dry; weak (crumbles easily).	0 = Background Hnu	10, 16, 18, 19		
	3					
	4	Brown sandy shale; dry; From 4 ft to ~~5~~ 5.8 ft. From 5.8 to 6 ft it is a sandy clay, dry: 1.3 ft recovery.	Hnu = 0 (Background)	16, 15, 23, 29		
	5					
	6	Brown sandy clay w/ traces of shale; dry; slightly more stiff; 1.9 ft recovery	Hnu = 0 (Background)	10, 16, 17, 26		
	7					
	8	Brown to yellowish brown sandy clay; ~~moist~~ wet at 8 ft, dry elsewhere. 1.1 ft recovery. Also traces of shale	Hnu = 0 (Background)	8, 17, 20, 26		
	9					
	10					

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works	Joe Deatherage	TNTC-MW#3	3 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	Blow Count (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Brown to gray sandy clay w/ traces of chert; stiff; wet at 11.3 ft; moist elsewhere. 1.3 ft recovery	Hnu=0 (Background)	11,21 23,28		
	12	Light gray to gray sandy clay w/ shale to 13.0 ft. weathered light gray to gray shale from 13 ft to 13.5 ft. 1.2 ft recovery. moist.	Hnu=0 (Background)	9,15, 50 over 5"		
	14	gray highly weathered shale; dry; 0.9 ft recovery	Hnu=0 (Background)	47,50 over 1"		End of Drilling (refusal at 14.5 ft)
	15					
	16					

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER	TNTC-MW04
SHEET 1 OF 3 SHEETS	
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services Inc.
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: D-50 diesel
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4 inch ID hollowstem auger; 5 ft long; 24" split spoon sampler. 140 lb drop hammer.	8. HOLE LOCATION: TNT Area C
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-12-94 / 11. DATE COMPLETED: 10-13-94
12. OVERBURDEN THICKNESS: 18 ft	15. DEPTH GROUNDWATER ENCOUNTERED: approx 16 ft
13. DEPTH DRILLED INTO ROCK: 0.7 ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: N/A
14. TOTAL DEPTH OF HOLE: 18.7 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A

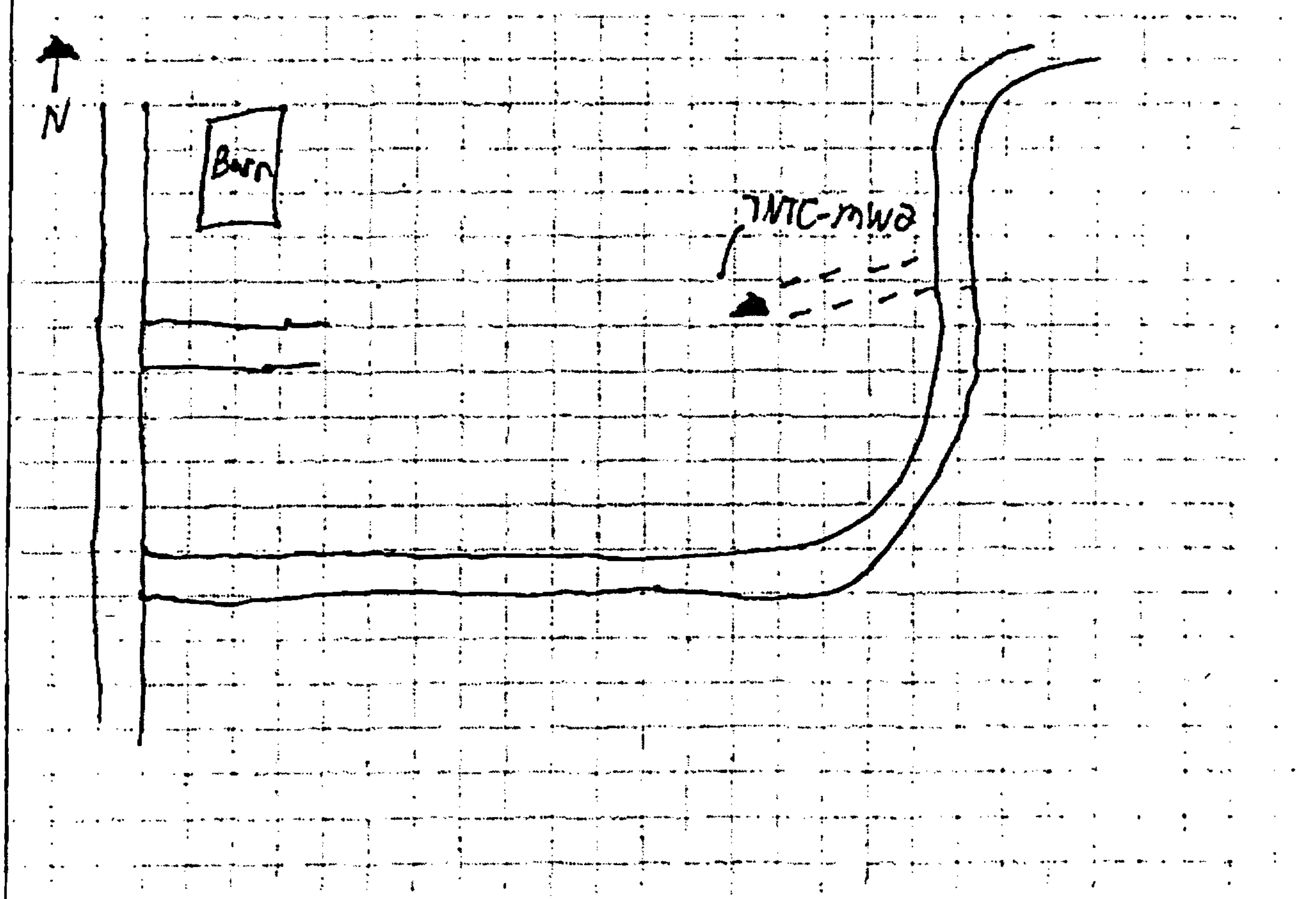
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
N/A	-		Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deathrage

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER: TNTC-MW04

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Deatherage

SHEET 2 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	Blow-count (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–2	Brown to Brownish yellow sandy clay; dry; 1.5 ft recovery;	Hnu=0 (Background)	9,7, 9,10 JD		
	2–4	Brown sandy clay; dry except moist at 4 ft; 0.8 ft recovery;	Hnu=0 (Background)	9,10, 10,11		
	4–6	Brown to gray sandy clay; dry; 1.6 ~~inches~~ feet recovery	Hnu=0 (Background)	12,17, 20,29		
	6–8	Brown sandy clay w/ shale (JD) mixed; dry; a bit more stiff; 1.5 ft recovery	Hnu=0 (Background)	10,19 25,50 over 5"		
	8–10	Olive gray to brownish yellow sandy clay; small traces of shale; dry except moist at 8 ft; 1.5 ft recovery	JD ~~16,25 26,29~~ Hnu=0 (Background)	16,25, 26,29		

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

PNTC-mk-4

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works	Joe Deatherage	3 of 3 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	Blow counts (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	gray to olive gray sandy clay w/ traces of shale; slightly moist (damp); 1.7 feet recovery	Hnu=0 (Background)	7, 15, 21, 32		
	12	Olive gray sandy clay w/ traces of shale; very moist soil, wet spoon; stiffer; 1.3 feet recovery.	Hnu=0 (Background)	8, 17, 21, 27		▽
	14	Gray sandy clay w/ small traces of shale; stiff; wet at 16'; 0.2 ft recovery;	Hnu=0 (Background)	17, 20 20, 20		
	16	Gray clay; very stiff; small traces of shale; wet spoon; moist soil; 1.8 ft recovery	Hnu=0 (Background)	10, 15 21, 30		
	18	Gray weathered shale, dry spoon and dry shale	Hnu=0 (Background)	50 over 4 inches,		rock at 18' End of drilling
	19					
	20					

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG *original location*

HOLE NUMBER	TNTC-MW5
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services, Inc.
SHEET	1 OF 2 SHEETS
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Darryl
6. MANUFACTURER'S DESIGNATION OF DRILL	D-50 diesel
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼ inch Ø hollow stem auger 24" split spoon sampler. The augers are 5ft in length. 140 # drop hammer
8. HOLE LOCATION	
9. SURFACE ELEVATION	~~10-13-94~~
10. DATE STARTED	10-13-94
11. DATE COMPLETED	10-14-94
12. OVERBURDEN THICKNESS	Unknown
15. DEPTH GROUNDWATER ENCOUNTERED	N/A
13. DEPTH DRILLED INTO ROCK	N/A
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	N/A
14. TOTAL DEPTH OF HOLE	3.7 ft
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	N/A

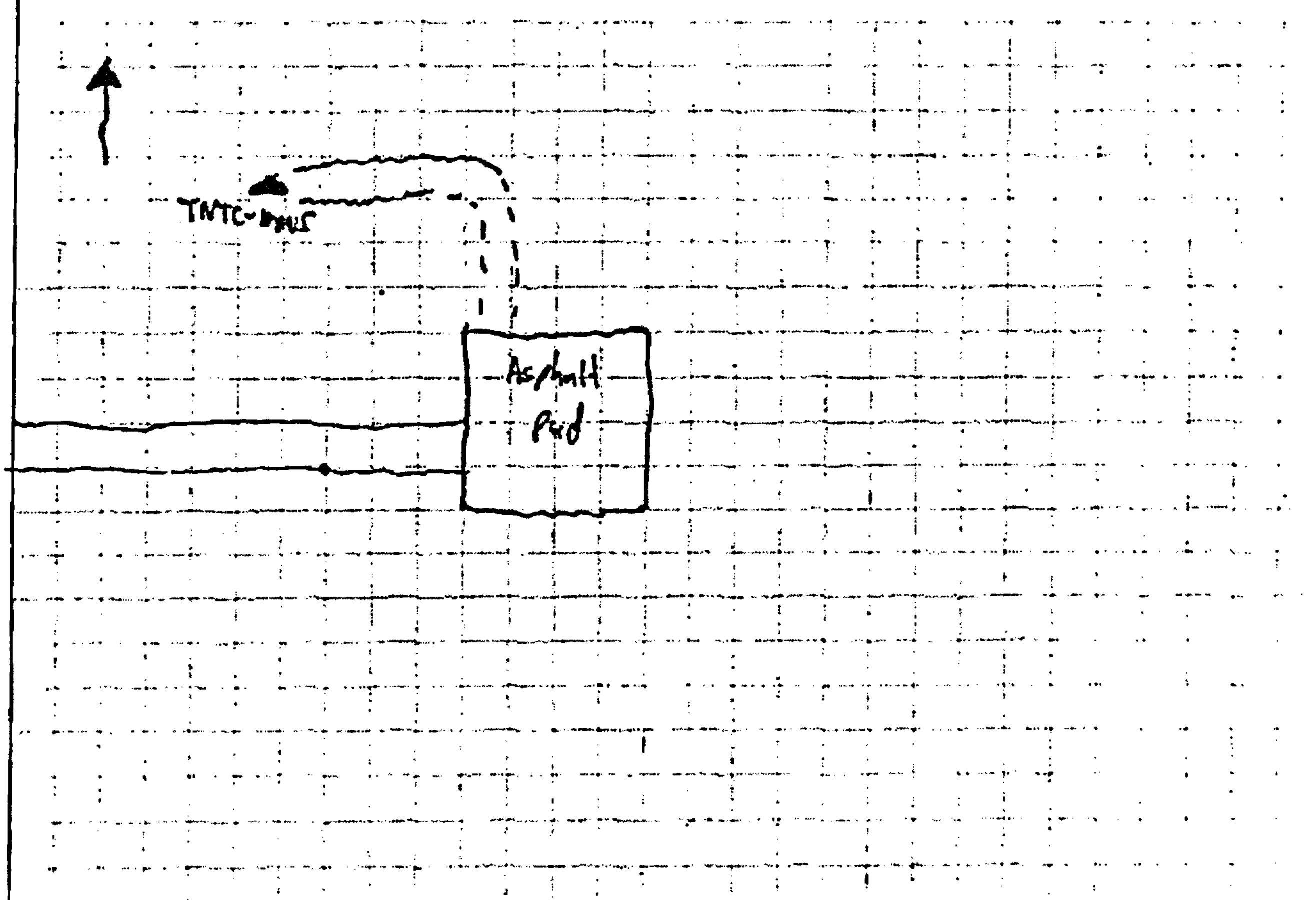
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
N/A			Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	X			Joe Deatherage

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG *original location

TNTC-MW5

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Deatherage | SHEET 1 OF 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
		Dark Brown sand; well graded; dry	Hnu=0 (Background)			Blow Count = 4,8,7,12
		gravel (limestone?), dry				Run: 2'
	1					Rec: 1.5'
		Brownish yellow sand, well graded, dry				lost: 0.5'
	2	Brownish yellow well graded sand; dry	Hnu=0 (Background)			Blow Count = 9,12,40) refusal
						Run: 1.5'
	3					Rec: 1.3'
						lost: 0.2'
	4					Refusal at 3.7'
	5					
	6					
	7					
	8					
	9					
	10					

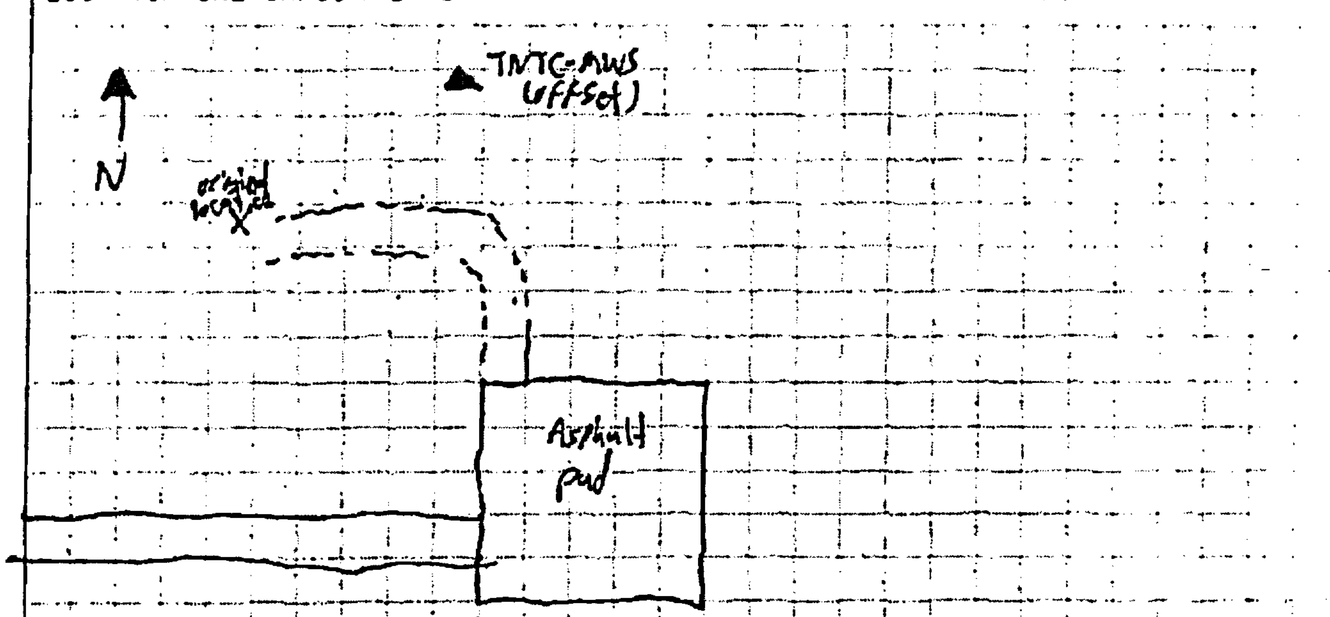
PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG *Offset*

Field	Entry
Hole Number	TNTC-MW5
1. Company Name	Dames & Moore
2. Drilling Subcontractor	Belasco Drilling Services, Inc.
Sheet	1 of 4 sheets
3. Project	Plum Brook Ordnance Works
4. Location	Sandusky, Ohio
5. Name of Driller	Darryl
6. Manufacturer's Designation of Drill	D-50 diesel
7. Sizes and Types of Drilling and Sampling Equipment	4¼ inch ϕ hollow stem auger, 24" split spoon sampler. The augers are 5 ft in length. 140 lb drop hammer.
8. Hole Location	TNT Area C
9. Surface Elevation	
10. Date Started	10-13-94
11. Date Completed	10-14-94
12. Overburden Thickness	Unknown (refusal not met)
13. Depth Drilled into Rock	N/A (0)
14. Total Depth of Hole	29.7 ft
15. Depth Groundwater Encountered	approx 7 ft
16. Depth to Water and Elapsed Time After Drilling Completed	N/A
17. Other Water Level Measurements (Specify)	N/A
18. Geotechnical Samples	None
Disturbed	---
Undisturbed	
19. Total Number of Core Boxes	N/A
20. Samples for Chemical Analysis	N/A
VOC	-
Metals	
Other (Specify)	Explosives
Other (Specify)	
Other (Specify)	
21. Total Core Recovery	N/A
22. Disposition of Hole – Backfilled	
Monitoring Well	X
Other (Specify)	
23. Signature of Inspector	Joe Deatherage

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG *Offset*

PROJECT	INSPECTOR	HOLE NO.	SHEET
Plum Brook Ordnance Works	Joe Deatherage	TNC-MW5	2 of 4 sheets

ELEV. (C)	DEPTH (D)	DESCRIPTION OF MATERIALS (E)	FIELD SCREENING RESULTS (F)	GEOTECH SAMPLE OR CORE BOX NO. (G)	ANALYTICAL SAMPLE NO. (H)	REMARKS (I)
	0–2	Dark Brown, well graded clayey Sand; dry	Hnu=0 (Background)			Blow Count: 5,9,11,12 Ran: 2.0' Rec: 1.7' lost: 0.3'
	2–4	Dark Brown, well graded clayey sand; dry Brown Sandy clay; dry	Hnu=0 (Background)			Blow Count: 6,9,13,13 Ran: 2.0' Rec: 1.7' lost: 0.3'
	4–6	Brown well graded sand; dry Dark brown sandy clay; small trace of shale; dry	Hnu=0 (Background)			Blow Count= 8,13,17,23 Ran: 2.0' Rec: 1.9' lost: 0.1'
	6–8	Olive gray sandy clay; moderately stiff; slightly moist, with some wetness at 6.5 feet	Hnu=0 (Background)			Blow Count= 8,12,13,17 Ran: 2.0' Rec: 1.2' lost: 0.8'
	8–10	Olive gray sandy clay; moderately stiff; moist; with wetness at 8.2ft; slight wetness of spoon	Hnu=0 (Background)			Blow Count= 5,9,14,17 Ran: 2.0' Rec: 1.8' lost: 0.2'

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG *offset*

HOLE NUMBER: TNTC-MW5

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 3 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Olive gray sandy clay; wet, almost no recovery	Hnu=0 (Background)			Blow Count= 6,12,15,16 Run: 2.0' Rec: 0.1' lost: 1.9'
	12	Olive gray sandy clay; moderately stiff; moist with some traces of wetness within spoon,	Hnu=0 (Background)			Blow Count= 6,10,11,16 Run: 2.0' Rec: 1.0' lost: 1.0'
	14	Olive gray sandy clay w/ small traces of shale; moist with spotty wetness in spoon;	Hnu=0 (Background)			Blow Count= 7,9,9,12 Run: 2.0' Rec: 1.0' lost: 0.4'
	16	Olive gray clay; moderately stiff; moist with traces of wetness in spoon	Hnu=0 (Background)			Blow Count: 5,10,13,17 Run: 2.0' Rec: 2.0' lost: 0'
	18	Olive gray Clay; moderately stiff; moist with traces of wetness in spoon	Hnu=0 (Background)			Blow Count= 4,5,10,11 Run: 2.0 Rec: 0.6 lost: 1.4
	20					

PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER	TNTC-MW5
PROJECT	Plum Brook Ordnance Works
INSPECTOR	Joe Deatherage
SHEET	4 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20	Olive gray clay; relatively soft; moist, with traces of wetness in the spoon	Hnu = 1 (Background)			Blow Count: 7, 8, 10, 11 Ran: 2.0' Rec: 2.0' lost: 0'
	21					
	22	Olive gray clay; relatively soft; moist with traces of wetness in spoon	Hnu=1 (Background)			Blow Count: 4, 8, 13, 13 Ran: 2.0' Rec: 1.5' lost: 0.5'
	23					
	24	Olive gray clay; relatively soft; moist with traces of wetness in spoon	Hnu=1 (Background)			Blow Count = [illegible] [illegible], 13 ~~Ran: 0.4'~~ ~~Rec: 0.4'~~ ~~lost: 0~~ Ran: ~~[illegible]~~ 2.0' Rec: ~~[illegible]~~ 1.6' lost: ~~0~~ 0.4'
	25					
	26	Olive gray clay; relatively soft; a bit more wet; Traces of shale	Hnu = 1 (Background)			Blow Count = 5, 9, 10, 13 Ran: 2.0' Rec: 1.5' lost: 0.5'
	27					
	28	Olive gray clay; relatively soft; moist with traces of wetness; small traces of shale.	Hnu = 1 (Background)			Blow Count = 5, 10, 15, 12 Ran: 2.0' Rec: 1.2' lost: 0.8'
	29					
		End of drilling.				
	30					

PROJECT
Plum Brook Ordnance Works

HOLE NO.

HTRW DRILLING LOG

HOLE NUMBER: TNTC-MW6

1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services Inc.
SHEET 1 OF 3 SHEETS	
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: D-50 Diesel
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4" Ø 5 ft long hollow stem auger; 24" split spoon; 140 lb drop hammer	8. HOLE LOCATION: TNT Area C
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-16-94
	11. DATE COMPLETED: 10-16-94
12. OVERBURDEN THICKNESS: 12.2 ft	15. DEPTH GROUNDWATER ENCOUNTERED: approx 3.5 feet
13. DEPTH DRILLED INTO ROCK: 0	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED:
14. TOTAL DEPTH OF HOLE: 12.2 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A

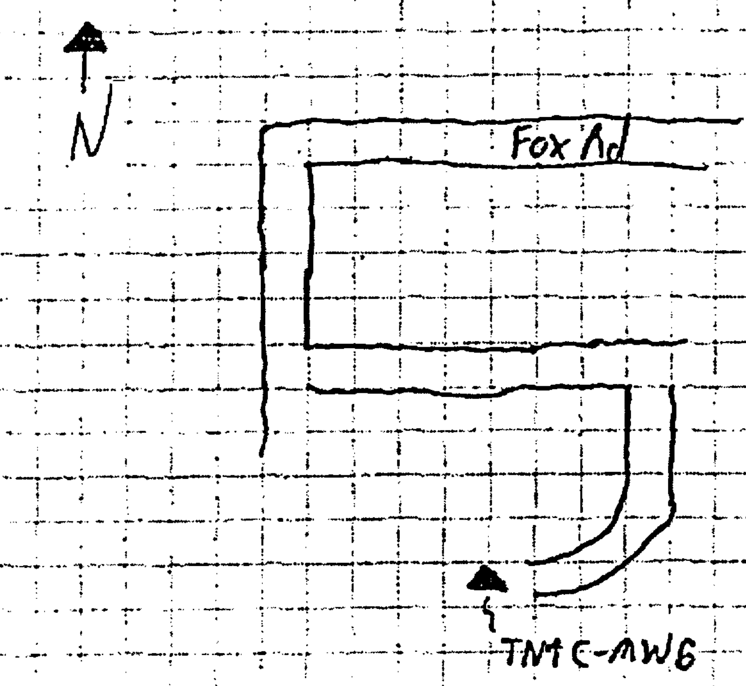
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
			Explosives			NA

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deatherage

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER: TPTC-MW6

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Deatherage | SHEET 2 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
		Dark Brown sandy organic material; dry	Hnu=1 (Background)			Blow Count=4,19,7,7 Ran: 2.0' Rec: 2.0' Lost: 0
	1	~~Hard~~ Weathered rock w/ hard gravel pieces				
		Brown to Lt. Brown well graded sand; dry				
	2		Hnu=1 (Background)			Blow Count= 4,5,6,6 Ran: 2.0 Rec: 1.5 Lost: 0.5
		Brownish yellow well graded sand; moist				
	3					
		Dark gray well graded sand, wet, 1" strip of Black sand.				
	4		Hnu=1 (Background)			Blow Count= 2,1,1,1 Ran: 2.0 Rec: 1.4 Lost: 0.6
	5	Dark gray well graded sand w/ black staining mixed in; wet; no significant odor.				
	6		Hnu=1 (Background)			Blow Count= 1,4,5,6 Ran= ~~0.5~~ 2.0' Rec = 0.5' Lost = 1.5'
	7					
		Dark Gray well graded sand w/ black staining; wet.				
		Gray, soft clay; wet; sandy				
	8		Hnu= 1 (Background)			Blow Count= 4,7,9,10 Ran: 2.0 Rec: 1.2 Lost: 0.8
	9	Gray sandy clay; very soft; wet				
		Gray weathered shale; moist				
	10					

PROJECT: Plum Brook Ordnance Works | HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER: TNTC-MW6

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Desthuny

SHEET 3 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Gray weathered shale; moist	Hnu=1 (Background)			Blow Count= 4,7,13,20 Ran: 2.0 Rec: 1.2 Lost: 0.8
	11					
	12	Gray weathered shale; moist.	Hnu=1 (Background)			Blow Count= 4, 50 over 2" Ran: 0.5 Rec: 0.5 Lost: 0
	13					End of Drilling. The well is ~~[illegible]~~ 12.2 ft deep.
	14					
	15					
	16					
	17					
	18					
	19					
	20					

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER	TNTA-MW10
SHEET 1 OF 3 SHEETS	
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services, Inc.
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: 0-50 Diesel
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4" ϕ hollow stem 5 ft long augers; 24" split spoons; 140 lb drop hammer	8. HOLE LOCATION: TNT Area A
	9. SURFACE ELEVATION:
10. DATE STARTED: 10-15-94	11. DATE COMPLETED: 10-15-94
12. OVERBURDEN THICKNESS: 11.0 ft	15. DEPTH GROUNDWATER ENCOUNTERED:
13. DEPTH DRILLED INTO ROCK: 0	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED:
14. TOTAL DEPTH OF HOLE: 11.0 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY):

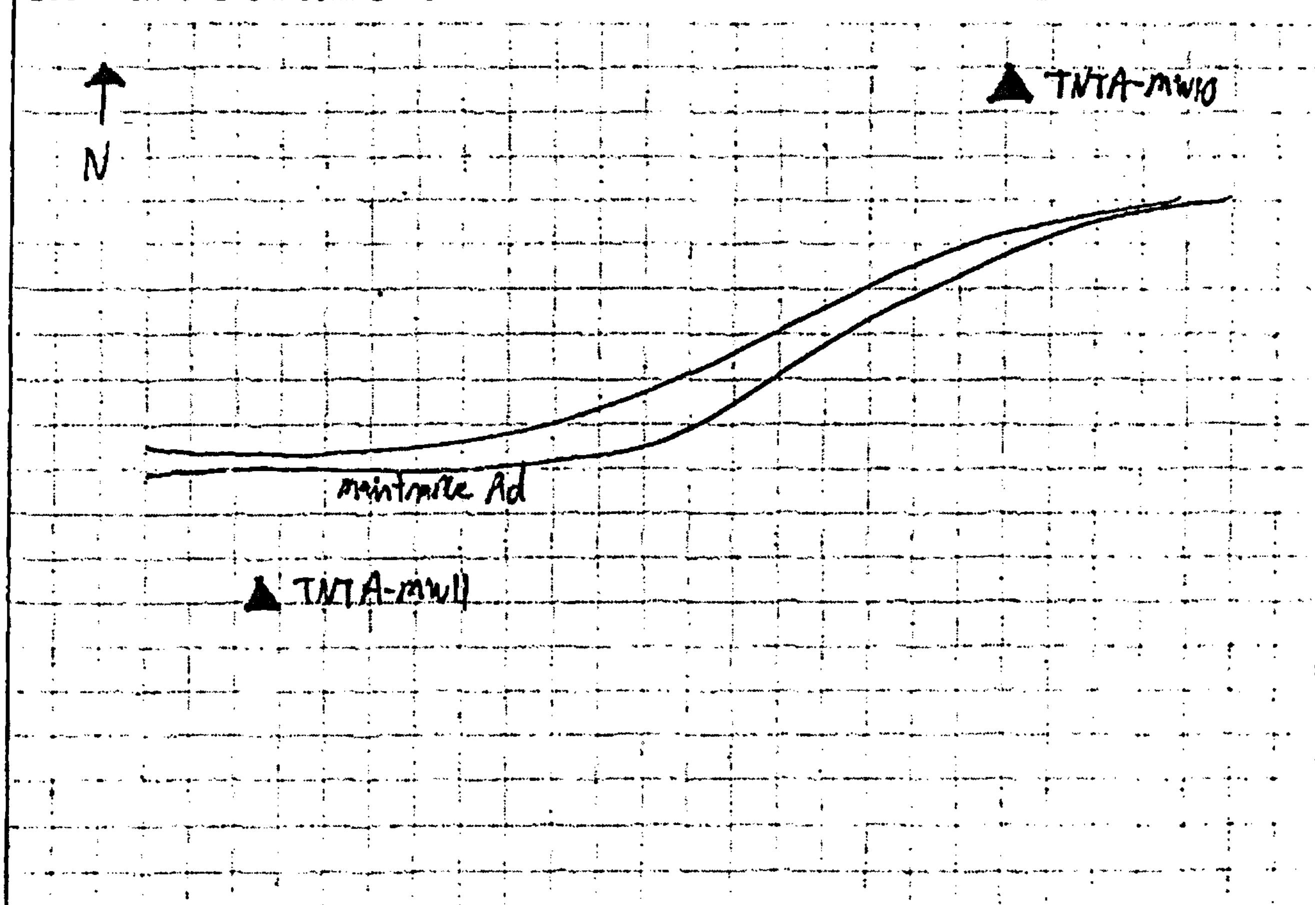
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deathing

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER: TNTA-MW10

SHEET 2 OF 3 SHEETS

PROJECT: Plum Brook Ordnance Works

INSPECTOR: Joe Deatherage

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	0–2	Dark Brown Sandy organic material; dry Brownish yellow well graded sand; moist	Hnu = 1 (Backyard)			Blow Count: 2,4,7,10 Ran: 2.0' Rec: 1.5' lost: 0.5
hole Plug	2–4	Dark Brown Sandy organic materials; moist Brown to Brownish yellow well graded sand with fines; wet	Hnu = 1 (Background)			Blow Count = 6,10,9,10 Ran: 2.0 Rec: 1.6 Lost: 0.4
	4–6	Brownish yellow well graded sand, wet Gray well graded sand, wet Gray moderately stiff clay; moist	Hnu = 1 (Background)			Blow Count: 3,3,5,12 Ran: 2.0 Rec: 1.4 lost: 0.6
Sand	6–8	Gray highly weathered Shale; slightly moist to dry	Hnu = 1 (Background)			Blow Count 6,15,16,19 Ran: 2.0' Rec: 1.2' lost: 0.8'
	8–10	Gray highly weathered Shale; moist with traces of wetness in spoon	Hnu = 1 (Background)			Blow Count 8,31,20,35 Ran: 2.0' Rec: 1.4' lost: 0.6'

screen (from 3 ft to 10 ft)

HTRW DRILLING LOG

HOLE NUMBER: TVTA-MW20
SHEET 3 OF 3 SHEETS

PROJECT: Plum Brook Ordnance Works
INSPECTOR: Joe Deatherage

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
Sand	10	Light Gray; weathered Shale, dry to moist	Hnu=1 (Background)			Blow Count= 15, 43, 50 over 3 inches. Run=1.0 Rec=1.0 lost=0
	11					Spoon refusal. End of Drilling, Total Depth of hole is 11.0 ft.
	12					

PROJECT: Plum Brook Ordnance Works
HOLE NO.:

HTRW DRILLING LOG

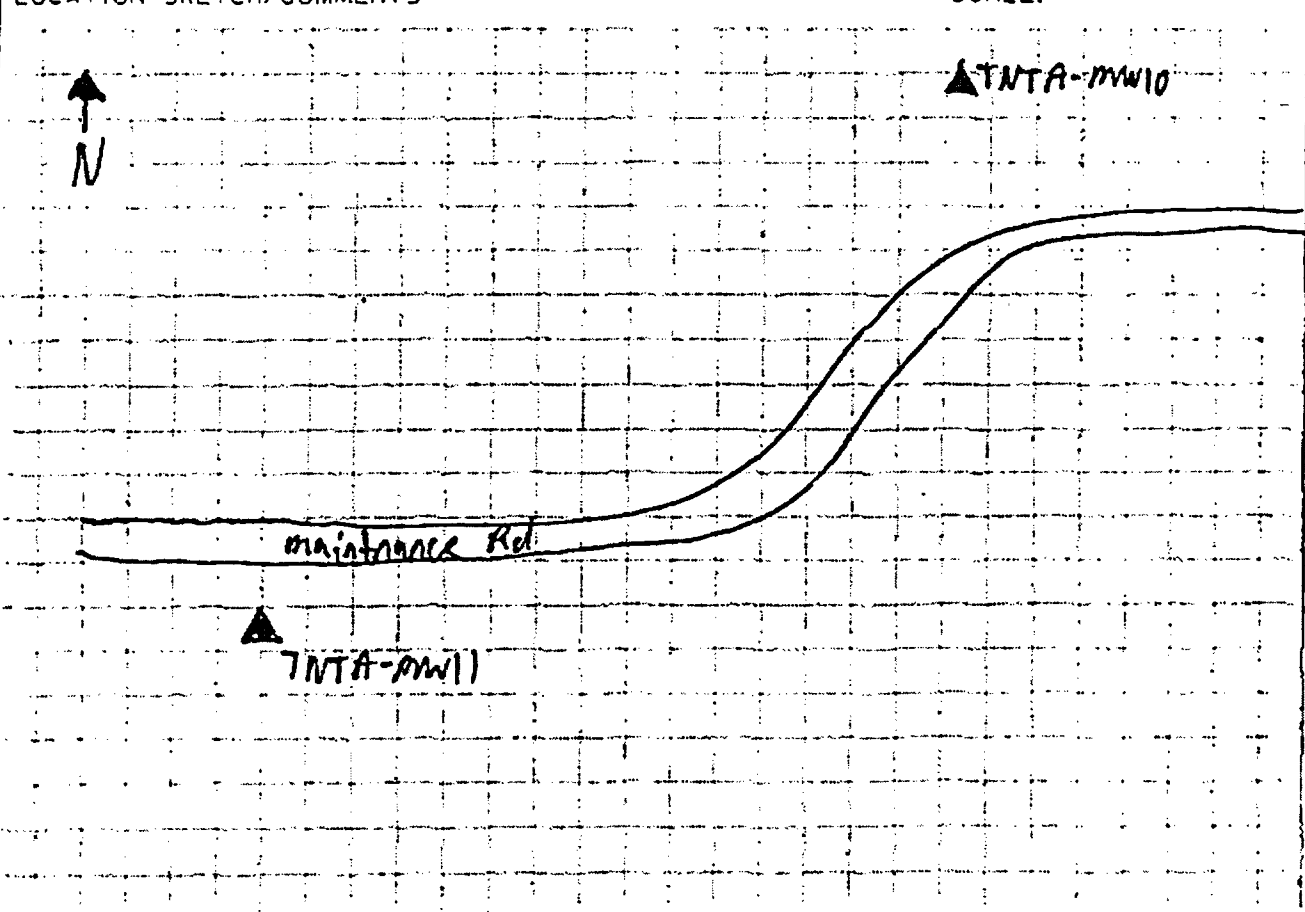
HOLE NUMBER	TNTA-MW11
SHEET 1 OF 9 SHEETS	
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Dilling, Inc.
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Darryl
6. MANUFACTURER'S DESIGNATION OF DRILL	D50 Diesel
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼ Ø hollow stem auger; 5 ft long; 24" split spoon; 140 lb drop hammer.
8. HOLE LOCATION	TNT Area A
9. SURFACE ELEVATION	
10. DATE STARTED	10-15-94
11. DATE COMPLETED	10-15-94
12. OVERBURDEN THICKNESS	10.0 ft
13. DEPTH DRILLED INTO ROCK	1.4 ft
14. TOTAL DEPTH OF HOLE	11.4 ft
15. DEPTH GROUNDWATER ENCOUNTERED	N/A
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	N/A
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	N/A
18. GEOTECHNICAL SAMPLES	None
DISTURBED	---
UNDISTURBED	
19. TOTAL NUMBER OF CORE BOXES	N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	-		Explosives			

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deathey

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER: TVTA-MW11

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Joe Deathuage | SHEET 2 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–2	Dark Brown, Sandy organic material; dry	Hnu=1 (Background)			Blow Count=3,5,10,10 Ran: 2.0' Rec: 1.7' Lost: 0.3
	2–4	Dark Brown sandy organic materials dry	Hnu=1 (Background)			Blow Count=5,8,8,9 Ran: 2.0' Rec: 1.5' Lost: 0.5'
	4–5	Dark Brown sandy organic material, Dry	Hnu=1 (Background)			Blow Count=4,5,7,8 Ran: 2.0' Rec: 1.6' Lost: 0.4'
	5–6	Olive gray clay w/ weathered Shale mix; dry				
	6–8	Gray highly weathered Shale ; dry	Hnu=1 (Background)			Blow Count=8,16,18,22 Ran: 2.0 Rec: 1.6 Lost: 0.4
	8–10	Gray highly weathered shale ; dry	Hnu=1 (Background)			Blow Count=12,22,38,48 Ran: 2.0' Rec: 1.7' Lost: 0.3'

PROJECT: Plum Brook Ordnance Works | HOLE NO.

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works	Joe Dealbuas	INTA-MW11	3 OF 3 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Gray shale ; hard	Hnu = 1 (Background)			Blow Count = 28, 34, 50 over 4 inches. Run = 1.4 ft Rec: 1.4 Lost: 0
	11					
						Refusal at 11.4 ft.
	12					
	13					
	14					
	15					
	16					
	17					
	18					

HTRW DRILLING LOG

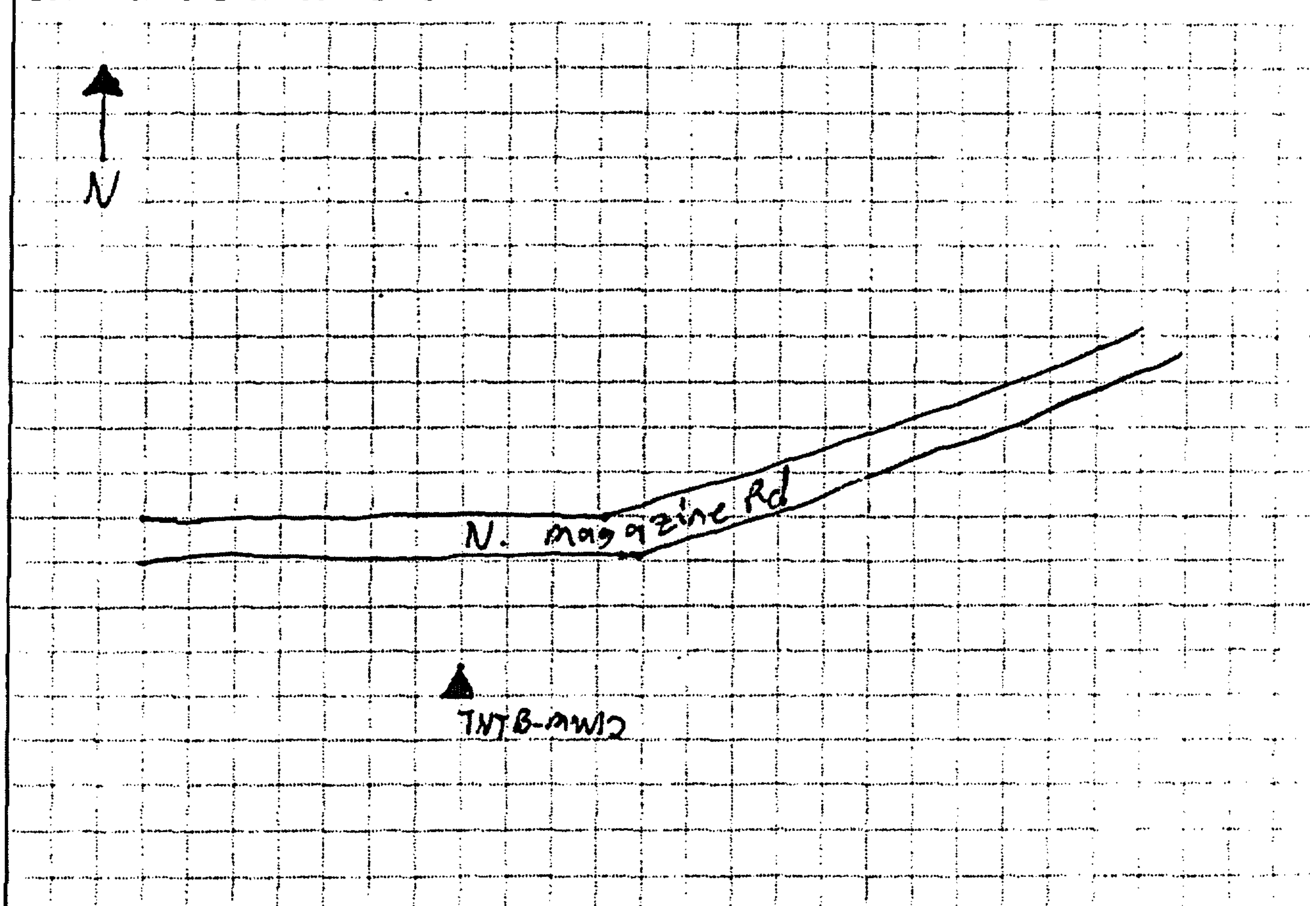
HOLE NUMBER	TNTB-MW12	
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services, Inc.	SHEET 1 OF 2 SHEETS
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio	
5. NAME OF DRILLER: Darryl	6. MANUFACTURER'S DESIGNATION OF DRILL: D-50 Diesel	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" Ø hollow stem 5 foot long augers; 24" split spoons; 140 # drop hammer	8. HOLE LOCATION: TNT Area B	
	9. SURFACE ELEVATION:	
	10. DATE STARTED: 10-14-94	11. DATE COMPLETED: 10-14-94
12. OVERBURDEN THICKNESS: ~~[illegible]~~ 5.5 ft	15. DEPTH GROUNDWATER ENCOUNTERED: N/A	
13. DEPTH DRILLED INTO ROCK: ~~[illegible]~~ 0	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: N/A	
14. TOTAL DEPTH OF HOLE: 5.5 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): N/A	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		N/A

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	-		Explosives			N/A

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Joe Deatherage

LOCATION SKETCH/COMMENTS SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	

HTRW DRILLING LOG

HOLE NUMBER	TNTB-MW12
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	2 OF 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0–2	Dark Brown Sandy organic material; dry	~~Hnu=2~~ ~~FB~~ ~~50~~	Hnu=2 (Background)		Blow Count: 3 4 4 5 Run: 2.0 Rec: 1.3 lost: 0.7
	2–4	Dark brown weathered shale; dry; moderately hard		Hnu=2 (Background)		Blow Count: 8, 17, 27, 36 Run: 2.0' Rec: 1.3' lost: 0.7'
	4–5.5	Dark Brown weathered shale, dry; moderately hard		Hnu=2 (Background)		Blow Count: 8, 50 over 5 inches
	5.5					Auger refusal at 5.5ft. We will place a 5ft screen, put sand from 5.5ft to 1ft, and put bentonite from 1ft to ground surface. The well will then be called complete.

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW13

1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Balasco Drilling Services, Inc
SHEET 1 OF 1 SHEETS	
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Al Dudley	6. MANUFACTURER'S DESIGNATION OF DRILL: Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID HSA w/cont. sampling; 6¼" ID HSA, 2' Split Spoons; NX core Equipment, 6" Roller Cone	8. HOLE LOCATION: EPA Road
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-12-94 / 11. DATE COMPLETED: 11-8-94
12. OVERBURDEN THICKNESS: 40.7' BGS	15. DEPTH GROUNDWATER ENCOUNTERED: not encountered until coring commenced ...
13. DEPTH DRILLED INTO ROCK: 40.7' – 75.5' BGS	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 20.41' BTOC 24hrs
14. TOTAL DEPTH OF HOLE: 75.5' BGS, 78.10' BTOC	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 43.01' 11-16-94

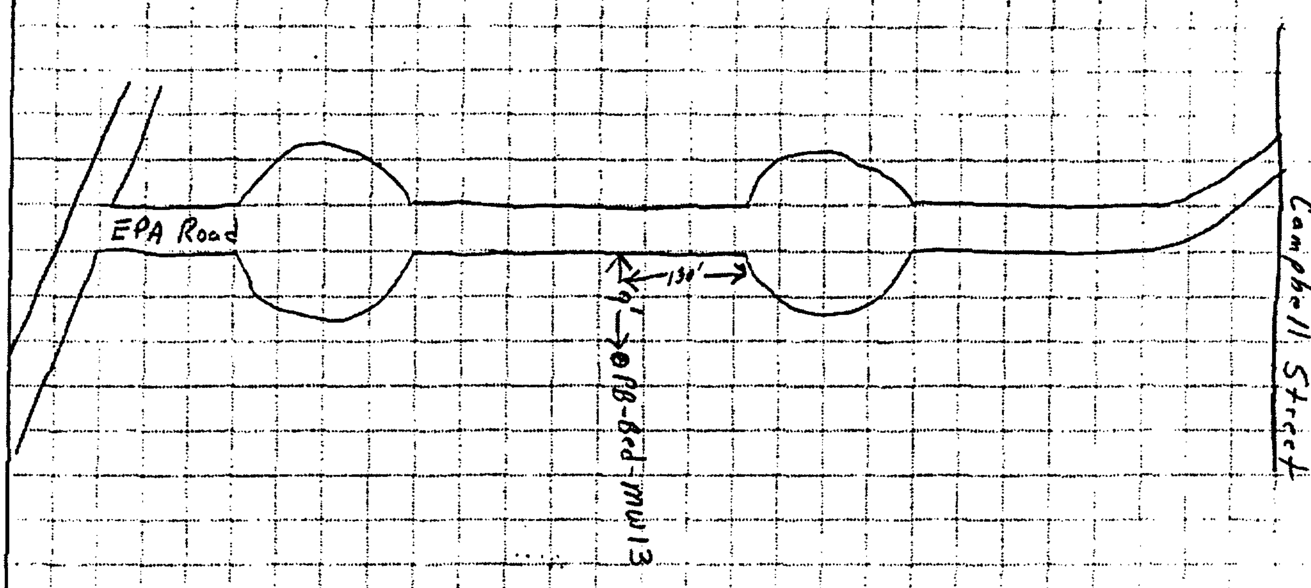
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
None	-		Explosives			93%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS

SCALE: Not to Scale



PROJECT: Plum Brook Ordnance Works

HOLE NO. PB-Bed-MW13

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW13

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works		2 of 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Dark Brown to Brownish Black Silty Fine Sand with organics		3		
				5		
		Yellow Brown to Reddish Brown Fine Sandy Silt to Silty Fine Sand Some root modeling present Dry		6		
				8		24" Recovery
	2			4		
				5		
				5		
		Tanish Brown and Gray silty Clay moist		6		24" Recovery
	4	Same as above with a couple sand zones less than ¼ inch in thickness - dry		3		
				3		
				6		
				7		22" Recovery
	6	silty Clay Grades mainly Gray - layered in thin sheets		3		
				6		
				9		
				16		24" Recovery
	8	Gray Silty Clay with a 2" Brownish Yellow med sand zone at 9.0'		4		
				9		
				12		
				18		24" Recovery
	10					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW13

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-MW13	3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Same as above, grading to very highly weathered shale layered and powdery		8		
				12		
				20		
				50/5		20" Recovery
	12			16		
				50/4		10" Recovery
				Straight Auger very Hard		13' Straight Auger, too hard to sample, not hard enough to core
	14			↓		
	16					
	18					
	20					

PROJECT: Plum Brook Ordnance Works

HOLE NO. PB-Bed-MW13

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW 13

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 4 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20					Continue straight Augering
	22					
						Very Hard
	24					
	26					
						27' Picking up an odor from Bore hole, appears to be due to augers cutting the very hard weathered shale cuttings very hot. HNu = occasionally 3 in Breathing zone. Burnt oil odor
	28					
	30					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW13

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-MW13	5 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	30					Straight Auger
	32					
	34					
	36					
	40					Auger Refusal 40'

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW13

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-mw13

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 6 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40.7	Limestone				Auger Refusal 40.7
	Ti Break Ti Break	Shale, medium Dark Gray (N4), very thinly laminated, slightly calcareous, with occasional bivalve fossils and very slight amount of pyrite, slight oil odor from shale				Run 1 40.7'-45.8' 250 psi Down pressure Initial core recovery of 14 3/4" Have to go back in to get remaining core
		Ti Break Ti Break				
	42	Ti Break Ti Break		Box 1		
	43	Ti Break				20 min/5 ft Core 61.5" Rec 61.5"
	44					
		Ti Break				
	45	Ti Break				End Run 1 at 45.8'
						Roller Cone
	46	Same as above with numerous bivalves, pyrite more numerous, occasional natural fractures				Begin Run 2 at 46.0' 4" casing set to 46.0'
Open Break		Ti Break				
	47	Ti Break Ti Break		Box 1		21 min/9.6 feet
						Core 115" Rec 96" Lost 19"
	48	Ti Break Ti Break				
	49	Ti Break Ti Break Ti Break				
	50					

4.6'

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-mw13

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW13

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 7 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	50			Box 1		
		Ti Break				
	51	Ti Break				
		Grades to pale yellowish Brown (10YR 6/2) and medium Dark Gray with petroleum odor Ti Break Ti Break				
	52	Spin				
		Ti Break				
	53	Spin		Box 2		
		Spin Broken up due to coring				
	54					
		Ti Break				
	55	Spin				End Run 2 at 55.6' Begin Run 3 at 55.6'
	56	Ti Break Spin				
	57	Spin Spin				20 min/10 ft H_2S reading 1 ppm after coring
	58	Spin Ti Break Ti Break				Hear gurgling sound in borehole core 120" Rec 117" Lost 3"
	59	Ti Break Spin				
	60					

PROJECT: Plum Brook Ordnance Works | HOLE NO.: PB-Bed-MW13

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW13

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 9 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	60	Spin		Box 2		
		T. Break				
	61	Ti Break				
		T. Break				
	62	Ti Break		Box 3		
		Ti Break				
	63	Ti Break				
		Ti Break				
	64	Ti Break				
		Ti Break				
		Ti Break				
	65					
		Ti Break				End Run 3 at 65.5'
		Grades medium Dark Gray (N4). Spots of oil on Core				Begin Run 4 at 65.5'
	66	Ti Break				Lost approx 6' of core down hole, blocking borehole at 46', cant get it out, will have to roller cone it out with 3¾" roller cone next week.
		Ti Break				
	67					
		T. Break				
	68	Ti Break				11-8-94 Cleared Blockage with roller cone, installed core barrel, only able to recover 3.3' of remaining core.
		Ti Break				
		Ti Break				
		Ti Break				
	69					Core 120"
						Rec 75"
		Ti Break				Lost 45"
	70			Box 4		

PROJECT: Plum Brook Ordnance Works

HOLE NO. PB-Bed-MW13

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-mw13	9 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	70	Broken up due to coring ↓				
	71					
	72			Box 4		
	73					
	74					
	75					End Run 4 at 75.5'
	76					Borehole PB-Bed-mw13 Terminated at 75.5' on 11-8-94
	77					
	78					
	79					
	80					

PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-mw13

HTRW DRILLING LOG

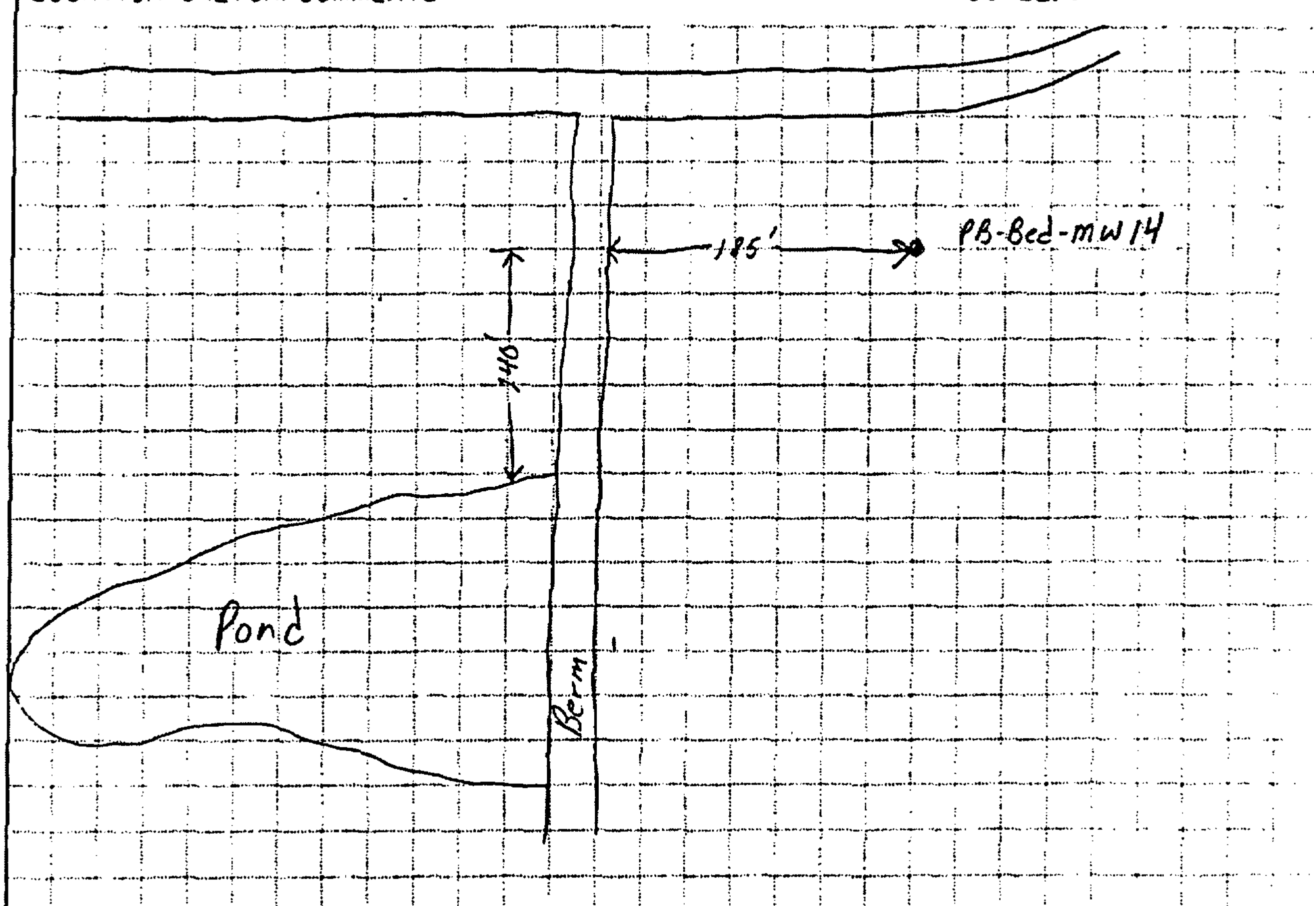
HOLE NUMBER	PB-Bed-MW14
SHEET	1 OF 1 SHEETS
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Al Dudley
6. MANUFACTURER'S DESIGNATION OF DRILL	Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID HSA, 2' Split Spoons; 6¼" ID HSA; HQ Core Barrell, 6" Roller cone; NX Core Barrell
8. HOLE LOCATION	West Area Ponds
9. SURFACE ELEVATION	
10. DATE STARTED	10-17-94
11. DATE COMPLETED	11-12-94
12. OVERBURDEN THICKNESS	24.5' BGS
15. DEPTH GROUNDWATER ENCOUNTERED	18' BGS
13. DEPTH DRILLED INTO ROCK	24.5' - 49.4' BGS
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	24.07' BTOC 48 hrs
14. TOTAL DEPTH OF HOLE	52.2' BGS, 55.0' BTOC
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	24.45' BTOC 11-16-94

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		3

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			97%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS SCALE: not to scale



PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-MW14

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW14
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	2 OF 2 SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	0	Dark Brown Silty Fine Sand with roots - Dry	HNu 0	1 2	H	20" Recovery
	1	Grades to Yellow Brown		2 3		
	2	Grades with trace clay - dry	HNu 0	3 5 7 7		20" Recovery
	3					
	4	Brownish Gray + Brownish Orange Clayey Silty Fine Sand dry - horizontal layering	HNu 0	3 4 6 7		22" Recovery
	5					
	6	Grades with 1/4" Brownish Yellow Silty Fine Sand lenses about every 2 inchs Dry	HNu 0	2 3 5 7		24" Recovery
	7					
	8	Brown + Brownish Yellow thinly layered silty Fine Sand	HNu 0	3 5 8 7		24" Recovery
	9					
	10					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW14

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10		HNu	3		24" Recovery
		Gray Clayey silt - moist	0	3		
	11			3		
				4		
	12	Gray Silty Clay - moist		2		24" Recovery
				3		
	13			4		
				4		
	14	Same as above		2		24" Recovery
				2		
	15			3		
				3		
	16	Gray Fat Clay - moist		1		24" Recovery
				1		
	17			2		
				2		
	18	Same as above moist to wet		wt of Hammer		24" Recovery
				1		
	19			1		
				1		
	20					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW14

PROJECT: Plum Brook Ordnance Works | INSPECTOR: Charles Way | SHEET 4 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	20	Same as above with fragments of weathered shale moist to wet	HNu 0	wt of Hammer 1 1 1		24" Recovery
	22	Same as above with lots of weathed shale	HNu 0	2 5 7 50/0		10" Recovery
	24					Auger Refusal at 24.5'
	24.5	Limestone, medium Dark Gray (N4) fine to medium crystalline, Strong, fresh with occasional bivalve fossils		Box 1		Begin Run 1 at 24.5' HQ Core Barrel All breaks appear to be breaks from coring process Core 60" Rec 57" Lost 3" Set 4" casing to 29.0' End Run 1 at 29.3'
	29.3	Limestone, medium Dark Gray (N4), Strong, Fresh intermixed with zones of Clay Shale Dark Gray (N3), weak, fresh to slightly weathered at open breaks, occasional fossils		Box 2		Begin Run 2 at 29.3' on 11-12-94 with NQ core barrell and clear water
	30					

PROJECT: Plum Brook Ordnance Works | HOLE NO.: PB-Bed-MW14

HTRW DRILLING LOG

HOLE NO. PB-Bed-MW14

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET OF 5 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	30	Ti Break				
		Ti Break — Limy shale zone 30.4 to 31.6				
		Ti Break				
	31	Ti Break				Core 60" Rec 54" Lost 6"
		Ti Break				
		Ti Break				
	32	Open Break — Limy shale zone 32.1 to 32.5				23min/5ft Lost about 30 gals at open breaks
		Open Break				
	33	Ti Break — Limy shale zon 33.0 - 33.1				
	34			Box 2		End Run 2 at 34.3'
		Grades to Fossiliferous limestone, light Brownish Gray (5YR 6/1), finely crystalline, strong, fresh, with stylolitic surfaces, very slight petroleum odor				Begin Run 3 at 34.3'
	35	45° open Break				Core 112" Rec 112" 35min/9.3'
	36					
		Ti Break				
	37					
	38					
	39	Open Break				
	40					

PROJECT: Plum Brook Ordnance Works

HOLE NO. PB-Bed-MW14

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW14

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 6 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40	Ti Break				
	41					
	42			Box 2		
		Ti Break				
	43					End Run 3 at 43.6'
						Begin Run 4 at 43.6'
	44	Begin vertical, partially rehealed fracture				
	45					Core 70" Rec 70"
		End vertical, partially rehealed fracture				17 min/5.7'
	46	Open Break		Box 3		
	47	Ti Break				
		Begin vertical, partially rehealed fracture				
	48					
		Ti Break - small oil sheen				
	49					End Run 4 at 49.4'
		Add 25' screen, remainder riser 2.75' stickup				Boring terminated at 49.4' on 11-12-94
	50					

PROJECT: Plum Brook Ordnance Works | HOLE NO. PB-Bed-MW14

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15
SHEET 1 OF 1 SHEETS

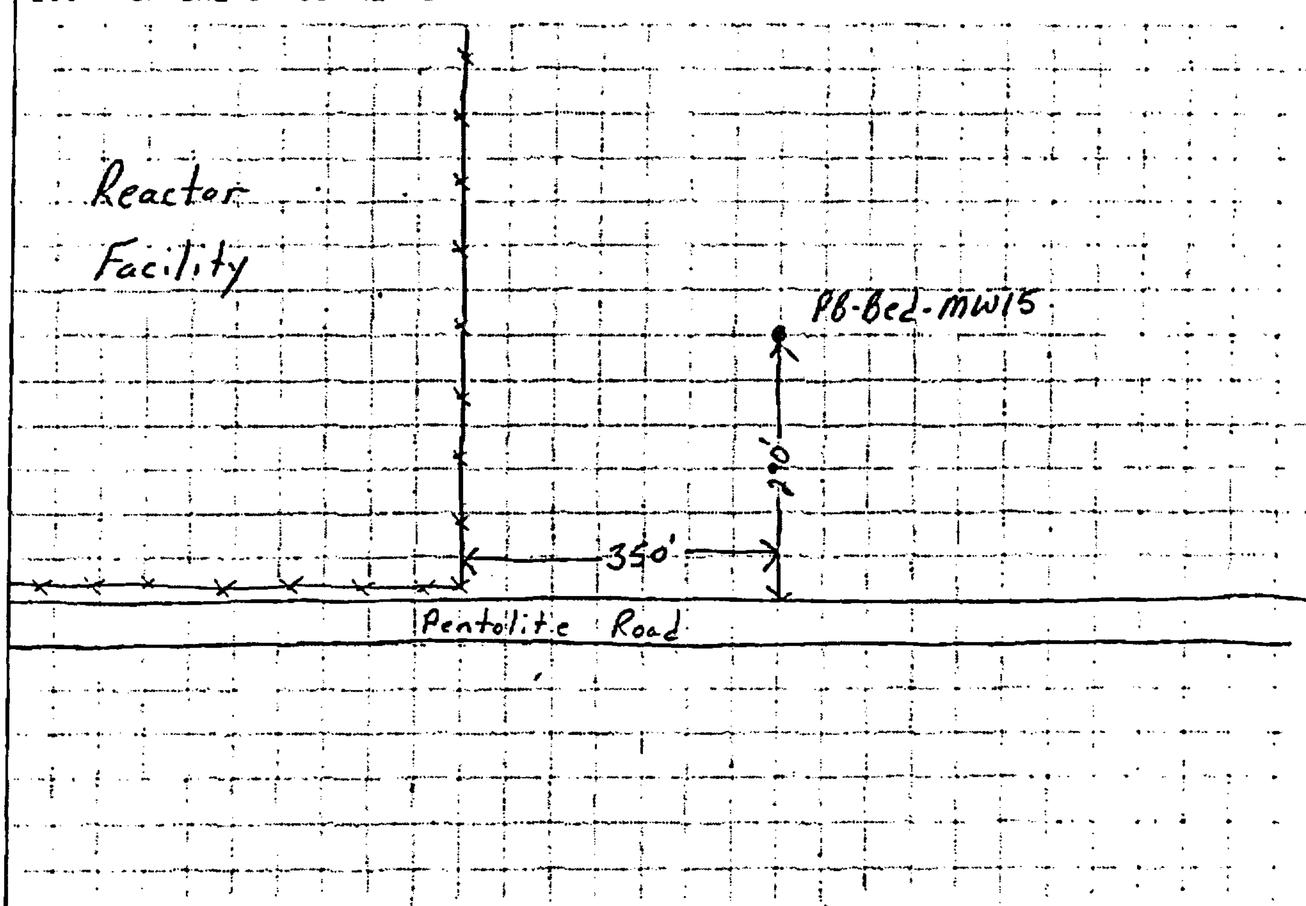
Field	Entry
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Al Dudley
6. MANUFACTURER'S DESIGNATION OF DRILL	Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID HSAs, 6¼" ID HSAs; HQ Core Equipment; NX Core Equipment, 6" Roller Cone; 2' Split Spoons
8. HOLE LOCATION	Pentolite Road Ponds
9. SURFACE ELEVATION	
10. DATE STARTED	10-18-94
11. DATE COMPLETED	11-11-94
12. OVERBURDEN THICKNESS	24.3' BGS
13. DEPTH DRILLED INTO ROCK	24.3 - 74.4' BGS
14. TOTAL DEPTH OF HOLE	74.4' BGS, 77.0' BTOC
15. DEPTH GROUNDWATER ENCOUNTERED	10.0' BGS
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	25.89' BTOC 48 hrs
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	37.41' BTOC 11-16-94

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			99%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
-		X		Charles Way

LOCATION SKETCH/COMMENTS SCALE:



PROJECT: Plum Brook Ordnance Works
HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 2 OF 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Brown + Grayish Brown Silty Fine Sand - Dry	HNu 0	3, 4, 7, 6		20" Recovery
	1					
	2	Grades with Brownish Yellow - Dry	HNu 0	6, 6, 7, 7		24" Recovery
	3					
	4	Gray + Brown Clayey Silt with small amount of fine Sand - Dry	HNu 0	5, 7, 10, 9		24" Recovery
	5					
	6	Gray Silty Clay - moist	HNu 0	4, 5, 5, 7		24" Recovery
	7					
	8	Gray Clayey Silt - moist	HNu 0	2, 3, 4, 6		24" Recovery
	9					
	10					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10'	Same as above moist to wet	HNu 0	3 2 3 4		24" Recovery
	11					
	12	Same as above moist to wet	HNu 0	1 2 2 4		24" Recovery
	13					
	14	Gray Silty Clay with fragments of weathered shale - moist	HNu 0	1 2 2 4		24" Recovery
	15					
	16	Same as above moist	HNu 0	1 2 3 4		20" Recovery
	17					
	18	Same as above few more shale fragments Becomes dryer	HNu 0	1 2 5 8		22" Recovery
	19					
	20					

PROJECT: Plum Brook Ordnance Works | HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20	Same as above	HNu 0	4 7 7 13		24" Recovery
	21					
	22	Same as above, with larger shale fragments dryer	HNu 0	5 7 12 50/6		10" Recovery
	23					
	24					Auger Refusal at 24.3'
		Limestone, medium Dark Gray (N4), fine to medium crystalline, strong, Fresh with occasional bivalves	Rec 78.5/86	RQD 78.5/86		Begin Run 1 at 24.3'
	25	Void 25.5'-26.0'				Core 86" Rec 78.5" Lost 7.5"
	26			Box 1		
	27					
	28					
	29					
	30					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 5 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	30					set and grouted 4" casing to 31.5'
	31					Left .2' in Btm hole End Run 1 at 31.5'
						Roller Cone
	32	Fossiliferous Limestone, medium Dark Gray (N4), Fine to medium crystalline, strong, fresh, with accasional stylolite surfaces and bivalve fossil spin Slight Petroleum odor	Rec / Core	74" / Core		Begin Run 2 at 31.7 using 12'3" NQ core barrell and clear water 11-10-94
	33	Ti Break				Core 93" Rec 91" Lost 2"
	34	Ti Break	91" / 93"	91" / 93		27min/7.7ft
	35			Box 2		
	36	Ti Break				
	37	Ti Break				
	38					
	39	Ti Break, black staining at stylolite				End Run 2 at 39.4'
						Begin Run 3 at 39.4' 11-11-94
	40					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 6 OF SHEETS

ELEV. (c)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40					
	41					
	42					
		Ti Break at stylolite, black stain				Core 120" Rec 122" Gain 2"
	43			Box 2		
	44					
		Ti Break				34min/10ft
	45	Open Break at shale seam				
	46	Ti Break at stylolite, black stain				
	47					
		Open Break - clay seam 1/2"				
	48			Box 3		
	49					End Run 3 at 49.4'
						Begin Run 4 at 49.4'
	50					

PROJECT: Plum Brook Ordnance Works | HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

HOLE NUMBER	PROJECT	INSPECTOR	SHEET
PB-Bed-MW15	Plum Brook Ordnance Works		OF 7 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	50					
	51	Ti Break				
	52					Core 120" Rec 120"
	53			Box 3		41 min/10 ft
	54	Ti Break Ti Break				
	55	Ti Break				
	56					
	57					
	58					
	59	Partial rehealed vertical fracture begins				End Run 4 at 59.4' Begin Run 5 at 59.4'
	60					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NO. / SHEET
Plum Brook Ordnance Works		PB-Bed-MW15 / SHEET 8 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	60			Box 3		almost entire run had partial rehealed vertical fracture which seperated when rock was broken to fit in core box
	61					
	62					Core 120" Rec 120
	63					
	64	Ti Break		Box 4		39 min/10 ft
	65					
	66					
	67	Partial rehealed vertical fracture ends				
	68					
	69					End Run 5 at 69.4' Begin Run 6 at 69.4'
	70					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW15

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 9 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	70					No Breaks
	71					Core 60" Rec 59" Lost 1"
	72			Box 4		25 min/5 ft
	73					
	74					End Run 6 at 74.4'
						Boring terminated at 74.4' on 11-11-94
	75					
	76					
	77					
	78					
	79					
	80					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW15

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW16
SHEET 1 OF 1 SHEETS

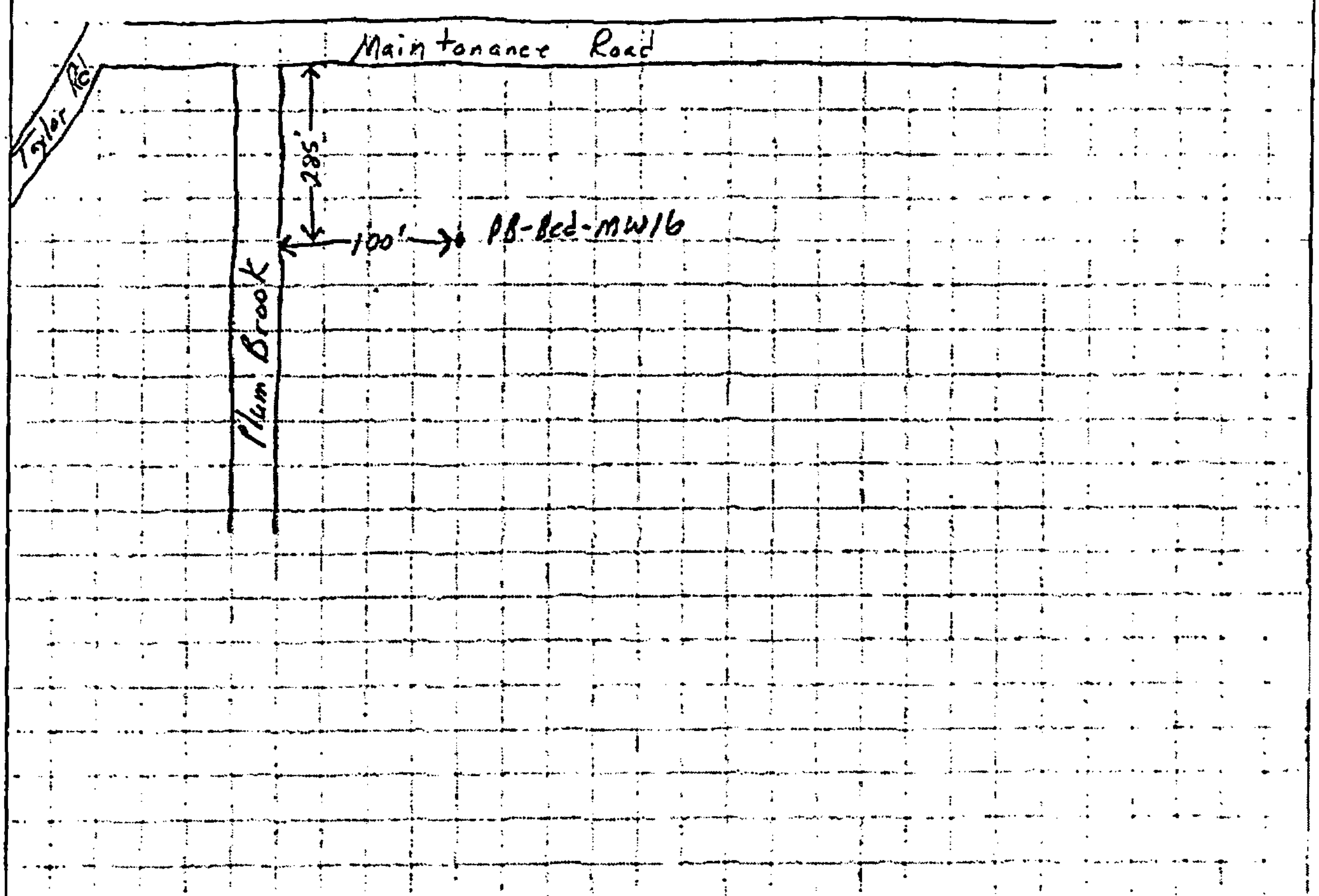
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Al Dudley	6. MANUFACTURER'S DESIGNATION OF DRILL: Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID HSA, 6¼" ID HSA; 6" Roller Cone; NX Core Equipment, 2' Split Spoons	8. HOLE LOCATION: Toluene Tanks
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-15-94 / 11. DATE COMPLETED: 10-30-94
12. OVERBURDEN THICKNESS: 44.2' BGS	15. DEPTH GROUNDWATER ENCOUNTERED: not encountered until coring commenced
13. DEPTH DRILLED INTO ROCK: 44.2' – 74.0' BGS	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 45.45' BTOC 15 hrs
14. TOTAL DEPTH OF HOLE: 74.0' BGS, 76.5' BTOC	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 64.64' BTOC 11-16-94

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		3

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			93%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-MW16

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW-16

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 2 OF 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Grayish Black + Brown Silty Fine sand with organics Dry	HNu 0	2		24" Recovery
				4		
				12		
				12		
	2		HNu 0	5		20" Recovery
				6		
		Mottled Brown + Gray Clayey Silt with roots - Dry		6		
				7		
	4		HNu 0	4		20" Recovery
				8		
				8		
		Grades to Mottled Brown + Gray Silty Clay - Dry		12		
	6		HNu 0	4		24" Recovery
		Mottled Grayish Brown + Brownish Yellow Silty Fine Sand		7		
				12		
				15		
	8		HNu 0	5		24" Recovery
		Gray Clayey Silt - Dry		6		
		Mottled Brownish Gray + Brownish Red (Iron Staining) Silty Fine Sand - Dry		9		
				12		
	10					

PROJECT: Plum Brook Ordnance Works | HOLE NO. PB-Bed-MW16

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW16

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Gray + Brownish Yellow Silty Clay + Clayey Silt, moist in clayey zones, dry in silty zones	HNu 0	3 6 8 17		24" Recovery
	12	Gray Highly weathered, horizontally layered shale Dry - powdery	HNu 0	25 50/4		10" Recovery
	14	Same as above	HNu 0	27 50/4		10" Recovery Straight Auger from 15'
	16					
	18					
	20					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW16

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER / SHEET
Plum Brook Ordnance Works		PB-Bed-MW-16 / SHEET 4 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20'	Same as above, Gray highly weathered shale				Hard augering
	22					
	24					
	26					
	28					
	30					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW16

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW-16

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works		5 of SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	30	Gray highly weathered shale				
	31					
	32					
	33					
	34					
	35					
	36					
	37					
	38					
	39					
	40					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW16

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-mw16	of 6 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40	Gray highly weathered Shale				Hard Augering
	41					
	42					
	43					
	44					Refusal at 44.2'
		Shaley Limestone, medium Dark Gray (N4) to Dark Gray (N3), finely crystalline, strong, Fresh with occasional fossils & pyritized fossils	core/rec	74"/rec		Run 1 44.2' with NX core barrel on 10-15-94
	45		36.5/60	36.5/60		Other two feet left in hole, core catcher wont grab core
	46	Ti Break				Core 60" Rec 36.5" Lost 23.5"
				Box 1		
	47					
	48					
	49					4" Casing set at 49.2' End Run 1 at 49.2'
						Begin Run 2 at 49.2' with NX core barrell on 10-30-94
		Ti Break				
	50					

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-MW16	of 7 sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	50	Fossiliferous Limestone, medium Dark Gray (N4) to Dark Gray (N3), finely crystalline fresh, strong with pyrite deposition at 51.8'				
	Ti Break					
	51		76/78	59/78		19min/6.5 ft
		Ti Break				
	52					Natural fractures at 50.3, 51.85, 52.4, 53.6 54.4, 54.6 and 55.4
		Ti Break		Box 1		
	53					Core 78" Rec 76" Lost 2"
	Ti Break	At 53.3 becomes slightly weathered to Light Brownish Gray (5YR 6/1) with numerous fossils				
	54	Ti Break Ti Break				
	55	Ti Break				End Run 2 at 55.5'
		Same as above, with stylolites, petroleum smell + discoloration small amount of oil on rock core				Begin Run 3 at 55.5
	56	Ti Break	104/120	104/120		HNu reading 16ppm off rock core
	57			Box 2		natural fractures at 56.6', 59.2', 61.2', 61.6, 63.0 and 64.1
	58					Left 16" in hole pick it up next run
	59	Ti Break				Core 120" Rec 104" Lost 16"
	60					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW16

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 8 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	60					
	61	Ti Break				
		Ti Break				
	62			Box 2		
	63	Ti Break				
	64	Ti Break				
	65	Ti Break				
		Ti Break				End Run 3 at 65.5'
		Same as above, with large calcite concretions from 68.2-68.8				Begin Run 4 at 65.5
	66	Ti Break				
	67			Box 3		
	68					
	69					
	70	Ti Break				

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW16

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW16
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	9
OF	SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	70					
	71		117.5/102	106/102		picked up 16" from previous run
		Ti Break				natural fractures at 65.1, 65.2, 65.3, 66.75, 70.0, 71.45, 73.0 and 73.6
	72			Box 3		Core 102" Rec 117.5" Gain 15.5"
	73	Ti Break				
		Ti Break				End Run 4 at 74.0'
	74					Borehole PB-Bed-MW16 terminated at 74.0' on 10-30-94
	75					
	76					
	77					
	78					
	79					
	80					

HTRW DRILLING LOG

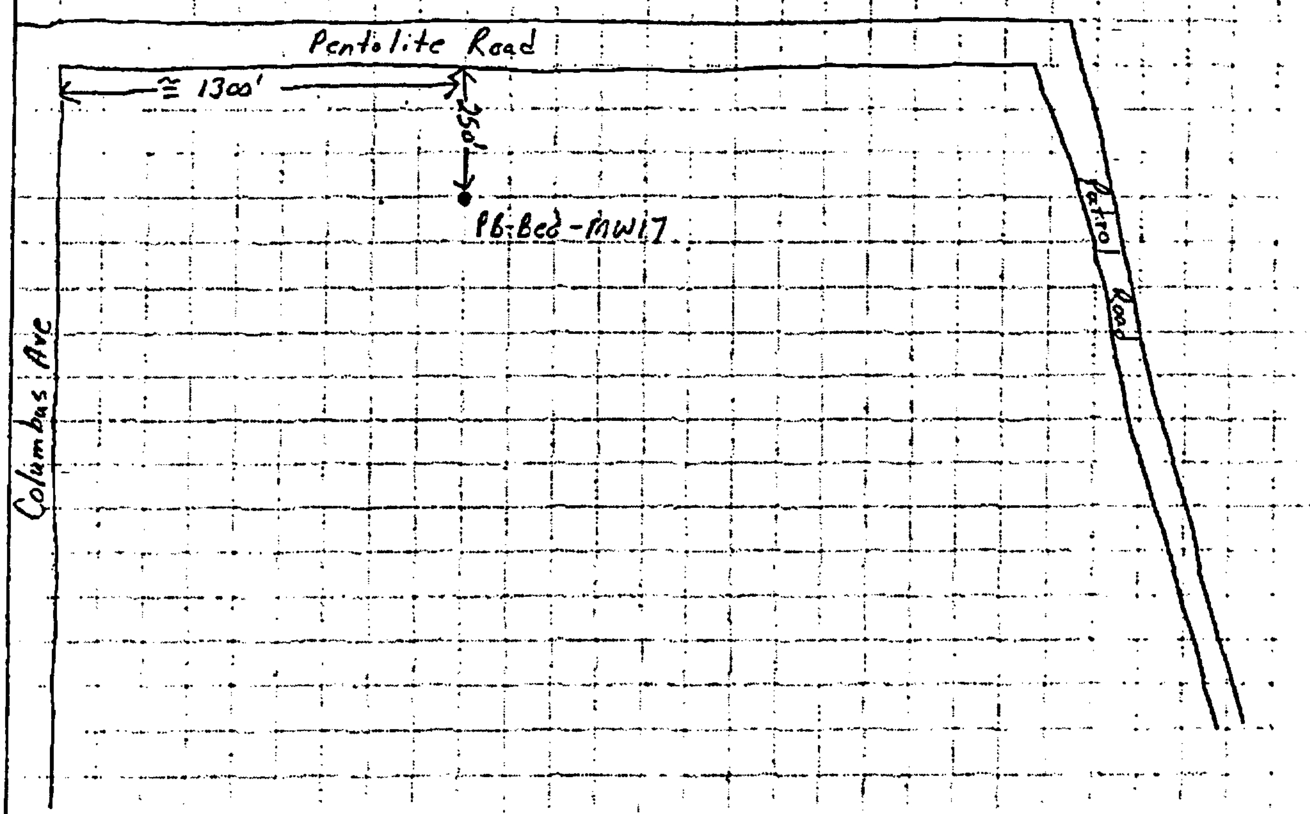
HOLE NUMBER	PB-Bed-MW17
SHEET	1 OF SHEETS
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Al Dudley
6. MANUFACTURER'S DESIGNATION OF DRILL	Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID HSA, 6¼" ID HSA 2' Split Spoons, 6" Roller Cone NX Core Equipment
8. HOLE LOCATION	Pentolite Road
9. SURFACE ELEVATION	
10. DATE STARTED	10-26-94
11. DATE COMPLETED	11-11-94
12. OVERBURDEN THICKNESS	37.3' BGS
15. DEPTH GROUNDWATER ENCOUNTERED	Not encountered until coring commenced ...
13. DEPTH DRILLED INTO ROCK	37.3' BGS - 64.4' BGS
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	28.23' BTOC 15 hrs
14. TOTAL DEPTH OF HOLE	64.4' BGS, 67.0' BTOC
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	26.88' BTOC 11-16-94

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		3

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
–			Explosives			99%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-MW17

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW17
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	of 2 SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	0	Black to Dark Brown Silty Fine Sand - dry roots	HNu 0	3		22" Recovery
				4		
	1			5		
		Grades Brownish Yellow and Gray with trace Clay - dry		7		
	2	Brownish Yellow and Gray Clayey Silt with weathered shale fragments and cemented Sand fragments - dry	HNu 0	5		20" Recovery
				5		
	3			6		
				7		
	4	Grades with Brown, no cemented sand fragments Dry	HNu 0	4		24" Recovery
				6		
	5			10		
				15		
	6		HNu 0	4		24" Recovery
				12		
	7			15		
		Grades with olive gray, dry hard		20		
	8	Gray Silty Clay - dry	HNu 0	3		24" Recovery
				8		
	9			10		
				12		
	10					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW17

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW17

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Same as above - dry	HNu 0	6 10		22" Recovery
	11	Gray thinly laminated highly weathered shale Dry		34 50/4		
	12	Same as above - dry	HNu 0	24 50/3		10" Recovery
	13					Straight Auger
	14					
	15					
	16					
	17					
	18					
	19					
	20					

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW17
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	4 OF 4 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20	Gray weathered shale				Straight Auger
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW17

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-MW17	5 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	30					
	31					
	32					
	33					
	34					
	35					
	36					
	37					Auger Refusal 37.3'
	T: Break T: Break 38	Limestone, medium Dark Gray (N4) to Olive Gray (5Y4/1), finely crystalline, strong, fresh with occasional bivalve fossils Hard	Rec/Core 59/59	74"/Core 51/59 Box 1		Begin Run 1 at 37.3' with NX core barrell on 10-26-94 Natural fracture at 37.75', 37.9', 37.97', 40.0', 40.4' Core 59" Rec 59"
	39					
	40	T: Break				

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW17

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW17

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 6 OF SHEETS

ELEV. (c)	DEPTH (b)	DESCRIPTION OF MATERIALS (d)	FIELD SCREENING RESULTS (e)	GEOTECH SAMPLE OR CORE BOX NO. (f)	ANALYTICAL SAMPLE NO. (g)	REMARKS (h)
	40	Ti Break				
				Box 1		
	41					
	42					End Run 1 at 42.2'
						Begin Run 2 at 42.2' 10-27-94
			35/36	35/36		
	43			Box 1		35min/3ft
						350 lbs/down pressure
						Core 36" Rec 35" Lost 1"
	44					44.9'-44.95' busted up with Hammer
	45					End Run 2 at 45.2' Roller Cone
		Fossiliferous Limestone, medium Dark Gray (N4), strong, Fresh, with numerous stylolites and a petroleum odor. Finely crystalline. Ti Break				Begin Run 3 at 45.3' with NQ core barrell and clear water on 11-11-94
	46					
		T. Break		Box 2		
	47	Ti Break				Core 109" Rec 108.5"
	48					26 min/9.1 ft
		T. Break				
		Weathered Broken up zone + grades to yellowish gray (5Y 7/2)				
	49	Ti Break				
	50					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW17

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW17

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET
OF 7 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	50	30° Weathered Break with mineral decomposition				
	51					
		Ti Break		Box 2		
		Ti Break				
	52					
	53					
	54	Ti Break at stylolite				End Run 3 at 54.4'
						Begin Run 4 at 54.4'
	55					
		Ti Break				Core 120" Rec 120.5"
	56					27.5 min/10 ft
	57					
	58					
	59					
		Ti Break				
	60					

PROJECT: Plum Brook Ordnance Works

HOLE NO.:

HTRW DRILLING LOG

HOLE NUMBER	PROJECT	INSPECTOR	SHEET
PB-Bed-MW17	Plum Brook Ordnance Works		8 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	60			Box 2		
	61	Open Break, Black Stained				
	62			Box 3		Losing core water 30-40 gals
		Ti Break				
	63					
		Ti Break				
	64	Ti Break				End Run 4 at 64.4'
	65					Borehole terminated at 64.4' on 11-12-94
	66					
	67					
	68					
	69					
	70					

PROJECT: Plum Brook Ordnance Works | HOLE NO.

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-mw18

1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services
SHEET 1 OF 1 SHEETS	
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Al Dudley	6. MANUFACTURER'S DESIGNATION OF DRILL: Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼ HSA's, 6¼ HSA's; 2' Split Spoons; NX Core Equipment, 6" Roller Cone	8. HOLE LOCATION: East of TNT Area A
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-24-94 / 11. DATE COMPLETED: 11-2-94
12. OVERBURDEN THICKNESS: 30.8' BGS (Below ground surface)	15. DEPTH GROUNDWATER ENCOUNTERED: 8.5'
13. DEPTH DRILLED INTO ROCK: 30.8' - 75.4' BGS	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 29.87' 24 hrs
14. TOTAL DEPTH OF HOLE: 75.4' BGS, 78.10' BTOC	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 29.69' BTOC 11-16-94

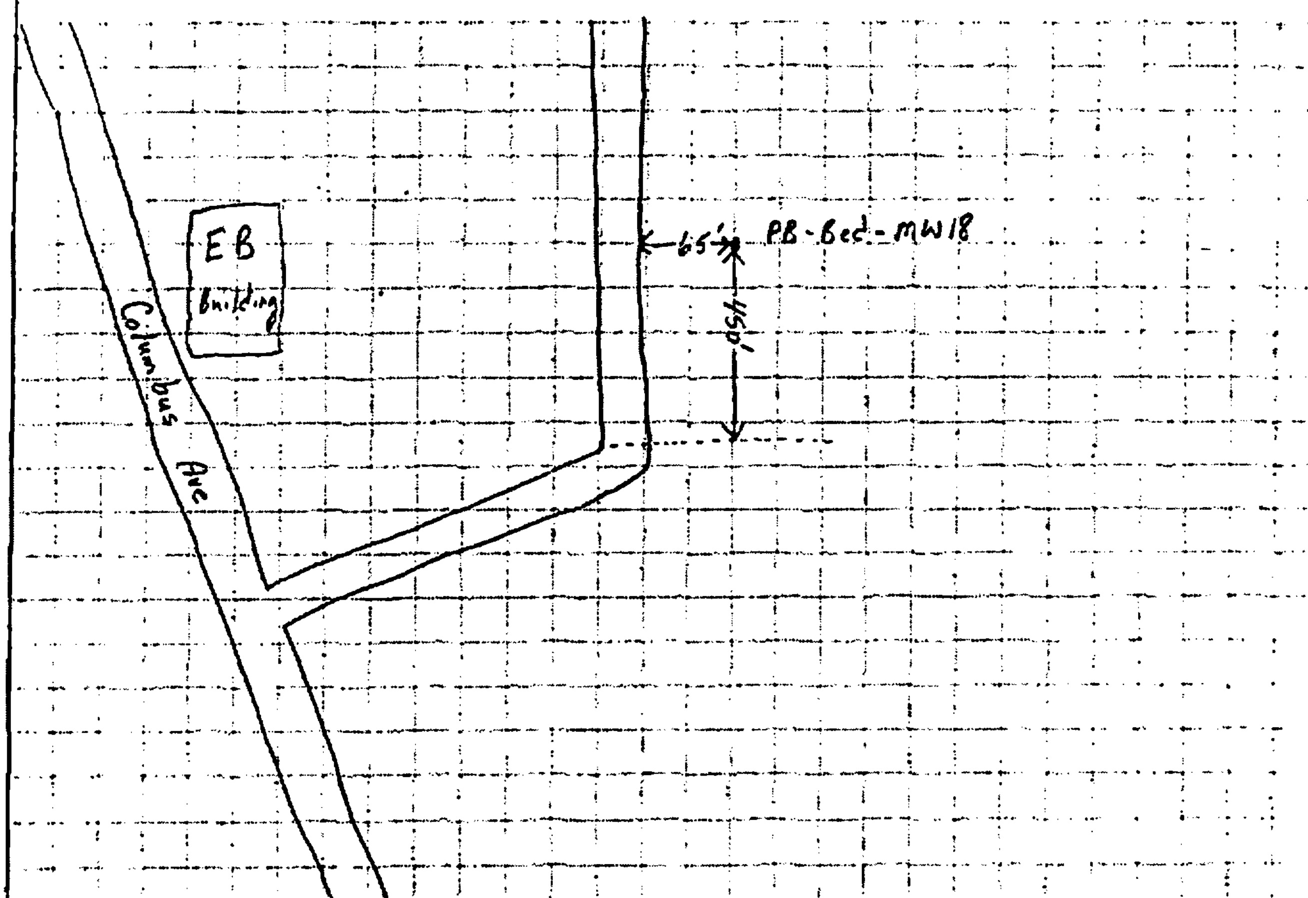
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
-			Explosives			84%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charlie Way

LOCATION SKETCH/COMMENTS

SCALE:



PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-mw18

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW18

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 2 OF 2 SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	0	Dark Brown Silty Fine Sand	HNu	1		20" Recovery
		Grades to Brownish Yellow	0	3		
	1			4		
		Grades back to Dark Brown with gravels		8		
	2	Dry	HNu 0	5		24" Recovery
				6		
	3	Grades brownish Yellow		5		
				5		
	4		HNu	3		20" Recovery
		Mottled Brown, Brownish Yellow and Gray Silty Sandy Clay with gravels - Dry	0	5		
	5			4		
				6		
	6		HNu 0	3		24" Recovery
				5		
	7	Grades to Brownish Yellow and Gray Silty Clay - Dry		7		
				12		
	8		HNu	4		20" Recovery
		Gray Gravelly Clay - weathered rock fragments - wet	0	22		
	9			37		
				50/5		
	10					

PROJECT: Plum Brook Ordnance Works | HOLE NO.: PB-Bed-MW18

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW18

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Weathered shale in shoe wet		23		1" Recovery
				39		
	11			39		
				50/4		
	12	Layered weathered shale + clay Hard Augering				Straight Auger
	13					
	14					
	15					
	16					
	17					
	18					
	19	Weathered shale becomes dry				
	20					

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW-18
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	4 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	20	Weathered Shale dry				Straight Auger
	21					
	22					
	23					
	24					
	25					
	26					
	27					
	28					
	29					
	30					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW18

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW18

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 5 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	30					
	31	Shale, medium Dark Gray (N4) to dark gray (N3), highly weathered, slightly calcareous	Rec/core 55"/58"	74"/core 29"/58"		Begin Run 1 at 30.8' with NX core barrell on 10-24-94 17.75 min/5ft
	32					250 lbs downpressure
	33					Core 58" Rec 55" Lost 3"
	34			Box 1		
	35					End Run 1 at 35.7' Begin Run 2 at 35.7'
	36		62"/60"	55/60		
	37					18.5 min/5ft 250 lbs/down pressure
	38					Core 60" Rec 62" Gain 2"
	39					
	40					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW18

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW18

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET 6 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	40			Box 1		End Run 2 at 40.7'
						Begin Run 3 at 40.7'
	41		50.5/60	50.5/60		18.5 min/5ft 250 lb down pressure
	42					Core 60" Rec 50.5" Lost 9.5"
	43					
	44			Box 2		
	45					End Run 3 at 45.7'
						Begin Run 4 at 45.7'
	46		64/60	60/60		24 min/5ft 250 lb down pressure
	47					Core 60" Rec 64" Gain 4"
	48					
	49					
	50					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW18

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET OF 7 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	50			Box 2		End Run 4 at 50.7'
	51					Roller cone set 4" PVC casing to 51.0'
	52	Same as above	40/45	20/45		Begin Run 5 at 51.7' with NX core barrell on 11-1-94
	53			Box 3		Core 45" Rec 40" Lost 5"
	54					
	55					End Run 5 at 55.4' Begin Run 6 at 55.4'
	56					Low recovery in this weathered shale would suggest that rock was blocking bit causing rock to be ground up rather than going into barrel
	57		51/120	0/120		
	58					Core 120" Rec 51" Lost 69"
	59					
	60					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW18

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER	SHEET
Plum Brook Ordnance Works		PB-Bed-MW18	8 OF SHEETS

ELEV.	DEPTH	DESCRIPTION OF MATERIALS	FIELD SCREENING RESULTS	GEOTECH SAMPLE OR CORE BOX NO.	ANALYTICAL SAMPLE NO.	REMARKS
	60					
	61					
	62					
	63			Box 3		
	64					
	65					End Run 6 at 65.4' / Begin Run 7 at 65.4'
	66	65.9' becomes fresh to slightly weathered with pyrite present in small quantities a few bivalves present				
	67		114/120	95/120		38 min/10 ft; Left 6" in borehole
	68			Box 4		Core 120"; Rec 114"; Lost 6"
	69	68.5 Shaley Limestone, medium Dark Gray (N4) to Dark Gray (N3), finely crystalline, fresh to slightly weathered with bivalve fossils and small amounts of pyrite				
	70					

HTRW DRILLING LOG

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works		9 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	70					
	71					
	72			Box 4		
	73					
	74					
	75					End Run 7 at 75.4'
						Boring terminated at 75.4' on 11-2-94 Install 30' screen in borehole with riser to insure hole does not collapse.
	76					
	77					
	78					
	79					
	80					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW18

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW19
1. COMPANY NAME	Dames & Moore
2. DRILLING SUBCONTRACTOR	Belasco Drilling Services
SHEET	1 OF 1 SHEETS
3. PROJECT	Plum Brook Ordnance Works
4. LOCATION	Sandusky, Ohio
5. NAME OF DRILLER	Al Dudley
6. MANUFACTURER'S DESIGNATION OF DRILL	Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID HSA, 6¼" ID HSA, 2' Split Spoons, 6" Roller Cone, NQ Core Equipment
8. HOLE LOCATION	North of West Area Ponds
9. SURFACE ELEVATION	
10. DATE STARTED	11-8-94
11. DATE COMPLETED	11-13-94
12. OVERBURDEN THICKNESS	19.1'
15. DEPTH GROUNDWATER ENCOUNTERED	Not encountered until coring commenced
13. DEPTH DRILLED INTO ROCK	19.1' BGS – 49.5' BGS
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	22.56' BTOC 15 hrs
14. TOTAL DEPTH OF HOLE	49.5' BGS, 52.2' BTOC
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	22.25' BTOC 11-16-94

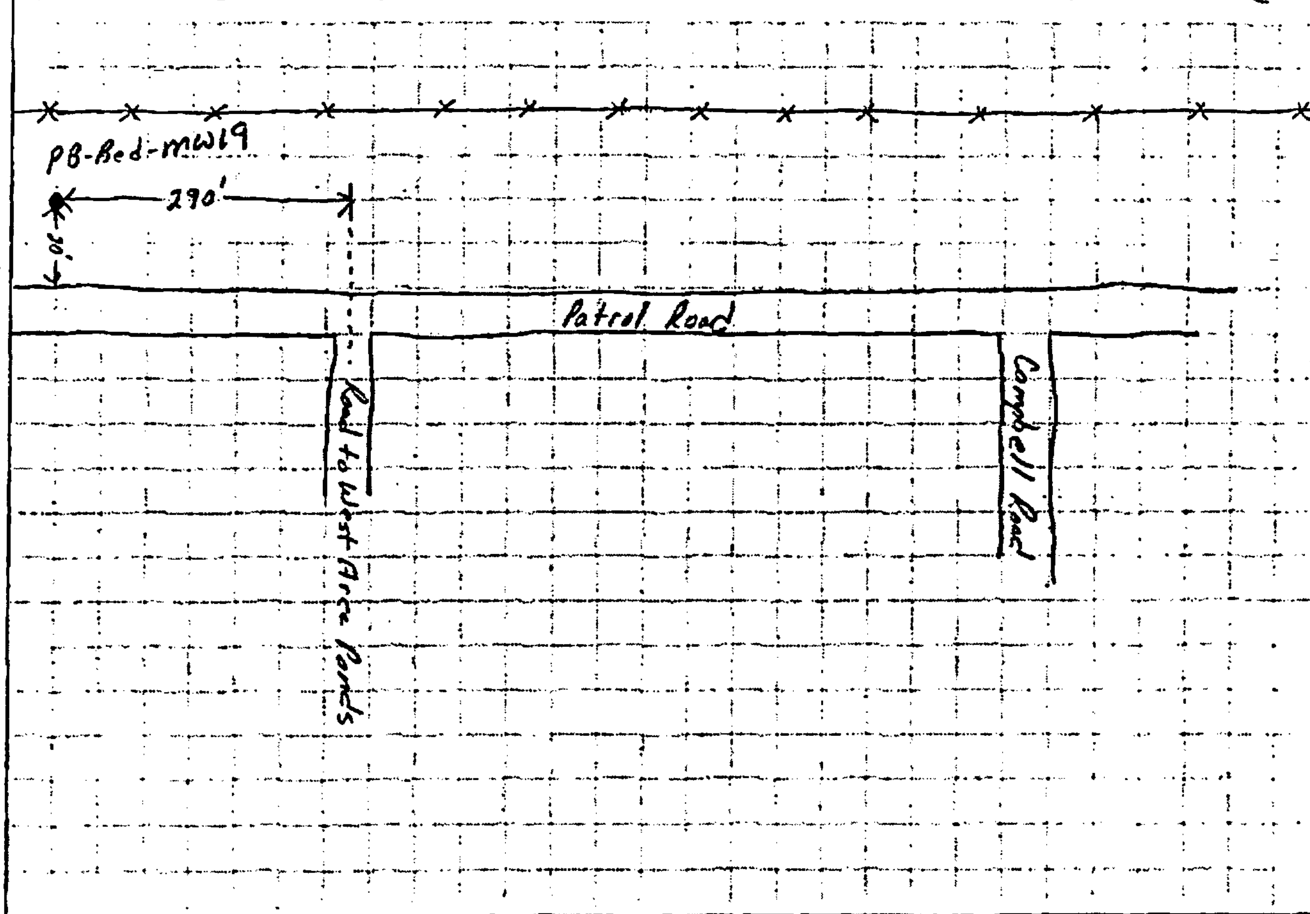
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		3

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			100%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS

SCALE: Not to scale



PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-MW19

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW19

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 2 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Dark Brownish Black Silty Fine Sand with roots	HNu 0	2, 3		24" Recovery
	1	Grades to Brownish Yellow		4, 6		
	2		HNu 0	3, 3		20" Recovery
	3	Brownish Yellow and Gray Clayy Silt		5, 6		
	4	Same as above	HNu 0	3, 4		20" Recovery
	5			7, 7		
	6	Grades mainly Brownish Yellow, some gray moist	HNu 0	2, 4		24" Recovery
	7			5, 7		
	8		HNu 0	3, 3		24" Recovery
	9	Gray Silty Clay-moist		4, 4		
	10					

PROJECT: Plum Brook Ordnance Works | HOLE NO. PB-Bed-MW19

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW19

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10	Same as above - moist	HNu 0	1 2 2 4		24" Recovery
	11					
	12	Same as above - moist Slight plasticity	HNu 0	2 2 2 3		24" Recovery
	13					
	14	Same as above with a few small fragments of weathered shale	HNu 0	1 1 2 2		24" Recovery
	15					
	16	Same with small fragments of weathered shale	HNu 0	1 2 2 4		24" Recovery
	17					
	18	Same as above	HNu 0	1 10		10" Recovery
	19	Weathered shale				Auger Refusal at 19.1'
		Limestone, medium Dark Gray (N4), finely crystalline, strong, fresh with occasional fossils		50/0 Box 1		Begin Run 1 at 19.1'
	20					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW19

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER / SHEET
Plum Brook Ordnance Works		PB-Bed-MW19 — Sheet 4 of __ sheets

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20					
		Open Break	Rec / Core	74" / Core		
	21					
	22					30 min/10 ft
		Grades to Fossiliferous limestone medium Dark Gray (N4), strong, fresh, with zones of weathered shale, Dark Gray (N3)	120" / 120"	106" / 120"		Core 120" Rec 120"
	23					
	24					Lost all return water
		Open Break				
	25					
		~~Open Break~~				
		Weathered shale – T Break				
	26	Fossiliferous limestone				
		Weathered shale Highly Broken up ↓				
	27	Fossiliferous limestone				
		Weathered shale with pyrite flakes				
		Fossiliferous limestone				
	28	Open Break				
	29					End Run 1 at 29.1'
						Roller cone ↓
	30					

HTRW DRILLING LOG

PROJECT	INSPECTOR	SHEET
Plum Brook Ordnance Works		OF 5 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	30					Roller cone
	30.5			Box 1		Begin Run 2 at 30.5' core 15" Rec 15"
	31.5	T. Break				End Run 2 at 31.75
	32					Roller cone set 4" PVC casing to 32.0'
	32.5	Fossiliferous limestone, medium Dark Gray (N4), finely crystalline, strong, Fresh, with numerous stylolites; T. Break				Begin Run 3 at 32.4' on 11-13-94 with NQ core barrell and clear H_2O
	33.5	Open Break				Core 86" Rec 86"
	34.5	Open Break				
	35.5					19 min/7.1 ft
	36	T. Break - Black stained		Box 2		
	37	T. Break				
	38	Open Break - Black stained				
	39	T. Break				End Run 3 at 39.5'
	39.5					Begin Run 4 at 39.5'
	40					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW19

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW19

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 6 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40					
	41					Core 120" Rec 120"
	42	Ti Break		Box 2		
	43	Ti Break				34 min/10 ft
	44	Ti Break				
	45	Open Break				
	46					
	47			Box 3		
	48	Ti Break				H_2S odor after Run 4 completed, borehole bubbling
	49	Ti Break				End Run 4 at 49.5'
						Borehole Terminated at 49.5' on 11-13-94. Set 25' screen remainder riser
	50					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW19

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW20

SHEET 1 OF 1 SHEETS

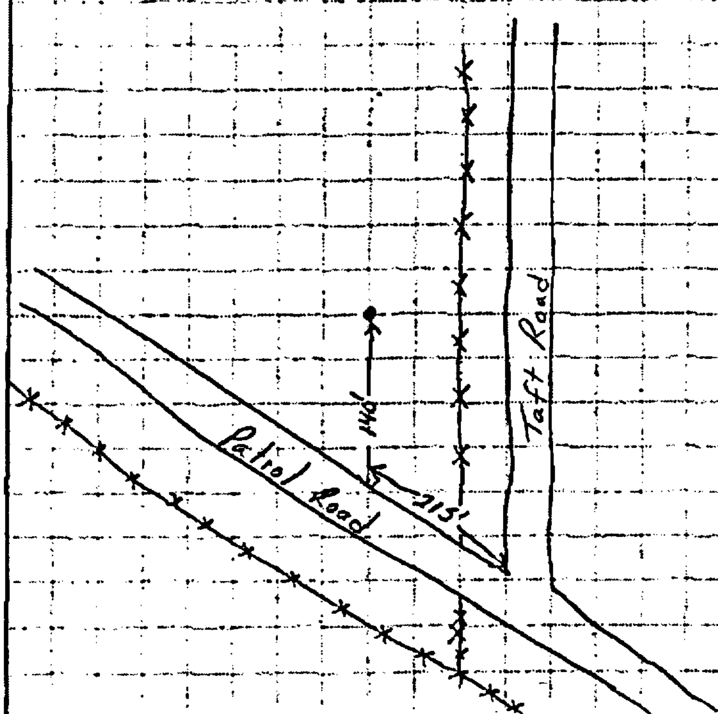
1. COMPANY NAME: Dames & Moore	2. DRILLING SUBCONTRACTOR: Belasco Drilling Services
3. PROJECT: Plum Brook Ordnance Works	4. LOCATION: Sandusky, Ohio
5. NAME OF DRILLER: Al Dudley	6. MANUFACTURER'S DESIGNATION OF DRILL: Diedrich D-120
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID HSA, 6¼" ID HSA; 2' Split spoons, 6" Roller cone; NX core equipment	8. HOLE LOCATION: South Patrol Road - Background
	9. SURFACE ELEVATION:
	10. DATE STARTED: 10-28-94 / 11. DATE COMPLETED: 11-13-94
12. OVERBURDEN THICKNESS: 21.5'	15. DEPTH GROUNDWATER ENCOUNTERED: Not encountered until coring commenced
13. DEPTH DRILLED INTO ROCK: 21.5' BGS - 49.5' BGS	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 17.17' BTOC 24 hrs
14. TOTAL DEPTH OF HOLE: 49.5' BGS, 52.3' BTOC	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 18.69' BTOC 11-16-94

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
None	---		

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
			Explosives			93%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Charles Way

LOCATION SKETCH/COMMENTS SCALE:



PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW20

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-MW20

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 2 OF 2 SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	0	Brownish Yellow and Gray Silty Clay with trace fine sand and roots. - dry	HNu 0	3 5 8 12		20" recovery
	1					
	2	Brownish Yellow and Tanish Gray Silty Fine Sand with trace clay	HNu 0	4 7 10 14		22" Recovery
	3					
	4		HNu 0	6 8 6 9		24" Recovery
	5	Grades Yellow Brown and Gray - moist, without clay				
	6			22 50/2		
		Blackish Gray weathered shale				Straight Auger
	7					
	8					
	9					
	10					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW20

HTRW DRILLING LOG

PROJECT	INSPECTOR	HOLE NUMBER / SHEET
Plum Brook Ordnance Works		PB-Bed-MW20 / SHEET 3 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	10.0'	Grades to Gray weathed shale				Straight Auger
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-mW20

PROJECT: Plum Brook Ordnance Works | INSPECTOR: | SHEET 4 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	20					
	21					Auger Refusal at 21.5'
	21.5–25'10"	Shale, Dark Gray (N3) slightly weathered to Fresh non calcareous, with occasional zones of shale, Dark greenish gray (5GY 4/1) intermixed. Breaks to numerous to put of log	Rec/Core 16/52"	74"/core 0/52" Box 1		Begin Run 1 at 21.5' Core 52" Rec 16" Lost 36" End Run 1 at 25'10"
	25'10"–30	Same as above. Breaks to numerous to put on Log. Becomes weathered	88"/58	71/58 Box 1		Begin Run 2 at 25'10" 30" from core Run 1 Core 58" Rec 88" Gain 30"
	30					

PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW20

HTRW DRILLING LOG

HOLE NUMBER	PB-Bed-MW20
PROJECT	Plum Brook Ordnance Works
INSPECTOR	
SHEET	5 OF SHEETS

ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	30					
		Becomes Fresh		Box 1		End Run 2 at 30.7'
		Same as above, with zones of pyrite deposition				Begin Run 3 at 30.7'
	31		51/57	51/57		Left 6" in hole
	32	Ti Break				Core 57" Rec 51" Lost 6"
	33	Ti Break		Box 2		
	34	Ti Break				
	35	Ti Break				Set 4" PVC casing to 35.0' End Run 3 at 35.5'
						Roller Cone ↓
	36	Ti Break Shale, Dark Gray (N3), non calcareous, strong, Fresh with occasional zones of Shale, Dark greenish gray (5GY 4/1) intermixed				Begin Run 4 at 36.0' on 11-13-94 with NQ core barrel and clear water
	37					Core 102" Rec 84" Lost 18"
	38	38.25-38.3 Pyrite deposition				31 min/8.5'
	39					
	40					

PROJECT	HOLE NO.
Plum Brook Ordnance Works	PB-Bed-MW20

HTRW DRILLING LOG

HOLE NUMBER: PB-Bed-mw20

PROJECT: Plum Brook Ordnance Works

INSPECTOR:

SHEET ___ OF 6 SHEETS

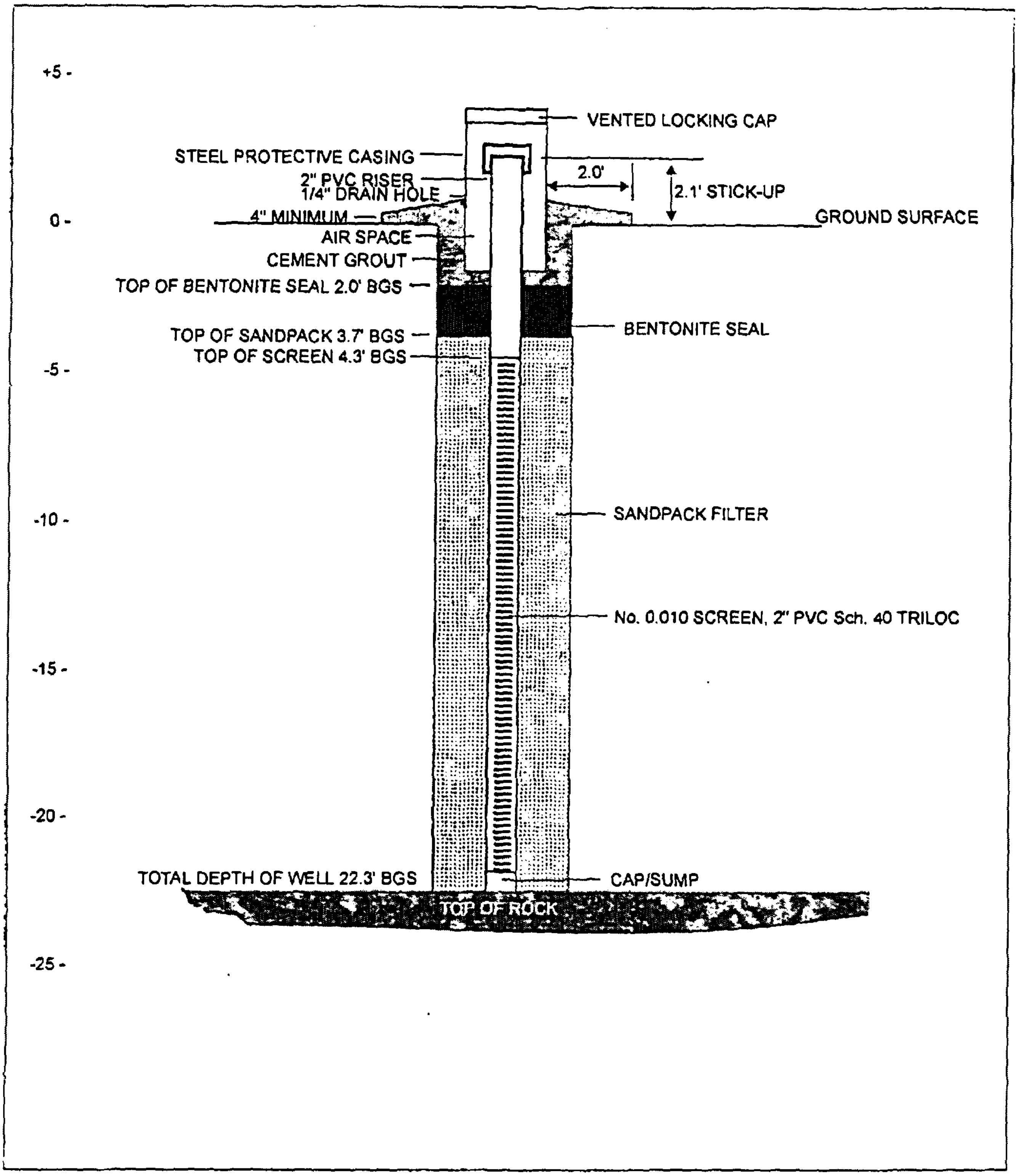
ELEV. (a)	DEPTH (b)	DESCRIPTION OF MATERIALS (c)	FIELD SCREENING RESULTS (d)	GEOTECH SAMPLE OR CORE BOX NO. (e)	ANALYTICAL SAMPLE NO. (f)	REMARKS (g)
	40					
	41					
		Thin pyrite zone				
	42					
	43	T: Break Becomes fissile, slightly weathered				
						Loss of 20-30 gals water
	44					
		Open Break				End Run 4 at 44.5'
						Begin Run 5 at 44.5'
	45					
	46					Core 60" Rec 67" Gain 7"
						22.5 min/5 ft
	47					measure H_2O at 26.42' at 11:30, take lunch, at 12:40 H_2O at 27.28'
		Open Break, black stained				Can hear bubbling in well
	48					
						Left 1' of core in borehole making Total depth 48.6'
	49					Install 20' screen, rest riser. 2.75' stickup
						End Run 5 at 49.5'
	50					

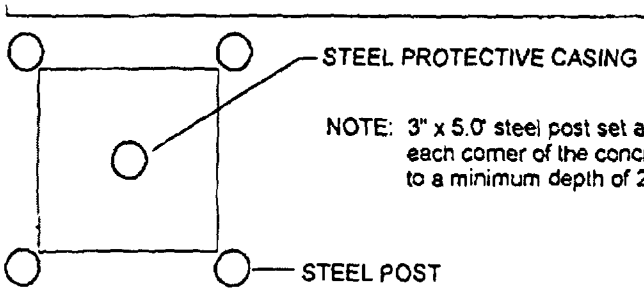
PROJECT: Plum Brook Ordnance Works

HOLE NO.: PB-Bed-MW20

APPENDIX C

MONITORING WELL CONSTRUCTION DIAGRAMS



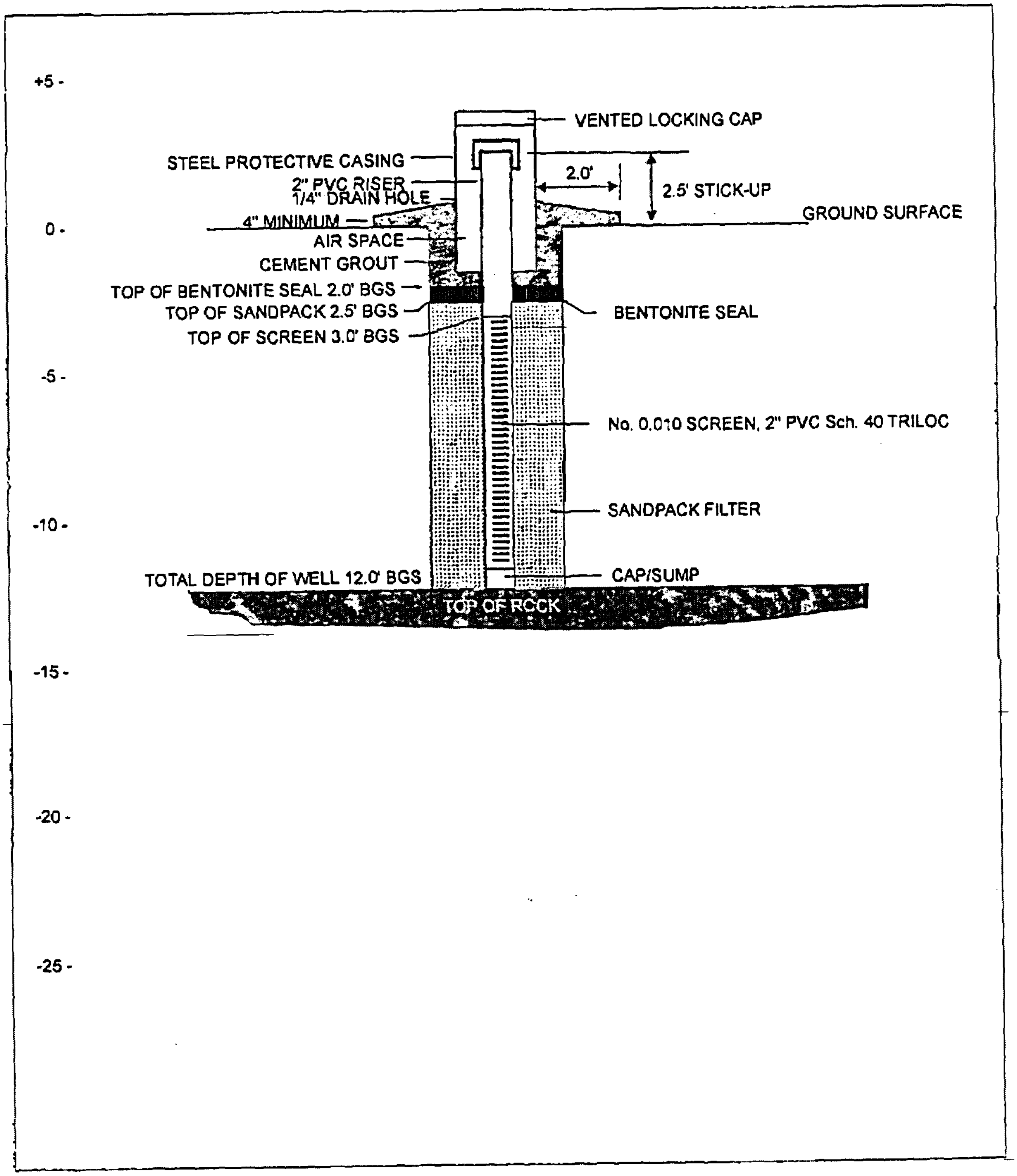


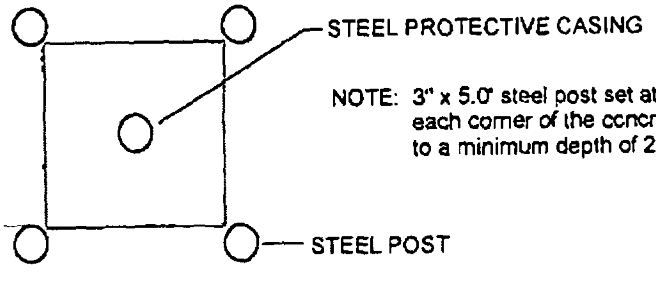
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-WA-MW1
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



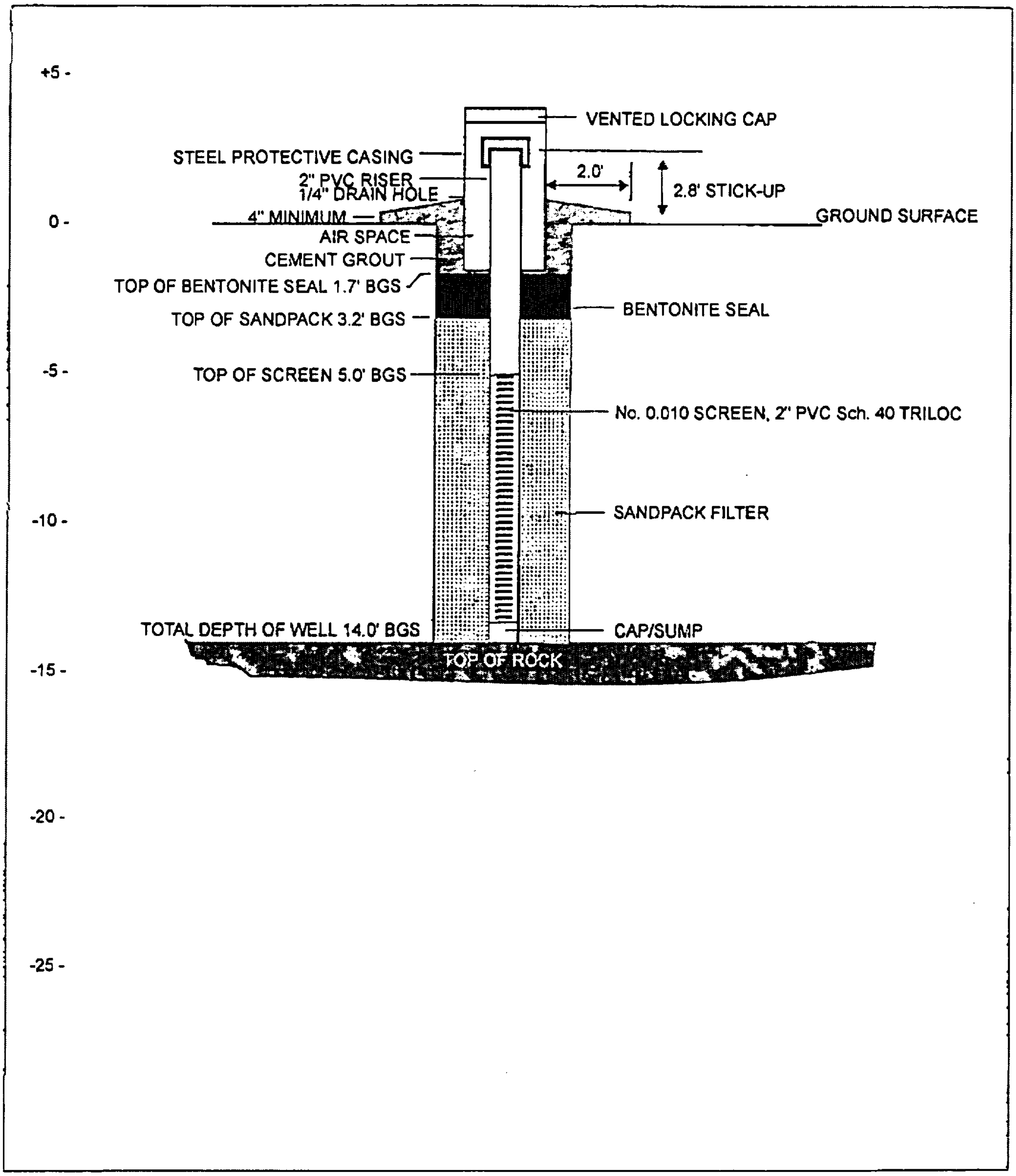


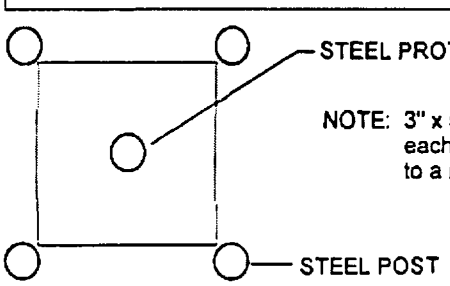
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-WA-MW2
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



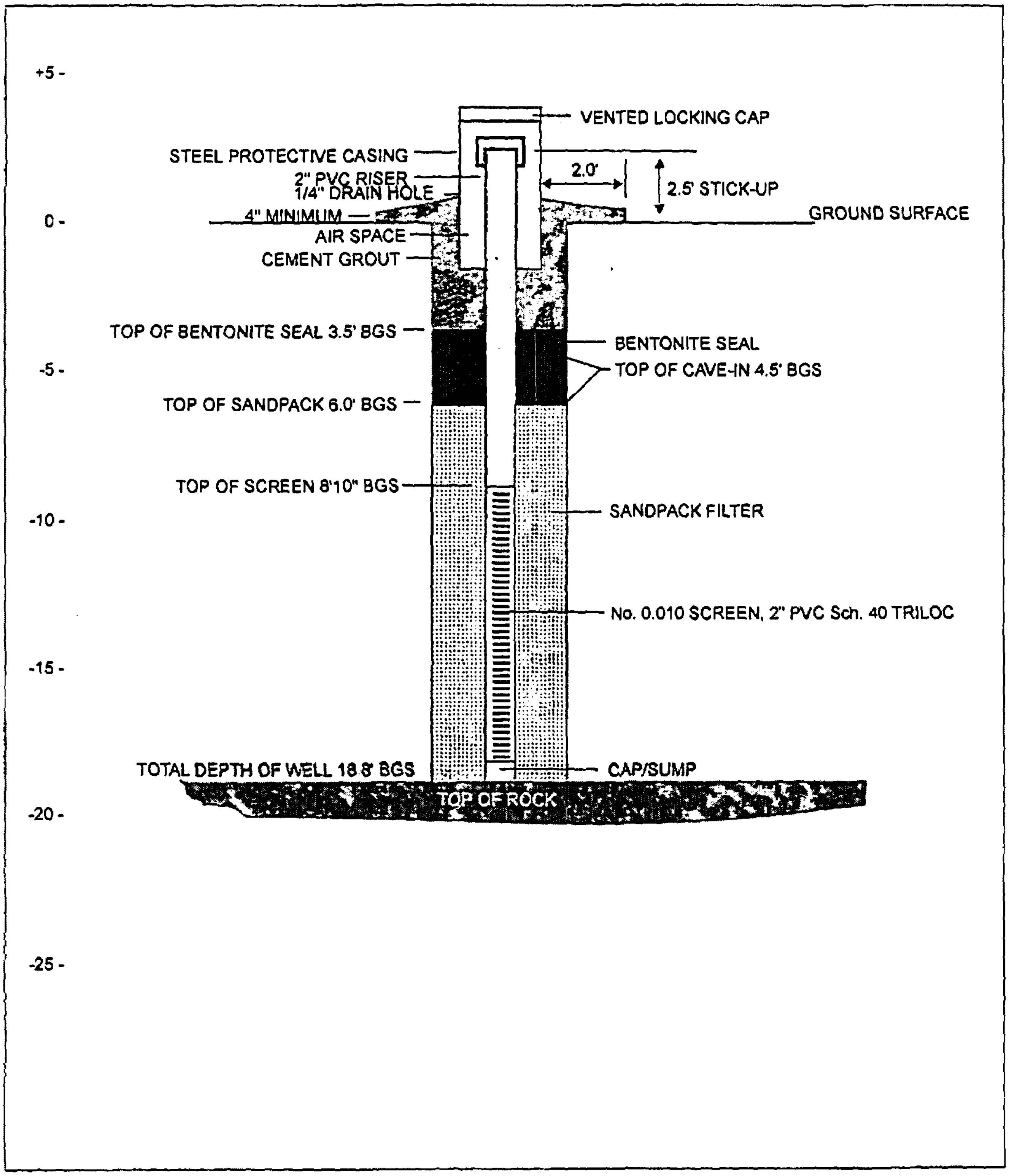


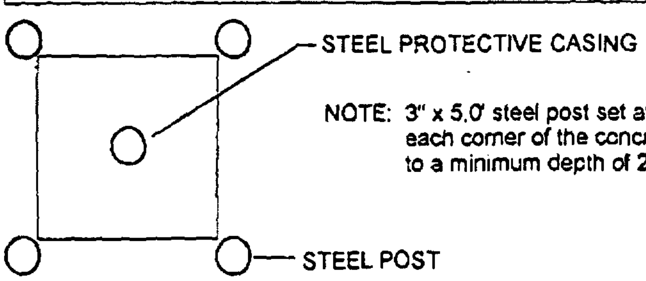
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

TNTC-MW3
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



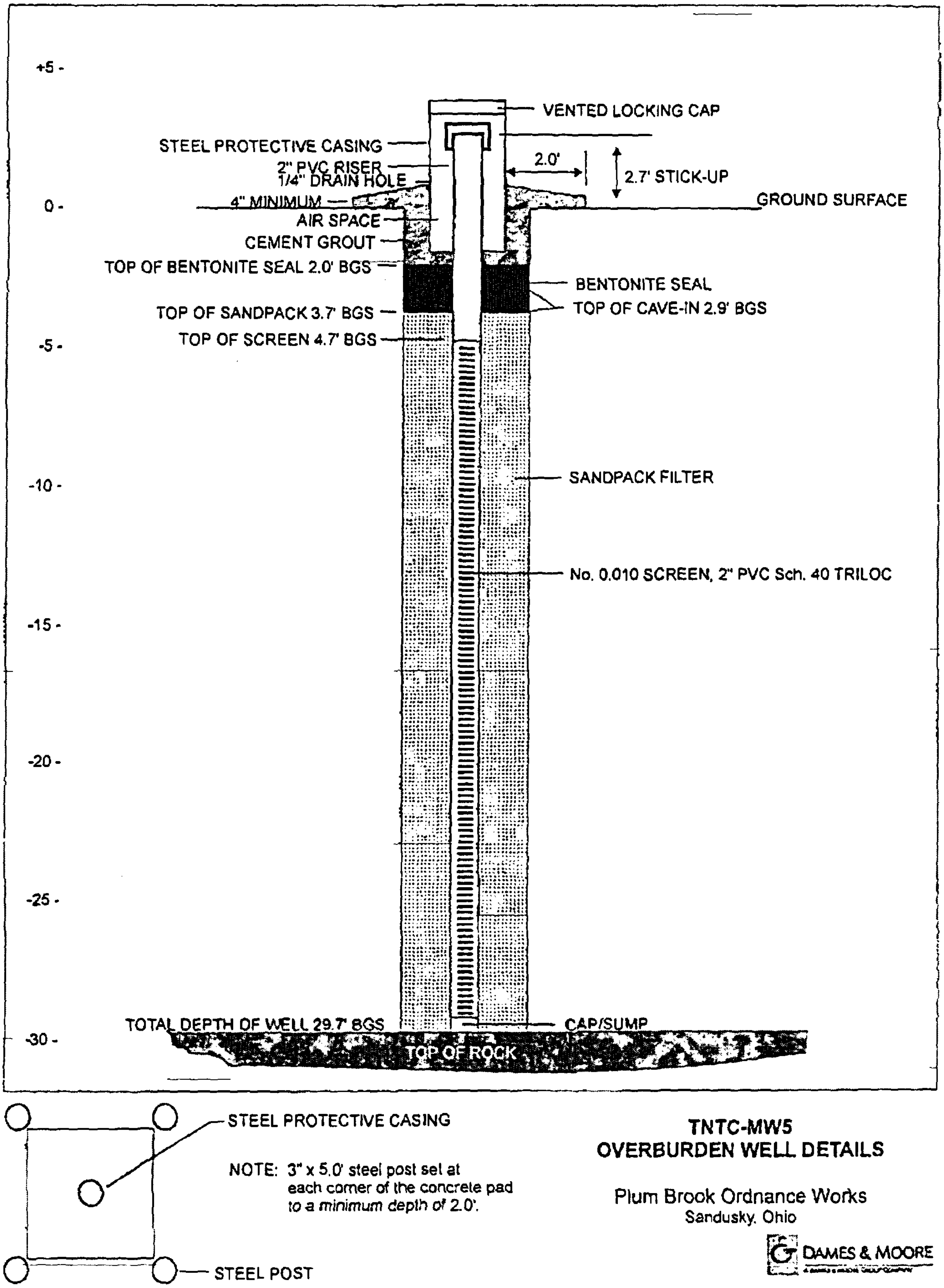


NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

TNTC-MW4
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

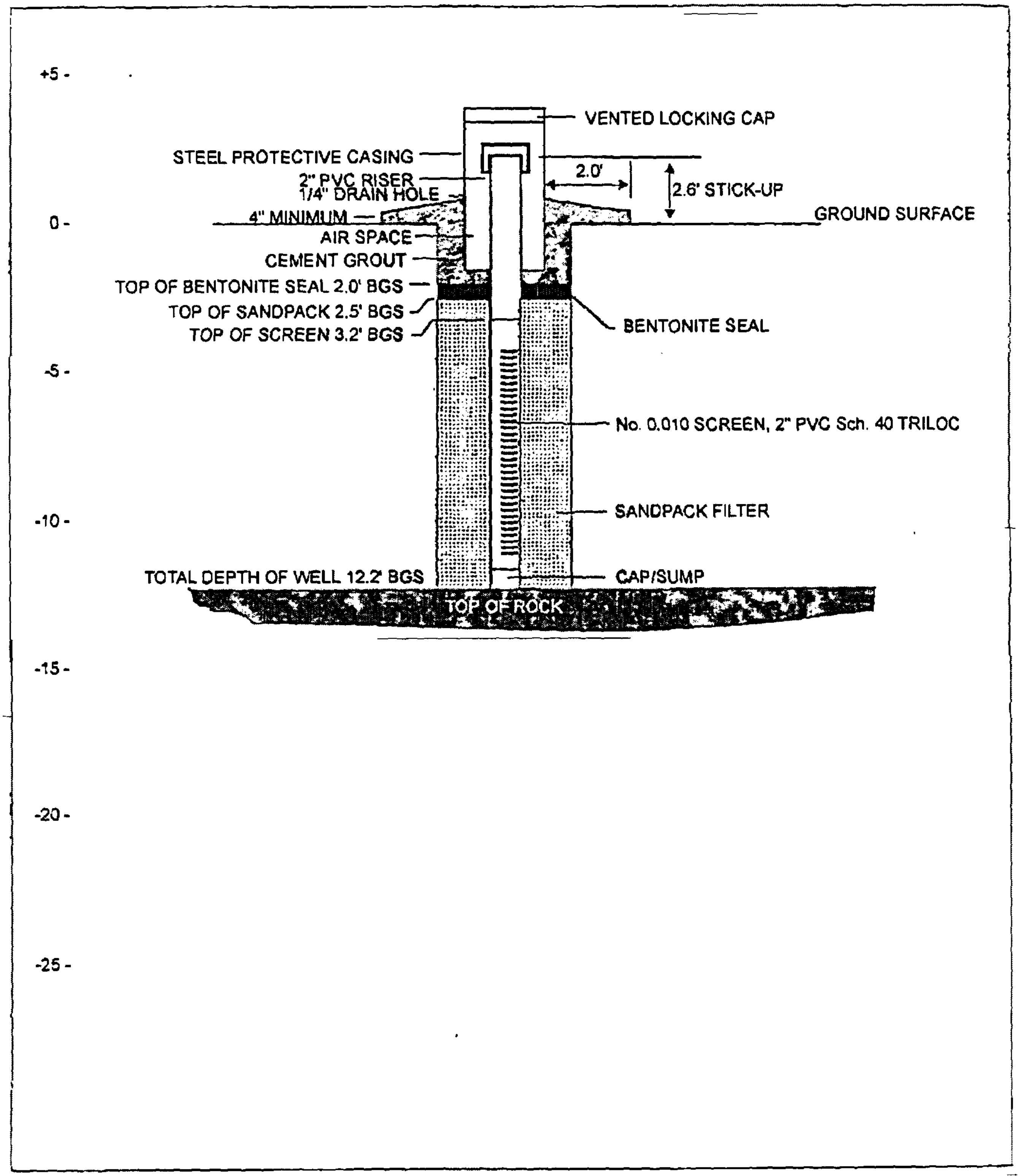
DAMES & MOORE

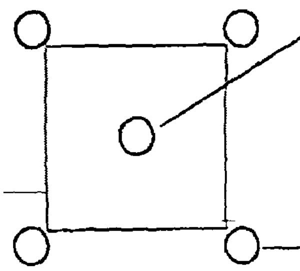


TNTC-MW5
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



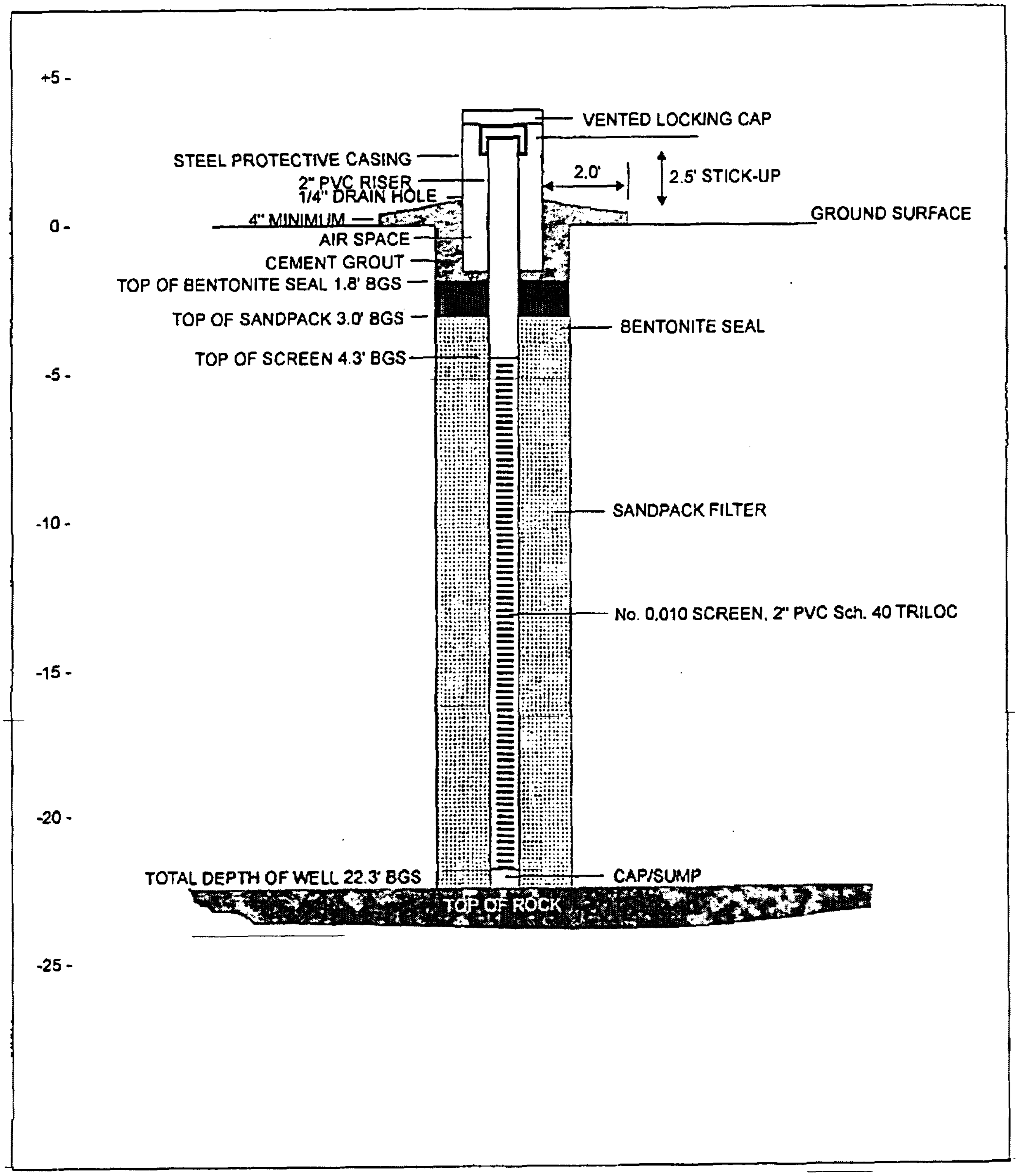


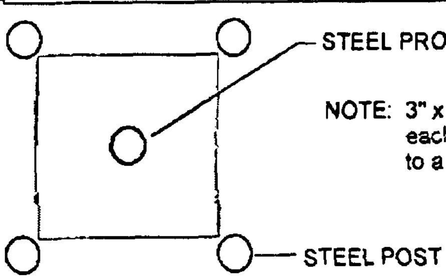
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

TNTC-MW6
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



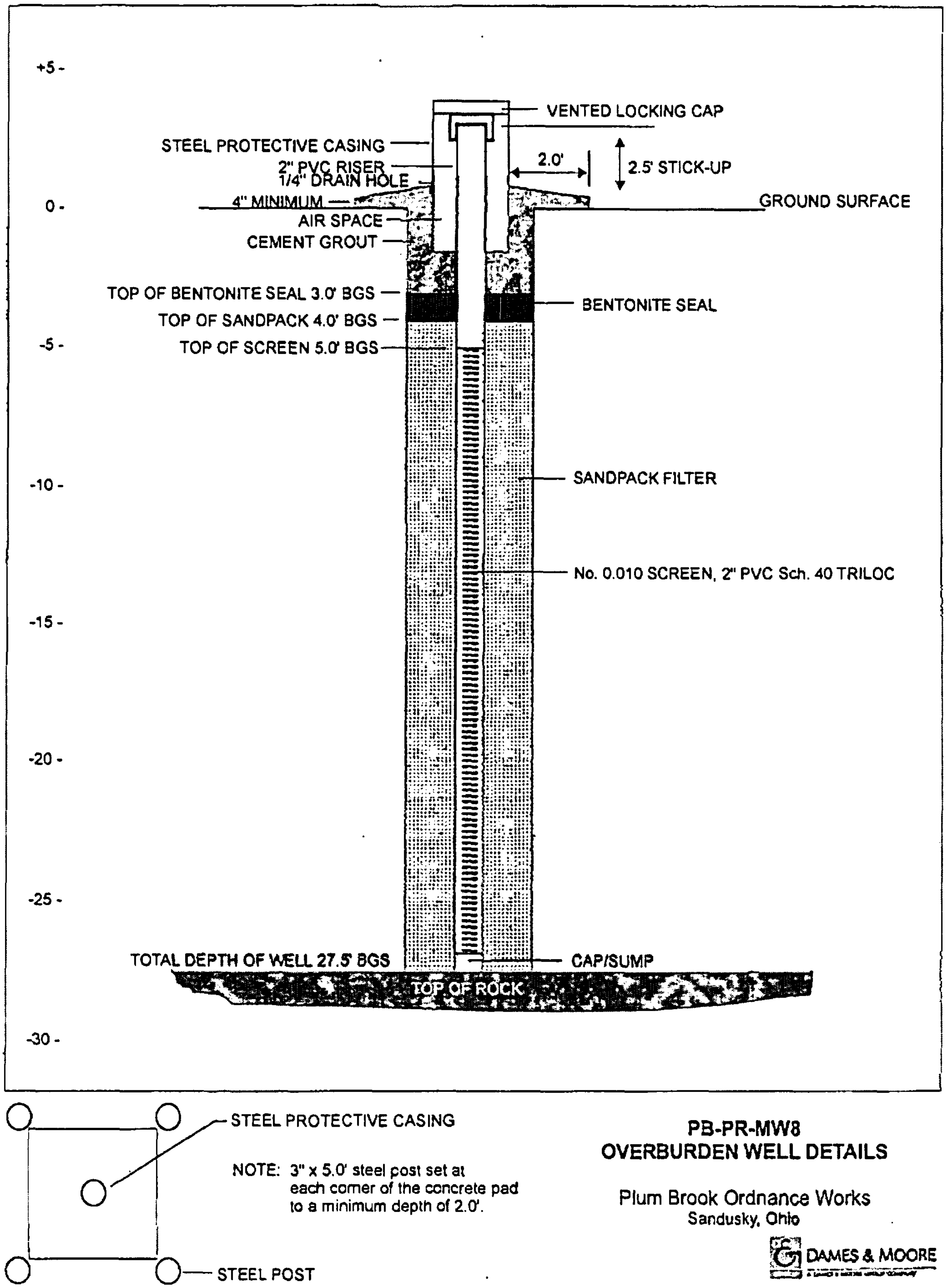


NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-PR-MW7
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE

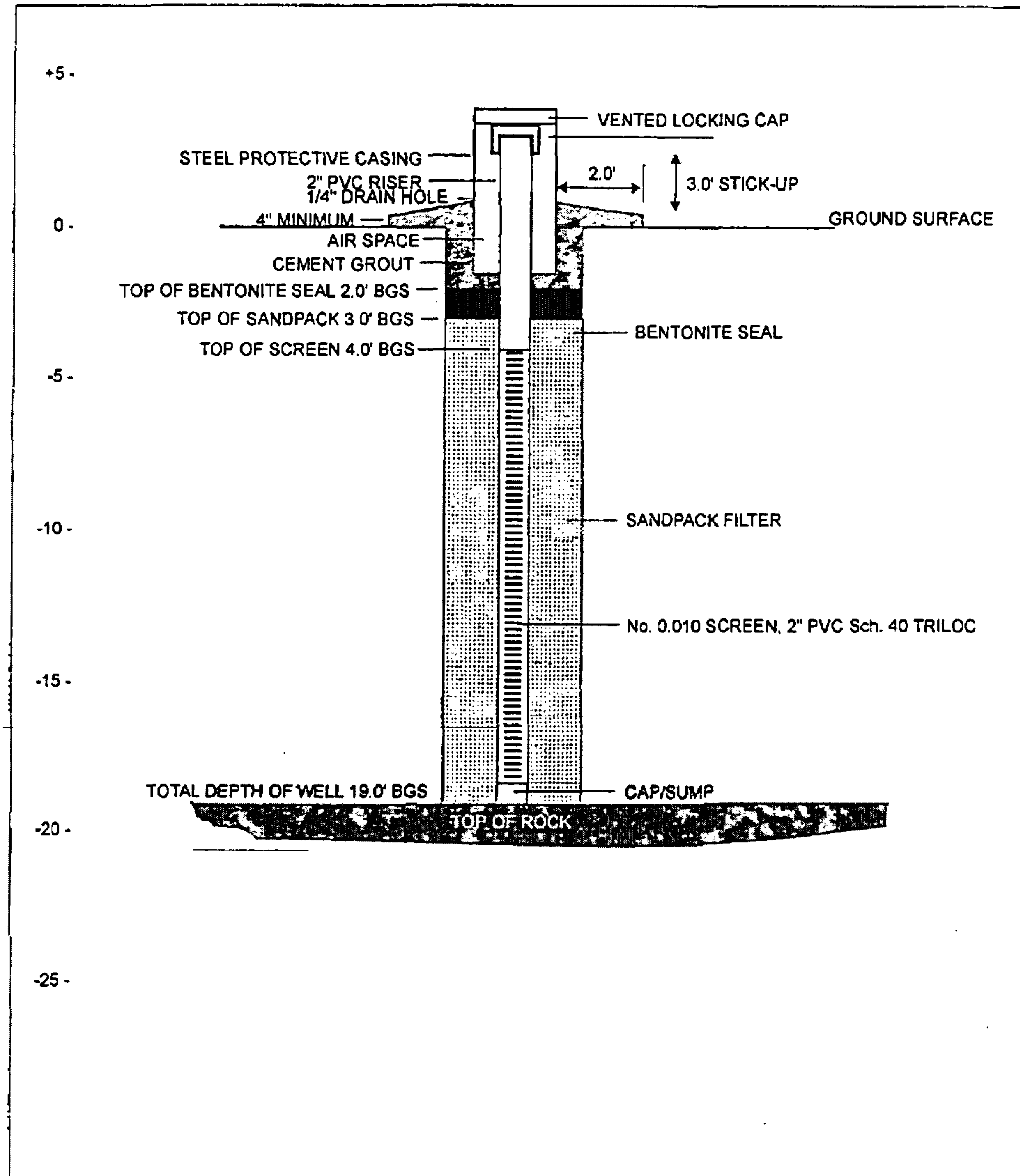


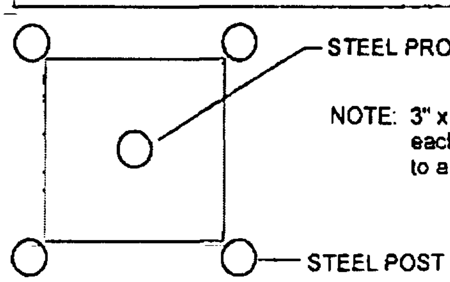
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-PR-MW8
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



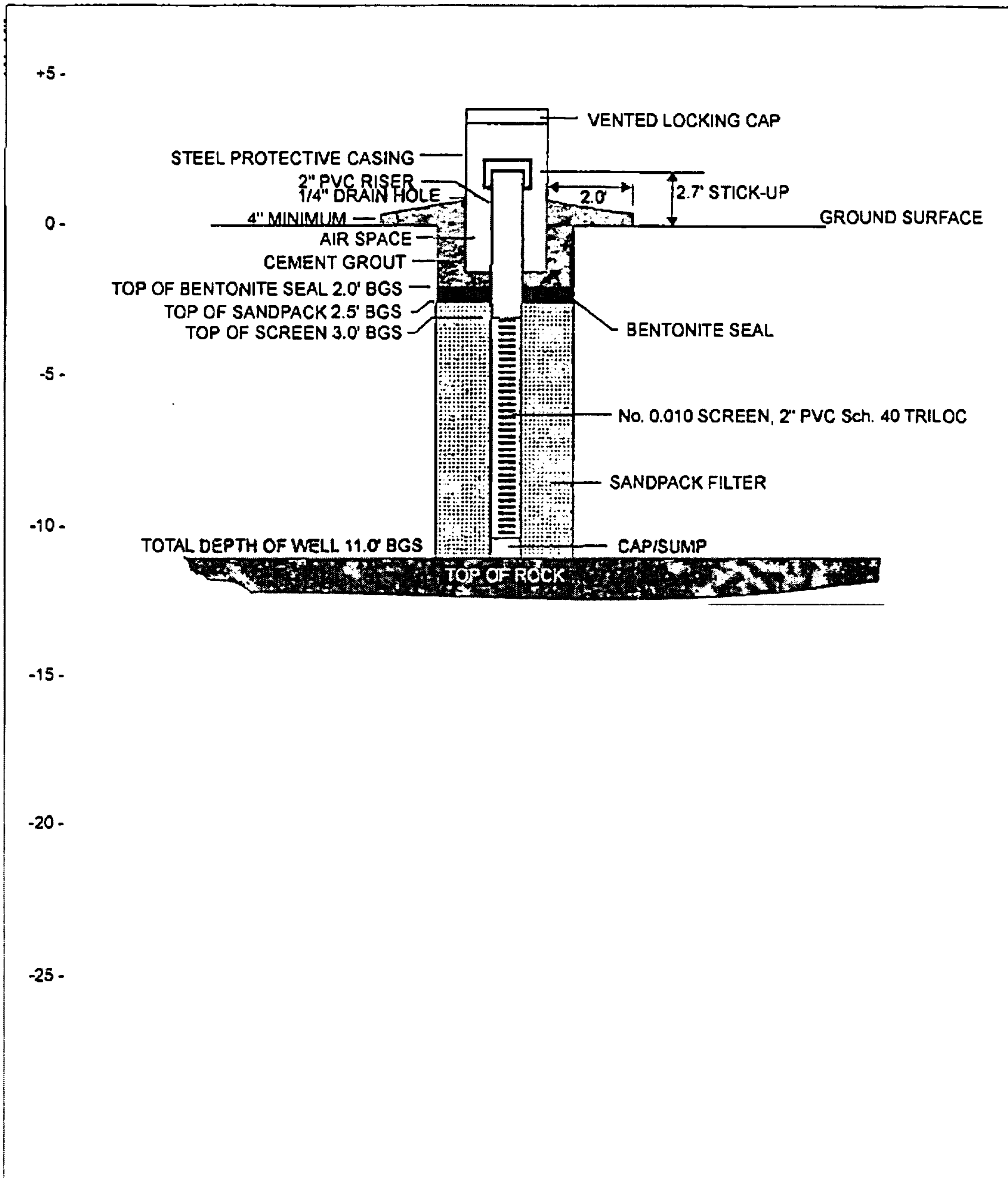


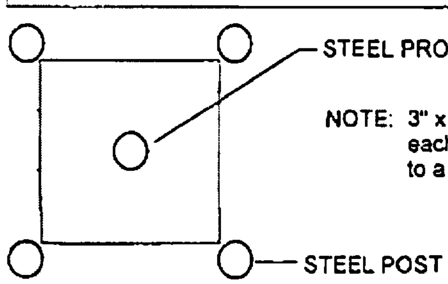
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-PR-MW9
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



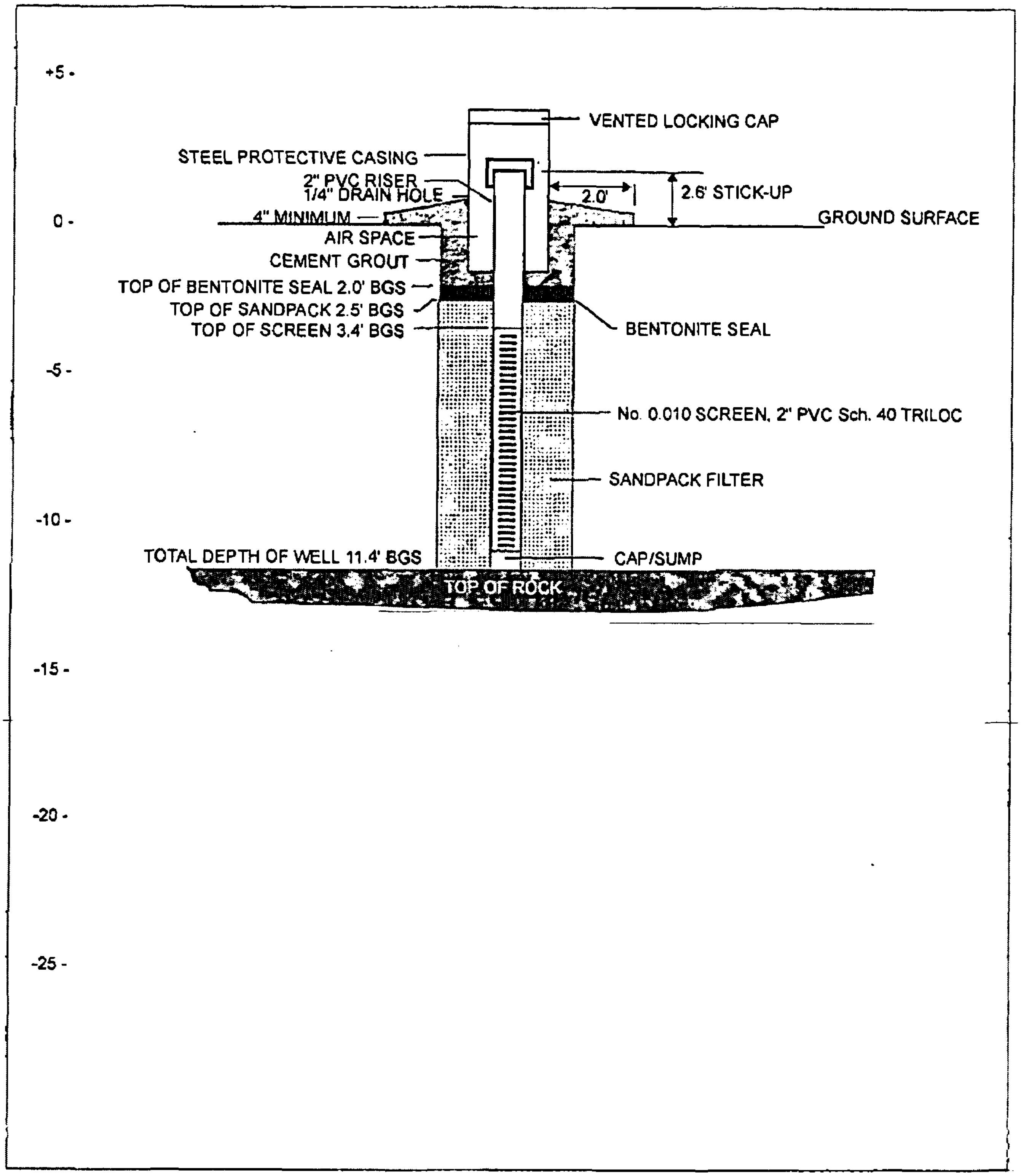


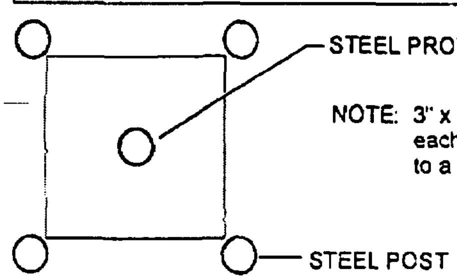
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

TNTA-MW10
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



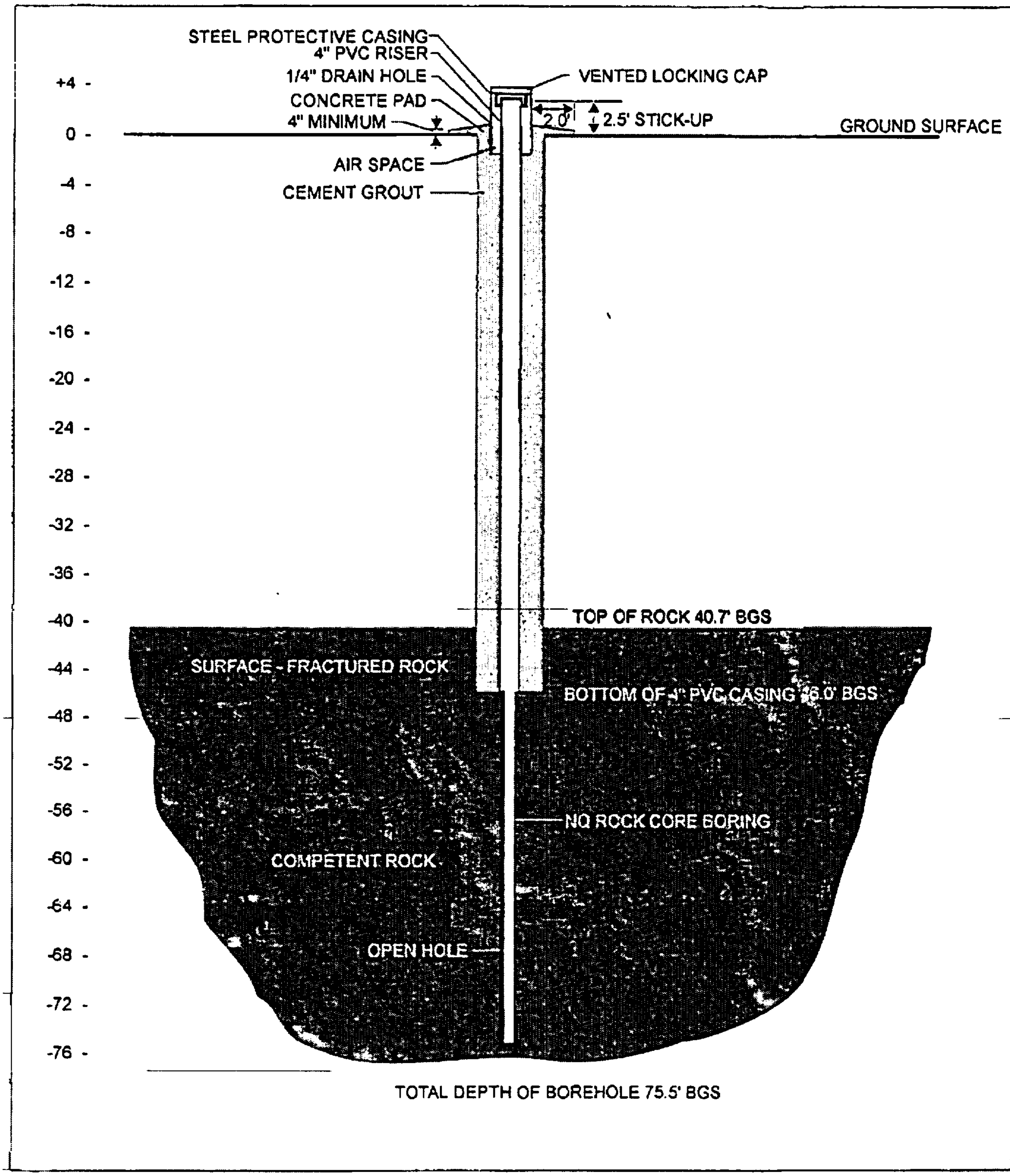


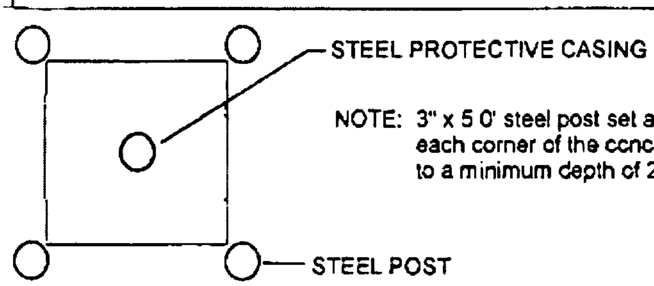
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

TNTA-MW11
OVERBURDEN WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



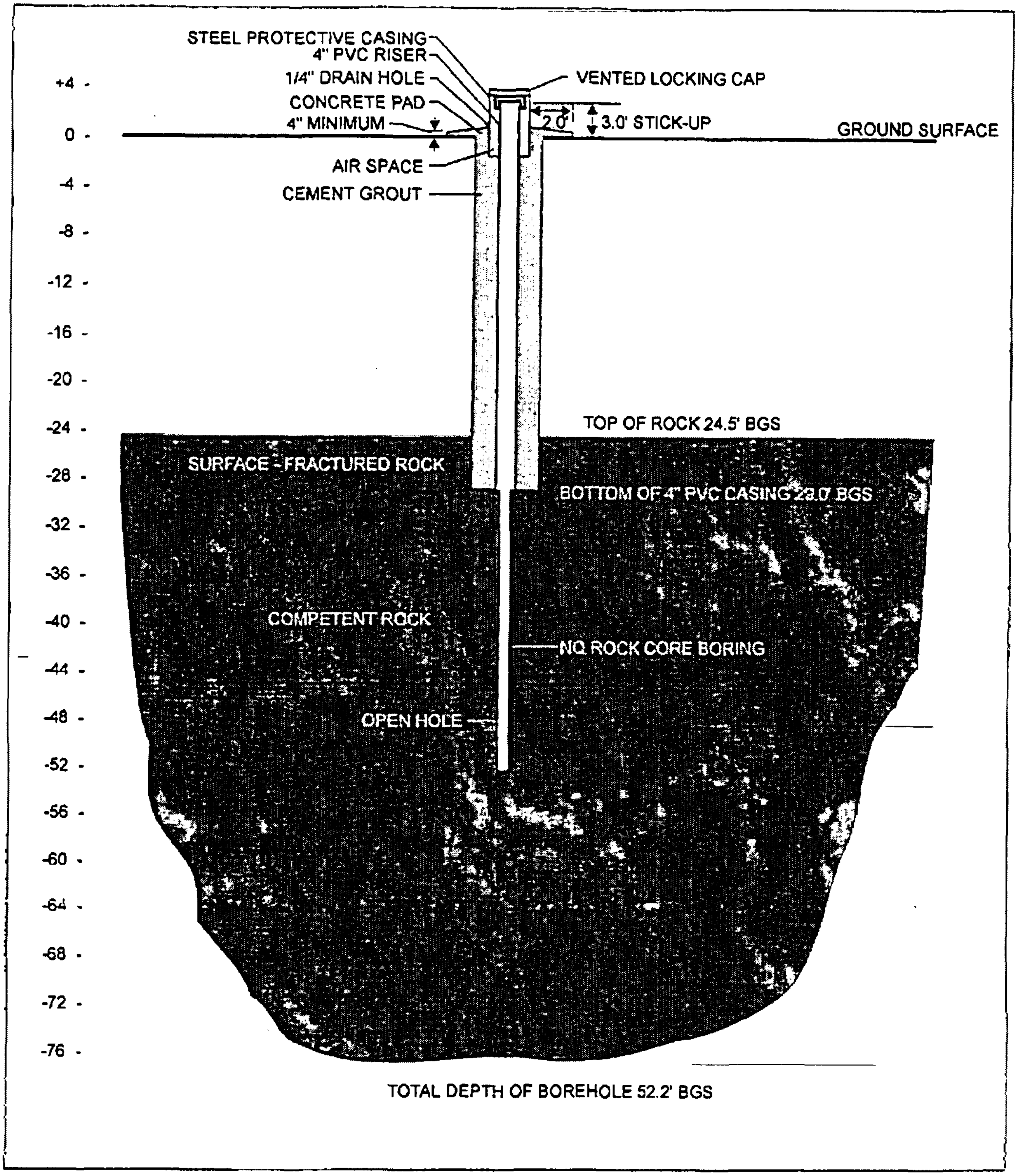


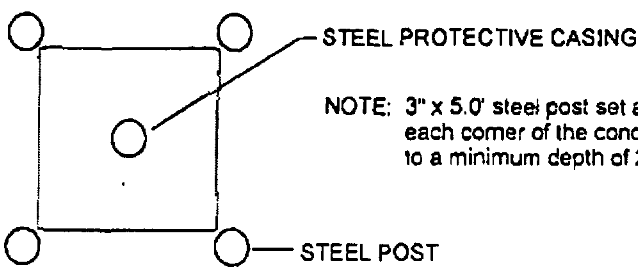
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-13
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE

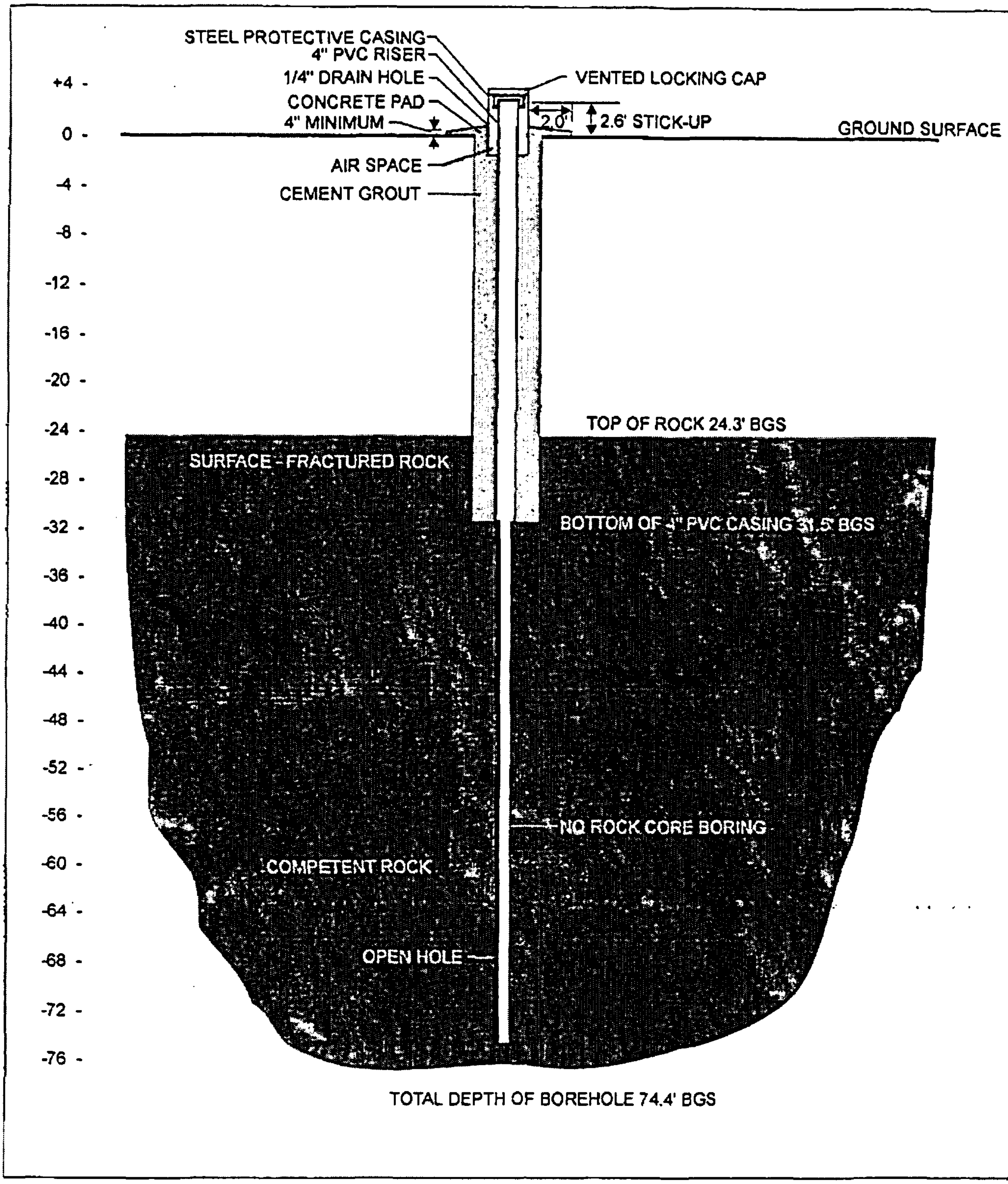


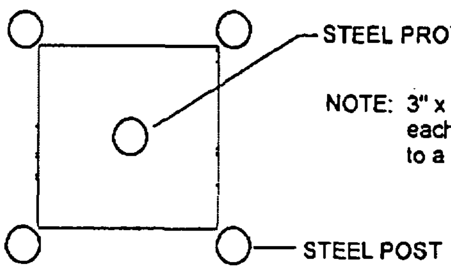


PB-Bed-MW-14
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



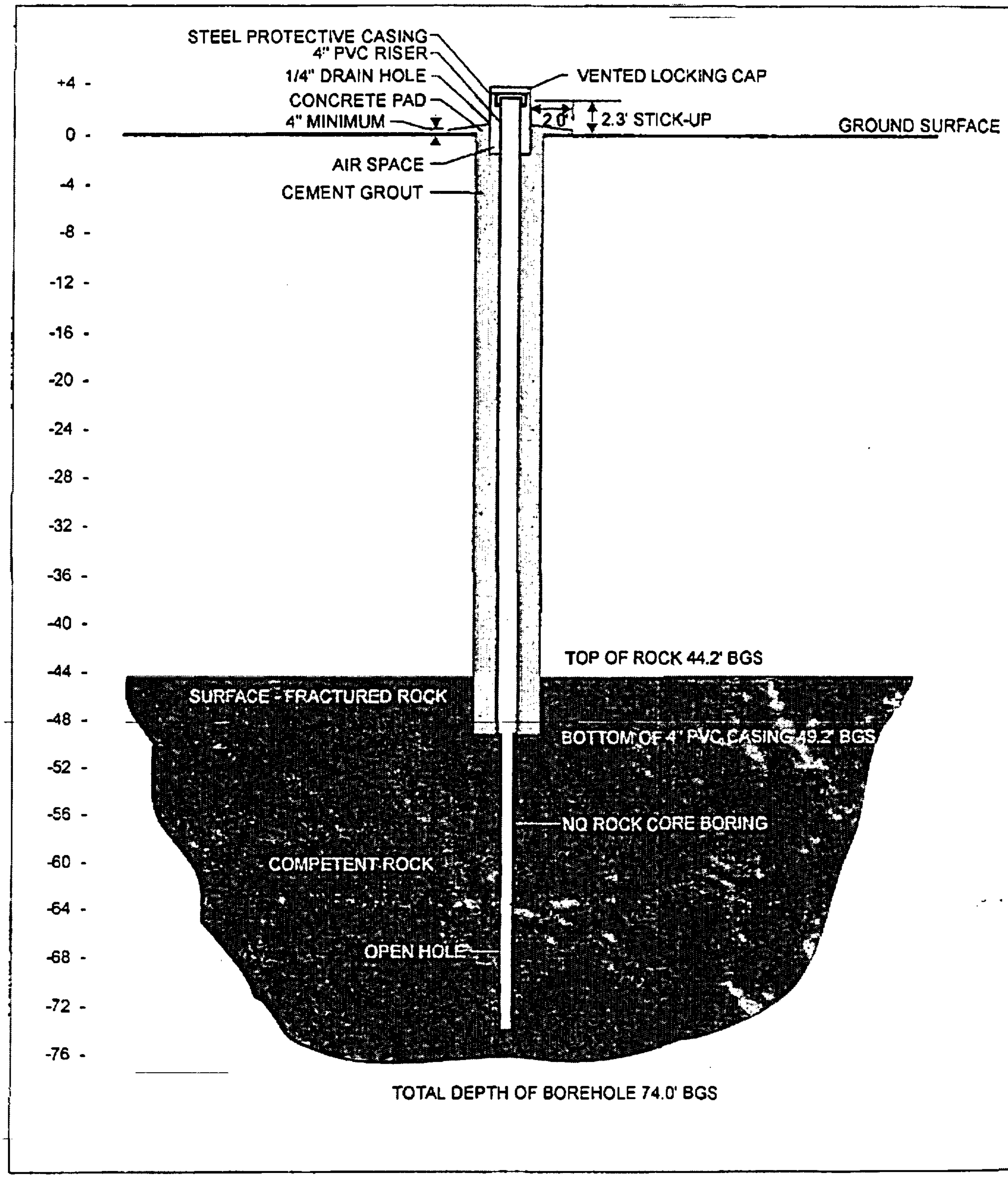


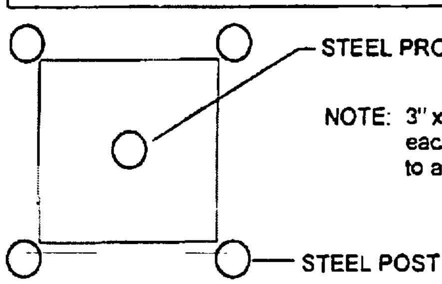
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-15
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



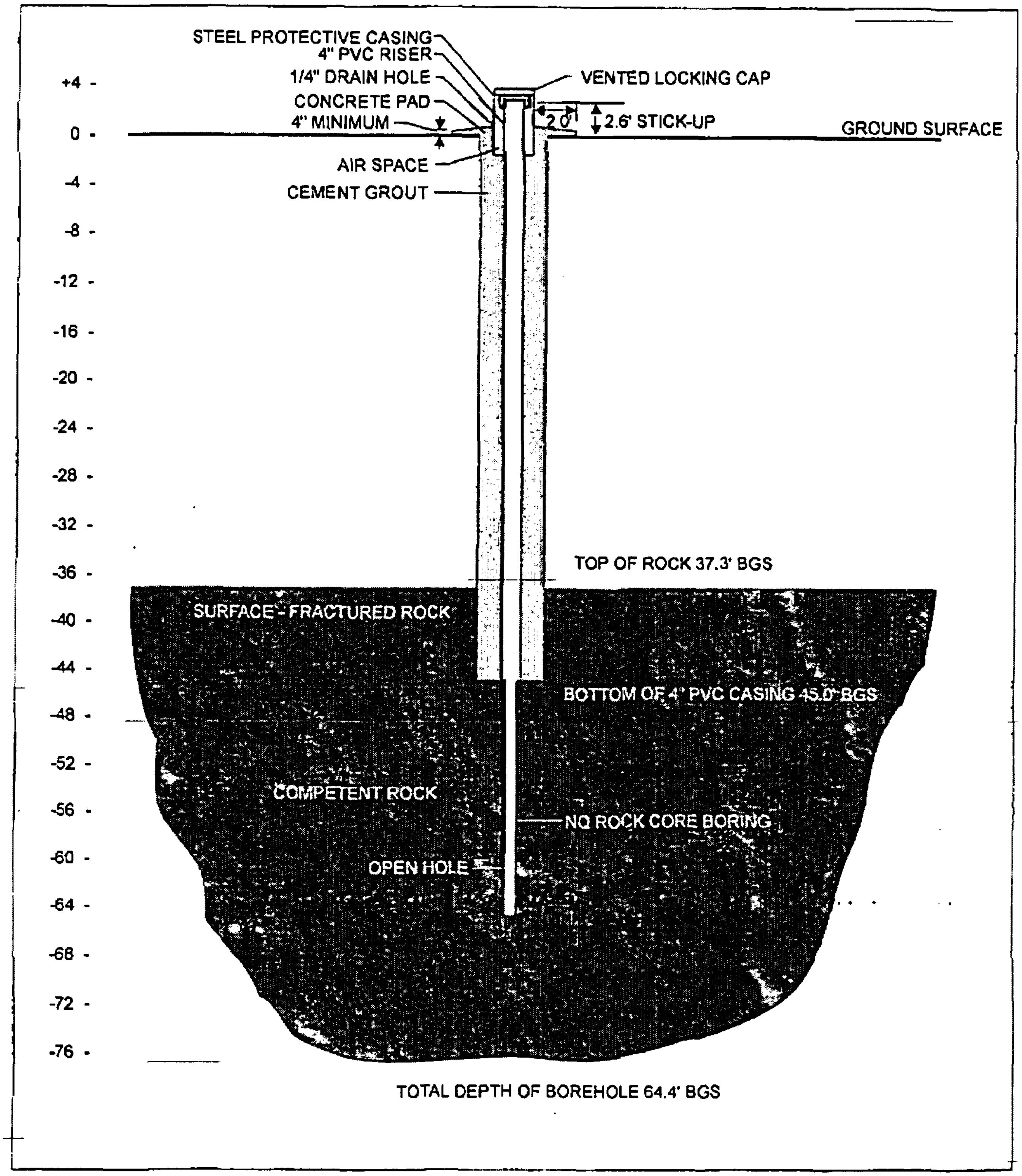


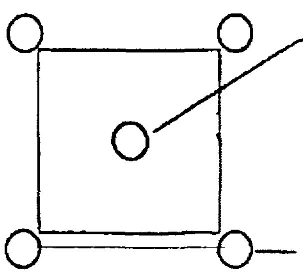
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-16
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



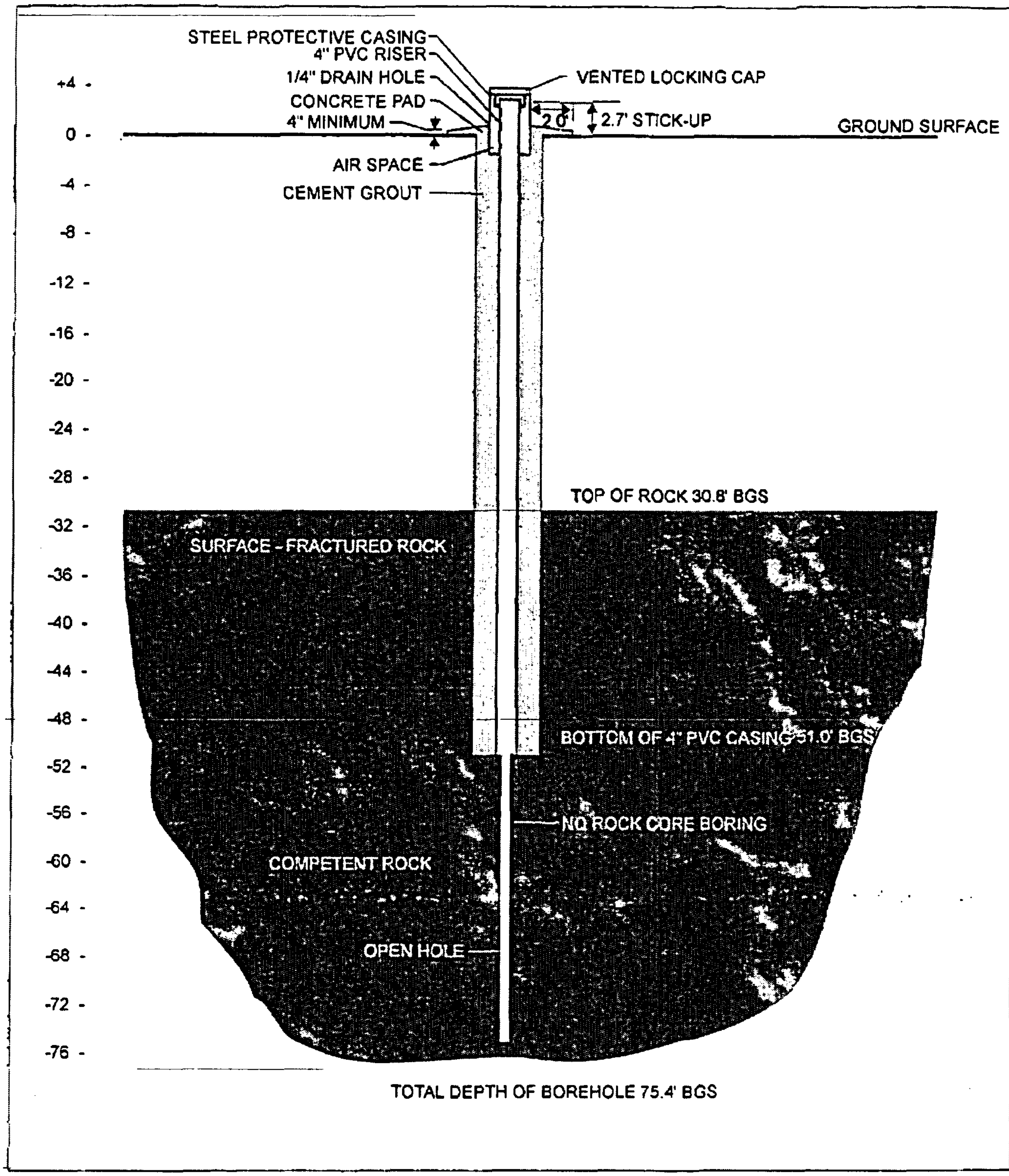


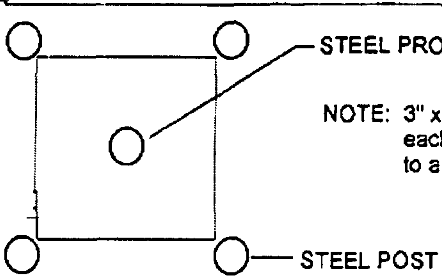
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-17
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



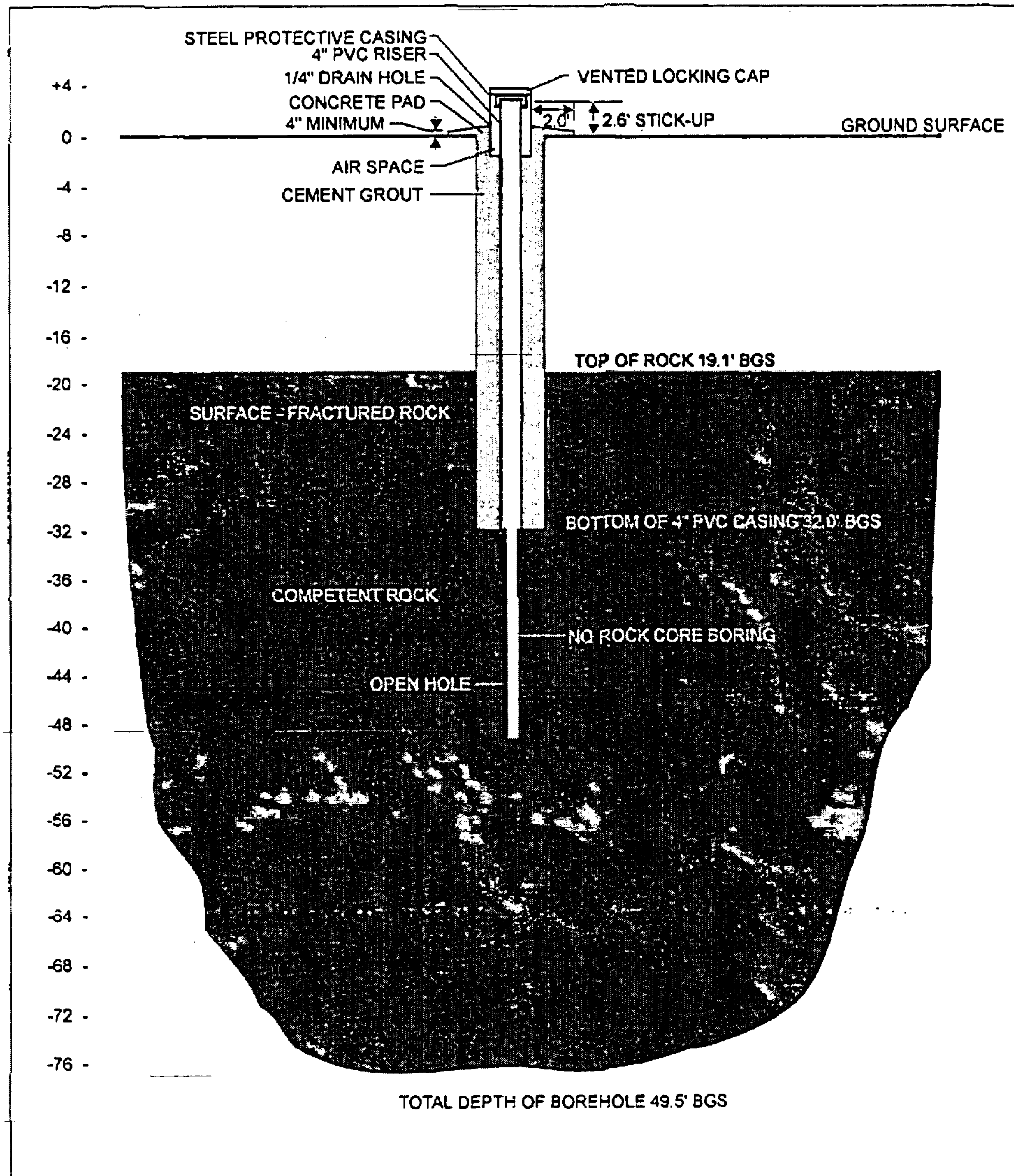


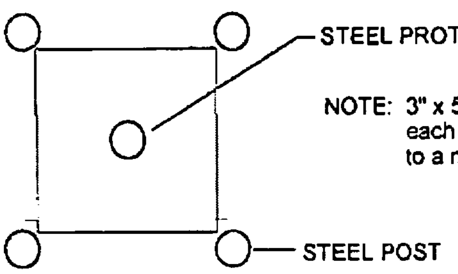
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-18
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE



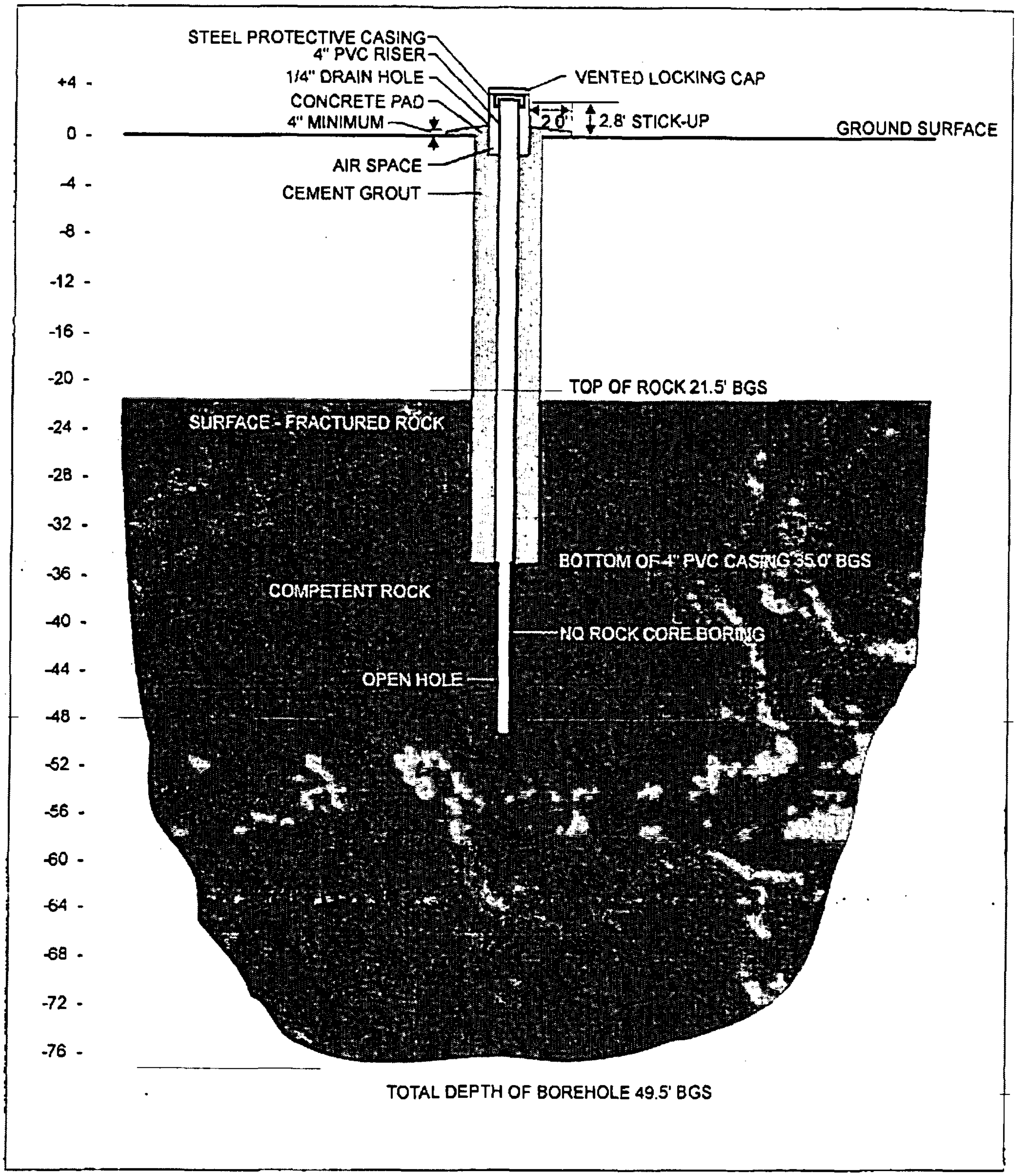


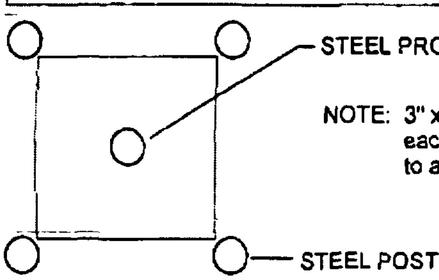
NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-19
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

DAMES & MOORE





NOTE: 3" x 5.0' steel post set at each corner of the concrete pad to a minimum depth of 2.0'.

PB-Bed-MW-20
BEDROCK WELL DETAILS

Plum Brook Ordnance Works
Sandusky, Ohio

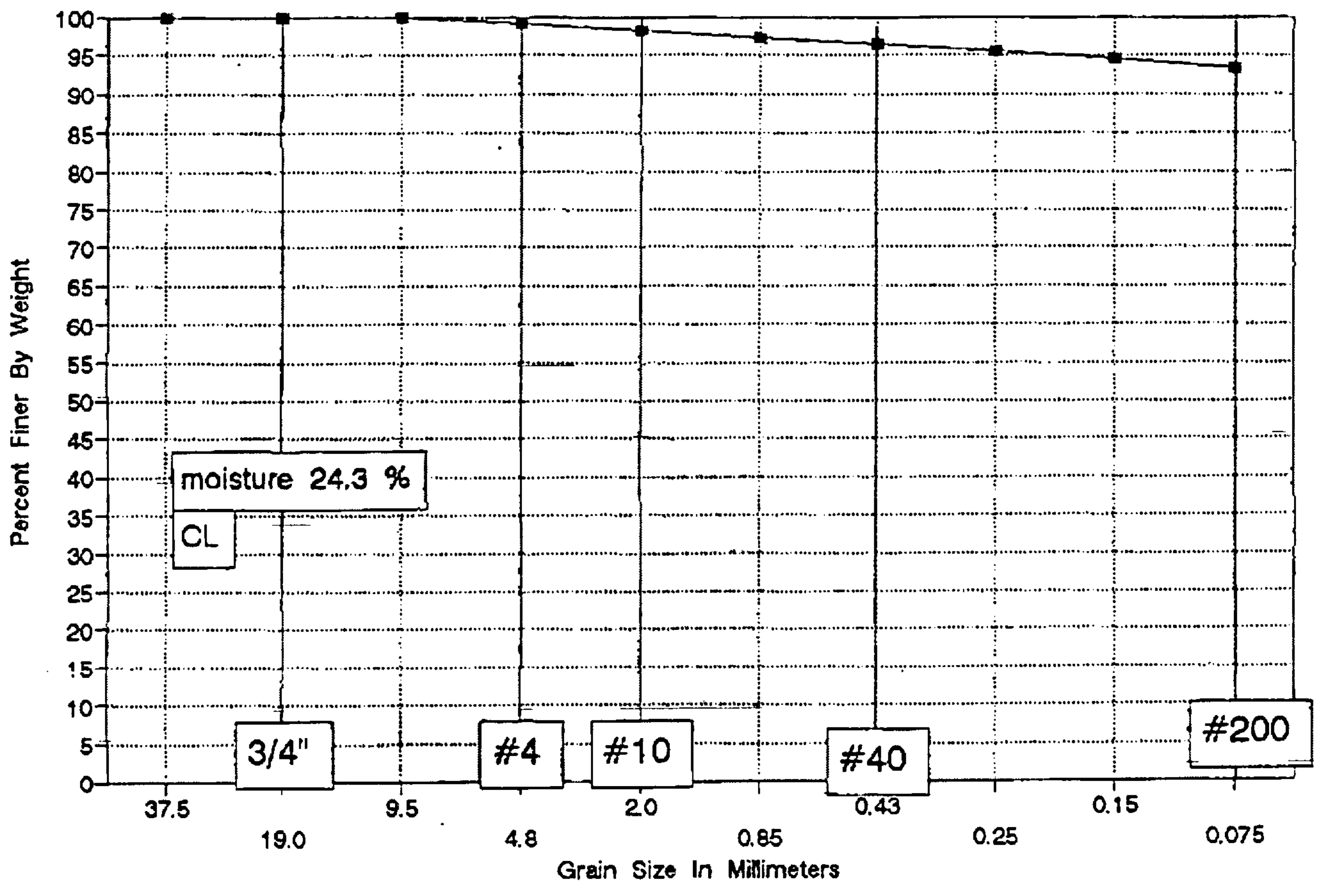
DAMES & MOORE

APPENDIX D

SIEVE ANALYSES

GRADATION CURVE

Boring PB-WA-MW1, Sample at 4-22.4 ft



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-WA-MW1		Wet soil & dish	390
Sample at 4-22.4 feet		Dry soil & dish	336
		Dish	113.6

Moisture Content = 24.3

SIEVE ANALYSIS

Dry weight of total sample= 222.4

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	1.83	99.18%	99.2	4.8
# 10	3.79	98.30%	98.3	2.0
# 20	5.98	97.31%	97.3	0.85
# 40	7.8	96.49%	96.5	0.43
# 60	9.67	95.65%	95.7	0.25
# 100	11.68	94.75%	94.7	0.15
# 200	14.6	93.44%	93.4	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 11/3/94 BY RJH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOK ORDINANCE

LOCATION

BORING PB-WH-MW1 SAMPLE DEPTH 4-22.4'

NUMBER OF RINGS		DISH	21
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	390.0
WT. OF RINGS		WT. OF DISH & DRY SOIL	336.0
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	113.6
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ________ DRY SIEVE ________ WEIGHT OF OVEN DRY SOIL ________ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		1.83		
		PAN				
		TOTAL				

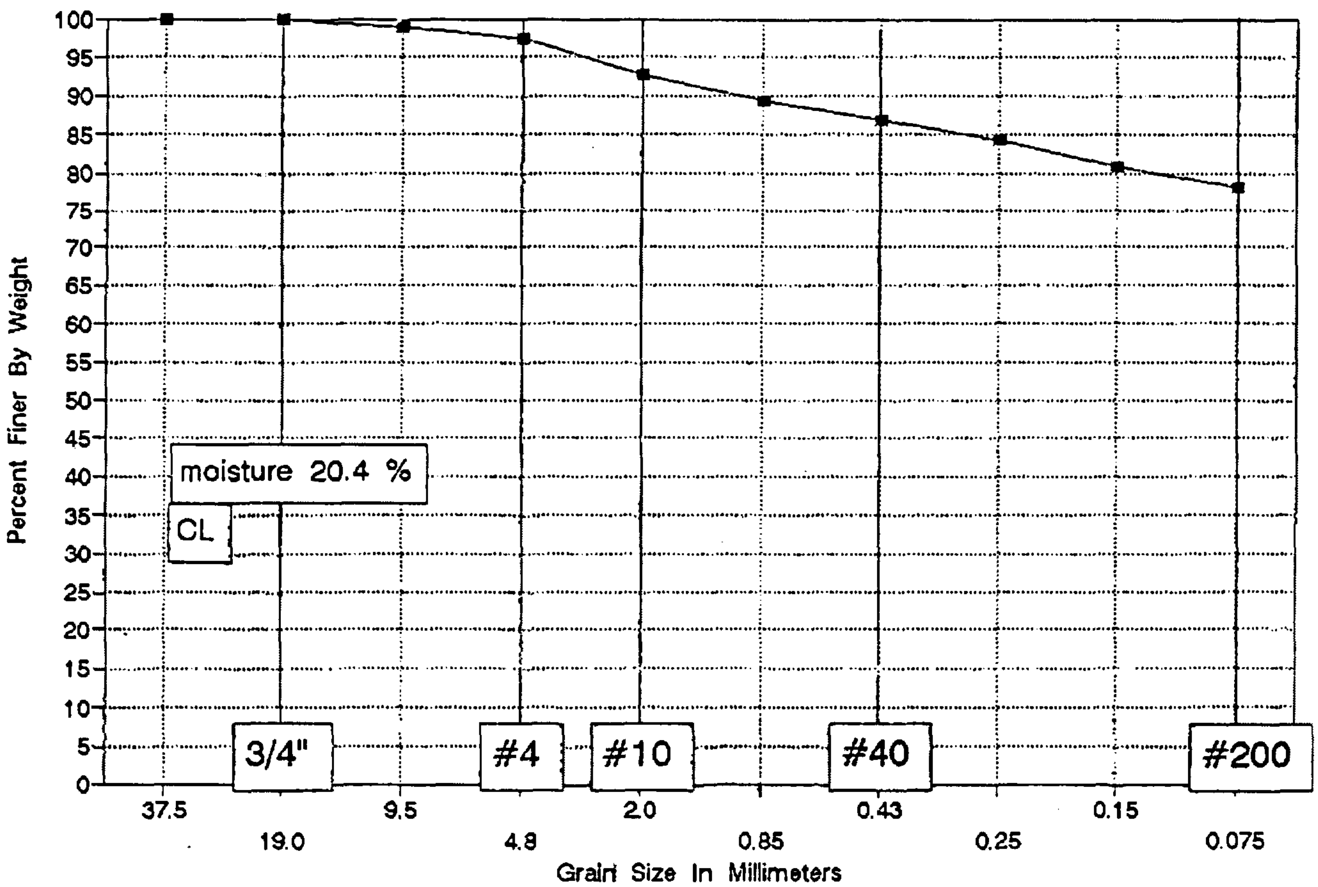
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		3.79			
		#20		5.98			
		#40		7.80			
		#60		9.67			
		#100		11.68			
		#200		14.60			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring PB-WA-MW2, Sample at 4-12 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-WA-MW2
Sample at 4 to 12 feet

Wet soil & dish	396.4
Dry soil & dish	347.3
Dish	106.8

Moisture Content = 20.4

SIEVE ANALYSIS

Dry weight of total sample= 240.5

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	2.54	98.94%	98.9	9.5
# 4	5.88	97.56%	97.6	4.8
# 10	17.19	92.85%	92.9	2.0
# 20	25.9	89.23%	89.2	0.85
# 40	31.72	86.81%	86.8	0.43
# 60	37.78	84.29%	84.3	0.25
# 100	45.82	80.95%	80.9	0.15
# 200	52.76	78.06%	78.1	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RJH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOK ORDINANCE

LOCATION

BORING PB-WA-MW2 SAMPLE DEPTH 4-12'

NUMBER OF RINGS		DISH	4
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	396.4
WT. OF RINGS		WT. OF DISH & DRY SOIL	347.3
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	106.8
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"		0		
		3/8"		2.54		
		#4		5.88		
		PAN				
		TOTAL				

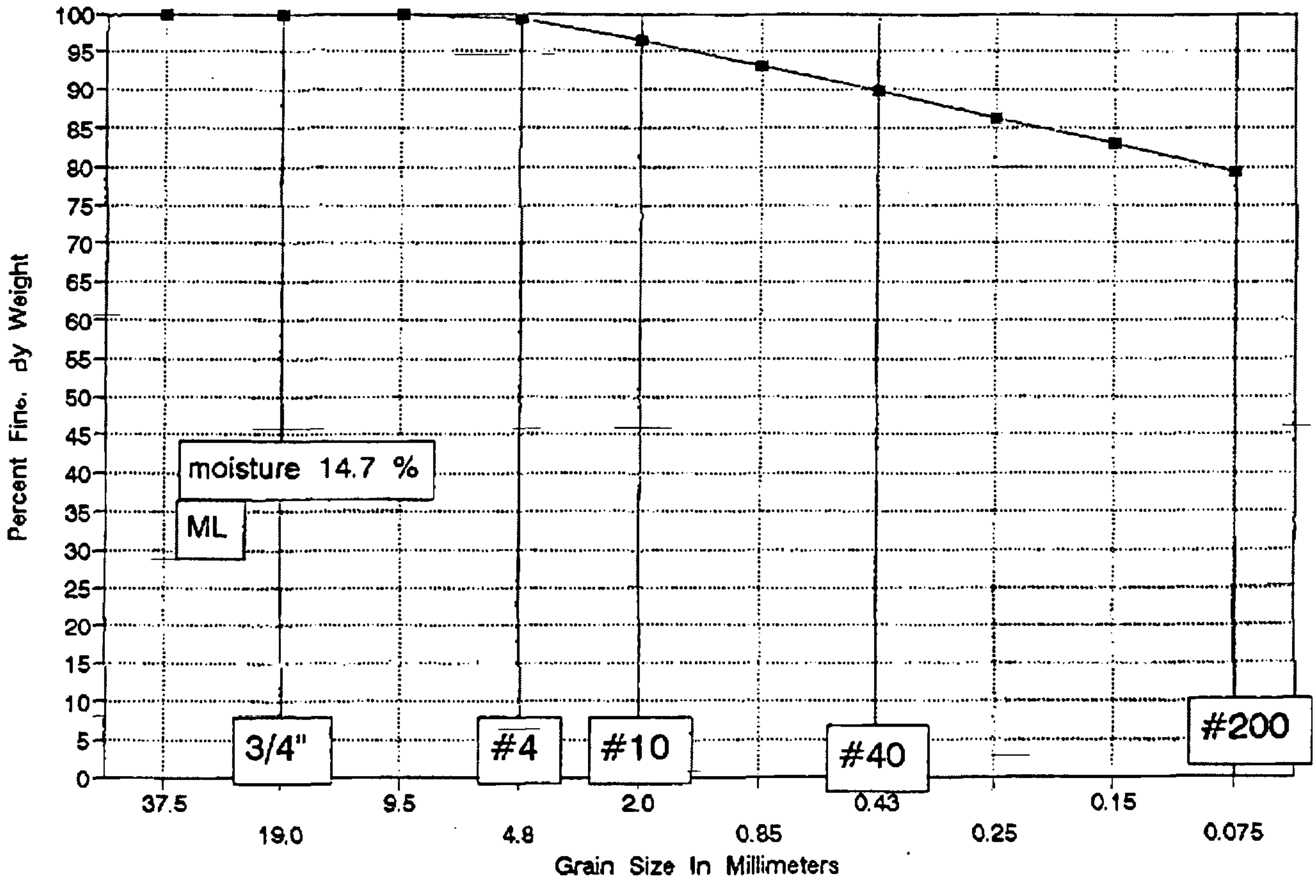
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	ACCUMULATIVE PERCENT PARTIAL FINER	ACCUMULATIVE PERCENT TOTAL FINER
		#10		17.19			
		#20		25.90			
		#40		31.72			
		#60		37.78			
		#100		45.82			
		#200		52.76			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring TNTC-MW3, Sample at 5-14 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTC-MW3
Sample at 5-14 feet

Wet soil & dish	396
Dry soil & dish	359.4
Dish	109.7

Moisture Content = 14.7

SIEVE ANALYSIS

Dry weight of total sample= 249.7

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	1.72	99.31%	99.3	4.8
# 10	8.4	96.64%	96.6	2.0
# 20	17.28	93.08%	93.1	0.85
# 40	25.6	89.75%	89.7	0.43
# 60	34.01	86.38%	86.4	0.25
# 100	42.69	82.90%	82.9	0.15
# 200	51.78	79.26%	79.3	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RJH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION ?

BORING TNTC-MW3 (13) SAMPLE DEPTH 5'-14'

NUMBER OF RINGS			DISH	ST-27
WT. OF RINGS & WET SOIL			WT. OF DISH & WET SOIL	396.0
WT. OF RINGS			WT. OF DISH & DRY SOIL	359.4
WT. OF WET SOIL			WT. OF MOISTURE	
FIELD DENSITY			WT. OF DISH	109.7
DRY DENSITY			WT. OF DRY SOIL	
			FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		1.72		
		PAN				
		TOTAL				

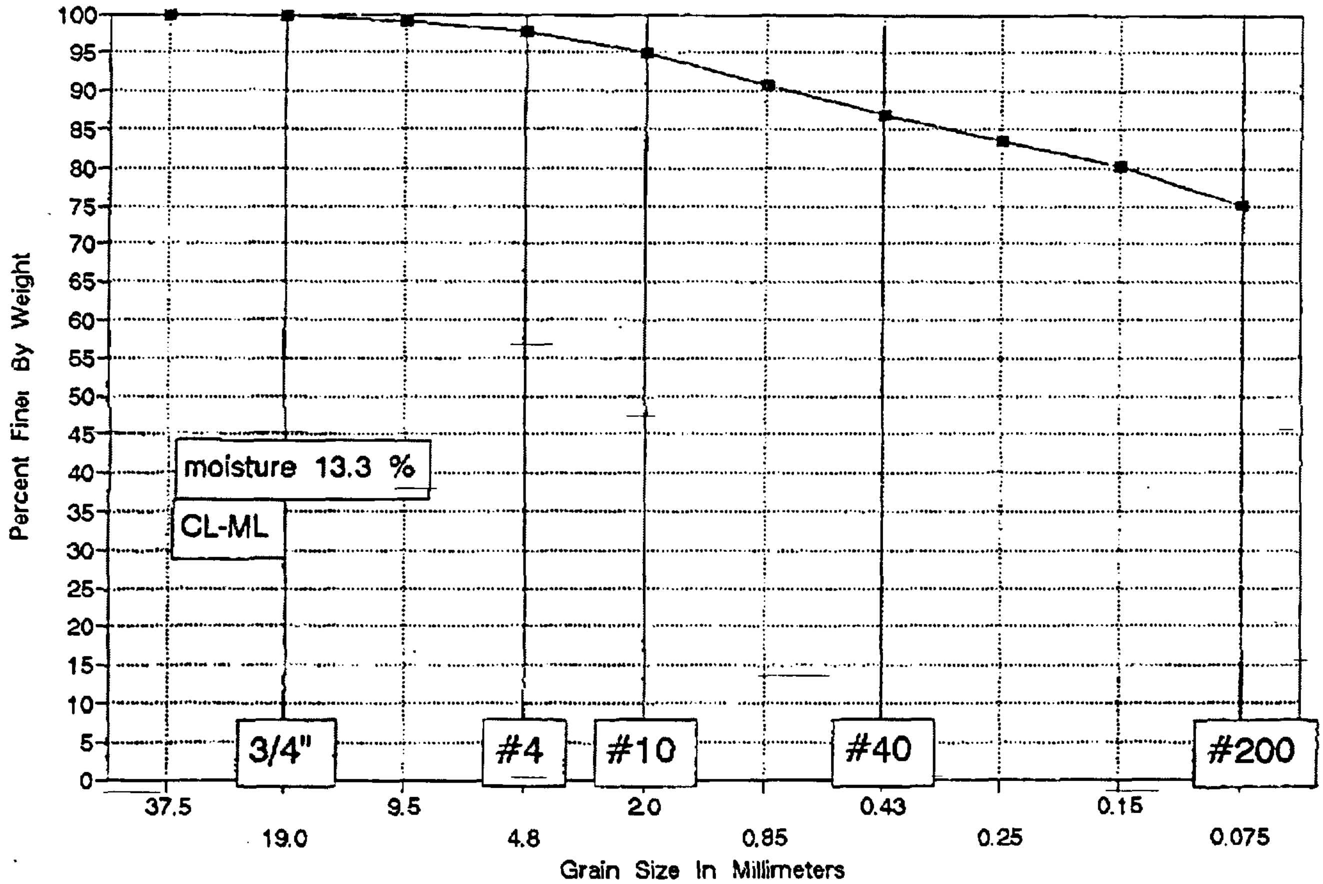
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		8.40			
		#20		17.28			
		#40		25.60			
		#60		34.01			
		#100		42.69			
		#200		51.78			
		PAN					
		TOTAL					

ML

Dames & Moore

GRADATION CURVE

Boring TNTC-MW4, Sample at 8 to 18.5 ft



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTC-MW4		Wet soil & dish	461.1
Sample at 8 to 18.8 feet		Dry soil & dish	420.1
		Dish	112

Moisture Content = 13.3

SIEVE ANALYSIS

Dry weight of total sample= 308.1

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	2.74	99.11%	99.1	9.5
# 4	7.39	97.60%	97.6	4.8
# 10	15.64	94.92%	94.9	2.0
# 20	28.61	90.71%	90.7	0.85
# 40	40.31	86.92%	86.9	0.43
# 60	50.8	83.51%	83.5	0.25
# 100	61.08	80.18%	80.2	0.15
# 200	76.58	75.14%	75.1	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION

BORING TNTC-MW4 SAMPLE DEPTH 8' - 18'10"

NUMBER OF RINGS	
WT. OF RINGS & WET SOIL	
WT. OF RINGS	
WT. OF WET SOIL	
FIELD DENSITY	
DRY DENSITY	

DISH	210
WT. OF DISH & WET SOIL	461.1
WT. OF DISH & DRY SOIL	420.1
WT. OF MOISTURE	
WT. OF DISH	112.0
WT. OF DRY SOIL	
FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

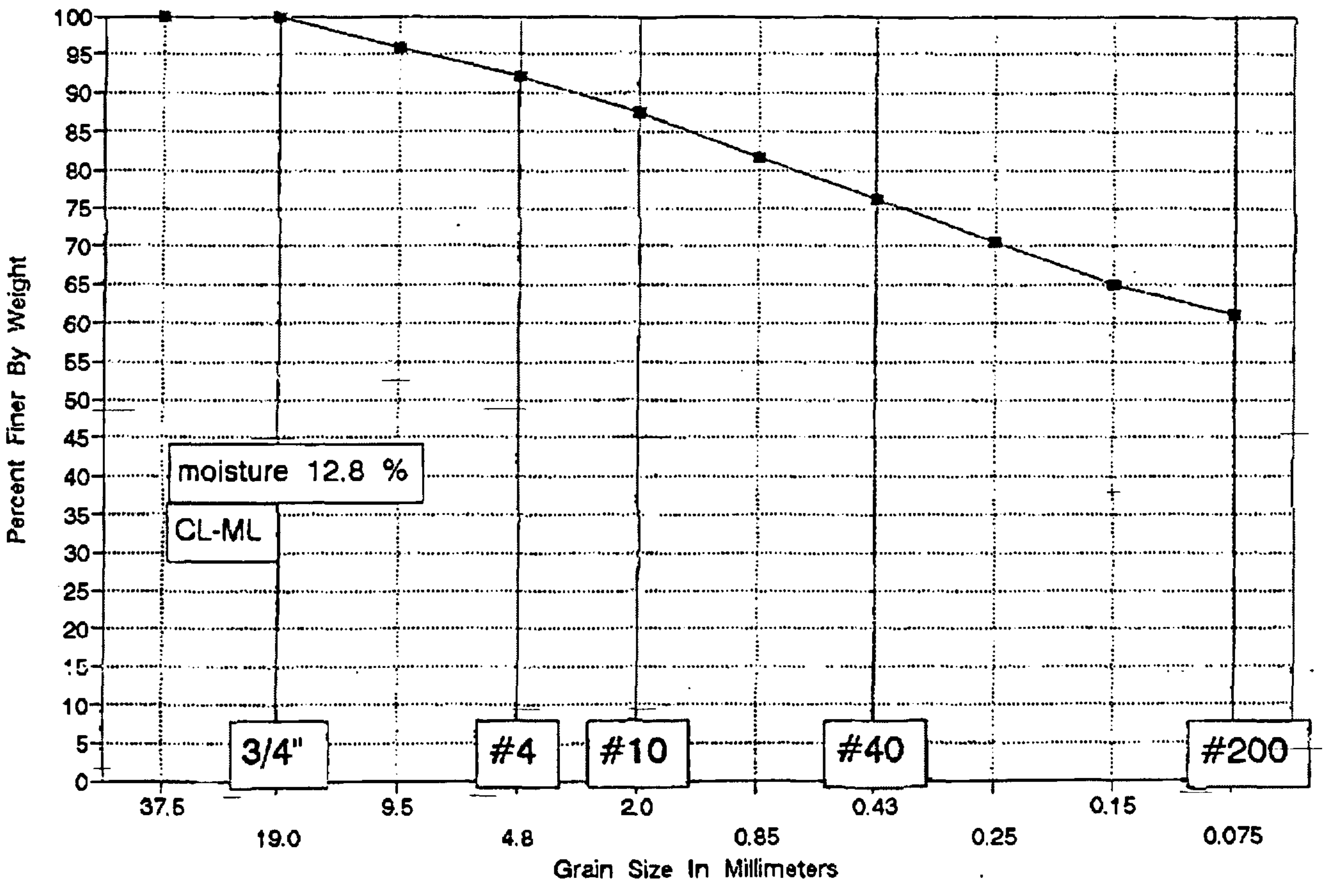
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"		0		
		3/8"		2.74		
		#4		7.39		
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	ACCUMULATIVE PERCENT PARTIAL FINER	ACCUMULATIVE PERCENT TOTAL FINER
		#10		15.64			
		#20		28.61			
		#40		40.31			
		#60		50.80			
		#100		61.08			
		#200		76.58			
		PAN					
		TOTAL					

CL-ML

GRADATION CURVE

Boring TNTC-MW5, Sample at 6-30 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTC-MW5
Sample at 6 to 30 feet

Wet soil & dish	399.4
Dry soil & dish	366.1
Dish	106.4

Moisture Content = 12.8

SIEVE ANALYSIS

Dry weight of total sample= 259.7

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	11.08	95.73%	95.7	9.5
# 4	20.79	91.99%	92.0	4.8
# 10	32.73	87.40%	87.4	2.0
# 20	47.59	81.68%	81.7	0.85
# 40	61.89	76.17%	76.2	0.43
# 60	76.17	70.67%	70.7	0.25
# 100	91.07	64.93%	64.9	0.15
# 200	100.85	61.17%	61.2	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION

BORING TNTC-MW5 SAMPLE DEPTH 6'-30'

NUMBER OF RINGS	
WT. OF RINGS & WET SOIL	
WT. OF RINGS	
WT. OF WET SOIL	
FIELD DENSITY	
DRY DENSITY	

DISH	8
WT. OF DISH & WET SOIL	399.4
WT. OF DISH & DRY SOIL	366.1
WT. OF MOISTURE	
WT. OF DISH	106.4
WT. OF DRY SOIL	
FIELD MOISTURE CONTENT	

WASH SIEVE ________ DRY SIEVE ________ WEIGHT OF OVEN DRY SOIL ________ (grams)

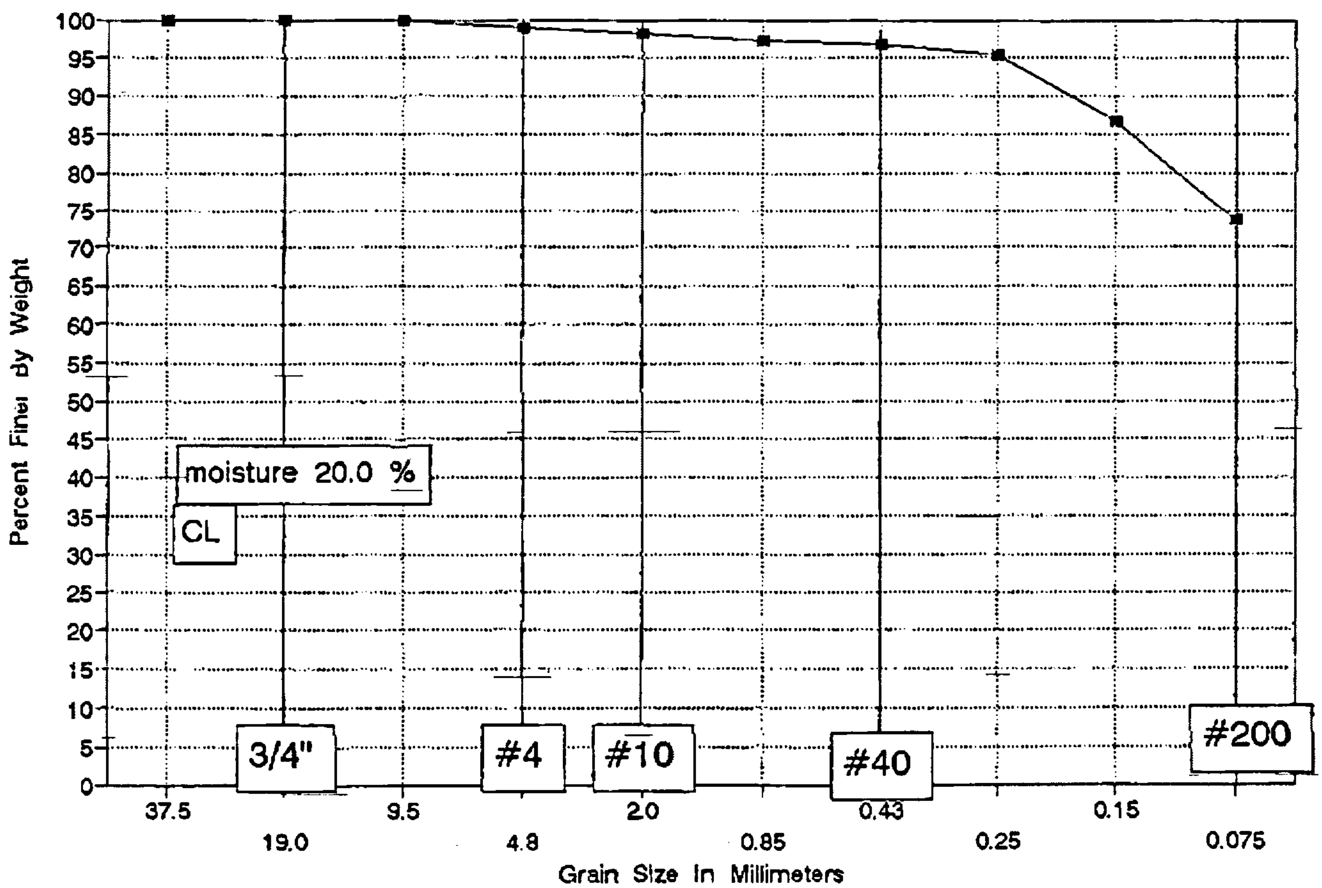
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"		0		
		3/8"		11.08		
		#4		20.79		
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	ACCUMULATIVE PERCENT PARTIAL FINER	ACCUMULATIVE PERCENT TOTAL FINER
		#10		32.73			
		#20		47.59			
		#40		61.89			
		#60		76.17			
		#100		91.07			
		#200		100.85			
		PAN					
		TOTAL					

CL-ML

GRADATION CURVE

Boring TNTC-MW6, at 10-16 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTC-MW6
Sample at 10-16 feet

Wet soil & dish	374
Dry soil & dish	330.2
Dish	111

Moisture Content = 20.0

SIEVE ANALYSIS

Dry weight of total sample= 219.2

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	2.37	98.92%	98.9	4.8
# 10	3.92	98.21%	98.2	2.0
# 20	5.84	97.34%	97.3	0.85
# 40	6.97	96.82%	96.8	0.43
# 60	9.82	95.52%	95.5	0.25
# 100	29.3	86.63%	86.6	0.15
# 200	58.03	73.53%	73.5	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 11/3/94 BY RH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOK ORDINANCE

LOCATION

BORING TNTC-MW16 SAMPLE DEPTH 10-16'

NUMBER OF RINGS			DISH	ST-29
WT. OF RINGS & WET SOIL			WT. OF DISH & WET SOIL	374.0
WT. OF RINGS			WT. OF DISH & DRY SOIL	330.2
WT. OF WET SOIL			WT. OF MOISTURE	
FIELD DENSITY			WT. OF DISH	111.0
DRY DENSITY			WT. OF DRY SOIL	
			FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		2.37		
		PAN				
		TOTAL				

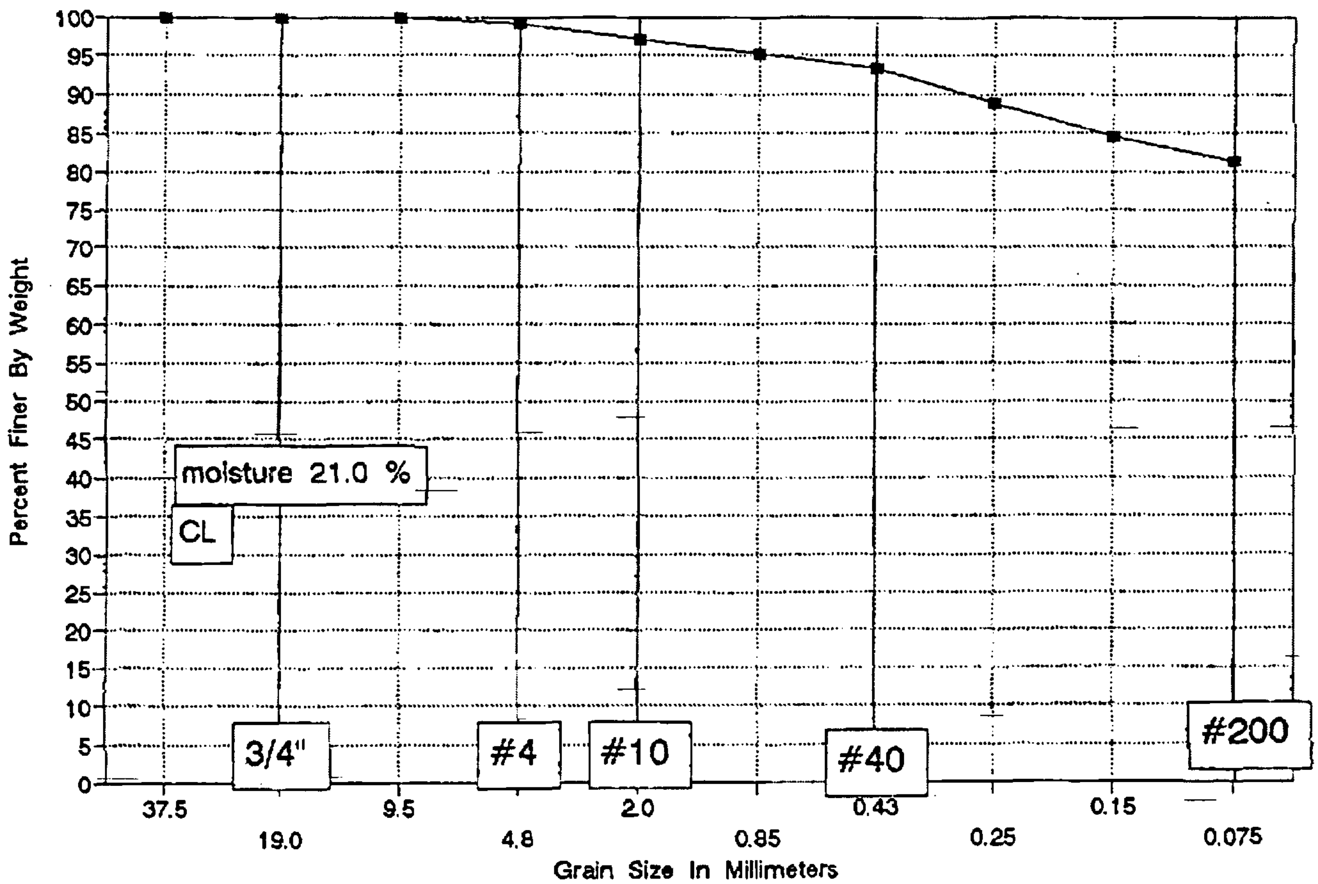
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	PARTIAL FINER	TOTAL FINER
		#10		3.92			
		#20		5.84			
		#40		6.97			
		#60		9.82			
		#100		29.30			
		#200		58.03			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring PB-PR-MW7, at 4-22 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-PR-MW7		Wet soil & dish	474.7
Sample at 4-22 feet		Dry soil & dish	411.7
		Dish	111.9

Moisture Content = 21.0

SIEVE ANALYSIS

Dry weight of total sample= 299.8

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	2.58	99.14%	99.1	4.8
# 10	8.54	97.15%	97.2	2.0
# 20	14.42	95.19%	95.2	0.85
# 40	20.11	93.29%	93.3	0.43
# 60	33.48	88.83%	88.8	0.25
# 100	46.16	84.60%	84.6	0.15
# 200	55.98	81.33%	81.3	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE ______ BY RH
JOB NUMBER 24037-035 OWNER/CLIENT PLUM BROOKS ORDINANCE
LOCATION ______
BORING PB-PR-MW7 SAMPLE ______ DEPTH 4-22'

NUMBER OF RINGS		DISH	123
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	474.7
WT. OF RINGS		WT. OF DISH & DRY SOIL	411.7
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	111.9
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		2.58		
		PAN				
		TOTAL				

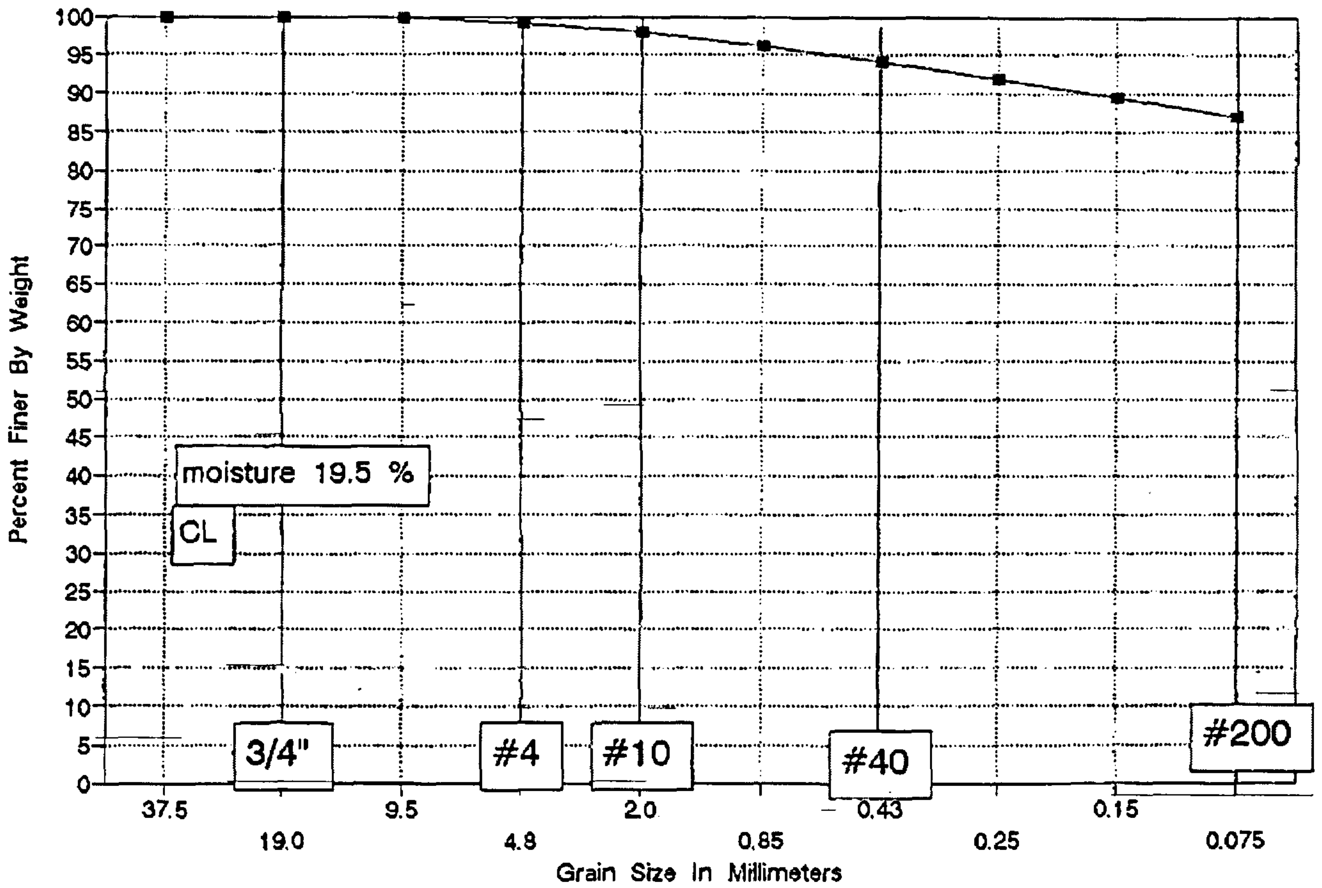
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		8.54			
		#20		14.42			
		#40		20.11			
		#60		33.48			
		#100		40.16			
		#200		55.98			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring PB-PR-S14-MW8, at 5-27.5 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-PR-S14-MW8
Sample at 5-27.5 feet

Wet soil & dish	327.2
Dry soil & dish	292
Dish	111.5

Moisture Content = 19.5

SIEVE ANALYSIS

Dry weight of total sample= 180.5

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	1.41	99.22%	99.2	4.8
# 10	3.58	98.02%	98.0	2.0
# 20	6.9	96.18%	96.2	0.85
# 40	10.57	94.14%	94.1	0.43
# 60	14.71	91.85%	91.9	0.25
# 100	19.07	89.43%	89.4	0.15
# 200	23.5	86.98%	87.0	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 11/3/94 BY RH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOK ORDINANCE

LOCATION

BORING PB-PR-S14-MW8 SAMPLE DEPTH 5'-27.5'

NUMBER OF RINGS			DISH	ST-30
WT. OF RINGS & WET SOIL			WT. OF DISH & WET SOIL	327.2
WT. OF RINGS			WT. OF DISH & DRY SOIL	292.0
WT. OF WET SOIL			WT. OF MOISTURE	
FIELD DENSITY			WT. OF DISH	111.5
DRY DENSITY			WT. OF DRY SOIL	
			FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

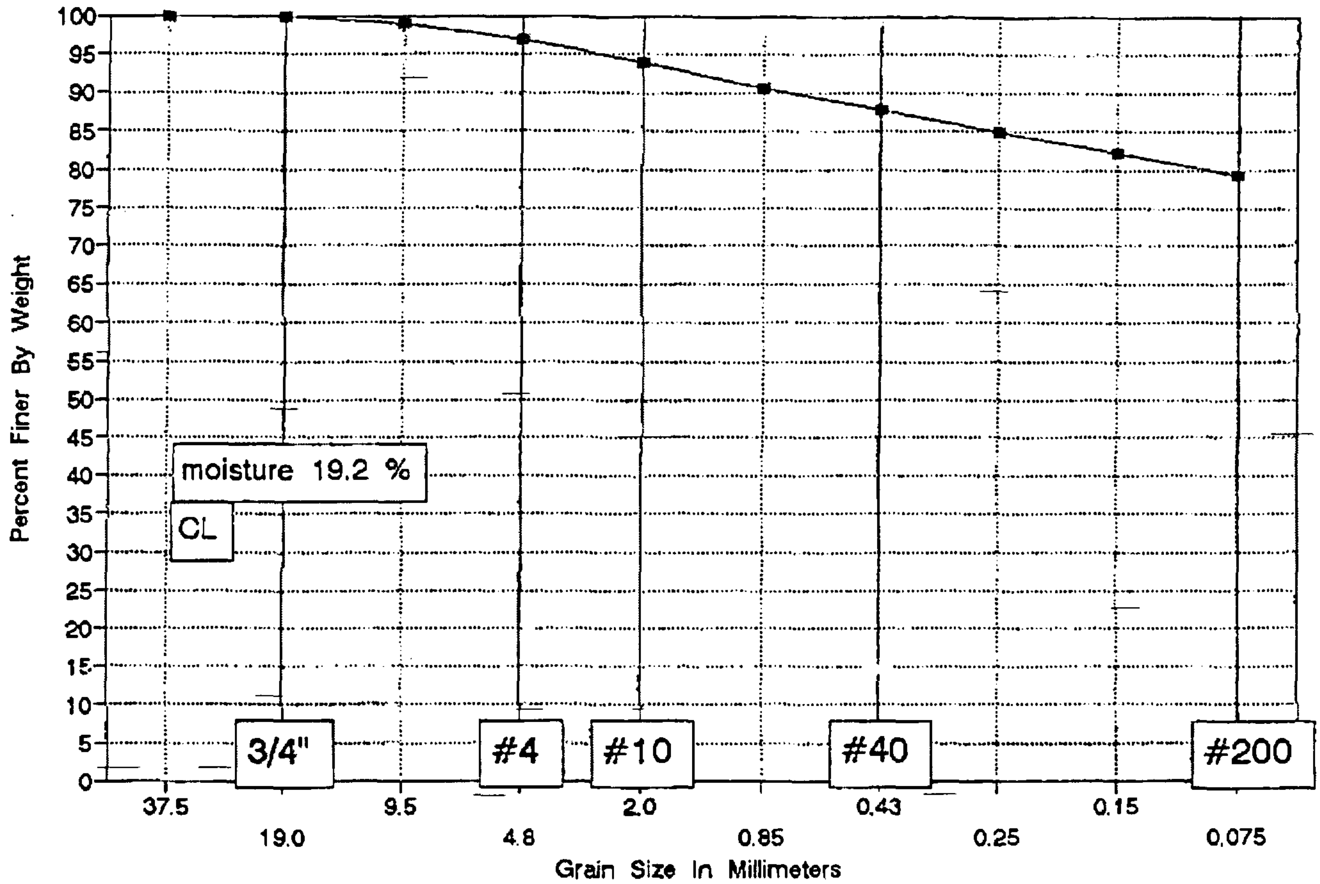
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		1.41		
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		3.58			
		#20		6.90			
		#40		10.57			
		#60		14.71			
		#100		19.07			
		#200		23.50			
		PAN					
		TOTAL					

CL

GRADATION CURVE

Boring PB-PR-MW9, Sample at 4-19 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-PR-MW9
Sample at 4 to 19 feet

Wet soil & dish	486.8
Dry soil & dish	426.8
Dish	114.8

Moisture Content = 19.2

SIEVE ANALYSIS

Dry weight of total sample= 312

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	3.01	99.04%	99.0	9.5
# 4	9.39	96.99%	97.0	4.8
# 10	18.82	93.97%	94.0	2.0
# 20	29.48	90.55%	90.6	0.85
# 40	38.03	87.81%	87.8	0.43
# 60	47.29	84.84%	84.8	0.25
# 100	55.67	82.16%	82.2	0.15
# 200	65.06	79.15%	79.1	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH

JOB NUMBER OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION

BORING PB-PR-MW9 SAMPLE DEPTH 4-19'

NUMBER OF RINGS		DISH	313
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	486.8
WT. OF RINGS		WT. OF DISH & DRY SOIL	426.8
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	114.8
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ____ DRY SIEVE ____ WEIGHT OF OVEN DRY SOIL ____ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"		0		
		3/8"		3.01		
		#4		9.39		
		PAN				
		TOTAL				

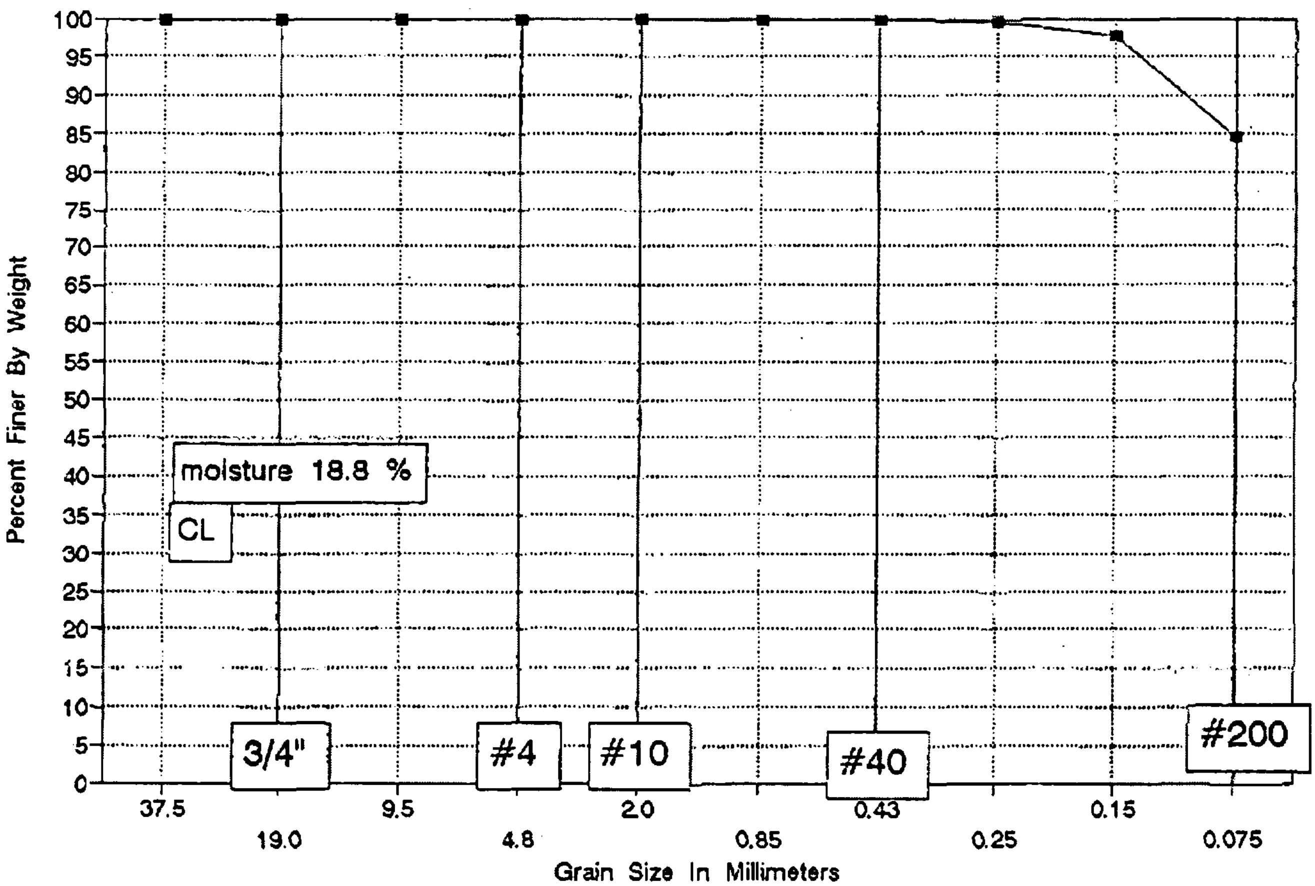
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		18.82			
		#20		29.48			
		#40		38.03			
		#60		47.29			
		#100		55.67			
		#200		65.06			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring TNTA-MW10, Sample at 2-11 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTA-MW10		Wet soil & dish	526.3
Sample at 2-11 feet		Dry soil & dish	461
		Dish	113.4

Moisture Content = 18.8

SIEVE ANALYSIS

Dry weight of total sample= 347.6

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	0.3	99.91%	99.9	4.8
# 10	0.46	99.87%	99.9	2.0
# 20	0.9	99.74%	99.7	0.85
# 40	1.17	99.66%	99.7	0.43
# 60	1.69	99.51%	99.5	0.25
# 100	8.4	97.58%	97.6	0.15
# 200	53.35	84.65%	84.7	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH

JOB NUMBER ______ OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION ______

BORING TNTA - MW-10 SAMPLE ______ DEPTH 2'-11'

NUMBER OF RINGS	
WT. OF RINGS & WET SOIL	
WT. OF RINGS	
WT. OF WET SOIL	
FIELD DENSITY	
DRY DENSITY	

DISH	209
WT. OF DISH & WET SOIL	526.3
WT. OF DISH & DRY SOIL	461.0
WT. OF MOISTURE	
WT. OF DISH	113.4
WT. OF DRY SOIL	
FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		.30		
		PAN				
		TOTAL				

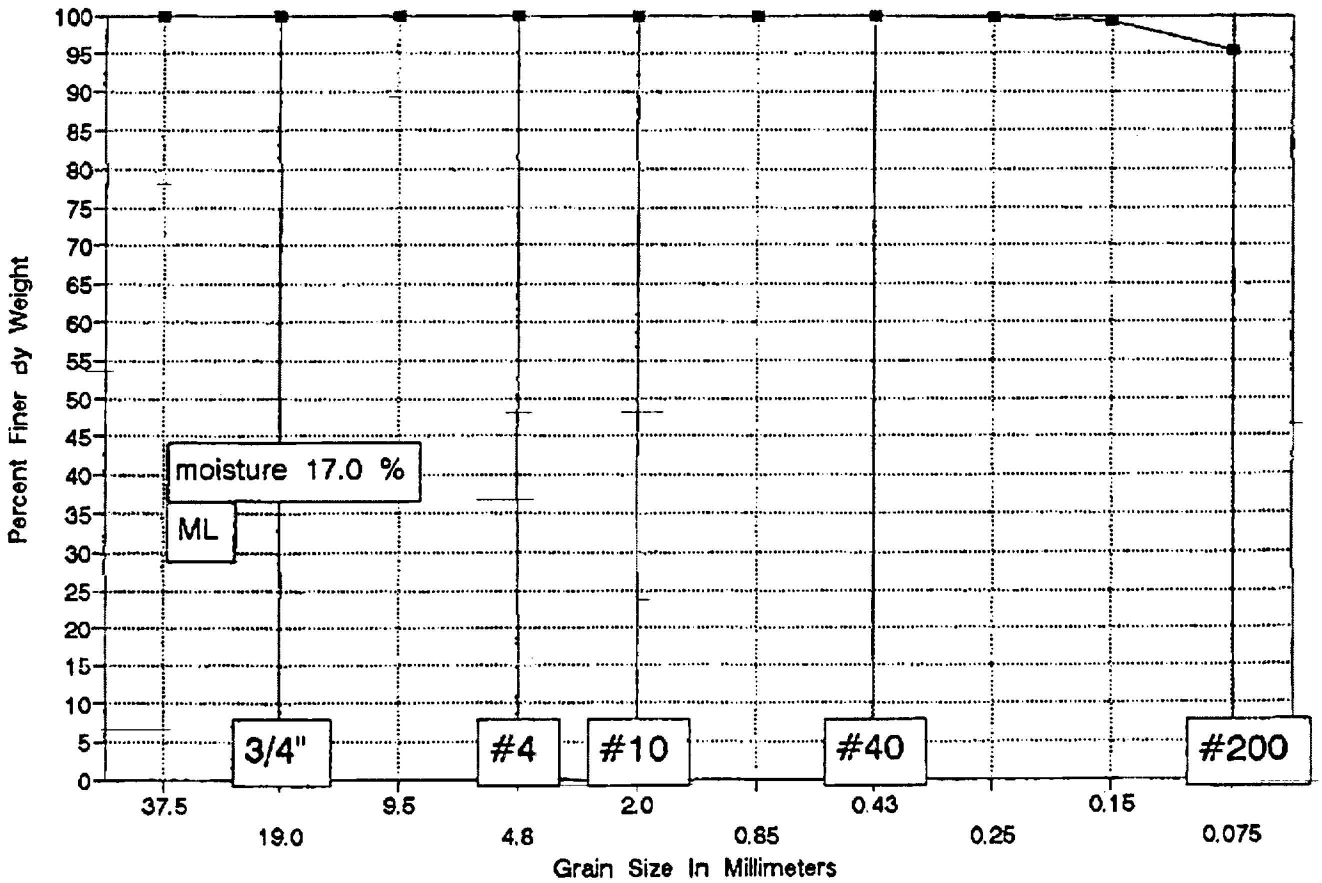
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		.46			
		#20		.90			
		#40		1.17			
		#60		1.69			
		#100		8.40			
		#200		53.35			
		PAN					
		TOTAL					

CL

Dames & Moore

GRADATION CURVE

Boring TNTA-MW11, Sample at 6-11 feet



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTA-MW11
Sample at 6 to 11 feet

Wet soil & dish	346.5
Dry soil & dish	312.7
Dish	113.3

Moisture Content = 17.0

SIEVE ANALYSIS

Dry weight of total sample= 199.4

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	0	100.00%	100.0	4.8
# 10	0	100.00%	100.0	2.0
# 20	0.1	99.95%	99.9	0.85
# 40	0.26	99.87%	99.9	0.43
# 60	0.5	99.75%	99.7	0.25
# 100	1.42	99.29%	99.3	0.15
# 200	9.13	95.42%	95.4	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH
JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOKS ORDINANCE
LOCATION
BORING TNT A - MW111 SAMPLE DEPTH 10-11'

NUMBER OF RINGS		DISH	206
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	346.5
WT. OF RINGS		WT. OF DISH & DRY SOIL	312.7
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	113.3
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

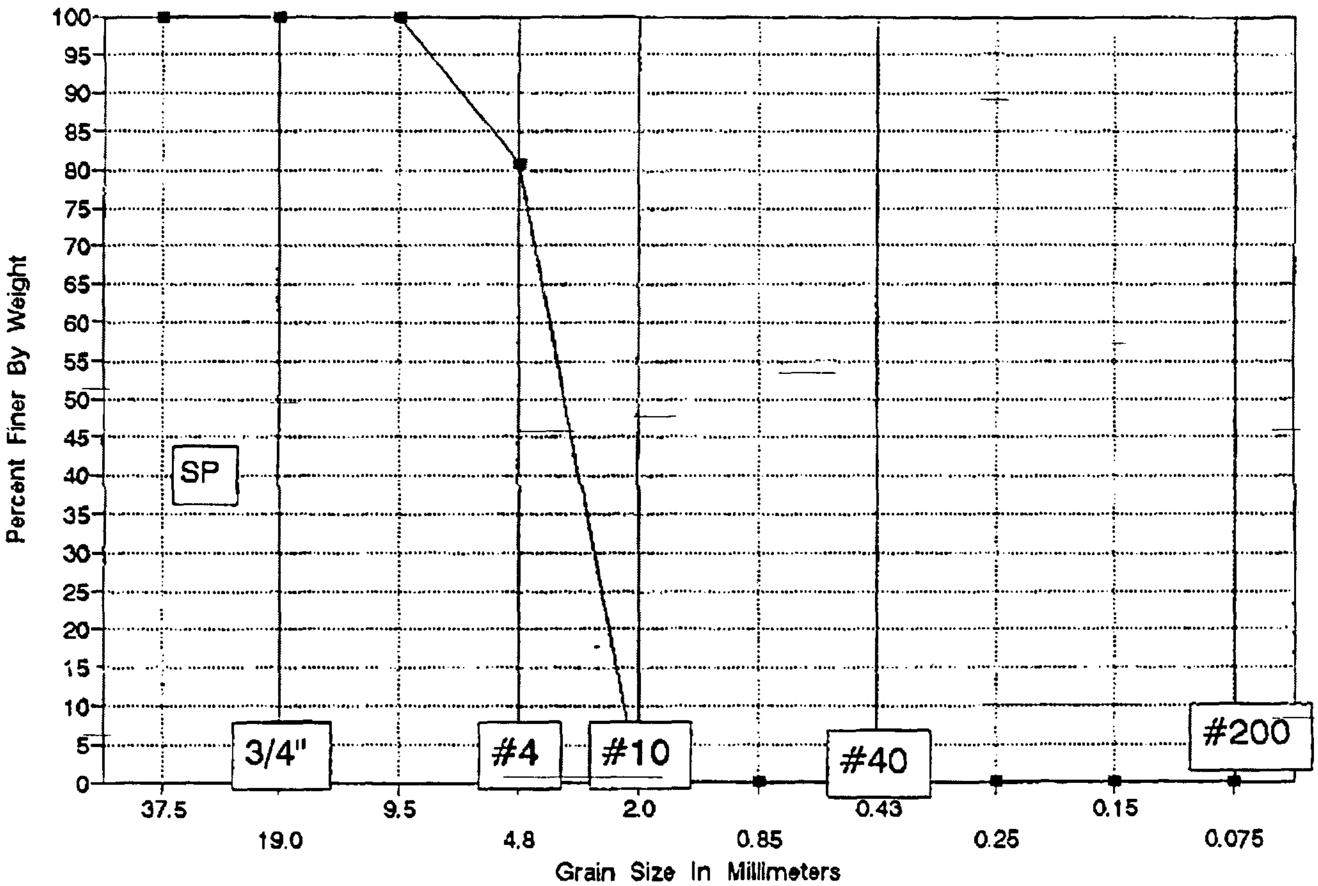
DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"				
		#4				
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	ACCUMULATIVE PERCENT PARTIAL FINER	ACCUMULATIVE PERCENT TOTAL FINER
		#10		0			
		#20		.10			
		#40		.26			
		#60		.50			
		#100		1.42			
		#200		9.13			
		PAN					
		TOTAL					

Dames & Moore

GRADATION CURVE

Boring TNTC-MW4, Sand # 5



Plum Brook Ordinance Works
Sandusky Ohio

Boring TNTC-MW4		Wet soil & dish	238.2
Sand # 5		Dry soil & dish	238.2
		Dish	111.7

Moisture Content = 0.0

SIEVE ANALYSIS

Dry weight of total sample= 126.5

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	24.25	80.83%	80.8	4.8
# 10	126.3	0.16%	0.2	2.0
# 20	126.37	0.10%	0.1	0.85
# 40	126.38	0.09%	0.1	0.43
# 60	126.39	0.09%	0.1	0.25
# 100	126.44	0.05%	0.0	0.15
# 200	126.44	0.05%	0.0	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 11/3/94 BY RH

JOB NUMBER ______ OWNER/CLIENT RUM BROOK ORDINANCE

LOCATION ______

BORING TNTC-MW4 SAMPLE SAND #5 DEPTH ______

NUMBER OF RINGS		DISH	316
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	238.2
WT. OF RINGS		WT. OF DISH & DRY SOIL	~~237.7~~ 238.1
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	111.7
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

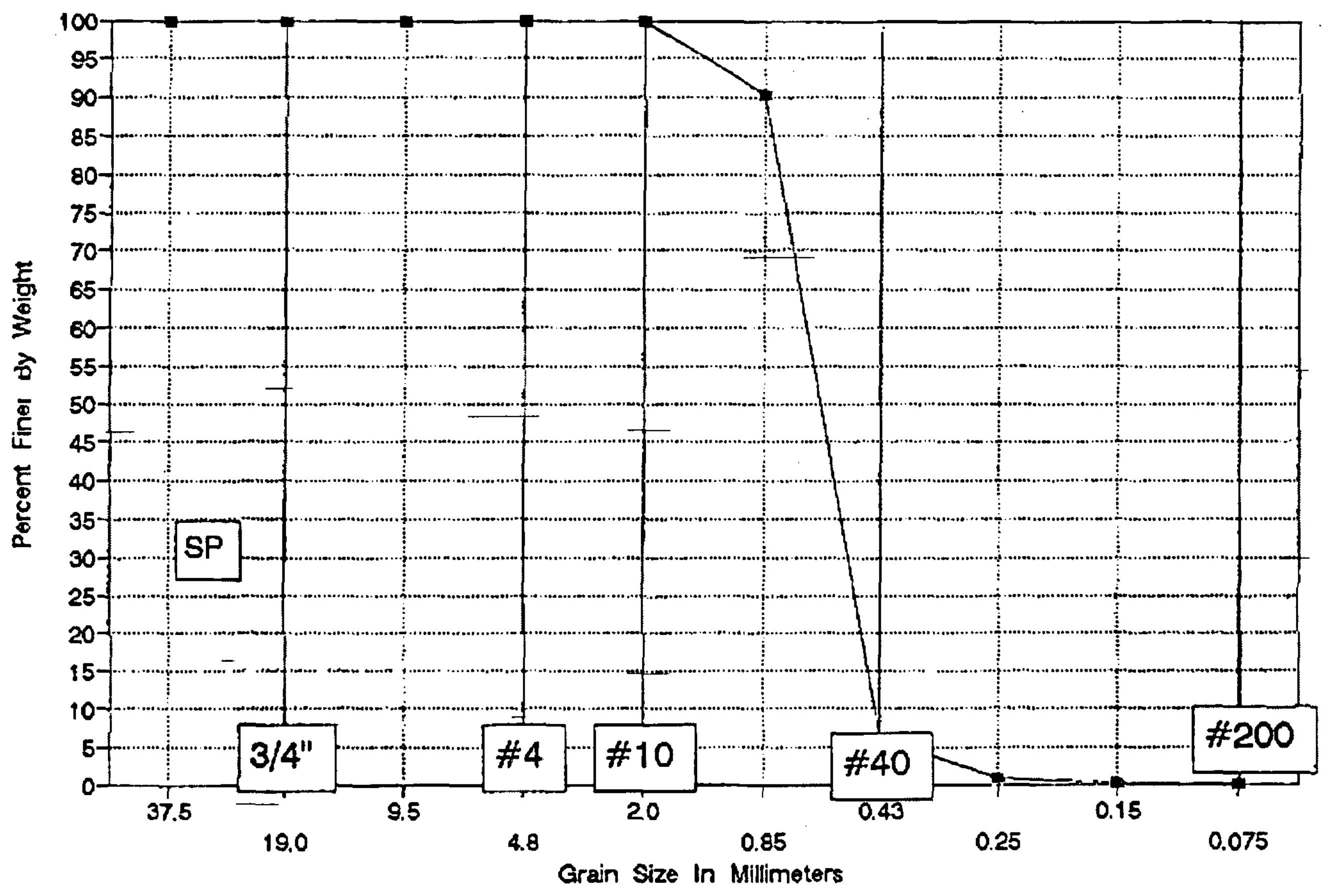
WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______(grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT	
					RETAINED	FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"		0		
		#4		24.25		
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT		
					PARTIAL		TOTAL
					RETAINED	FINER	FINER
		#10		126.30			
		#20		126.37			
		#40		126.38			
		#60		126.39			
		#100		126.44			
		#200		126.44			
		PAN					
		TOTAL					

GRADATION CURVE

Boring PB-WA-MW1, Sand # 7



Plum Brook Ordinance Works
Sandusky Ohio

Boring PB-WA-MW1
Sand #7

Wet soil & dish	197.6
Dry soil & dish	197.6
Dish	111.9

Moisture Content = 0.0

SIEVE ANALYSIS

Dry weight of total sample= 85.7

Sieve #	weight retained	Finer	% Finer	mm
1.5 inch	0	100.00%	100.0	37.5
3/4 inch	0	100.00%	100.0	19.0
3/8 inch	0	100.00%	100.0	9.5
# 4	0	100.00%	100.0	4.8
# 10	0	100.00%	100.0	2.0
# 20	8.46	90.13%	90.1	0.85
# 40	80.48	6.09%	6.1	0.43
# 60	84.92	0.91%	0.9	0.25
# 100	85.52	0.21%	0.2	0.15
# 200	85.61	0.11%	0.1	0.075

MECHANICAL ANALYSIS (SA) HA -#200

DATE 12/3/94 BY RH

JOB NUMBER 24637-035 OWNER/CLIENT PLUM BROOKS ORDINANCE

LOCATION

BORING PB-WA-MW1 SAMPLE SAND #7 DEPTH

NUMBER OF RINGS		DISH	ST-23
WT. OF RINGS & WET SOIL		WT. OF DISH & WET SOIL	197.6
WT. OF RINGS		WT. OF DISH & DRY SOIL	~~197.2~~ 197.6 RH
WT. OF WET SOIL		WT. OF MOISTURE	
FIELD DENSITY		WT. OF DISH	111.9
DRY DENSITY		WT. OF DRY SOIL	
		FIELD MOISTURE CONTENT	

WASH SIEVE ______ DRY SIEVE ______ WEIGHT OF OVEN DRY SOIL ______ (grams)

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUMULATIVE WEIGHT RETAINED	ACCUMULATIVE PERCENT RETAINED	ACCUMULATIVE PERCENT FINER
		3"				
		1-1/2"				
		3/4"				
		3/8"				
		#4				
		PAN				
		TOTAL				

DISH NUMBER	DISH WEIGHT	SIEVE NUMBER	WEIGHT RETAINED	ACCUM. WEIGHT RETAINED	ACCUMULATIVE PERCENT PARTIAL RETAINED	ACCUMULATIVE PERCENT PARTIAL FINER	ACCUMULATIVE PERCENT TOTAL FINER
		#10		0			
		#20		8.46			
		#40		80.48			
		#60		84.92			
		#100		85.52			
		#200		85.61			
		PAN					
		TOTAL					

Dames & Moore

APPENDIX F

WELL SURVEY DOCUMENTATION

[illegible]e: [illegible]TNTA.[illegible]

POINT	NORTHING	EASTING	ELEVATION	NOTE
1000	32580.1577	27844.9668	638.0465	MK-MW22 CAS
1001	32580.3630	27844.3376	635.5575	MK-MW22 GND
1002	32935.1711	29414.2443	639.4729	MK-MW23 CAS
1003	32934.0916	29414.5169	636.9500	MK-MW23 GND
1004	30493.6231	27420.8660	657.1164	MK-MW24 CAS
1005	30494.7073	27420.4812	654.4446	MK-MW24 GND
1006	32095.2811	27479.5229	640.1783	PB-TNTA-MW10 CAS
1007	32093.1214	27478.6611	637.5025	PB-TNTA-MW10 GND
1008	31733.6648	26832.7054	640.4990	PB-TNTA-MW11 CAS
1009	31731.5058	26832.6482	637.8648	PB-TNTA-MW11 GND

ile: [illegible].CRS

POINT	NORTHING	EASTING	ELEVATION	NOTE
2000	24937.4730	22260.6698	674.3227	MK-MW16 CAS
2001	24938.5128	22260.1230	671.3271	MK-MW16 GND
2002	26671.1286	22021.0026	664.6425	MK-MW17 CAS
2003	26670.7095	22019.8256	660.9672	MK-MW17 GND

[illegible]

POINT	NORTHING	EASTING	ELEVATION	NOTE
3000	29408.6978	15531.0263	645.4149	PB-TNTC-MW3 CAS
3001	29408.8887	15532.7451	642.5686	PB-TNTC-MW3 GND
3002	28334.5197	14635.8790	654.4254	PB-TNTC-MW4 CAS
3003	28332.1101	14634.9910	651.8891	PB-TNTC-MW4 GND
3004	28645.6081	15969.9882	651.8103	PB-TNTC-MW5 CAS
3005	28645.9387	15972.1375	649.0699	PB-TNTC-MW5 GND
3006	28411.4613	17171.1652	659.4018	PB-TNTC-MW6 CAS
3007	28413.0296	17169.5598	656.8196	PB-TNTC-MW6 GND

File: NWA-WELLS.GRI

POINT	NORTHING	EASTING	ELEVATION	NOTE
4000	30428.4220	14380.0948	639.5980	IT-MW002 CASING
4001	30428.0835	14379.8283	636.6895	IT-MW002 GND
4002	30428.3357	14379.9481	639.6292	IT-MW002 MEAS PT
4003	31783.0116	14647.2616	640.8941	MK-MW10 CAS
4004	31784.0924	14646.6469	638.0600	MK-MW10 GND
4005	31782.0442	15925.8393	637.6858	MK-MW11 CAS
4006	31782.6482	15926.8071	634.7066	MK-MW11 GND
4007	30549.5032	14060.0756	644.4319	PB-WA-MW-1 CASING
4008	30549.4006	14060.5771	642.3200	PB-WA-MW-1 GND
4009	30038.2737	14301.1933	633.6505	PB-WA-MW-2 CASING
4010	30038.9137	14301.2543	631.1569	PB-WA-MW-2 GND

[illegible] C:PEN-WELL.[illegible]

POINT	NORTHING	EASTING	ELEVATION	NOTE
5000	33122.3541	23074.6346	633.9861	PB-PR-MW7 CAS
5001	33122.1380	23074.6900	631.5000	PB-PR-MW7 GND
5002	33022.0426	23365.0504	635.0205	PB-PR-MW8 CAS
5003	33022.1700	23364.7000	632.5000	PB-PR-MW8 GND
5004	33229.7381	23561.4850	633.6999	PB-PR-MW9 CAS
5005	33227.1940	23564.6760	630.7000	PB-PR-MW9 GND
5006	33482.7542	23520.4311	634.9943	IT-MW05 CAS
5007	33481.1410	23518.7250	631.9147	IT-MW05 GND

C:\MISCWELL.PRN

POINT	NORTHING	EASTING	ELEVATION	NOTE
6000	29006.7777	16324.7729	648.2731	PB-BED-MW13 CAS
6001	29004.7448	16324.8381	645.8093	PB-BED-MW13 GND
6002	30640.9823	14567.4105	646.0366	PB-BED-MW14 CAS
6003	30640.6739	14564.9269	643.0537	PB-BED-MW14 GND
6004	34311.2880	23307.8310	631.6394	PB-BED-MW15 CAS
6005	34311.2752	23310.1041	629.0737	PB-BED-MW15 GND
6006	31463.0050	24687.7929	636.0178	PB-BED-MW16 CAS
6007	31461.0305	24688.0338	633.6826	PB-BED-MW16 GND
6008	33666.0038	28164.0776	629.9697	PB-BED-MW17 CAS
6009	33667.9151	28164.7514	627.3369	PB-BED-MW17 GND
6010	32130.3503	29563.1857	651.5041	PB-BED-MW18 CAS
6011	32128.0488	29563.0032	648.8318	PB-BED-MW18 GND
6012	31782.9542	14256.5847	643.0705	PB-BED-MW19 CAS
6013	31780.9102	14256.3225	640.5050	PB-BED-MW19 GND
6014	20646.7145	27306.6374	676.3317	PB-BED-MW20 CAS
6015	20645.1156	27305.6314	673.5732	PB-BED-MW20 GND
6016	34874.6151	21994.7173	630.1175	REACTOR1 CAS
6017	34874.7528	21994.7061	630.2061	REACTOR1 GND
6018	34762.4651	22017.2722	630.6801	REACTOR2 CAS
6019	34762.6821	22017.2191	630.7188	REACTOR2 GND
6020	34790.0313	22161.7567	630.8760	REACTOR3 CAS
6021	34790.0394	22161.8592	630.7346	REACTOR3 GND
6022	34735.1486	22161.2091	631.1532	REACTOR4 CAS
6023	34735.1918	22161.2332	630.7567	REACTOR4 GND

File: C:WA-SOIL.CR5

NT	NORTHING	EASTING	ELEVATION	NOTE
7000	30006.1890	14404.1956	631.8186	PB-WA-S1
7001	29954.2200	14345.3691	624.3863	PB-WA-S2
7002	29932.7040	14250.8353	626.0317	PB-WA-S3
7003	30183.0401	14061.7649	633.3041	PB-WA-S4
7004	30159.2497	14065.3231	633.0988	PB-WA-S5
7005	30147.6119	13844.2866	633.3705	PB-WA-S6
7006	30184.1411	13752.1463	635.3703	PB-WA-S7
7007	30354.5831	13748.0405	637.7745	PB-WA-S8
7008	30441.3753	14085.3392	639.3238	PB-WA-S9
7009	30331.5225	14694.5146	632.1665	PB-WA-S11
7010	30166.2900	14696.1580	627.5275	PB-WA-S12
7011	30066.0276	14455.5353	631.5901	PB-WA-S13
7012	30058.3731	14678.7106	629.1723	PB-WA-S14
7013	30531.8066	14752.4694	632.8720	PB-WA-S15
7014	30433.0133	14278.0708	638.2466	PB-WA-S16
7015	30334.9682	14416.1803	633.1152	PB-WA-S17
7016	30192.6733	14442.4040	631.5738	PB-WA-S18
7017	30442.8399	14461.8418	632.3120	PB-WA-S19
7018	30092.2223	14361.9554	631.3624	PB-WA-S20
7019	30105.3354	14387.2320	630.8781	E POND H2O ELEV
7020	30091.9365	14312.4992	634.9013	W POND H2O ELEV
7021	30411.8869	14299.0826	0.0000	GRID A,0
22	30312.0487	14304.8151	0.0000	GRID 2
23	30362.2829	14301.7802	0.0000	GRID 1
7024	30263.3419	14307.5367	0.0000	GRID 3
7025	30214.0439	14310.2108	0.0000	GRID 4
7026	30164.6824	14313.1814	0.0000	GRID 5
7027	30115.9103	14315.8810	0.0000	GRID 6
7028	30039.5931	14317.2538	0.0000	GRID 7
7029	30080.1290	14267.4196	0.0000	GRID B'
7030	30084.4724	14220.4927	0.0000	GRID C'
7031	30088.0436	14168.2477	0.0000	GRID D'
7032	30106.6105	14145 6197	0.0000	GRID 6'
7033	30156.6212	14143.6142	0.0000	GRID 5'
7034	30205.4939	14112.9276	0.0000	GRID E'
7035	30202.9630	14063.6400	0.0000	GRID F'
7036	30203.0170	14014.3397	0.0000	GRID G'
7037	30203.0974	13964.5085	0.0000	GRID H'
7038	30202.7904	13915.0375	0.0000	GRID I'
7039	30197.5543	13867.1776	0.0000	GRID J'
7040	30198.9283	13817.7907	0.0000	GRID K'
7041	30201.5060	13763.7801	636.6574	GRID L' BOB
7042	30230.3993	13771.3730	0.0000	GRID 3'
7043	30280.8029	13768.3270	0.0000	GRID 2'
7044	[illegible].9362	13765.6018	636.8394	GRID 1' BOB
7045	30380.2308	13764.6497	0.0000	GRID 0'
7046	30410.8059	13751.3223	0.0000	GRID L
7047	30413.6969	13801.2278	0.0000	GRID K
48	30415.0239	13851.4200	0.0000	GRID J
7049	30416.6131	13902.1923	0.0000	GRID I
7050	30418.5878	13950.5357	0.0000	GRID H
7051	30417.7195	14001.1511	0.0000	GRID G
7052	30416.4089	14050.5125	0.0000	GRID F
7053	30415.9302	14101.0651	0.0000	GRID E
7054	30415.1270	14150.0190	0.0000	GRID D
7055	[illegible]	14200.1267	0.0000	GRID [illegible]

POINT	NORTHING	EASTING	ELEVATION	NOTE
7056	30412.9637	14249.8965	0.0000	GRID B
7057	30411.3433	14231.3303	635.9779	BOB (BOT OF BANK
7058	30415.9536	14232.9379	639.3188	TOB (TOP OF BANK)
7059	30387.0836	14301.1532	637.6700	TOB
7060	30374.3088	14301.9589	634.8275	BOB
7061	30368.4182	14314.1058	635.1599	BOB
7062	30358.6547	14336.7958	637.5027	BERM
7063	30226.2309	14339.8316	638.1550	BERM
7064	30227.7183	14321.0614	635.4249	BOB
7065	30074.9673	14323.4755	638.4649	BERM
7066	30085.9520	14318.9367	636.1066	BOB
7067	30067.9813	14230.8525	637.9243	BERM
7068	30075.3576	14224.2036	635.9106	BOB
7069	30078.5948	14142.1937	638.5194	BERM
7070	30085.1195	14144.8041	636.3330	BOB
7071	30129.2379	14126.9881	637.7410	BERM
7072	30132.4814	14132.5218	635.9668	BOB
7073	30190.0450	14110.7680	638.1967	BERM
7074	30199.0133	14115.1351	635.3406	BOB
7075	30193.9837	14063.9819	636.1324	BREECH
7076	30189.3128	13957.6800	638.1029	BERM
7077	30194.4934	13956.8308	635.9451	BOB
7078	30195.9626	13763.0785	638.0533	BERM
7079	30255.0272	13748.0461	637.4130	EDGE LOW AREA
7080	30266.2094	13754.2036	636.0354	BOB
7081	30323.5849	13754.0661	637.2612	EDGE LOW AREA
7082	30360.1172	13798.4222	637.7170	TOB
7083	30356.4426	13802.7049	635.9964	BOB
7084	30384.3376	13851.3515	635.9836	BOB
7085	30388.2027	13847.7164	638.6041	TOB
7086	30416.7064	13937.8332	637.8301	TOB
7087	30409.4718	13943.9074	635.4179	BOB
7088	30434.4388	14035.9950	635.9225	BOB
7089	30442.5649	14040.6405	636.8063	BOB
7090	30423.0000	14047.0726	639.2780	TOB
7091	30421.8045	14046.8447	635.6744	BOB
7092	30412.0179	14130.6031	635.3740	BOB
7093	30413.6284	14129.3554	638.0894	TOB

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POINT	NORTHING	EASTING	ELEVATION	NOTE
8000	33227.1240	22964.6760	633.5100	P-BH1
8001	33022.1240	22964.7000	633.0200	P-BH2
8002	32922.1240	22964.7120	633.0800	P-BH3
8003	33122.1380	23074.6900	631.4900	P-MW4
8004	32922.1670	23074.7120	631.2100	P-BH5
8005	33227.1470	23164.6770	631.3200	P-BH6
8006	33022.1470	23164.7000	631.1100	P-BH7
8007	33517.1580	23264.6430	633.6700	P-BH8
8008	33322.1580	23264.6650	631.1200	P-BH9
8009	33122.1590	23264.6880	631.1000	P-BH10
8010	32922.1610	23284.7120	632.2900	P-MW11
8011	33422.1700	23364.6540	630.4200	P-BH12
8012	33227.1700	23364.6760	632.8100	P-BH13
8013	33022.1700	23364.7000	632.4800	P-MW14
8014	33322.1830	23464.6670	633.0200	P-BH15
8015	33122.1820	23464.6880	634.5400	P-BH16
8016	32922.1820	23464.7120	631.1900	P-BH17
8017	33422.1920	23564.6540	629.8800	P-BH18
8018	33227.1940	23564.6760	630.7300	P-MW19
8019	33122.1940	23564.6880	631.6100	P-BH20
8020	33110.0910	23177.0110	630.5700	PB-PR-S21
8021	33162.1750	23394.6850	634.6300	P-BH21A
22	33275.8650	23282.9030	630.3200	PB-PR-S22
23	33369.6920	23353.9460	629.8300	PB-PR-S23
8024	33373.7880	23447.8330	629.9700	PB-PR-S24

APPENDIX J

FRACTURE TRACE ANALYSIS

J.0 FRACTURE TRACE ANALYSIS

A preliminary fracture trace analysis was performed at the PBS to try to identify optimal locations for installation of wells in the limestone and shale bedrock underlying the site. The geology of the subsurface at the PBS is similar to other locations where fracture trace analysis has been useful in evaluating the occurrence and movement of groundwater. Fracture trace analysis was also felt to be useful in locating zones of preferential flow beneath PBS, and therefore aid in locating future monitoring wells.

J.1 APPLICABILITY OF FRACTURE TRACE ANALYSIS TO PBS SITE

Lattman (1958) defined a fracture trace as follows:

> *A photogeologic fracture trace is a natural linear feature consisting of topographic (including straight stream segments), vegetation, or soil tonal alignments, visible primarily on aerial photographs, and expressed continuously for less than one mile. Only natural linear features not obviously related to the outcrop pattern of tilted beds, lineation and foliation, and stratigraphic contacts are classified as fracture traces.*

The importance of fracture traces to groundwater hydrogeology comes from the observation that these features are often underlain by zones of closely-spaced fractures or faults in the bedrock. These zones are capable of transmitting larger quantities of water than the adjacent less-fractured bedrock, and of localizing groundwater flow.

In typical sedimentary rocks and unconsolidated sediments, groundwater is contained in pore spaces between individual grains. Groundwater movement is controlled by the movement of water within and between pore spaces. Within individual units, aquifers are often considered somewhat homogeneous and isotropic. In carbonates and shales like those that underlie PBS, groundwater occurs along joints, bedding planes, faults or other fracture zones. Groundwater movement is controlled by the distribution, interconnectivity and orientation of the joints, faults, bedding planes and fracture zones. These fractured aquifers are, therefore, strongly non-homogeneous and anisotropic. Groundwater flow rates along zones of fracture concentration are typically orders of magnitude higher than flow in the surrounding rock. Therefore, the locations of the zones of fracture concentration must be considered when locating monitoring wells and interpreting groundwater flow patterns for a particular region.

Fracture traces are considered to be surface expressions of vertical or near-vertical zones of fracture concentration. They are straight, cut across topography, and often independent of regional structural trends. Typical thicknesses range from 6 to 70 feet (Gold and Parizek, 1976).

The fracture trace technique is basically a method for locating narrow zones of highly fractured rock. It has been very successful in geological settings where solutioned limestones are exposed or have a thin soil mantle. It can also be used in areas of glacial cover, as bedrock fractures tend to be propagated upward through the overburden by means of a complex combination of drainage enhancement, differential settling, and erosion. Fracture trace analysis for water well location is not foolproof. The fracture trace technique is simply a means to maximize the chances of obtaining well yields in the upper end of the range possible for a particular geological and hydrological setting.

The geology in the vicinity of PBS consists of gently dipping carbonate and shale bedrock units overlain by a thin veneer of glacial sediments. Carbonates underlie the northern and western portion of the site, and shales underlie the south and eastern portion of the site. Karst topography has been observed in carbonate bedrock in northern and western Erie county, north and west of PBS. The depth to bedrock ranges from zero to 25 feet.

Groundwater flow in the carbonate and shale bedrock units is probably influenced by joints, faults, bedding planes and other zones of fracture concentration. Identifying these zones of fracture concentration is important in understanding the groundwater flow patterns in the vicinity of the site, and for locating monitoring wells.

The thinness of the glacial covering lends itself to fracture trace analysis. The zones of fracture concentration in the bedrock can be propagated through the thin glacial covering as described above. Fracture trace analysis is both relevant and applicable for the PBS.

J.2 AERIAL PHOTO INTERPRETATION

J.2.1 Aerial Photos Interpreted

Aerial photos at three different scales at PBS have been interpreted for fracture traces. The scales range from the largest scale of 1:6000 to the smallest scale of 1:20400. These photos generally overlap enough so that stereoscope analysis is possible. Table J-1 lists the essential details for three photo sets. The photo sets are named based on their identification numbers printed on each photo in the set.

The recommended scale of aerial photography for fracture trace analysis is 1:20000 (Meiser and Earl, 1982). The aerial photography available for PBS ranges from scales smaller to scales larger than the recommended scale. The photography available also ranges from 1950 to 1988, providing coverage during most of the period of time that PBS was actively in use. The 3823 photo set has significant snow cover in all photos. This snow cover makes photo interpretation for fracture trace analysis more difficult.

J.2.2 Photo Interpretation Methods

Fracture trace analysis was performed for each set of photographs. The procedure used for fracture trace analysis is described below.

1. The photographs were fit together into a photomosaic of the site. A clear plastic overlay was prepared to overlay the photomosaic. A few major road features were transferred to the photomosaic, so the overlay could be oriented over any individual photograph.

TABLE J-1

PBS AERIAL PHOTOGRAPHS

Photo Set	Scale	Date of Photos	Number of Photos	Coverage
PW Set	1:20400 (1" = 1700 ft)	October, 1950	8	All except SE corner
733 Set	1:8400 (1" = 700 ft)	??	7	Only NE portion
3823 Set	1:6000 (1" = 500 ft)	??	61	Entire site

2. The photomosaic was dismantled, and fracture trace analysis was performed using multiple methods. These methods include:

   - Stereoscope Viewing: Most of the fracture traces were identified using a stereoscope. Two photos at a time were used for stereoscopic viewing. The stereoscope was moved over the appropriate portion of the photos, and the linear features noted.

   - Non-stereoscope Viewing: Each photo was also examined individually, without the benefit of the stereoscope. This method was particularly successful in the large scale photographs, because the linear features were generally larger than the field of view of the stereoscope in these photographs. The photographs were examined using both high and low angles, and the photograph was rotated to check all possible orientations.

   - Alternate light sources: For both stereoscope and non-stereoscope viewing, several different light sources were used. Incandescent lighting and daylight were both used for reflected light viewing. Various positions for the light sources were also used. Transmitted light was also used during the non-stereoscope viewing. In some cases, the transmitted light highlighted fracture traces that were difficult to discern using reflected light.

3. For all of the viewing methods, the photographs were directly viewed without the clear overlay. After each fracture trace was identified, the clear plastic overlay was placed on the photo and the linear feature recorded on the overlay. The overlay was then removed, and the search for more linear features continued. This procedure was used to record the location of the linear features without marking or in any other way biasing the photographs. This procedure also allowed all of the linear features for each set of photographs to be recorded on a single integrated overlay. The overlay was used for all photos in the set. For mapping the entire PBS site, this procedure was easier and resulted in less bias than the traditional method of marking the ends of the linear features.

4. For all scales of photographs, only those linear features which had apparently non-human origins were recorded. Mapped linear features included topographic lows, straight segments of streams, vegetation alignments, and soil tonal alignments. No roads, power lines, plow lines, or other clearly man-made features were recorded. In some cases, it was difficult to assess whether some of the features were the result of human activities. In many areas, lines of trees exist, and the origin of these lines are not clearly apparent.

5. In order to synthesize the fracture trace information, the observed fracture traces at the various photo scales were plotted on a common scale. The fracture traces interpreted from each set of aerial photos were transferred to a clear overlay of a USGS quadrangle map of the PBS site (USGS Sandusky and Kimball Quadrangles), at a 1:24000 scale. In order to transfer the fracture traces to the map overlay, the fracture traces were numbered and described. Then the approximate location of each fracture trace was plotted on the map overlay. This process was performed for each set of fracture traces. The locations of the fracture traces plotted on the map overlays are approximate, since many features have changed over time, and several features from the aerial photos are difficult to locate exactly on the map.

J.2.3 Results of Air Photo Interpretation

The PW photo set (1:20400) covers most of the PBS site, except for the extreme southeast portion. This photo set is the closest to the recommended scale for aerial photo analysis. Seventy fracture traces were mapped in and near the PBS site on the PW photo set. Figure J-1 shows the USGS map overlay of the fracture traces mapped in the PW photo set, and Table J-2 lists the corresponding fracture traces. This photo set was taken in October of 1950, and the mapped linear features were identified based on soil tonal alignment, vegetation alignment, and observed depressions. Some linear features were mapped based on straight stream segments.

TABLE J-2

LISTING OF FRACTURE TRACES IN PW AERIAL PHOTO SET

Fracture Trace Number	Approximate Orientation	Photo Evidence	Equivalent Fracture Traces in other Photo	Ground Truth Area	Ground Truth Evidence
PW-1	NE	aqueduct?			
PW-2	NNE	aqueduct?			
PW-3	NE	dark soil tonal alignment	733-1		
PW-4	NW	light soil tonal alignment	733-16	TNTA	man-made
PW-5	NE	dark soil tonal alignment	733-17;3823-4	TNTA	slight depression
PW-6	NW	depression and vegetation alignment		TNTA	no evidence- too wooded
PW-7	NE	soil tonal alignment	733-8	TNTA	no evidence- too wooded
PW-8	NNW	soil tonal alignment	733-7		
PW-9	NNW	light soil tonal alignment	733-10	TNTA	man made
PW-10	E	vegetation alignment	733-9	TNTA	man-made
PW-11	NE	light soil tonal alignment			
PW-12	NE	ditch and soil line			
PW-13	N	vegetation alignment	3823-44		
PW-14	E	vegetation alignment		SRBP	slight depression
PW-15	N	vegetation alignment	3823-38		
PW-16	NE	depression and vegetation alignme	3823-42		
PW-17	NE	soil tonal alignment	3823-36	BW	boundary of plowed field
PW-18	NNW	vegetation alignment			
PW-19	N	light soil tonal alignment			
PW-20	N	light soil tonal alignment			
PW-21	NW	soil tonal alignment		SRBP	slight depression
PW-22	N	light soil tonal alignment		SRBP	no evidence
PW-23	N	vegetation alignment		SRBP	no evidence
PW-24	NE	ditch and soil alignment		TNTB	man made ditch
PW-25	N	vegetation alignment		TNTB	no evidence
PW-26	N	vegetation alignment		TNTB	no evidence
PW-27	NNE	vegetation alignment		TNTB	no evidence
PW-28	NNE	light soil tonal alignment		TNTB	no evidence
PW-29	NW	dark soil tonal alignment	733-26; 3823-15		
PW-30	NEE	vegetation alignment		BW	man made
PW-31	N	dark soil tonal alignment		MTT	no evidence
PW-32	E	vegetation alignment	3823-33		
PW-33	N	soil tonal alignment		MTT	broad depression
PW-34	NE	straight stream segment	733-21; 3823-12		
PW-35	NE	aqueduct?		PR RWP	aqueduct
PW-36	NE	straight stream and light soil align	733-28	PR RWP	aligned ditches
PW-37	NNW	depression		PR RWP	man made
PW-38	E	depression		SA	no evidence
PW-39	NE	soil tonal alignment		PR RWP	good depression
PW-40	N	vegetation alignment		PR RWP	no evidence
PW-41	NE	straight stream segment	733-41		

TABLE J-2

LISTING OF FRACTURE TRACES IN PW AERIAL PHOTO SET

Fracture Trace Number	Approximate Orientation	Photo Evidence	Equivalent Fracture Traces in other Photo	Ground Truth Area	Ground Truth Evidence
PW-42	NNE	straight stream segment			
PW-43	NE	dark soil tonal alignment			
PW-44	NEE	dark soil tonal alignment			
PW-45	NEE	dark soil tonal alignment			
PW-46	NEE	dark soil tonal alignment			
PW-47	NE	dark soil tonal alignment			
PW-48	NNE	dark soil tonal alignment			
PW-49	N	vegetation alignment			
PW-50	E	straight stream segment		WA RWP	man made ditch
PW-51	N	vegetation alignment		TNTC	man made?
PW-52	NW	vegetation alignment		TNTC	man made?
PW-53	NE	vegetation alignment		TNTC	man made?
PW-54	NNE	straight stream segment	3823-53	WA RWP	straight stream
PW-55	NE	soil tonal alignment		WA RWP	broad depression
PW-56	NE	vegetation alignment	3823-55	WP RWP	very slight topography
PW-57	NE	soil tonal alignment			
PW-58	N	soil and vegetation alignment		TNTC	man made?
PW-59	NNW	vegetation alignment and depression		TNTC	man made?
PW-60	NNW	soil tonal alignment		TNTC	man made?
PW-61	NNW	soil tonal alignment		TNTC	no evidence - overgrown
PW-62	N	vegetation alignment			
PW-63	NE	light soil tonal alignment			
PW-64	NW	light soil tonal alignment		TRBP	no evidence
PW-65	NNW	straight stream segment	3823-43	TRBP	no evidence
PW-66	NW	light soil tonal alignment and depression		STT	no evidence
PW-67	NNW	soil tonal alignment		STT	slight depression
PW-68	N	soil tonal alignment	3823-59	STT	no evidence
PW-69	NWW	soil tonal alignment		STT	slight depression
PW-70	NE	soil tonal alignment			

The 733 photo set (1:8400) covers only the northeast portion of the site. Thirty-one fracture traces were mapped in the region covered by the 733 photo set. Table J-3 lists the corresponding fracture traces, as well at their approximate orientations and identifying evidence. The mapped linear features were mainly due to soil tonal and vegetative alignments, as well as straight stream segments.

The 3823 photo set (1:6000) covers the entire site at a large scale using 61 photos. However, significant snow cover exists in the photos. This snow cover prevents mapping fracture traces based on soil tonal alignment, and makes it more difficult to map vegetative alignment. Also, the snow cover makes it much more difficult to evaluate whether the straight line segments are due to human activities. The mapped fracture traces are mainly due to depressions in the snow surface or alignment of large vegetation. Sixty-one fracture traces were mapped. Table J-4 lists the corresponding fracture traces, as well at their approximate orientations and identifying evidence.

Many of the fracture traces mapped in one photo set are different from fracture traces mapped in other photo sets. This phenomenon is expected, since the photos cover different seasons and cover a range of nearly 40 years. Fracture traces that are mapped in more than one set of photos may be a result of strong expression of zones of fracture concentration, or a result of human activities. Table J-5 shows the number of mapped fracture traces that are common between various photo sets. The tables listing the fracture traces for each photo set also contain a column listing the common fracture traces between photo sets.

J.3 FIELD CHECKING OF PHOTO FEATURES

In order to locate wells using the fracture trace technique, it is important to field check the photo evidence. This process is made difficult because there are often several clues of different types which define a fracture trace, and some of the linear features may be due to human activity. The most common land features seen on the ground are topographic lows or depressions, stream alignments, vegetation alignments, and soil tones.

TABLE J-3

LISTING OF FRACTURE TRACES IN 733 AERIAL PHOTO SET

Fracture Trace Number	Approximate Orientation	Photo Evidence	Equivalent Fracture Traces in other Photo	Ground Truth Area	Ground Truth Evidence
733-1	NE	aqueduct?	PW-3		
733-2	NE	soil tone alignment			
733-3	NW	vegetation alignment			
733-4	NE	soil tone alignment			
733-5	NNW	light soil tonal alignment			
733-6	NW	vegetation and dark soil tone			
733-7	NNW	soil tone alignment	PW-8		
733-8	NE	soil tone alignment	PW-7		
733-9	E	soil tonal alignment	PW-10		
733-10	NNW	light tonal alignment	PW-9		
733-11	NE	vegetation alignment			
733-12	NW	light soil tonal alignment	3823-7		
733-13	NE	dark soil tonal alignment			
733-14	NNW	light soil tonal alignment			
733-15	NE	depression and dark soil tone			
733-16	NW	light soil tonal alignment	PW-4		
733-17	NE	light soil tonal alignment	PW-5	TNTA	slight depression
733-18	NE	vegetation and dark soil tone		TNTA	no evidence
733-19	NE	vegetation alignment		TNTA	man-made ditch
733-20	NW	vegetation and dark soil tone		TNTA	broad low depression
733-21	NE	straight stream segment	PW-34		
733-22	NNE	dark soil tonal alignment			
733-23	N	depression			
733-24	NE	straight stream segment	PW-41		
733-25	E	soil tonal alignment			
733-26	NE	dark soil tonal alignment	PW-29		
733-27	NE	aqueduct?	3823-17	PR RWP	aqueduct
733-28	NE	straight stream segment	PW-36		
733-29	ME	aqueduct?	PW-29		
733-30	NNE	topographic line		PR RWP	near power line - no evidence
733-31	NE	vegetation alignment		SA	wide, slight depression

TABLE J-4

LISTING OF FRACTURE TRACES IN 3823 PHOTO SET

Fracture Trace Number	Approximate Orientation	Photo Evidence	Equivalent Fracture Traces in other Photo Sets	Ground Truth Area	Ground Truth Evidence
3823-1	NE	snow tone - depression			
3823-2	NNE	snow tone - depression			
3823-3	NE	high snow mound			
3823-4	NW	vegetation and depression	PW-5		
3823-5	NE	vegetation alignment		TNTA	partially man made, partly natural
3823-6	NW	depression		TNTA	man made ditch
3823-7	NE	dark tree line and depression	733-12		
3823-8	NNW	depression			
3823-9	NNW	tree line		TNTA	no evidence - too wooded
3823-10	E	vegetation and snow tone alignment			
3823-11	NE	snow tone - depression			
3823-12	NE	straight stream segment	PW-34		
3823-13	N	vegetation alignment		PR RWP	tree alignment, no depression
3823-14	E	vegetation alignment			
3823-15	N	vegetation alignment	PW-29		
3823-16	NE	depression and vegetation alignment			
3823-17	NE	snow tone - depression	733-27	SA	aqueduct
3823-18	NNW	depression and vegetation alignment		PWWDB	sharp and marshy depression
3823-19	N	vegetation alignment		PWWDB	shallow depression and marsh
3823-20	N	vegetation alignment			
3823-21	NW	topographic alignment	PW-44		
3823-22	N	topographic alignment			
3823-23	N	depression			
3823-24	NE	depression			
3823-25	N	depression			
3823-26	N	topographic alignment			
3823-27	NNE	topographic alignment			
3823-28	NNE	topographic alignment			
3823-29	NW	depression			
3823-30	NEE	straight stream segment		MTT	man made
3823-31	N	vegetation and topographic alignment			
3823-32	E	depression			
3823-33	N	tree line	PW-32		
3823-34	NE	depression			
3823-35	NE	depression and vegetation alignment			
3823-36	NE	depression and vegetation alignment	PW-17	BW	no evidence - overgrown
3823-37	NNW	tree alignment		BW	man made - old road
3823-38	E	vegetation alignment	PW-15		
3823-39	NE	vegetation alignment			
3823-40	N	depression and snow tone			
3823-41	NE	snow tone			
3823-42	NNE	snow tone line	PW-16		
3823-43	NE	vegetation and topographic alignment	PW-65		

TABLE J-4

LISTING OF FRACTURE TRACES IN 3823 PHOTO SET

Fracture Trace Number	Approximate Orientation	Photo Evidence	Equivalent Fracture Traces in other Photo Sets	Ground Truth Area	Ground Truth Evidence
3823-44	NEE	vegetation alignment	PW-13		
3823-45	NEE	vegetation alignment			
3823-46	NEE	vegetation alignment			
3823-47	NE	depression			
3823-48	NNE	depression and vegetation alignment			
3823-49	N	depression and vegetation alignment		TNTB	broad shallow depression
3823-50	E	vegetation and straight stream segment		TNTB	man made ditch
3823-51	N	depression		TRBP	depression and grass alignment
3823-52	NW	vegetation alignment			
3823-53	NE	straight stream segment	PW-54	WA RWP	straight stream
3823-54	NNE	straight stream segment and depression		WA RWP	segment of Plum Brook- man made?
3823-55	NE	vegetation alignment	PW-56	WA RWP	very slight high and low topography
3823-56	NE	topographic alignment			
3823-57	NE	topographic alignment		TNTC	sharp topographic line, man made ?
3823-58	N	vegetation alignment		G-8 BGA	no evidence-too wooded
3823-59	NNW	vegetation alignment	PW-68		
3823-60	NNW	topographic alignment			
3823-61	NNW	topographic alignment			

TABLE J-5

FRACTURE TRACES COMMON AMONG PHOTO SETS

	PW Set	733 Set	3823 Set
PW Set	70	11	13
733 Set		31	2
3823 Set			61

Since zones of closely spaced fractures are more easily weathered and eroded than surrounding rock, the most common form of ground truth is a linear sag, swale or valley along the fracture zone. Abrupt changes in the courses of streams are often related to region joint sets in bedrock. In carbonate bedrock, it is common to find sinkholes and closed depressions aligned along a zone of fracture concentration.

Vegetation alignments form because the deeper weathering along a fracture zone results in deeper root development along fracture traces. Vegetation along a fracture trace may be larger or more dense than neighboring vegetation. This evidence is often difficult to see at the ground level.

Soil tonal alignments are often easy to see in aerial photos, but much more difficult to discern on the ground. The field of view on the ground is very limited. The amount of sunlight, plant cover, and time since the last rainfall can all effect the usefulness of soil tonal alignments as a tool for ground checking.

At the PBS site, ground checking of the fracture traces was performed on March 13 and 14, 1995. No snow cover was present at the site during the ground checking. Not every fracture trace observed in the aerial photos was checked on the ground. Only those fracture traces situated in areas of the site where monitoring wells are likely to be located were checked. Fracture traces were checked on the ground in 13 general areas. These areas and the corresponding fracture traces that were checked in each area are listed in Table J-6.

The results of field checking of these fracture traces are also included in Tables J-2, J-3, and J-4. If a fracture trace was field checked, the general area in which it is located is listed in the appropriate table. The ground evidence for the fracture trace is also provided. In general, the ground evidence for fracture traces fell into several categories: (1) human activity, (2) no evidence, (3) slight to strong depressions or other evidence. Many of the fracture traces observed in the aerial photos were the result of human activities, and field checking allowed man made features to be easily identified. Twenty of the fracture traces which were field checked were thought to be a result of human activities.

TABLE J-6

FRACTURE TRACES FIELD CHECKED

General Area	Fracture Traces Field Checked
Snake Road Burn Pit (SRBP)	PW-14,21,22,23
Taylor Road Burn Pit (TRBP)	PW-63,64; 3823-51
South Toluene Tank (STT)	PW-66,67,68,70
G-8 Burn Ground Area (G8BG)	3823-57
Sellite Area (SA)	PW-38; 733-27,31; 3823-17
TNT Area A (TNTA)	PW-4,5,6,7,9,10, 29,30; 733-17,18,19,20; 3823-5,6,9
TNT Area B (TNTB)	PW-24,25,26,27,28; 3823-49,50
TNT Area C (TNTC)	PW-51,52,53,58,59,60,61; 3823-57
Middle Toluene Tanks (MTT)	PW-31,33; 3823-30
Pentolite Road Red Water Ponds (PR RWP)	PW-35,36,37,39,40; 733-27,30; 3823-13
Pentolite Waste Water Disposal Basin (PWWDB)	3823-18,19
West Area Red Water Ponds (WARWP)	PW-50,54,55,56; 3823-53,54,55
Background Well Area (BW)	PW-17,30; 3823-36,37,51

For many of the fracture traces observed in the photos, no ground evidence could be found. Many times, the photo evidence was a result of soil tonal alignments, and this evidence could not be seen on the ground. However, a lack of ground confirmation does not rule out the possibility that these fracture traces exist. Soil tonal alignments are very difficult to see on the ground, yet may overly significant zones of fracture concentration. In other cases, the vegetative cover was simply too thick or too wooded to see any evidence of fracture traces. The photos may have been taken when the vegetation was much smaller, and subsequent growth has hidden all ground evidence of these fracture traces.

Depression were observed on the ground for a number of the fracture traces. These features range from very slight depressions of less than a few inches to depressions greater than a foot. The width of the depressions range from several feet to over 20 feet. Some of the depressions were aligned with vegetative evidence. No sinkholes or other evidence of karst topography was observed.

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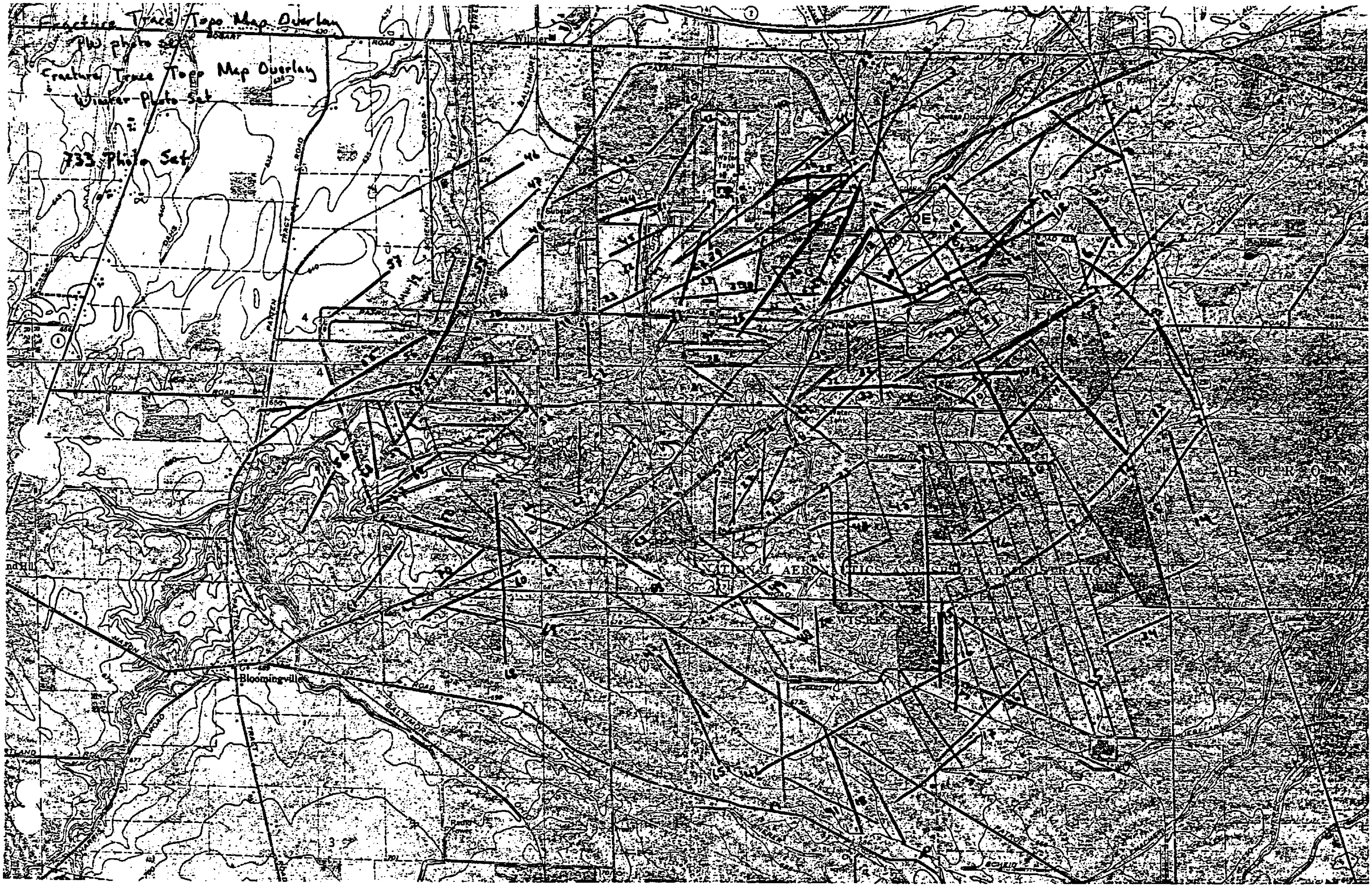
Fracture Trace Topo Map Overlay
Fracture Trace Topo Map Overlay
Winter Photo Set
733 Photo Set
Wilmer
Bloomingville
BALTIMORE
ROAD

APPENDIX A

SECTION 10

1997 Site-wide Groundwater Investigation

(IT, September 1997)

Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works
Sandusky, Ohio

Submitted To:

Commander
U.S. Army Corps of Engineers
Nashville District
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Revision 1

September 1997

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List of Acronyms

AR/COC	Analysis Request/Chain of Custody
ASTM	American Society for Testing and Materials
bgs	below ground surface
BNA	base/neutral and acid extractables
BTEX	benzene, toluene, ethyl benzene, and xylene
CLP	Contract Laboratory Program
D&M	Dames & Moore, Inc.
DERP	Defense Environmental Restoration Program
DQE	data quality evaluation
DNB	dinitrobenzene
DNT	dinitrotoluene
DOD	U.S. Department of Defense
EPA	U.S. Environmental Protection Agency
GSA	General Services Administration
GWI	groundwater investigation
H_2S	hydrogen sulfide
HRS	Hazard Ranking System
HSA	hollow-stem auger
IDW	investigation-derived waste
IT	IT Corporation
LeRC	Lewis Research Center
μg/L	micrograms per liter
MCL	maximum contamination level
MK	Morrison and Knudsen Corporation
msl	mean sea level
NASA	National Aeronautics and Space Administration
OEPA	Ohio Environmental Protection Agency
PBOW	Plum Brook Ordnance Works
PBS	Plum Brook Station
PCB	polychlorinated biphenyl
PPE	personnel protective equipment
QAPP	quality assurance project plan
QC	quality control

List of Acronyms *(Continued)*

RBC	risk-based concentration
RDX	royal demolition explosive
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SOW	statement of work
SVOC	semivolatile organic compounds
TNB	trinitrobenzene
TNT	trinitrotoluene
TNTA	TNT Area A
TNTB	TNT Area B
TNTC	TNT Area C
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VOC	volatile organic compound
WARWP	West Area Red Water Pond

Executive Summary

IT Corporation (IT) conducted a sitewide groundwater investigation (GWI) at the former Plum Brook Ordnance Works (PBOW) from September through October 1996 under contract to the U.S. Army Corps of Engineers (USACE) Nashville District. The PBOW is an approximately 9,000-acre site near Sandusky, Ohio and was used during World War II for manufacturing explosives. The site is currently owned and operated by the National Aeronautics and Space Administration (NASA) as a science research facility.

This work was conducted under the Defense Environmental Restoration Program (DERP) Formerly Used Defense Sites (FUDS) and included installation of overburden monitoring wells, redevelopment of existing monitoring wells, collection of groundwater samples, laboratory analysis of groundwater samples, evaluation of analytical and field data, and preparation and submittal of reports. The objectives of the sitewide GWI at PBOW were to acquire supplementary data of the sitewide groundwater levels and contaminants to add to an existing database, and to fill in existing data gaps in groundwater levels and contamination in western portion of PBOW. This report presents summaries of field activities, findings, conclusions, and recommendations derived from the data acquired during this sitewide GWI.

Sitewide Hydrogeology. Two major water-bearing zones exist at PBOW. The overburden water-bearing zone consists of glacial till and lacustrine deposits with varying thickness. The bedrock water-bearing zone is mainly developed in a limestone/dolomite formation containing some evaporite. General groundwater flow direction in both water-bearing zones is to the north and northeast. However, the local flow regime in the overburden may be different depending on soil thickness, topography, and surface water features and exhibits strong seasonal dependence. Some overburden wells may become dry at certain times of the year. The groundwater flow regime in the bedrock water bearing zone is believed to be influenced by the orientation and connectivity of solutionally enlarged fractures. The difference in water level elevations in both water-bearing zones indicates a predominant downward flow, but water in the shallow depth can also move upward and be lost to evapotranspiration. Data gaps were identified with respect to groundwater quality and water level elevations, especially in the middle and eastern portion of the facility.

West Area Red Water Ponds. The overburden water-bearing zone exhibits impacts by nitroaromatic compounds in the central portion of the West Area Red Water Ponds (WARWP) area, while inorganic compounds are present at concentrations exceeding the RBCs throughout this area. Detected metals in groundwater in the WARWP area will require further evaluation to determine whether these are due to site contamination.

The bedrock water-bearing zone has been impacted by nitroaromatic and organic compounds north of the WARWP area, but does not exhibit impacts by any constituents in the central portion of the WARWP area. Inorganic compounds have also exceeded the RBCs north of the WARWP area, but these exceedances will require further evaluation to determine their source.

Pentolite Road Red Water Pond. The overburden water-bearing zone in the Pentolite Road Red Water Pond area has been impacted by nitroaromatic compounds, while the bedrock water-bearing zone exhibits impacts by benzene, toluene, ethyl benzene, and xylene (BTEX), semi-volatile organic compounds (SVOC), and nitroaromatic compounds. This area has been considered as a source area of nitroaromatic contamination because of its past land use. Although the Pentolite Road Red Water Pond area water-bearing zones exhibit larger suites of inorganic compounds at concentrations exceeding the RBCs than other areas of PBOW, further evaluation is necessary to determine whether they are attributable to site contamination.

TNT Area A. Groundwater sampling results indicate that the overburden water-bearing zone has been impacted by nitroaromatic contaminants in the vicinity of MK-MW22 in the western part of TNT Area A (TNTA). The bedrock water-bearing zone exhibits impacts by BTEX and nitroaromatic compounds in the northeastern part of TNTA. Further evaluation is, however, necessary to determine whether detected inorganic in the two water-bearing zones are attributable to site contamination

TNT Area B. The overburden water-bearing zone has been impacted by nitroaromatic compounds downgradient of TNT Area B (TNTB). Further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions. The bedrock water-bearing zone within this area has not been investigated.

TNT Area C. The overburden water-bearing zone in TNT Area C (TNTC) has not been impacted by organic compounds, nitroaromatic compounds, or pesticides and polychlorinated biphenyls (PCB). A small number of metals were detected and exceeded the risk-based concentration (RBC) in the dissolved phase, but further evaluation is needed to determine whether these detections are attributable to site contamination. The bedrock water-bearing zone has been impacted by nitroaromatic and organic compounds in TNTC. Inorganic compounds have also exceeded the RBC in TNTC area, but these exceedances will require further evaluation to determine their source.

Sitewide Groundwater Quality. Analysis of groundwater samples collected from wells across the PBOW has shown that the overburden water-bearing zone has been impacted by nitroaromatic compounds with the exception of TNTC. Nitroaromatic compounds were also detected in six of the eight bedrock wells sampled, indicating that nitroaromatic contamination is evident in both water-bearing zones. Organic compounds (volatile organic compounds [VOC] and SVOCs) at concentrations exceeding the RBCs were present exclusively in overburden water-bearing zones in the two red water pond areas. At least one BTEX compound was detected in all bedrock wells, except BED-MW14 and -MW20. Free product was found in BED-MW16 located near the central toluene tank area. A variety of metals were present in groundwater samples from both water-bearing zones and some of them exceeded the RBCs. However, it is not clear whether these elevated metals are attributable to site contamination or are naturally occurring constituents. Hydrogen sulfide (H_2S) gas was encountered in three bedrock wells indicating a possible reducing environment in the bedrock zone. Pesticides and PCBs were not detected in any wells sampled during this investigation. Groundwater samples collected from five overburden wells and one bedrock well contained cyanide. However, the presence of cyanide in water samples is attributable to suspended solids since cyanide was not detected in filtered samples.

Overall groundwater quality in both water-bearing zones at PBOW showed evidence of impacts from past use of the site, including manufacturing explosives by the former PBOW in the 1940s and post-PBOW operations by NASA. Based on the GWI conducted at PBOW, additional sampling efforts are recommended. These efforts include additional well installation, quarterly water level measurements, seasonal groundwater sampling, and delineation of the lateral extent of contamination in the two red water pond areas as well as geochemical study of bedrock water quality to determine the source of H_2S.

1.0 Introduction

The U.S. Army is conducting studies of the environmental impact of suspected hazardous waste sites at properties previously owned by the U.S. Department of Defense (DOD). This work is being pursued by the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP). The former Plum Brook Ordnance Works (PBOW) in Sandusky, Erie County, Ohio is a DERP FUDS project currently being managed and technically overseen by the Nashville District of USACE. Figure 1-1 shows the geographic location of the former PBOW site. IT Corporation (IT) performed a sitewide groundwater investigation (GWI) at PBOW from September to October 1996. This work was performed under Delivery Order 0016 of Contract Number DACA62-94-D-0030.

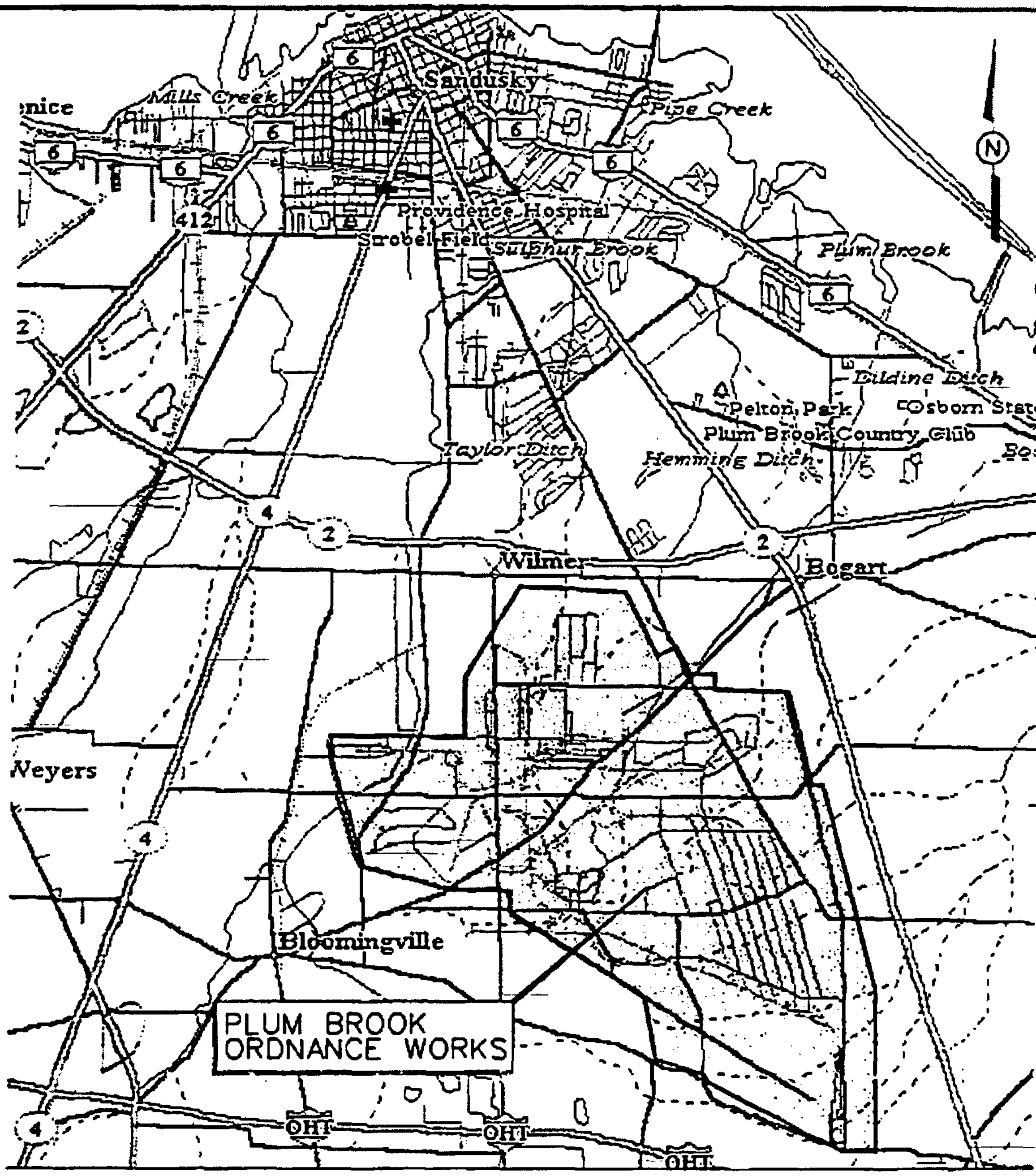
1.1 Scope of Work and Project Objectives

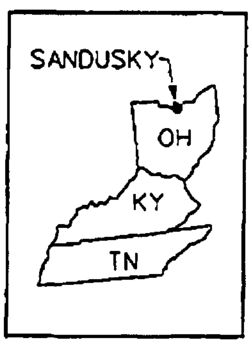
The scope of this GWI as specified in the statement of work (SOW) (USACE, 1995) includes a site inspection, preparation and completion of site specific work plans, completion of various field investigation activities, evaluation of analytical results from samples collected during the field investigation, preparation and submittal of reports characterizing activities, conclusions, and recommendations for further actions. Based on the findings of previous investigations, this GWI acquired supplemental data on the hydrogeologic characteristics and groundwater contamination at the PBOW site, with particular focus being placed in the western portion of the site including the West Area Red Water Ponds (WARWP) and Trinitrotoluene (TNT) Area C (TNTC). Figure 1-2 identifies the areas of concern at the PBOW site.

Activities completed during the field investigation included conducting a site visit, drilling, installing 3 new monitoring wells and 1 piezometer, redeveloping 28 existing monitoring wells, collecting groundwater samples from 28 existing and 3 newly installed wells, conducting a land survey, and handling investigation-derived waste (IDW). Groundwater samples collected for chemical analysis included primary samples and field quality control (QC) samples.

The purpose of this GWI was to collect supplemental information on groundwater levels and contaminants at PBOW and to fill in data gaps identified in the western portion of the site. Specifically, the objectives of the GWI at PBOW were to:

- Define or confirm local groundwater flow conditions in both residual and bedrock aquifers in areas of concern including WARWP and TNTC.





NOT TO SCALE

FIGURE 1-1
VICINITY MAP

PLUM BROOK ORDNANCE WORKS
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

STARTING DATE: 6-11-96 | DRAWN BY: R. KNIGHT | DATE LAST REV.: | DRAWN BY: | DRAFT. CHCK. BY: CET | ENGR. CHCK. BY: G YU | INITIATOR: G YU | PROJ MGR: D BURTON | DWG NO: 766952ES.005 | PROJ NO: 766952

766952ES.005 14:16:12 JUL 1, 1996 KHB

- Further delineate the extent and magnitude of groundwater contamination in residual and bedrock water-bearing zones in the vicinity of the WARWP and TNTC.
- Document any changes in groundwater quality since last sampling event and assess if there is any notable trend of possible contaminant migration off site via groundwater.

1.2 Site History and Potential for Contamination

The 9,009-acre PBOW site was built in early 1941 as a manufacturing plant for 2,4,6-TNT, dinitrotoluene (DNT), and pentolite. Production of explosives began on December 16, 1941 and continued until 1945. It is estimated that more than 1 billion pounds of explosives were manufactured during the 4-year operating period.

After the plant was shut down, decontamination of TNT, acid, pentolite, and DNT processing lines began and was completed during the last quarter of 1945. The property was initially transferred to the Ordnance Department, then to the War Assets Administration after it was certified by the U.S. Army to be decontaminated. In 1949, PBOW was transferred to the General Services Administration (GSA).

The National Aeronautics and Space Administration (NASA) acquired PBOW on March 15, 1963 and is presently utilizing the site. On April 18, 1978, NASA declared approximately 2,152 acres of land as excess. The Perkins Township Board of Education acquired 46 acres of the excess and uses this area as a bus transportation center. GSA retains the remaining acreage and currently has a use agreement with the Ohio National Guard for 604 acres of the land. NASA presently controls approximately 6,400 acres and is using the site to conduct space research as a satellite operation of NASA's Lewis Research Center (LeRC) in Cleveland, Ohio. The details of these land transactions are listed in the site management plan and can be found at the NASA Plum Brook Station (PBS).

Potential contaminants in the groundwater at PBOW, based on review of historical use of the site and findings of previous investigations, may include nitroaromatic compounds (explosive residual), volatile organic compounds (VOC), semivolatile organic compounds (SVOC), pesticides/polychlorinated biphenyls (PCB), cyanide, and dissolved metals.

1.3 Summary of Previous Environmental Studies

Previous investigations of site hydrogeology and groundwater contamination were documented in the contamination evaluation report (IT, 1991), the site inspection report (Morrison and Knudsen Corporation [MK], 1994), and the sitewide GWI draft report (Dames & Moore, Inc. [D&M], 1995).

In 1989, IT conducted the contamination evaluation focusing on areas associated with past DOD operations at PBOW under contract for the USACE Nashville District Office. The objective of this preliminary evaluation was to confirm or deny the presence of residual chemical contamination from operational activities conducted at the site during DOD operations. As part of the investigation, four groundwater monitoring wells were installed in the residual aquifer. IT-MW01 was placed at the intersection of Scheid Road and Patrol Road to monitor the quality of groundwater entering the site. IT-MW02 and IT-MW05 were installed in the presumed downgradient locations close to Waste Disposal Areas 1 (also known as Pentolite Road Red Water Ponds) and 2 (also known as WARWP), respectively. IT-MW06 was located near the north perimeter of the site and monitors the quality of groundwater exiting the site. Groundwater samples were collected for analyses of VOCs, SVOCs, nitroaromatic compounds, nitrates, sulfates, and metals. Analytical results indicated that several VOCs and SVOCs were present at concentrations in the low parts per billion range, including acetone, carbon disulfide, 2,6-DNT, and 2,4-DNT. Concentrations of chromium, manganese, and sulfate were also detected in some groundwater samples at elevated concentrations. The contamination evaluation concluded that these detected organic and inorganic compounds in groundwater represented groundwater contamination from past activities at the facility. The Hazard Ranking System (HRS) score was calculated for the site based on the results of this evaluation. The HRS score was zero because there are no target users of impacted groundwater or surface water within 3 miles of the site.

A site inspection was conducted at PBOW by MK from June through July of 1993 under contract for NASA. The purpose of the site inspection was to collect information concerning conditions at the PBS facility sufficient to assess the threat posed to human health and the environment and to determine the need for any additional investigation. A total of 13 monitoring wells were installed in the overburden water-bearing zone by MK in multiple areas. The results of the MK investigation identified limited contamination by nitroaromatics and metals.

From May to June of 1995, D&M conducted a GWI under contract to Nashville and Huntington USACE districts. The objectives of the D&M investigation were to evaluate groundwater occurrence and flow conditions in the overburden and bedrock water-bearing zone; to assess the groundwater quality in the overburden water-bearing zone and at the Red Water Ponds and TNT Manufacturing areas; to investigate on a sitewide basis the baseline groundwater quality of the bedrock water-bearing zone, and to evaluate the necessity of additional work at PBOW. A total of 11 monitoring wells were installed in the overburden water-bearing zone and 8 wells were placed in the limestone bedrock. The general groundwater flow directions in both water-bearing zones as indicated on the contour maps are to the north, eventually toward Lake Erie. However, the investigation also found that the groundwater flow in the overburden exhibited a strong vertical component in most of the site and the presence of groundwater in the overburden water-bearing zone was seasonally dependent. Groundwater samples were collected from 25 wells and analyzed for nitroaromatics, nitrates, and metals. Samples from bedrock wells were also analyzed for VOCs and base/neutral and acid extractables (BNA). The analytical results indicate that significant levels of explosive residues (including 1,3,5-trinitrobenzene [TNB], 1,3-dinitrobenzene [DNB], and 2,4-DNT) are present in the groundwater in the overburden water-bearing zone in the vicinity of both Red Water Pond areas. However, away from the ponds, the levels of detected explosives in groundwater decrease. Low levels of explosives were also reported in some overburden wells placed in TNT Area A (TNTA), TNT Area B (TNTB), and in several bedrock wells at both Red Water Ponds and in TNTC. Several VOCs and BNAs were detected in bedrock aquifer including hydrocarbons compounds with benzene concentrations in seven of the nine bedrock wells at or above the regulatory action level. In addition, 11 metals were detected in groundwater samples in a few limited areas, with concentrations of copper, manganese, nickel, and thallium occasionally exceeding their respective regulatory action levels.

1.4 Summary of Existing Site Conditions

The former PBOW site is currently owned by the NASA and is operated as the PBS of the NASA LeRC in Cleveland, Ohio. Most of the aerospace testing facilities built in the 1960s at the site are in standby or inactive status. The site is located approximately 4 miles south of Sandusky, Ohio and is specifically located in the Perkins, Oxford, Huron, and Milan Townships. The site is bounded on the north by Bogart Road, on the south by Mason Road, on the west by County Road 43, and on the east by U.S. Highway 250. The areas surrounding PBOW is mostly agricultural and residential.

The topography of PBOW site is characterized by a fairly flat ground surface that slopes gradually northward toward Lake Erie at an average gradient of less than two percent. Elevations at the site range from 675 feet above mean sea level (msl) at the southeast edge of the site to about 625 feet msl in the northern portion of the installation at Bogart Road. Eleven streams exist within the site and flow toward Lake Erie. Plum Brook, Ransom Brook, and Pipe Creek are the three major streams and are being monitored by NASA PBS. The climate in north-central Ohio is typical continental and shows significant influence by Lake Erie. Mean annual precipitation is 33.90 inches and the average monthly precipitation is approximately 1.65 inches for February and 3.70 inches for the month of July.

Bedrock geology at PBOW is characterized by Devonian and Silurian carbonate and clastic rocks, generally dipping to the southeast. The thickness of glacial till or lacustrine deposit cover ranges from approximately 5 feet or less for most of the site to approximately 20 feet in the northern boarder of the site. In many locations, bedrocks are exposed on the ground surface. According to the PBOW preliminary assessment (Science Applications International Corporation [SAIC], 1991) some karst features are present in the carbonate rocks forming a water-bearing formation underneath the soil cover.

Public access is restricted at PBOW except during the annual deer hunting season.

2.0 Field Activities

Field activities were conducted by IT personnel from September 23 to October 5, and continued from October 13 through October 24 1996. Mr. Keith Peecook, the environmental coordinator of NASA PBS, acted as the project contact and approved drilling/digging permit and extended work hours during the course of the project. Mr. Ron Nabors of Ohio Environmental Protection Agency (OEPA) visited the site on October 24, 1996.

2.1 Monitoring Well Installation

Three monitoring wells were installed in the overburden water-bearing zone as part of this investigation. In addition, one piezometer was also installed in place of the planned monitoring well IT-MW07. Monitoring well IT-MW08 was installed to a depth of 15 feet below ground surface (bgs) approximately 50 feet north of the old pump house near Power House No.2. IT-MW09 was located south of an abandoned barn across a path that intersects Campbell Street to the west. IT-MW10 (renamed from IT-MW06 specified in the sampling and analysis plan [SAP] to avoid duplication of previous well identifications) was placed northwest of the WARWP, approximately 20 feet south of a west-east oriented road that intersects Patrol Road to the west. IT-MW07 was originally planned southwest of the WARWP approximately 200 feet northwest of existing well WA-MW2. However, access to the intended drilling location was impossible due to site conditions, and a temporary piezometer was installed to a depth of 5 feet using a portable earth-digging device at the same location to allow for collection of water samples. All new and existing monitoring wells that were sampled during this GWI are shown in Figure 2-1.

Monitoring wells were installed in accordance with guidelines specified in EM-1110-1-4000 (USACE, 1994) and following procedures established in the sitewide SAP (IT, 1996a). Specifically, monitoring wells were installed as follows.

A Dietrich D-50 truck-mounted rotary drill rig was used to drill boreholes in the overburden soil for well installation. The boring was advanced using 8.25-inch outside diameter (4.25-inch inside diameter) hollow-stem auger (HSA) to the depth of auger refusal. Soil core samples were collected continuously from the ground surface to the terminating depth using a 2-foot-long and 2-inch-diameter stainless-steel split spoon. Soil samples were visually examined by the IT field geologist for lithologic description and boring logs were completed on site to document soil profiles. Three discrete soil samples were collected from each borehole for geotechnical testing. At least one of the three geotechnical samples was collected from the screened interval to allow for selection of proper size of filter materials. Geotechnical testing results are included in Appendix A. Soil samples were also scanned using an HNu for the presence of VOCs. The terminating depths for the three well boreholes were all at top of bedrock: MW10 at 20 feet bgs, MW08 at 15 ft bgs, and MW09 at 13.8 ft bgs, respectively.

New monitoring well construction details are summarized in Table 2-1. Drilling logs and monitoring well construction diagrams are included in Appendix A of this report.

2.2 Monitoring Well Development and Purging

Well development of the new wells was performed by surging followed by either bailing or pumping. Two wells (IT-MW09 and IT-MW10) exhibited extremely low well yield and were bailed dry before the well development criteria as set forth in the SAP (IT, 1996a) were met. The recovery rates in both wells were too low to allow for the completion of well development within a reasonable time frame. These two wells are considered not fully developed and will need additional surging/purging prior to any sampling effort in the future. It is believed that the extremely low recharge rate of these wells reflects seasonal conditions. Monitoring well IT-MW08 was developed by surging and pumping. A total of 68 gallons of water were removed and placed in 55-gallon sealable drums for later disposal. Upon completion of well development, a water sample was collected from IT-MW08 and photographed. A well development log was completed for each well by the IT field geologist to document well development procedures, field parameters, and other pertinent information. Photographs of development water and well development logs are included in Appendix B.

In addition to developing new monitoring wells, a total of 28 existing wells and 3 new wells were purged prior to collection of representative groundwater samples for chemical analysis, following procedures specified in the SAP (IT, 1996a). Purging was performed to remove stagnant water column inside the well casing and in the filter pack to allow collection of representative water samples. Purging was performed using a bailer or a submersible pump. During purging, field measurements of pH , Eh, temperature, dissolved oxygen, turbidity, and conductivity were collected to monitor changes in water quality as purging processed.

All existing monitoring wells that were included in the GWI are listed in Table 2-2.

2.3 Groundwater Sampling

Groundwater samples were collected for chemical analysis after well development or purging. The procedures specified in the SAP (IT, 1996a) were followed during groundwater sampling.

Table 2-2

Existing Monitoring Well Construction Details
Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Well Depth (feet)	Date Installed	Installed By	Casing Type	Casing Diameter (inch)	Borehole Diameter (inch)	Screen Interval (feet, bgs)	Top of Filter Pack (feet, bgs)	TOC Elevation (feet, msl)	Ground Elevation (feet, msl)	Well Location
PB-TNTA-MW10	11.0	1994	D&M[a]	PVC (40)	2"	8"	3-11	2.5	640.17	637.6	Northwest side of TNT Area A
PB-TNTA-MW11	11.4	1994	D&M[a]	PVC (40)	2"	8"	3.4-11.4	2.5	640.49	637.86	West side of TNT Area A
PB-TNTC-MW3	14.0	1994	D&M[a]	PVC (40)	2"	8"	5-14	3.2	645.41	642.56	North of TNT Area C
PB-TNTC-MW4	18.8	1994	D&M[a]	PVC (40)	2"	8"	8.8-18.8	6.0	654.42	651.89	West side of TNT Area C
PB-TNTC-MW5	29.7	1994	D&M[a]	PVC (40)	2"	8"	4.7-29.7	3.7	651.81	649.07	North side of TNT Area C
PB-TNTC-MW6	12.2	1994	D&M[a]	PVC (40)	2"	8"	3.2-12.2	2.5	659.40	65682	Northeast of TNT Area C
PB-WA-MW1	22.3	1994	D&M[a]	PVC (40)	2"	8"	4.3-22.3	3.7	644.43	642.32	North of West area red water pond
PB-WA-MW2	12.0	1994	D&M[a]	PVC (40)	2"	8"	3-12	2.5	633.65	631.15	Southeast side of West area red water pond
PB-PR-MW7	22.3	1994	D&M[a]	PVC (40)	2"	8"	4.3-22.3	3.0	633.98	631.5	West side of Pentolite Road Red Water ponds
PB-PR-MW8	27.5	1994	D&M[a]	PVC (40)	2"	8"	5-27.5	4.0	635.02	632.5	South side of Pentolite Road Red Water Ponds
PB-PR-MW9	19.0	1994	D&M[a]	PVC (40)	2"	8"	4-19	3.0	633.69	630.7	East side of Pentolite Road Red Water Ponds
PB-BED-MW13	75.5	1994	D&M[a]	PVC (40)	4" to 46	10" to 46	(3") 46-75.5[b]	---	648.27	645.81	North of TNT Area C
PB-BED-MW14	52.2	1994	D&M[a]	PVC (40)	4" to 29	10" to 29	(3") 29-52.2[b]	---	646.04	643.05	East of West Area Red Water Pond, west of Campbell Street
PB-BED-MW15	74.4	1994	D&M[a]	PVC (40)	4" to 31.5	10" to 31.5	(3") 31.5-74.4[b]	---	631.64	629.08	North of Pentolite Road, East of Reactor Facility
PB-BED-MW16	74.0	1994	D&M[a]	PVC (40)	4" to 49.2	10" to 49.2	(3") 49.2-74[b]	---	636.02	633.68	South of Pentolite Road Red Water Pond, west of TNT Area A
PB-BED-MW17	64.4	1994	D&M[a]	PVC (40)	4" to 45	10" to 45	(3") 45-64.4[b]	---	629.97	627.34	Northeast of TNT Area A
PB-BED-MW18	75.4	1994	D&M[a]	PVC (40)	4" to 51	10" to 51	(3") 51-75.4[b]	---	651.50	648.83	East of TNT Area A
PB-BED-MW19	49.5	1994	D&M[a]	PVC (40)	4" to 32	10" to 32	(3") 32-49.5[b]	---	643.07	640.5	On north side of Patrol Road along the northern property boundary
PB-BED-MW20	49.5	1994	D&M[a]	PVC (40)	4" to 35	10" to 35	(3") 35-49.5[b]	---	676.33	673.57	Near intersection of Patrol Rd and TAFT Rd, west of a fence area
MK-MW10	14.0	1993	MK[c]	PVC (40)	2"	8"	4-14	2.0	641.25	638.23	Along Maintenance Rd, north of West Area Red Water Pond
MK-MW11	13.0	1993	MK[c]	PVC (40)	2"	8"	3-13	2.0	638.00	634.88	Along Maintenance Rd, north of West Area Red Water Pond
MK-MW16	8.0	1993	MK[c]	PVC (40)	2"	8"	3-8	2.0	674.64	671.45	Along West Scheid Rd directly behind TNT Area B
MK-MW17	6.0	1993	MK[c]	PVC (40)	2"	8"	2-6	1.0	661.90	661.43	Along north side of North Magazine Rd in front of TNT Area B
MK-MW22	9.5	1993	MK[c]	PVC (40)	2"	8"	4.5-9.5	3.5	638.95	635.84	North side of 7141 along Columbus Ave.
MK-MW23	16.0	1993	MK[c]	PVC (40)	2"	8"	6-16	4.0	640.01	637.01	Loop Rd behind 7141
MK-MW24	9.5	1993	MK[c]	PVC (40)	2"	8"	4.5-9.5	2.5	657.59	654.59	SW corner of PMU
IT-MW002	18.3	1989	IT Corp	PVC (40)	2"	8"	6-16	4.0	636.69	639.59	West area red water pond
IT-MW005	21.0	1989	IT Corp	PVC (40)	2"	8"	8.6-18.5	6.5	634.99	631.91	north of Pentolite Road Red Water Pond

[a]Dames & Moore
[b]Open hole interval in bedrock, no screen installed
[c]Morrison and Knudsen Corporation

Table 2-1

New Monitoring Well Construction Details
Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Well Depth (feet)	Date Installed	Casing Type	Casing Diameter (inch)	Borehole Diameter (inch)	Screen Interval (feet, bgs)	Top of Filter Pack (feet, bgs)	TOC Elevation[a] (feet, msl)	Ground Elevation[a] (feet, msl)
IT-MW007	5.5	10/1/96	PVC (40)	2	4.25	0.5 - 5.5	--	635.03	632.3
IT-MW008	13.4	9/27/96	PVC (40)	2	8.25	3.1 - 13.1	3.6	633.16	630.6
IT-MW009	14.5	9/26/96	PVC (40)	2	8.25	4.1 - 14.1	2.0	647.45	645.4
IT-MW010[b]	19.8	9/26/96	PVC (40)	2	8.25	9.3 - 19.3	8.6	644.80	642.2

[a] Reference to 1988 North America Vertical Datum (NAVD)
[b] Renamed from IT-MW06

Prior to groundwater sample collection, the volume of water in the well was calculated based on water level measurements and well construction information, assuming a 30 percent porosity in the filter pack material. During purging, 3 to 5 volumes of water contained in the well were removed or the well was bailed dry before the required volume was reached. After purging, groundwater samples were collected in the general order of VOCs, SVOCs, nitroaromatic explosives, metals, cyanide, and pesticides and PCBs using a disposable bailer fitted with a bottom-emptying device. Sampling bailers were discarded after each use to avoid cross contamination. Field parameters (pH, oxidation-reduction potential, temperature, dissolved oxygen, turbidity, and conductivity) were collected at the time of sampling. Tables 2-3 and 2-4 summarize field parameters measured during groundwater sampling and groundwater sample information, respectively.

2.4 Groundwater Level Measurement

Static groundwater levels were measured prior to purging the well for sample collection. Water level measurements were taken with a decontaminated water level indicator, and measured to the nearest 0.01 foot from the top of the polyvinyl chloride well riser at the surveyed notch. Table 2-5 presents the water level data obtained during September and October 1996 investigation. Water levels measured at the same well in December 1994 and March 1995 by D&M are also included for comparison. Based on the monitoring well water level data, groundwater level elevation contour maps were constructed for overburden and bedrock wells. The interpretations of these contour maps with respect to groundwater flow conditions are presented in Section 5.1.

2.5 Investigation-Derived Wastes

IDW generated during the GWI includes well development water, purge water, drill cuttings, decontamination water, and disposable personnel protective equipment (PPE). IDW was managed and handled in accordance with procedures described in the SAP (IT, 1996a).

Soil cuttings from each well borehole were placed in 55-gallon drums with drum liners. Well development and purge waters were also containerized in drums. Decontamination water was collected in drums prior to removal of the decontamination pad. All drums were labeled with the contained materials, content volume, date of generation, and source of origin as applicable. IDW drums were temporarily left at their point of origin before being disposed of in the designated IDW disposal area. Personal protective equipment was doubled-bagged and placed in the on-site industrial dumpster; remaining IDW was disposed of in the area located south of Pentolite Road, known as the Pentolite Road Red Water Ponds. Previous investigations (IT, 1991; MK, 1994; and D&M, 1996) have identified and confirmed soil and groundwater contamination by

Table 2-3

Field Measurements of Groundwater Parameters
Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Conductivity (µmhos/cm)	pH	Eh (mV)	Temperature (deg. C)	Turbidity (NTU)	Dissolved O_2 (ppm)	HNu (ppm)
Overburden Wells								
IT-MW08	10/17/96	1.78	6.54	-45	13.0	8	0.78	0
MK-MW24	10/22/96	2.44	6.75	20	16.4	49	3.97	0
MK-MW23	10/23/96	N/A[a]	N/A	N/A	N/A	N/A	N/A	N/A
MK-MW17	10/21/96	0.857	5.71	75	14.2	247	0.82	0
PB-TNTA-MW11	10/22/96	1.59	6.32	-35	14.1	33	1.71	0
PB-TNTA-MW10	10/22/96	1.41	6.89	N/A	14.2	37	1.47	0
MK-MW22	10/22/96	0.589	6.88	45	15.8	584	4.21	0
PB-PR-MW-07	10/21/96	13.4	6.67	N/A	14.2	598	4.77	N/A
IT-MW10[b]	10/20/96	0.841	6.00	75	11.5	90	1.84	0
IT-MW09	10/18/96	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]
IT-MW05	10/20/96	0.665	7.33	N/A	11.5	999	0.57	0
PR-MW09	10/20/96	7.05	7.04	N/A	11.5	69	1.29	0
PB-PR-MW-08	10/20/96	35.6	6.76	N/A	11.1	675	1.18	0.2
IT-MW007	10/16/96	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]	Dry[c]
MK-MW-10	9/27/96	0.543	7.14	N/A	15.7	609	4.13	N/A
MK-MW-11	9/27/96	0.814	7.00	N/A	14.7	999	5.27	N/A
DM-MW-03	9/27/96	3.42	6.80	N/A	12.8	999	N/A	N/A
PB-TNTC-MW4	9/30/96	2.27	7.26	160	14.0	999	4.42	N/A
PB-TNTC-MW5	9/30/96	1.55	7.02	120	11.5	510	5.24	N/A
PB-TNTC-MW6	10/2/96	1.21	6.95	190	16.3	469	3.98	N/A
PB-WA-MW1	9/30/96	1.05	6.91	175	11.4	N/A	2.97	N/A
PB-WA-MW2	9/30/96	4.98	6.94	190	14.5	999	0.82	N/A
IT-MW02	9/30/96	2.33	6.61	185	12.8	N/A	0.39	N/A
MK-MW16	9/30/96	1.27	5.73	175	19.9	3	2.38	N/A
Bedrock Wells								
PB-BED-MW19	10/17/96	1.91	6.71	N/A	13.8	69	1.68	N/A
PB-BED-MW18	10/22/96	32.4	6.40	N/A	13.1	214	0.44	4.3
PB-BED-MW20	10/23/96	49.4	6.79	-60	13.0	141	0.82	0
PB-BED-MW17	10/24/96	4.44	6.90	N/A	11.0	27	0.66	9.7
PB-BED-MW16	10/25/96	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PB-BED-MW15	10/21/96	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PB-BED-MW14	10/17/96	2.62	6.88	75	11.5	122	4.94	2.8
PB-BED-MW13	10/17/96	8.2	6.65	N/A	13.7	41	1.31	6.1

[a] Not measured due to instrument malfunction
[b] Renamed from IT-MW06
[c] Dry well

KN\3650\TBL2_3.XLS\Table 2-3\3/30/97\8:07 AM\FTI\E(5-8-97)

Table 2-4

Summary of Primary Groundwater Samples
Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Sample Identification	Sampling Date	Laboratory Reference Number
PB-TNTA-MW10	PBOW-96-GW-TNTAMW10-5050	10/22/96	5050
PB-TNTA-MW11	PBOW-96-GW-TNTAMW11-5060	10/22/96	5060
PB-TNTC-MW3	PBOW-96-GW-TNTCMW3-5070	9/27/96	5070
PB-TNTC-MW4	PBOW-96-GW-TNTCMW4-5080	9/30/96	5080
PB-TNTC-MW5	PBOW-96-GW-TNTCMW5-5090	9/30/96	5090
PB-TNTC-MW6	PBOW-96-GW-TNTCMW6-5100	10/2/96	5100
PB-WA-MW1	PBOW-96-GW-WAMW1-5110	9/30/96	5110
PB-WA-MW2	PBOW-96-GW-WAMW2-5120	9/30/96	5120
PB-PR-MW7	PBOW-96-GW-PRMW07-5130	10/20/96	5130
PB-PR-MW8	PBOW-96-GW-PRMW08-5140	10/20/96	5140
PB-PR-MW9	PBOW-96-GW-PRMW09-5150	10/20/96	5150
PB-BED-MW13	PBOW-96-GW-BEDMW13-5160	10/17/96	5160
PB-BED-MW14	PBOW-96-GW-BEDMW14-5170	10/17/96	5170
PB-BED-MW15	PBOW-96-GW-BEDMW15-5180	10/21/96	5180
PB-BED-MW16	PBOW-96-GW-BEDMW16-5190	10/25/96	5190
PB-BED-MW17	PBOW-96-GW-BEDMW17-5200	10/24/96	5200
PB-BED-MW18	PBOW-96-GW-BEDMW18-5210	10/22/96	5210
PB-BED-MW19	PBOW-96-GW-BEDMW19-5220	10/17/96	5220
PB-BED-MW20	PBOW-96-GW-BEDMW20-5230	10/23/96	5230
MK-MW10	PBOW-96-GW-MKMW10-5240	9/27/96	5240
MK-MW11	PBOW-96-GW-MKMW11-5250	9/27/96	5250
MK-MW16	PBOW-96-GW-MKMW16-5260	9/30/96	5260
MK-MW17	PBOW-96-GW-MKMW17-5270	10/21/96	5270
MK-MW22	PBOW-96-GW-MKMW22-5280	10/22/96	5280
MK-MW23	PBOW-96-GW-MKMW23-5290	10/23/96	5290
MK-MW24	PBOW-96-GW-MKMW24-5300	10/22/96	5300
IT-MW002	PBOW-96-GW-ITMW02-5310	9/30/96	5310
IT-MW005	PBOW-96-GW-ITMW05-5320	10/20/96	5320
IT-MW010 *	PBOW-96-GW-ITMW06-5010	10/20/96	5010
IT-MW007 **	DRY	-	-
IT-MW008	PBOW-96-GW-ITMW08-5030	10/17/96	5030
IT-MW009	DRY	-	-

* Renamed from IT-MW-006

** Temporary piezometer

Table 2-5

Groundwater Level Elevations
Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	TCC Elevation (feet, msl)	Ground Elevation (feet, msl)	Water Level Elevation Dec-94 (feet, msl)	Water Level Elevation Mar-95 (feet, msl)	Water Level Elevation Oct-96 (feet, msl)	Water Level Change since Mar. 95 (feet)	Notes
PB-TNTA-MW10	640.18	637.5	633.71	637.04	635.62	-1.42	
PB-TNTA-MW11	640.50	637.86	630.56	632.82	633.56	0.74	
PB-TNTC-MW3	645.41	642.57	Dry, <628.57	639.2	635.01	-4.19	
PB-TNTC-MW4	654.43	651.89	634.87	651.07	648.51	-2.56	
PB-TNTC-MW5	651.81	649.07	628.01	647.62	643.28	-4.34	
PB-TNTC-MW6	659.40	656.82	651.93	655.2	654.56	-0.64	
PB-WA-MW1	644.43	642.32	619.85	619.45	624.99	5.54	
PB-WA-MW2	633.65	631.16	629.59	631.91	628.75	-3.16	
PB-PR-MW7	633.99	631.5	626.32	631.65	629.64	-2.01	
PB-PR-MW8	635.02	632.5	624.55	629.98	627.56	-2.42	
PB-PR-MW9	633.70	630.7	622.92	630.12	626.57	-3.55	
PB-BED-MW13	648.27	645.81	607.85	619.29	621.79	2.5	
PB-BED-MW14	646.04	643.05	621.76	624.39	625.23	0.84	
PB-BED-MW15	631.64	629.08	603.54	598.91	610.22	11.31	
PB-BED-MW16	636.02	633.68	571.38	633.68	630.17	-3.51	
PB-BED-MW17	629.97	627.34	602.57	602.9	602.76	-0.14	
PB-BED-MW18	651.50	648.83	625.05	620.39	621.68	1.29	
PB-BED-MW19	643.07	640.5	621.07	623.52	622.92	-0.6	
PB-BED-MW20	676.33	673.57	661.35	661.28	661.98	0.7	
MK-MW10	640.89	638.06	626.66	Not Measured	632.23	--	
MK-MW11	637.69	634.71	625.22	631.36	628.89	-2.47	
MK-MW16	674.32	671.33	667.14	669.36	668.42	-0.94	
MK-MW17	664.64	660.97	659.58	661.1	660.56	-0.54	
MK-MW22	638.05	635.56	628.85	631.55	630.07	-1.48	
MK-MW23	639.07	636.95	620.88	628.12	632.14	4.02	
MK-MW24	657.12	654.44	648.31	650.77	649.61	-1.16	
IT-MW002	639.63	636.69	627.32	633.75	629.33	-4.42	
IT-MW005	634.99	631.91	620.19	629.62	623.36	-6.26	
IT-MW07	635.03	632.3	-	-	dry, < 627.3	--	piezometer
IT-MW08	633.16	630.6	-	-	619.96	--	new well/survey data
IT-MW09	647.45	645.4	-	-	dry, < 632	--	new well/survey data
IT-MW010	644.80	642.2	-	-	626.41	--	new well/survey data

Note: TCC and ground surface elevations were reported in Table 5-2 of Dames & Moore Site-Wide Groundwater Investigation report (Dames & Moore, 1996) unless otherwise indicated.

nitroaromatic compounds and metals in the disposal area; this area was designated by IT in December 1996, (IT, 1996) and approved by OEPA and Nashville USACE for use as the disposal site for IDW.

2.6 Land Surveying

The land surveys at the investigation sites were conducted in late October 1996 by a Ohio registered professional land surveyor and included both new and existing monitoring wells. Horizontal coordinates were surveyed to the closest 1.0 foot and referenced to both the Ohio State Plane Coordinate System and the NASA PBS coordination system. Vertical coordinates (land surface elevation and top of casing elevation) were surveyed to the nearest 0.01 foot and referenced to the 1929 National Geodetic Vertical Datum. Land survey data referenced to NASA PBS coordination system were utilized in generating site map and figures included in this report. The complete survey data based on two survey coordinations are presented in Appendix C.

2.7 Decontamination Procedures

Decontamination of sampling equipment was performed in accordance with the procedures prescribed in Section 4.4.3 of the SAP (IT, 1996a). A decontamination pad for the drill rig and drilling equipment was set up on the north side of the red barn, east of Campbell Street. This site was made available by NASA PBS for use during the investigation. Specifically, the drill rig and augers were steam-cleaned before and after each use. The sampling equipment, including hand augers, spoons, and pans, were decontaminated according to the following procedures:

- Rinse with potable water obtained from the PBS fire station.
- Wash and scrub using a brush with nonphosphatic detergent.
- Rinse with potable water
- Rinse with deionized water (American Society for Testing and Materials [ASTM]) Type II).
- Rinse with methanol followed by a hexane rinse.
- Final rinse with deionized water (ASTM Type II). The rinse volume was at least five times of the volume of methanol used.
- Air dry.
- Wrap in aluminum foil for transport to sampling locations.

2.8 Variances/Nonconformance

Variances are defined as necessary changes to the standard operating procedures employed in the field or office activities and modification to the original SOW as specified in the SAP (IT, 1996a) and the quality assurance project plan (QAPP) (IT, 1996c). Variances do not significantly affect the quality of the data or process being changed. However, nonconformances are defined as malfunctions, deficiencies, or deviations that may render the quality of information or data unacceptable or indeterminate. All nonconformance reports and variance logs were prepared by IT field personnel and are retained in project files.

Three nonconformance reports were generated during the GWI. The first report concerned the failure to conduct rising-head slug tests in two new monitoring wells (MW09 and MW10) due to extremely low well yield. The second nonconformance reported the failure to collect the groundwater sample from the piezometer installed in lieu of IT-MW07 due to the piezometer not producing any water. The last nonconformance report concerned the failure to collect the groundwater sample from monitoring well IT-MW09 due to the well not producing enough water at the time of sampling.

In addition, two variance logs were recorded during the GWI. One variance concerned the collection of an extra 1 liter of water for nitroaromatic analysis due to the elevated content of suspended solids in the groundwater samples. The other variance recorded the replacement of the proposed monitoring well IT-MW07 with a piezometer due to inaccessibility of the proposed drilling site.

3.0 Analytical Program

All groundwater samples for chemical analysis were analyzed by Quanterra Environmental Services located in Knoxville, Tennessee. The data quality evaluation (DQE) report was prepared by an IT project chemist and is provided in Appendix D. Data validation was performed by an independent third party contractor and the results are presented in Appendix E. The laboratory analytical data packages are included in Appendix F.

3.1 Analytical Parameters and Methodologies

Chemical analyses for the GWI were performed in accordance with guidelines in the U.S. Environmental Protection Agency (EPA) document entitled *Test Methods for Evaluating Solid Waste* (SW-846) (EPA, 1986). Methods used for analysis by the laboratory are shown in Table 3-1. All analytical data were reported in accordance with the EPA Level IV Contract Laboratory Program (CLP)-like data package and were in compliance with the EPA definitive data requirements. The regulatory compound/analyte list reported was the target compound list for organics and the target analyte list for inorganics as defined by the most recent CLP SOW. These data packages have been reviewed for completeness, accuracy, and representativeness as prescribed in the QAPP (IT, 1996c). All analytical data presented in this report were validated and blank corrected. Data validation was performed by an independent subcontractor and the validation summary is presented in Appendix E. All samples were submitted to the laboratory accompanied by an Analysis Request/Chain of Custody (AR/COC) form. The AR portion of the form provides project specific analytical specifications and QC instruction to the laboratories. A formal COC record was included as part of the document, ensuring documentation of custody for sample transportation, storage, and eventual disposition by the laboratory. Copies of all custody documentation are included in the data packages submitted. An assessment of the analytical data with regard to the project specific objectives is presented in Appendix B in the DQE report. In the DQE, all elements of data evaluation were compiled and used to determine the usability and overall applicability of the resulting data. Evaluation of the data using the specific data quality objectives established for the project resulted in the determination that the data set is valid and of sufficient quality to meet the objectives of the investigation. There were no significant problems observed that would adversely affect the application of the data or the success of the overall investigation.

Table 3-1

Summary of Analytical Methods for Groundwater Samples
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Analytical Parameters	Groundwater Analytical Method
TCL Volatile Organic Compounds	EPA SW-846 8260A
TCL Semivolatile Organic Compounds	EPA SW-846 3540/8270B
TAL Metals (Total and Dissolved)	EPA SW-846 3050A/6010A 7060A/7471A/7740
Pesticides/Polychlorinated Biphenyls	EPA SW-846 8081
Total Cyanide	EPA SW-846 9010A
Nitroaromatic Compounds	EPA SW-846 8330

TCL - Target compound list.
TAL - Target analyte list. Metals include Ag, Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Tl, V, Zn, As, Hg, and Se.

3rd Edition, September 1986 and subsequent revisions (Revision 1, December 1990, Update I, July 1992, and Update II, September 1994)

3.2 Blank Correction

The analytical data generated by the GWI were evaluated in regard to the results in associated field blanks, trip blanks, equipment rinsates, and laboratory method blanks. The method blank results reported with the analytical data were evaluated for high readings characteristic of background or process contamination. There were no significant concentrations detected in the designated blank samples that indicate any analytical process out of control or require further corrective action. The analytical data presented in this report were blank corrected as a function of the data validation process.

3.3 Screening Criteria

Groundwater analytical data were evaluated primarily using the risk-based concentrations (RBC) (EPA, 1996a). RBCs are media-specific contaminant levels used to eliminate selected contaminants from further consideration. The RBCs as developed by EPA Region III were calculated using toxicity data and standard risk-assessment exposure scenarios to produce concentrations at fixed levels of risk. The RBCs correspond to either a hazard quotient of 0.1 or a lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration. The cancer risk of 10^{-6} reflects the lower end of the target risk range as defined in the National Contingency Plan (EPA, 1990). Chemicals present in environmental media at concentrations below the RBCs will not contribute significantly to total site risk. RBCs are provided in the Region III tables for tap water, air, fish tissue, and soil. The groundwater chemical concentrations detected during the current investigation were compared with tap water RBCs in order to provide a conservative basis for the utilization of the data as well as for the decision-making process with regard to the site risk should future land use be changed.

Another screening criteria often used in evaluation of groundwater contamination is the maximum contamination level (MCL) from EPA Drinking Water Regulations and Health Advisories (EPA, 1996b). The MCLs are the maximum permissible levels of contaminants in water that is delivered to any user of a public system. The MCLs were not used explicitly in the evaluation of groundwater analytical data acquired during this GWI because the MCLs are less stringent than the RBCs in determining the potential site risk associated with groundwater contamination.

4.0 Analytical Results

A total of 28 existing and 2 new monitoring wells were sampled during the GWI at PBOW. Of these, 22 wells are screened to monitor the overburden and 8 are screened in the limestone bedrock. Because the wells are located in various locations across the PBOW site, the following presentation of analytical results is divided by geographic area and the monitored water-bearing zone. All detected constituents in groundwater samples are presented by well on Tables 4-1 through 4-3 and on Tables 4-4 through 4-6 for bedrock wells. Note that the discussion of analytical results focuses on those constituents that were detected at concentrations exceeding the respective RBCs. Overburden monitoring well locations are presented on Figure 4-1, and analytical results exceeding RBCs in these wells are shown on Figures 4-2 through 4-6. Figure 4-7 presents bedrock monitoring well locations, and Figures 4-8 through 4-10 present analytical results exceeding RBCs in these wells.

4.1 West Area Red Water Pond and TNT Area C

Eleven overburden and three bedrock wells were sampled in the vicinity of the WARWP and TNTC. These wells are summarized as follows:

- Overburden wells
  - IT-MW10 (renamed from IT-MW06), new well located in the WARWP.
  - IT-MW08, new well located in the WARWP.
  - IT-MW02, existing well located in the WARWP.
  - WA-MW01, existing well located in the WARWP.
  - WA-MW02, existing well located in the WARWP.
  - MK-MW10, existing well located north of the WARWP.
  - MK-MW11, existing well located north of the WARWP.
  - TNTC-MW03, existing well located in TNTC.
  - TNTC-MW04, existing well located in TNTC.
  - TNTC-MW05, existing well located in TNTC.
  - TNTC-MW06, existing well located in TNTC.

- Bedrock wells
  - BED-MW13, existing well located in TNTC.
  - BED-MW14, existing well located in the WARWP.
  - BED-MW19, existing well located north of the WARWP.

The following sections present the analytical results for the 11 overburden wells followed by the three bedrock wells. This discussion is divided by the monitored water-bearing zone and analytical parameters.

4.1.1 Overburden Wells

4.1.1.1 Volatile Organic Compounds

Of the 11 sampled overburden wells, only two wells (TNTC-MW03 and MK-MW10) exhibited detectable levels of VOCs (Table 4-1, Figure 4-2). However, none of the detected VOCs were present at levels exceeding the RBCs.

4.1.1.2 Semivolatile Organic Compounds

Three overburden monitoring wells (IT-MW02, WA-MW02, and TNTC-MW03), exhibited detectable levels of SVOCs (Table 4-1, Figure 4-2). Of these three wells, IT-MW02 and WA-MW02 had levels of SVOCs that exceeded the respective RBCs; both of these wells are located central portion of the WARWP. In IT-MW02, three nitroaromatic compounds (2,4-DNT at 110 micrograms per liter [μg/L], 2,6-DNT at 16 μg/L, and 4,6-dinitro-2-methylphenol at 60 μg/L) exceeded the RBCs under the SVOC analysis, and two nitroaromatic compounds (2,4-DNT at 30 μg/L and 3-nitroaniline at 110 μg/L) exceeded the RBCs in WA-MW02.

4.1.1.3 Nitroaromatic Compounds

Of the 11 overburden monitoring wells, IT-MW02, IT-MW06, and WA-MW02 had detectable levels of nitroaromatic compounds during the GWI (Table 4-2, Figure 4-3). Of these, only IT-MW02 and WA-MW02 exhibited nitroaromatic compounds at concentrations greater than the RBCs. In IT-MW02, 1,3,5-TNB (9.7 μg/L), 1,3-DNB (12 μg/L), 2,4-DNT (20 μg/L), and royal demolition explosive (RDX) (11 μg/L) exceeded the respective RBCs under the nitroaromatic analysis. A larger set of nitroaromatic compounds exceeded the RBCs in WA-MW02, and included 1,3,5-TNB (11 μg/L), 1,3-DNB (18 μg/L), 2,4,6-TNT (2.4 μg/L), 2,4-DNT (12 μg/L), and 4-amino-2,6-DNT (1.1 μg/L). Both of these wells also had detected levels of nitroaromatics exceeding the RBCs under the SVOC analysis.

4.1.1.4 Pesticides and PCBs

Pesticides and PCBs were not detected in any of the 11 overburden wells sampled during the GWI in the WARWP and TNTC (Table 4-2).

4.1.1.5 Inorganic Compounds

Each of the 11 overburden wells exhibited at least one total inorganic compound at a concentration exceeding the RBCs (Table 4-3, Figures 4-4 and 4-5). In IT-MW02, total iron (1,120 μg/L), lead (27.7 μg/L), and manganese (1,230 μg/L) exceeded the RBCs. In the dissolved phase, lead (28.4 μg/L) and manganese (1,190 μg/L) exceeded the RBCs in this well.

Seven total metals (aluminum, arsenic, barium, chromium, iron, lead, and manganese) exceeded the respective RBCs in IT-MW06, while only manganese exceeded the RBC in the dissolved phase in this well. This is indicative that, with the exception of manganese, the RBC exceedances of these inorganic compounds are due to suspended solids in the groundwater sample.

Only two metals (both total and dissolved) exceeded the RBCs in IT-MW08; total and dissolved manganese (263 and 211 µg/L, respectively) and total and dissolved vanadium (57.4 and 62.5 µg/L, respectively) exceeded the RBCs.

Two total metals (iron at 4,300 and manganese at 342 µg/L) exceeded the RBCs in WA-MW01. In the dissolved phase, only manganese (364 µg/L) exceeded the RBC in this well.

Overburden well WA-MW02 exhibited seven total metals (aluminum, arsenic, chromium, iron, manganese, nickel, and vanadium) and two dissolved metals (manganese and nickel) at concentrations exceeding the RBCs. Similar to the analytical results from IT-MW06, results from WA-MW02 indicate that, with the exception of manganese and nickel, these RBC exceedances are due to suspended solids in the unfiltered groundwater sample.

Monitoring wells MK-MW10 and MK-MW11 both exhibited total metals at concentrations exceeding the RBCs, but dissolved metals did not exceed any of the established RBCs. In MK-MW10, total aluminum, arsenic, chromium, iron, lead, and manganese exceeded the RBCs. A smaller set of metals exceeded the RBCs in the unfiltered (total) sample from MK-MW11, including iron, lead, and manganese. Because dissolved metals were detected at concentrations below the RBCs, the RBC exceedances of total metals from these two wells are attributable to suspended solids in the groundwater samples.

Of the four overburden wells located in TNTC, two (TNTC-MW03 and TNTC-MW04) exhibited the largest suites of metals at concentrations exceeding the RBCs. Total aluminum, arsenic, chromium, iron, lead, manganese, and vanadium exceeded the RBCs in each of these wells. In addition, total barium and nickel also exceeded the RBCs in TNTC-MW03. In the dissolved phase, only lead, manganese, and vanadium exceeded the RBCs in the two wells, indicating that the RBC exceedances for most of the total metals were due to suspended solids in the groundwater samples.

Detected total metals in TNTC-MW05 that exceeded the RBCs were limited to iron (6,540 µg/L), lead (23.6 µg/L), and manganese (717 µg/L), while only one dissolved metal exceeded the RBC (manganese at 503 µg/L). Similarly, three total metals (chromium at 50.7 µg/L, iron at 9,940 µg/L, and manganese at 2,580 µg/L) and one dissolved metal (manganese at 2,540 µg/L) exceeded the RBCs in TNTC-MW06. These results indicate that the total chromium (TNTC-MW06), iron (both wells), and lead (TNTC-MW05) RBC exceedances are due to suspended solids in the unfiltered samples.

4.1.1.6 Total Cyanide

Of the 11 overburden monitoring wells, only IT-MW02 and WA-MW02 had detectable levels of cyanide during the GWI, at concentrations of 26 and 57 µg/L, respectively (Table 4-3, Figure 4-4 and 4-5). The RBC value has not been established for cyanide.

4.1.2 Bedrock Wells

4.1.2.1 Volatile Organic Compounds

Each of the three sampled bedrock wells exhibited detectable levels of VOCs (Table 4-4, Figure 4-8). Concentrations of benzene in BED-MW13 (190 µg/L) and BED-MW19 (3.7 µg/l) exceeded the RBC criteria. All three bedrock wells (BED-MW13, BED-MW14 and BED-MW19) exhibited detectable levels of toluene and total xylenes, but only toluene exceeded the RBC in BED-MW13. Monitoring wells BED-MW13 and BED-MW19 had detectable concentrations of ethyl benzene below the RBC limits.

4.1.2.2 Semivolatile Organic Compcunds

All three of the sampled bedrock wells exhibited detectable levels of SVOCs (Table 4-4, Figure 4-8). Of these three wells, only BED-MW13 exhibited an SVOC compound (2-methylnaphthalene at 34 µg/L) that exceeded the RBC. Both BED-MW13 and BED-MW19 displayed detectable concentrations of naphthalenes below their respective RBC values. bis(2-Ethylhexyl)phthalate and 2,4-DNT were detected at concentrations below the RBCs in BED-MW14.

4.1.2.3 Nitroaromatic Compounds

Two of the three bedrock monitoring wells, BED-MW13 and BED-MW19, exhibited detectable concentrations of nitroaromatic compounds (Table 4-5, Figure 4-9). Monitoring well BED-MW13 exhibited levels of 4-amino-2,6-DNT that exceeded the RBC in both the total (4.4 µg/L) and the dissolved (3.9 µg/L) phase. In the total phase, both wells displayed a nitrobenzene concentration of 0.5 µg/L, while in the dissolved phase only BED-MW19 displayed a concentration of 0.4 µg/L. These levels exceed their respective RBCs.

4.1.2.4 Pesticides and PCBs

Pesticides and PCBs were not detected in any of the three bedrock wells sampled during the GWI in the WARWP and TNTC (Table 4-5).

4.1.2.5 Inorganic Compounds

Of the three bedrock wells exhibiting detectable concentrations of total and dissolved inorganic compounds, only BED-MW13 and BED-MW19 had levels exceeding their respective RBCs (Table 4-6, Figure 4-10). Each of the three bedrock wells displayed total and dissolved concentrations of manganese below the established RBC. In addition, all three wells displayed total concentrations of chromium below the RBC, while dissolved chromium was detected only in BED-MW13 and BED-MW14.

In BED-MW13, both barium and vanadium exceeded their RBCs in the total and dissolved phase. Total and dissolved barium concentrations were 3,700 and 3,300 µg/L, respectively, and total and dissolved vanadium concentrations were 52.4 and 55.3 µg/L, respectively. Also observed at this well during field sampling was the strong hydrogen sulfide (H_2S) gas, indicating a possible reducing environment in the bedrock zone.

Monitoring well BED-MW19 exceeded the RBC for total and dissolved barium concentrations at 2,130 and 1,940 µg/L, respectively.

4.1.2.6 Total Cyanide

Of the three bedrock monitoring wells, only BED-MW14 displayed a detectable level of cyanide (20 µg/L) during the GWI (Table 4-6, Figure 4-10). An RBC value has not been established for cyanide.

4.2 Pentolite Road Area

Four overburden and two bedrock wells were sampled in the vicinity of the Pentolite Road Red Water Pond area. These wells are summarized as follows:

- Overburden wells
  - IT-MW05
  - PR-MW07

- PR-MW08
- PR-MW09

- Bedrock wells
  - BED-MW15
  - BED-MW16

The following sections present the analytical results for the four overburden wells, followed by the two bedrock wells.

4.2.1 Overburden Wells

4.2.1.1 Volatile Organic Compounds

Of the four sampled overburden wells, only one well (IT-MW05) exhibited detectable levels of VOCs (Table 4-1, Figure 4-2). The detected concentrations of chlorobenzene (1.3 µg/L) and toluene (1.1 µg/L) were present at levels below the RBCs.

4.2.1.2 Semivolatile Organic Compounds

Three overburden monitoring wells (PR-MW07, PR-MW08, and PR-MW09) exhibited detectable levels of nitroaromatic compounds under the SVOC analysis (Table 4-1, Figure 4-2). Other SVOCs were not detected in any of the overburden wells. In PR-MW08, three nitroaromatic compounds (2,4-DNT at 530, 2,6-DNT at 52, and 4,6-dinitro-2-methylphenol at 870 µg/L, respectively) exceeded the RBCs under the SVOC analysis. In addition, PR-MW08 exhibited 2,4-dinitrophenol at a concentration of 690 µg/L; an RBC has not been developed for this compound. Two nitroaromatic compounds (2,4-DNT at 30 and 2,6-DNT at 6.8 µg/L) exceeded the RBCs in PR-MW09. Monitoring well PR-MW07 exhibited one nitroaromatic compound (2,6-DNT at 70 µg/L) exceeding the RBC criteria.

4.2.1.3 Nitroaromatic Compounds

Two overburden monitoring wells, PR-MW07 and PR-MW08, exhibited total and dissolved levels of 1,3,5-TNB, 1,3-DNB, 2,4-DNT, and RDX exceeding the RBC criteria (Table 4-2, Figure 4-3). In addition, PR-MW07 displayed total and dissolved concentrations of 2,6-DNT and PR-MW08 showed a dissolved level of 2,4,6-TNT, both exceeding their respective RBCs. In contrast, monitoring well PR-MW09 exceeded RBC concentrations for 1,3,5-TNB, 1,3-DNB, and 2,4-DNT in total samples, with nondetectable concentrations in the dissolved samples. Overburden well IT-MW05 did not exhibit detectable concentrations of nitroaromatics.

4.2.1.4 Pesticides and PCBs

Pesticides and PCBs were not detected in any of the four overburden wells sampled during the GWI (Table 4-2).

4.2.1.5 Inorganic Compounds

Three of the four overburden wells, PR-MW07, PR-MW08, and PR-MW09, exceeded the RBC criteria for chromium, cobalt, copper, iron, manganese, nickel, and vanadium in both the total and dissolved phases (Table 4-3, Figure 4-6). In addition, PR-MW07 and PR-MW08 exceeded the RBC for antimony in the total phase. Cadmium exceeded the RBC in the dissolved phase for overburden well PR-MW08. In IT-MW05, manganese concentrations, total and dissolved, surpassed the RBC limit. Arsenic, barium, and iron also exceeded the RBC threshold for IT-MW05 in the total phase.

4.2.1.6 Total Cyanide

Cyanide was detected in PR-MW07 (190 µg/L), PR-MW08 (430 µg/L), and PR-MW09 (620 µg/L), but was not detected in IT-MW05 (Table 4-3, Figure 4-6). An RBC value has not been established for cyanide.

4.2.2 Bedrock Wells

4.2.2.1 Volatile Organic Compounds

Each of the two sampled bedrock wells, BED-MW15 and BED-MW16, exhibited levels of benzene, chloroform, toluene, and ethyl benzene that surpassed the RBC criteria (Table 4-4, Figure 4-8). Additionally, BED-MW15 displayed total xylenes slightly below the RBC level, while BED-MW16 displayed concentrations in excess of the RBC. Petroleum product was observed floating above the water table at BED-MW16.

4.2.2.2 Semivolatile Organic Compounds

Each of the two sampled bedrock wells, BED-MW15 and BED-MW16, exhibited levels of 2-methylnaphthalene (72 and 69 µg/L, respectively) in excess of the RBC (Table 4-4, Figure 4-8). Naphthalenes were also detected in each sample; however, the concentrations were below the RBC levels. Bedrock well BED-MW15 displayed a concentration of bis(2-ethylhexyl)phthalate at 14 µg/L, exceeding the RBC value. Another SVOC (2,4-dimethylphenol) was also detected at BED-MW15 at a concentration of 16 µg/L. However, the RBC has not been established for this compound.

4.2.2.3 Nitroaromatic Compounds

Of the two bedrock monitoring wells, only BED-MW15 displayed nitroaromatic concentrations greater than the RBC values (Table 4-5, Figure 4-9). 1,3,5-TNT, 1,3-DNB, and RDX exceeded the RBCs in the total and dissolved phases of the BED-MW15 groundwater sample. Tetryl was also present, although at levels below the RBC. 2,6-DNT and Tetryl were detected in BED-MW16, but did not exceed the RBCs.

4.2.2.4 Pesticides and PCBs

Pesticides and PCBs were not detected in either of the two bedrock wells sampled during the GWI (Table 4-5).

4.2.2.5 Inorganic Compounds

Both of the bedrock wells exhibited detectable concentrations of total and dissolved inorganic compounds (Table 4-6, Figure 4-10). Bedrock well BED-MW15 exhibited total and dissolved concentrations of antimony (77.6 and 69.6 µg/L, respectively) and barium (1,850 and 2,390 µg/L, respectively) that exceeded the RBC values. Manganese and zinc were also detected in BED-MW15, although at levels below the RBC.

Bedrock well BED-MW16 displayed total concentrations of antimony (93.1 µg/L), barium (1,210 µg/L), chromium (33.4 µg/L), manganese (10,300 µg/L), and vanadium (362 µg/L) at concentrations exceeding their respective RBCs. In the dissolved phase, lead (44.4 µg/L) and vanadium (140 µg/L) exceeded the RBCs in BED-MW16.

4.2.2.6 Total Cyanide

Neither of the two bedrock wells, BED-MW15 and BED-MW16, displayed detectable concentrations of cyanide during the GWI (Table 4-6).

4.3 TNT Area A

Five overburden and two bedrock wells were sampled in the vicinity of TNTA. These wells are summarized as follows:

- Overburden wells
  - TNTA-MW10
  - TNTA-MW11
  - MK-MW22
  - MK-MW23
  - MK-MW24

- Bedrock wells
  - BED-MW17
  - BED-MW18

The following sections present the analytical results for the five overburden wells, followed by the two bedrock wells. This discussion is divided by the monitored water-bearing zone and analytical parameters.

4.3.1 Overburden Wells

4.3.1.1 Volatile Organic Compounds

Of the five sampled overburden wells, only one well (TNTA-MW10) exhibited detectable levels of VOCs (Table 4-1). The detected concentration of acetone (23 µg/L) was present at levels below the established RBC.

4.3.1.2 Semivolatile Organic Compounds

There were no detectable concentrations of SVOCs in the five overburden wells during this GWI (Table 4-1).

4.3.1.3 Nitroaromatic Compounds

Two of the five overburden wells exhibited detectable levels of nitroaromatic compounds (Table 4-2, Figure 4-3). Seven nitroaromatic compounds were detected in monitoring well MK-MW22, but only 1,3,5-TNB (0.34 µg/L, total), 4-amino-2,6-DNT (1.1 µg/L, total, and 0.63 µg/L, dissolved), and nitrobenzene (0.91 µg/L, total, and 0.68 µg/L, dissolved) exceeded the respective RBCs. Only one nitroaromatic compound, 2,6-DNT, was detected in MK-MW23, but at a concentration below the RBC.

4.3.1.4 Pesticides and PCBs

Pesticides or PCBs were not detected in any of the five overburden wells (Table 4-2).

4.3.1.5 Inorganic Compounds

Each of the five sampled overburden wells exhibited detectable concentrations of metals during the GWI (Table 4-3, Figure 4-4). Monitoring wells TNTA-MW10 and TNTA-MW11 displayed total concentrations of arsenic (12.2 and 12.5 µg/L, respectively), iron (26,200 and 11,500 µg/L, respectively), and manganese (2,740 and 457 µg/L, respectively) that exceeded the RBCs. Dissolved iron exceeded the RBC in TNTA-MW10 at a concentration of 19,500 µg/L, but was not detected in TNTA-MW11, while dissolved manganese exceeded the RBC in both wells (2,580 μg/L in TNTA-MW10 and 526 μg/L in TNTA-MW11).

In MK-MW22, total iron (4,520 μg/L), total manganese (643 μg/L), and dissolved manganese (269 μg/L) exceeded the respective RBCs. Monitoring well MK-MW23 exhibited only one inorganic compound, dissolved arsenic, at a concentration of 10.4 μg/L, exceeding the RBC of 0.045 μg/L. Four metals (iron, lead, manganese, and vanadium) exceeded the RBCs in MK-MW24. Total iron (4,720 μg/L), lead (4 μg/L), and manganese (348 μg/L) exceeded the respective RBCs, but these metals were not detected in the dissolved phase. Vanadium exceeded the RBC in both the total and dissolved samples from MK-MW24, with detected concentrations of 68.2 and 67.6 μg/L, respectively.

4.3.1.6 Total Cyanide
Total cyanide was not detected in any of the five sampled overburden wells (Table 4-3).

4.3.2 Bedrock Wells

4.3.2.1 Volatile Organic Compounds
Five VOCs (benzene, carbon disulfide, ethyl benzene, toluene, and total xylenes) were detected in both of the bedrock wells sampled during the GWI in TNTA (Table 4-4, Figure 4-8). Of these, benzene exceeded the RBC in BED-MW17 (18 μg/L) and BED-MW18 (7.9 μg/L), while ethyl benzene exceeded the RBC in BED-MW18 (130 μg/L) and toluene exceeded the RBC in BED-MW17 (140 μg/L).

4.3.2.2 Semivolatile Organic Compounds
Both bedrock wells exhibited detectable levels of SVOCs (Table 4-4, Figure 4-8). However, none of the detected SVOCs exceeded the established RBCs. One of the detected SVOCs in BED-MW18 (2,4-dimethylphenol at a concentration of 16 μg/L) does not have an established RBC.

4.3.2.3 Nitroaromatic Compounds
The two bedrock wells exhibited detectable levels of nitroaromatic compounds during the GWI (Table 4-5, Figure 4-9). Of the three detected nitroaromatics in BED-MW17 (2-nitrotoluene, nitrobenzene, and tetryl), only nitrobenzene exceeded the RBC at concentrations of 0.5 μg/L (total) and 0.51 μg/L (dissolved). In BED-MW18, 4-amino-2,6-DNT exceeded the RBC at

concentrations of 4 µg/L (total) and 21 µg/L (dissolved); 1,3-DNB and 2-nitrotoluene were also detected in this well, but at concentrations below the RBCs.

4.3.2.4 Pesticides and PCBs

Pesticides and PCBs were not detected in the two bedrock wells (Table 4-5).

4.3.2.5 Inorganic Compounds

Several inorganic compounds were detected in the two bedrock wells (BED-MW17 and BED-MW18). Four total metals (antimony at 61.4, barium at 1,230, iron at 428,000, and lead at 26.3 µg/L, respectively) exceeded the RBCs in BED-MW17, but only one dissolved metal (arsenic at 11.1 µg/L) exceeded the RBC (Table 4-6, Figure 4-10). In BED-MW18, three total metals (antimony at 109, barium at 1,290, and manganese at 131 µg/L, respectively) exceeded the RBC; dissolved metals were not detected in this well. In addition to total and dissolved inorganics in groundwater, strong H_2S gas was encountered during well sampling, indicating a possible reducing environment in the bedrock water-bearing zone.

4.3.2.6 Total Cyanide

Cyanide (total) was not detected in either of the two bedrock wells sampled in TNTA (Table 4-6).

4.4 TNT Area B

Two overburden wells were sampled in TNTB. These wells are summarized as follows:

- Overburden wells
  - MK-MW16
  - MK-MW17

The following sections present the analytical results for the two overburden wells.

4.4.1 Volatile Organic Compounds

Of the two sampled overburden wells, only MK-MW17 exhibited detectable levels of VOCs (Table 4-1). The detected concentration of toluene (1.8 µg/L) was present at levels below the established RBC.

4.4.2 Semivolatile Organic Compounds

Neither of the two overburden wells exhibited detectable concentrations of SVOCs (Table 4-1).

4.4.3 Nitroaromatic Compounds

Nitroaromatic compounds were not detected in MK-MW16 during the GWI. However, six nitroaromatic compounds (1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 2,6-DNT, and 4-amino-2,6-DNT) were present in groundwater from MK-MW17 (Table 4-2, Figure 4-2). Of these, 1,3-DNB (2.2 µg/L), 2,6-DNT (11 µg/L), and 4-amino-2,6-DNT (8.7 µg/L) exceeded the RBCs in the total phase, and 1,3,5-TNB (2.3 µg/L), 2,4,6-TNT (3.4 µg/L), 2,6-DNT (11 µg/L), and 4-amino-2,6-DNT (5.8 µg/L) exceeded the RBCs in the dissolved phase.

4.4.4 Pesticides and PCBs

Pesticides and PCBs were not detected in the two overburden wells (Table 4-2).

4.4.5 Inorganic Compounds

Several metals were detected in the total or dissolved phases at concentrations exceeding the RBCs from MK-MW16 and MK-MW17 (Table 4-3, Figure 4-4). Five total metals (aluminum at 3,760, iron at 12,100, lead at 34.8, manganese at 12,000, and nickel at 114 µg/L, respectively) exceeded the RBCs in MK-MW16, while dissolved RBC exceedances were limited to manganese (11,600 µg/L) and nickel (148 µg/L). In MK-MW17, four metals exceeded the RBCs in the total and dissolved samples: arsenic at 10.2 and 11.4 µg/L, respectively; iron at 34,800 and 38,300 µg/L, respectively; manganese at 1,430 and 1,680 µg/L, respectively; and nickel at 156 and 182 µg/L, respectively.

4.4.6 Total Cyanide

Total cyanide was not detected in either of the two overburden wells (Table 4-3).

4.5 Background Well PB-BED-MW20

Bedrock monitoring well PB-BED-MW20 was installed by D&M for use as a possible background well. Located near the intersection of Patrol Road and Taft Road in the southwestern portion of the PBOW, this well is hydrogeologically upgradient of all bedrock wells at the site.

4.5.1 Volatile Organic Compounds

Upgradient bedrock well BED-MW20 did not show detectable levels of VOCs during the GWI (Table 4-4).

4.5.2 Semivolatile Organic Compounds

SVOCs were not detected in bedrock well BED-MW20 (Table 4-4).

4.5.3 Nitroaromatic Compounds

Monitoring well BED-MW20 did not exhibit detectable levels of nitroaromatic compounds during the GWI (Table 4-5).

4.5.4 Pesticides and PCBs

Pesticides and PCBs were not detected in BED-MW20 (Table 4-5).

4.5.5 Inorganic Compounds

Five total metals and one dissolved metal exceeded the respective RBCs in bedrock well BED-MW20 (Table 4-6, Figure 4-10). Total antimony (96.3 µg/L), total barium (26,400 µg/L), total iron (5,760 µg/L), total manganese (173 µg/L), total vanadium (59.4 µg/L), and dissolved vanadium (61.8 µg/L) exceeded the established RBCs.

4.5.6 Total Cyanide

Total cyanide was not detected in BED-MW20 (Table 4-6).

5.0 Hydrogeologic Characteristics

This chapter summarizes the hydrogeologic characteristics and the groundwater quality of the two water-bearing zones based on the data collected during this investigation and those available from previous studies. The hydrogeologic characteristics of the site are presented in terms of water-bearing zone distribution, groundwater flow direction, and hydraulic properties of both the overburden and bedrock water-bearing zones.

5.1 Major Water-Bearing Zones

Groundwater at the PBOW site occurs in two basic water-bearing zones: the overburden soils and the carbonate/clastic bedrocks. The overburden soils consist of original glacial till materials that have undergone intensive modern pedogenesis. The bedrock formations are Silurian and Devonian in age and dip regionally to the east. Soil covers and the underlying bedrock make up the site media that controls groundwater flow and affects contaminant migration.

Soil covers across the PBOW site are highly variable in terms of thickness and hydraulic properties. According to Soil Survey of Erie County conducted by the U.S. Department of Agriculture in cooperation with Ohio Department of Natural Resources, two soil associations are present at PBOW. The Arkport-Galden group, characterized by clayey fine sand and silt, covers the northern and western portions of the PBOW. The Prout association is mainly found in the southern and eastern portions of the facility and is underlain by clastic bedrock (shale). Soils of this group are clayey silt and silty clay, containing considerable amount of shale fragments at the bottom.

Bedrock encountered at the site consists of limestone/dolomite and shale. Bedrock shows a similar pattern with respect to the areal distribution, with limestone and dolomite mainly occurring in the northern and western portion of the site and shale in the eastern and southern part of the site. According to the PBOW preliminary assessment (SAIC, 1991), the lithology of the shale formation (Ohio Shale) is described as a grayish-black, dense, and platy shale that contains high organic content. Carbonate rocks encountered at the site are Prout Limestone, Delaware limestone, and the underlying Columbus limestone. Of these, Prout limestone crops out in the middle of the site extending northeast as a narrow band. The lithology of the Prout Limestone is seen as a dark colored fossiliferous limestone; Delaware limestone crops out in the northwestern corner of the site, while much of the western portion of the site is underlain by Columbus limestone. Both limestone formations may contain some evaporite deposits such as gypsum and anhydrite (Shearrow, 1957; Janssens, 1977). The depths to bedrock revealed during soil boring and monitoring well drilling vary significantly across the site.

5.2 Groundwater Flow Conditions

5.2.1 Overburden Water-Bearing Zone

Twenty-three monitoring wells (including one piezometer) were measured in the overburden water-bearing zone. Among these wells, eight are at or near the WARWP, five at TNTC, two at TNTB, four at the Pentolite Road Red Water Ponds, and four at TNTA. The locations of these overburden wells are shown in Figure 4-7. Groundwater level elevation contours are plotted using water level data acquired in October 1996. Groundwater levels at most of these wells (except new wells installed during this investigation) were also measured by D&M in December 1994 and March 1995. These available data are used to characterize groundwater flow pattern in the overburden water-bearing zone.

Groundwater level elevation contour map for the overburden water-bearing zone was constructed for the October 1996 data as shown in Figure 5-1. It is noted that water level data are available in areas where investigations were conducted, while a large data gap exists in the central and southeastern portions of the site. Due to the fact that the overburden water-bearing zone at PBOW is highly variable with respect to its thickness and hydraulic properties, extrapolation of water level contours for a large area with no data might be subjective. Therefore, water level contours were constructed for four general areas of concern, including the WARWP/TNTC, the Pentolite Road Red Water Ponds, TNTA, and TNTB. Figure 5-1 shows the general groundwater flow in the overburden water-bearing zone is to the north, being the same as that reported by D&M (1996). In close vicinity of the WARWP, the local groundwater flow direction was shown to be quite different or even reverse, depending on the pool level of the surface water body.

Comparison of the October 1996 water level data to the two rounds of measurements (December 1994 and March 1995) showed considerable variations in water level elevations in most of the overburden wells. As shown in Table 2-5, with a few exceptions, water levels in October were generally lower than that in March and higher than in December, indicating strong seasonal fluctuation. During the field operations, standing water was observed in the vicinity of two overburden wells, PR-MW08 and PR-MW-09, both located in the Pentolite Road Red Water Pond area.

The site-specific hydraulic conductivity data of the overburden water-bearing zone are rare because of the difficulties in conducting well testing. The difficulty arose due to extremely low well yield in the overburden wells, possibly due to a seasonal low water level. Of the three monitoring wells installed, rising-head slug tests were successfully performed at IT-MW08, giving an average hydraulic conductivity of 9.62 feet per day (Appendix G). During the 1989 contamination evaluation conducted by IT (1991), a slug test was performed at IT-MW02 and the hydraulic conductivity was calculated to be 0.25 feet per day. No hydraulic conductivity data are available or reported at other overburden wells due to low well yield or the well being dry at the time of testing. In 1990, the U.S. Geological Survey (USGS) conducted a study on the hydraulic properties of glacial deposits in Ohio. Pumping test conducted in wells installed in till-bearing glacial and lacustrine deposits in Sandusky County indicated a hydraulic conductivity of 1.17 feet per day (Strobel, 1992).

5.2.2 Bedrock Water-Bearing Zone

Groundwater levels at eight bedrock wells installed by D&M were measured during this investigation. The locations of these bedrock wells are shown in Figure 4-7. Bedrock wells were installed in the competent limestone at depths ranging from 50 to 75 feet bgs and the depths to the top of bedrock ranged from approximately 20 to 44 feet bgs. Groundwater flow in the bedrock water-bearing zone occurs primarily along fracture zones. Since the underlying bedrocks are limestone, it is very likely that solutionally enlarged fractures serve as a preferential pathway for site groundwater. In fact, according to the USGS, the carbonate rocks in northern Ohio, including the Devonian Columbus limestones, are considered as part of the carbonate-bedrock water-bearing zone system (Bugliosi, 1990).

Figure 5-2 shows that the general groundwater flow in the bedrock water-bearing zone is to the north, being the same as that reported by D&M (D&M, 1996) and similar to that in the overburden water-bearing zone. The contour map as shown in Figure 5-2 is highly speculative because (1) only eight data points were used in construction of the contour map and (2) groundwater flow in the bedrock is controlled not only by regional gradient but also by the orientation of fracture zones which is little known at this area. Therefore, Figure 5-2 is presented only to demonstrate the general flow direction in the bedrock water-bearing zone at the site. In each area of concern, the determination of site-specific flow pattern and flow regime in the bedrock zone would require more water level data.

Table 4-1

Summary of Volatile and Semivolatile Organic Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		IT-MW10		IT-MW08		PB-TNTA-MW10		PB-TNTA-MW11		PB-TNTC-MW3		PB-TNTC-MW4		PB-TNTC-MW5	
Sample Number:		5010		5030		5050		5060		5070		5080		5090	
Sample Date:		10/18/96		10/17/96		9/27/96		9/27/96		9/27/96		9/30/96		9/30/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Volatile Organic Compounds															
Acetone	370	ND[b]	ND	ND	ND	23 J	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	0.36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl Benzene	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	75	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes (total)	1200	ND	ND	ND	ND	ND	ND	ND	ND	1.0 J	ND	ND	ND	ND	ND
Semivolatile Organic Compounds															
bis(2-Ethylhexyl)phthalate	4.8	ND	ND	ND	ND	ND	ND	ND	ND	1.2 J	ND	ND	ND	ND	ND
2,4-Dinitrophenol	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	3.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylphenol	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	230	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-Nitroaniline	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	0.18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	150	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	2200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 4-1

Summary of Volatile and Semivolatile Organic Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		PB-TNTC-MW6		PB-WA-MW1		PB-WA-MW2		PB-PR-MW7		PB-PR-MW8		PB-PR-MW9		MK-MW10		MK-MW11	
Sample Number:		5100		5110		5120		5130		5140		5150		5240		5250	
Sample Date:		10/2/96		9/30/96		9/30/96		10/21/96		10/20/96		10/20/96		9/27/96		9/27/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltere	filtered	unfiltere	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Volatile Organic Compounds																	
Acetone	370	ND[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.4 J	ND	ND	ND
Benzene	0.36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1 J	ND	ND	ND
Ethyl Benzene	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	75	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1 J	ND	ND	ND
Xylenes (total)	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organic Compounds																	
bis(2-Ethylhexyl)phthalate	4.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	na	ND	ND	ND	ND	ND	ND	ND	ND	*690 J*	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	**30**	ND	ND	ND	**530**	ND	**30**	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	3.7	ND	ND	ND	ND	2.8 J	ND	**70**	ND	**52 J**	ND	**6.8 J**	ND	ND	ND	ND	ND
2-Methylnaphthalene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylphenol	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	230	ND	ND	ND	ND	ND	ND	5.2 J	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitroaniline	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	*2.0 J*	ND	ND	ND	ND	ND
3-Nitroaniline	11	ND	ND	ND	ND	**110 J**	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,6-Dinitro-2-methylphenol	0.18	ND	ND	ND	ND	ND	ND	ND	ND	**870 J**	ND	ND	ND	ND	ND	ND	ND
4-Methylphenol	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	150	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	2200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 4-1

Summary of Volatile and Semivolatile Organic Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		MK-MW16		MK-MW17		MK-MW22		MK-MW23		MK-MW24		IT-MW02		IT-MW05	
Sample Number:		5260		5270		5280		5290		5300		5310		5320	
Sample Date:		9/30/96		10/21/96		10/22/96		10/23/96		10/22/96		9/30/96		10/20/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Volatile Organic Compounds															
Acetone	370	ND[b]	ND[b]	ND	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND[b]	ND	ND
Benzene	0.36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon Disulfide	100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.3 J	ND
Ethyl Benzene	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	75	ND	ND	1.8 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.1 J	ND
Xylenes (total)	1200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Semivolatile Organic Compounds															
bis(2-Ethylhexyl)phthalate	4.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrophenol	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**110 J**	ND	ND	ND
2,6-Dinitrotoluene	3.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**16 J**	ND	ND	ND
2-Methylnaphthalene	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylphenol	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrophenol	230	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
3-Nitroaniline	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.1 J	ND	ND	ND
4,6-Dinitro-2-methylphenol	0.18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**60 J**	ND	ND	ND
4-Methylphenol	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Naphthalene	150	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenol	2200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a] RBC value in µg/L for groundwater.

[b] ND - Compound analyzed for but below detection limit (non-detect).

60 J Detected concentration exceeds or equal to RBC.

690 J RBC not established for this compound.

Table 4-2

Summary of Explosives and Pesticides/PCB Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		IT-MW10		IT-MW08		PB-TNTA-MW10		PB-TNTA-MW11		PB-TNTC-MW3		PB-TNTC-MW4		PB-TNTC-MW5	
Sample Number:		5010		5030		5050		5060		5070		5080		5090	
Sample Date:		10/18/96		10/17/96		9/27/96		9/27/96		9/27/96		9/30/96		9/30/96	
Sample Filtration:		unfiltered	filtered	unfiltered		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Nitroaromatic Compounds (Explosives)															
1,3,5-Trinitrobenzene	0.18	ND[b]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dinitrobenzene	0.37	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4,6-Trinitrotoluene	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	3.7	0.22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4-Amino-2,6-dinitrotoluene	0.22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrotoluene	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	0.34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RDX	0.61	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetryl	37	0.41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pesticides/PCBs															
Pesticides and PCBs were all below detection limits.															

Table 4-2

Summary of Explosives and PCB/Pesticides Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 2 of 3)

Sample Location:		PB-TNTC-MW6		PB-WA-MW1		PB-WA-MW2		PB-PR-MW7		PB-PR-MW8		PB-PR-MW9		MK-MW10	
Sample Number:		5100		5110		5120		5130		5140		5150		5240	
Sample Date:		10/2/96		9/30/96		9/30/96		10/21/96		10/20/96		10/20/96		9/27/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Nitroaromatic Compounds (Explosives)															
1,3,5-Trinitrobenzene	0.18	ND[b]	ND	ND	ND	**11**	ND	**2000**	**2400**	**1700**	**2100 J**	**27**	ND	ND	ND
1,3-Dinitrobenzene	0.37	ND	ND	ND	ND	**18**	ND	**1400**	**1600**	**1400**	**1700 J**	**57**	ND	ND	ND
2,4,6-Trinitrotoluene	2.2	ND	ND	ND	ND	**2.4**	ND	ND	ND	ND	**160 J**	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	**12**	ND	**1100**	**1400**	**1400**	**1400 J**	**36**	ND	ND	ND
2,6-Dinitrotoluene	3.7	ND	ND	ND	ND	ND	ND	**310**	**300**	ND	ND	ND	ND	ND	ND
4-Amino-2,6-dinitrotoluene	0.22	ND	ND	ND	ND	**1.1**	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrotoluene	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	0.34	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
RDX	0.61	ND	ND	ND	ND	ND	ND	ND	**310**	ND	**630 J**	ND	ND	ND	ND
Tetryl	37	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pesticides/PCBs															
Pesticides and PCBs were all below detection limits.															

Table 4-2

Summary of Explosives and Pesticides/PCB Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 3 of 3)

Sample Location:		MK-MW11		MK-MW16		MK-MW17		MK-MW22		MK-MW23		MK-MW24		IT-MW02		IT-MW05	
Sample Number:		5250		5260		5270		5280		5290		5300		5310		5320	
Sample Date:		9/27/96		9/30/96		10/21/96		10/22/96		10/23/96		10/22/96		9/30/96		10/20/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Nitroaromatic Compounds (Explosives)																	
1,3,5-Trinitrobenzene	0.18	ND[b]	ND	ND	ND	ND	**2.3**	**0.34 J**	ND	ND	ND	ND	ND	**9.7**	ND	ND	ND
1,3-Dinitrobenzene	0.37	ND	ND	ND	ND	**2.2**	ND	0.26	ND	ND	ND	ND	ND	**12**	ND	ND	ND
2,4,6-Trinitrotoluene	2.2	ND	ND	ND	ND	ND	**3.4 J**	0.99	0.62	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	ND	ND	ND	2.2	0.24	0.22	ND	ND	ND	ND	**20**	ND	ND	ND
2,6-Dinitrotoluene	3.7	ND	ND	ND	ND	**11 J**	**11 J**	0.87	0.69	0.44	ND	ND	ND	2.3	ND	ND	ND
4-Amino-2,6-dinitrotoluene	0.22	ND	ND	ND	ND	**8.7 J**	**5.8**	**1.1**	**0.63**	ND	ND	ND	ND	ND	ND	ND	ND
2-Nitrotoluene	6.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nitrobenzene	0.34	ND	ND	ND	ND	ND	ND	**0.91**	**0.68**	ND	ND	ND	ND	ND	ND	ND	ND
RDX	0.61	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	**11**	ND	ND	ND
Tetryl	37	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pesticides/PCBs																	
Pesticides and PCBs were all below detection limits.																	

[a] RBC value in µg/L for groundwater.

[b] ND - Compound analyzed for but below detection limit (non-detect).

| 2.3 | Detected concentration exceeds RBC.

Table 4-3

Summary of Metal and Cyanide Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		IT-MW10		IT-MW08		PB-TNTA-MW10		PB-TNTA-MW11		PB-TNTC-MW3		PB-TNTC-MW4		PB-TNTC-MW5	
Sample Number:		5010		5030		5050		5060		5070		5080		5090	
Sample Date:		10/18/96		10/17/96		9/27/96		9/27/96		9/27/96		9/30/96		9/30/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Metals															
Aluminum	3.7	**4.35 J**	ND[b]	0.468	ND	ND	ND	1.92	ND	**9.54**	ND	**6.59**	ND	1.96	ND
Antimony	0.0015	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	0.000045	**0.0142**	ND	ND	ND	**0.0122**	ND	**0.0125**	ND	**0.0516**	ND	**0.0478**	ND	ND	ND
Barium	0.26	**0.264**	ND	ND	ND	0.229	0.212	ND	ND	**0.286**	ND	ND	ND	ND	ND
Beryllium	0.000016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.0018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	0.018	**0.0221**	ND	0.0153	0.0171	ND	0.01	0.0175	ND	**0.0575**	0.015	**0.0469**	ND	0.0174	ND
Cobalt	0.22	ND	ND	ND	ND	ND	ND	ND	ND	0.131	0.112	ND	ND	ND	ND
Copper	0.15	ND	ND	ND	ND	0.0331	ND	ND	ND	0.0486	ND	0.0318	ND	ND	ND
Iron	1.1	**16.7**	ND	0.997	0.144	**26.2**	**19.5**	**11.5**	ND	**41.1**	ND	**36.8**	0.188	**6.54**	ND
Lead	0.015	**0.0216**	0.0036	ND	ND	ND	ND	0.0129	ND	**0.0477**	**0.0361**	**0.0364**	**0.0209**	**0.0236**	ND
Manganese	0.073	**2.96**	**1.63**	**0.263**	**0.211**	**2.74**	**2.58**	**0.457**	**0.526**	**5.1**	**5.3 J**	**1.13**	**0.998 J**	**0.717**	**0.503 J**
Mercury	0.0011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	0.073	ND	ND	ND	ND	ND	ND	ND	ND	0.198	ND	0.0466	ND	ND	ND
Silver	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	0.00023	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.026	ND	ND	**0.0574**	**0.0625**	ND	ND	ND	ND	**0.0877**	**0.0686**	**0.0701**	**0.0525**	ND	ND
Zinc	1.1	0.126	0.0479	ND	0.0334	0.036	0.0263	0.0791	ND	0.133	0.0419	0.112	0.32	0.0489	0.045
Cyanide (total)															
Cyanide	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 4-3

Summary of Metal and Cyanide Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		PB-TNTC-MW6		PB-WA-MW1		PB-WA-MW2		PB-PR-MW7		PB-PR-MW8		PB-PR-MW9		MK-MW10	
Sample Number:		5100		5110		5120		5130		5140		5150		5240	
Sample Date:		10/2/96		9/30/96		9/30/96		10/21/96		10/20/96		10/20/96		9/27/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	fileterd	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Metals															
Aluminum	3.7	2.66 J	ND[b]	1.6	ND	13.4	ND	2.55 J	ND	0.965 J	0.859	ND	ND	11.1	
Antimony	0.0015	ND	ND	ND	ND	ND	ND	ND	ND	0.076	ND	0.0783	ND	ND	ND
Arsenic	0.000045	ND	ND	ND	ND	0.011	ND	ND	ND	ND	ND	ND	ND	0.01	ND
Barium	0.26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Beryllium	0.000016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.0018	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0072	ND	ND	ND	ND
Chromium	0.018	0.0507	0.0149	0.0114	ND	0.0307	0.0119	0.0355	0.0331	0.149	0.15	0.0279	0.0266	0.0247	ND
Cobalt	0.22	ND	ND	ND	ND	0.114	0.0662	2.25	2.24	6.34	6.48	0.762	0.692	ND	ND
Copper	0.15	ND	ND	ND	ND	0.0633	0.0312	0.964	0.931 J	4.68	4.71 J	0.445	0.414	0.0318	ND
Iron	1.1	9.94	0.146	4.3	ND	26.8	0.138	6.01	1.15	13.3	13.2	1.75	1.19	26.5	ND
Lead	0.015	ND	ND	0.0052	ND	0.0132	0.0046	ND	ND	ND	ND	ND	ND	0.0439	ND
Manganese	0.073	2.58	2.54	0.342	0.364 J	1.54	0.913 J	13.6	15.2	30.7	30.9	2.28	2.14	0.412	0.0235 J
Mercury	0.0011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	0.073	ND	ND	ND	ND	0.207	0.123	1.69	1.63 J	6.08	6.23 J	1.06	0.963 J	ND	ND
Silver	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	0.018	ND	ND	ND	ND	0.0079	0.006	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	0.00023	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.026	ND	ND	ND	ND	0.0705	ND	0.0828	0.0683	0.0652	0.0673	0.0589	0.0566	ND	ND
Zinc	1.1	0.0831	0.0329	0.0663	0.0446	0.107	0.0245	0.119	0.0859	ND	0.183	ND	0.674	0.0974	0.032
Cyanide (total)															
Cyanide	na	ND	ND	ND	ND	*0.057*	ND	*0.19*	ND	*0.43*	ND	*0.062*	ND	ND	ND

K/r03560\TBL4_3.XLS\Table 4-3, pg 2\9/30/97\8:27 AM\F I\E(5-9-97)

Table 4-3

Summary of Metal and Cyanide Analytical Results
Overburden Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 3-3)

Sample Location:		MK-MW11		MK-MW16		MK-MW17		MK-MW22		MK-MW23		MK-MW24		IT-MW02		IT-MW05	
Sample Number:		5250		5260		5270		5280		5290		5300		5310		5320	
Sample Date:		9/27/96		10/20/96		10/21/96		10/22/96		10/23/96		10/22/96		9/30/96		10/20/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Metals (mg/L)																	
Aluminum	3.7	1.97	ND	3.76	1.11	0.658	ND	2.04	ND	ND	ND	1.21	ND	0.431	ND	1.52 J	0.248
Antimony	0.0015	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	0.000045	ND	ND	ND	ND	0.0102	0.0114	ND	ND	ND	0.0104	ND	ND	ND	ND	0.0136	ND
Barium	0.26	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.277	0.236
Beryllium	0.000016	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	0.0018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	0.018	0.0121	ND	0.0106	ND	ND	ND	ND	ND	ND	ND	0.0162	ND	ND	ND	0.0116	ND
Cobalt	0.22	ND	ND	ND	0.0959	0.0785	0.0795	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	0.15	ND	ND	0.0262	0.0489	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron	1.1	8.02	ND	12.1	0.391	34.8	38.3	4.52	ND	ND	ND	4.72	ND	1.12	ND	7.84	ND
Lead	0.015	0.0376	0.0097	0.0348	ND	0.0034	ND	0.0076	ND	ND	ND	0.004	ND	0.0277	0.0284	ND	0.0052
Manganese	0.073	0.978	ND	12	11.6 J	1.43	1.68	0.643	0.269	ND	ND	0.348	ND	1.23	1.19 J	0.459	0.195
Mercury	0.0011	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	0.073	ND	ND	0.114	0.148	0.156	0.182	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	0.018	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	0.00023	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.026	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0682	0.0676	ND	ND	ND	ND
Zinc	1.1	0.0454	0.0441	0.0954	0.121	0.119	0.114	0.089	0.0248	ND	ND	0.126	ND	0.0322	0.071	ND	ND
Cyanide (total)																	
Cyanide	na	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NC	0.026	ND	ND	ND

[a] RBC value in mg/L for groundwater.
[b] ND - Compound analyzed for but below detection limit (non-detect).

11.1 — Detected concentration exceeds or equals to RBC.

0.057 — RBC not established for this compound.

KN\3860\TBL4_3.XLS\Table 4-3, pg 3 3/30/97 8 19 AM F1E(5-9-97)

Table 4-4

Summary of Volatile and Semivolatile Organic Analytical Results
Bedrock Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		PB-BED-MW13		PB-BED-MW14		PB-BED-MW15		PB-BED-MW16		PB-BED-MW17		PB-BED-MW18		PB-BED-MW19		PB-BED-MW20	
Sample Number:		5160		5170		5180		5190		5200		5210		5220		5230	
Sample Date:		10/17/96		10/17/96		10/21/96		10/25/96		10/24/96		10/22/96		10/17/96		10/23/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Volatile Organic Compounds																	
Benzene	0.36	190	ND[b]	ND	ND	1300	ND	810	ND	18	ND	7.9	ND	3.7 J	ND	ND	ND
Carbon Disulfide	100	3.7 J	ND	ND	ND	ND	ND	19 J	ND	6.0 J	ND	3.1 J	ND	ND	ND	ND	ND
Chlorobenzene	3.9	ND	ND	1.1 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloroform	0.15	ND	ND	ND	ND	8.6 J	ND	7.8 J	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl Benzene	130	86	ND	ND	ND	180	ND	180	ND	87	ND	130	ND	2.4 J	ND	ND	ND
Toluene	75	190	ND	1.5 J	ND	800	ND	540	ND	140	ND	73	ND	2.0 J	ND	ND	ND
Xylenes (total)	1200	860	ND	2.7 J	ND	1100	ND	1300	ND	380	ND	560	ND	19	ND	ND	ND
Semivolatile Organic Compounds																	
bis(2-Ethylhexyl)phthalate	4.8	4.7 J	ND	1.0 J	ND	14 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,4-Dimethylphenol	na	13 J	ND	ND	ND	16 J	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND
2,4-Dinitrotoluene	7.3	ND	ND	1.7 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylnaphthalene	30	34	ND	ND	ND	72 J	ND	69 J	ND	17 J	ND	11	ND	3.5 J	ND	ND	ND
2-Methylphenol	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.7 J	ND	ND	ND	ND	ND
4-Methylphenol	18	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7.3 J	ND	ND	ND	ND	ND
Naphthalene	150	36	ND	ND	ND	52 J	ND	51 J	ND	17 J	ND	18	ND	2.2 J	ND	ND	ND
Phenol	2200	ND	ND	ND	ND	40 J	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a] RBC value in µg/L for groundwater.

[b]ND - Compound analyzed for but below detection limit (non-detected).

190 — Detected concentration exceeds or equals to RBC.

13 J — RBC not established for this compound.

KN\3660\TBL4_4.XLS\Table 4-4\9/30/97\8.19 AM\F1\E(5-9-97)

Table 4-5

Summary of Explosives and Pesticides/PCB Analytical Results
Bedrock Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		PB-BED-MW13		PB-BED-MW14		PB-BED-MW15		PB-BED-MW16		PB-BED-MW17		PB-BED-MW18		PB-BED-MW19		PB-BED-MW20	
Sample Number:		5160		5170		5180		5190		5200		5210		5220		5230	
Sample Date:		10/17/96		10/17/96		10/21/96		10/25/96		10/24/96		10/22/96		10/17/96		10/23/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L		µg/L	
Nitroaromatic Compounds (Explosives)																	
1,3,5-Trinitrobenzene	0.18	ND[b]	ND	ND	ND	0.52	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3-Dinitrobenzene	0.37	0.22	0.2	ND	ND	0.44	0.66	ND	ND	ND	ND	0.31	ND	ND	ND	ND	ND
2,6-Dinitrotoluene	3.7	0.66	ND	ND	ND	ND	ND	1.4	1.9	ND	ND	ND	ND	ND	ND	ND	ND
4-Amino-2,6-dinitrotoluene	0.22	4.4	3.9	ND	ND	ND	ND	ND	ND	ND	ND	4	21	ND	ND	ND	ND
2-Nitrotoluene	6.1	ND	ND	ND	ND	ND	ND	ND	ND	0.72 J	0.47 J	0.33 J	ND	ND	ND	ND	ND
Nitrobenzene	0.34	0.5	ND	ND	ND	ND	ND	ND	ND	0.5	0.51	ND	ND	0.5	0.4	ND	ND
RDX	0.61	ND	ND	ND	ND	3.7	6.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetryl	37	1.8	ND	ND	ND	1.7	2.3	ND	1.6	0.74	ND	ND	ND	ND	ND	ND	ND
Pesticides/PCBs																	
Pesticides and PCBs were all below detection limits.																	

[a] RBC value in µg/L for groundwater.

[b] ND - Compound analyzed for but below detection limit (non-detect).

190 (boxed) Detected concentration exceeds or equals to RBC.

Table 4-6

Summary of Metal and Cyanide Analytical Results
Bedrock Monitoring Wells
Sitewide Groundwater Investigation
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:		PB-BED-MW13		PB-BED-MW14		PB-BED-MW15		PB-BED-MW16		PB-BED-MW17		PB-BED-MW18		PB-BED-MW19		PB-BED-MW20	
Sample Number:		5160		5170		5180		5190		5200		5210		5220		5230	
Sample Date:		10/17/96		10/17/96		10/21/96		10/25/96		10/24/96		10/22/96		10/17/96		10/23/96	
Sample Filtration:		unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered	unfiltered	filtered
Parameter	RBC[a]	mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L		mg/L	
Metals																	
Aluminum	3.7	ND[b]	ND	ND	0.246	ND	ND	0.387	ND	ND	ND	0.317	ND	ND	0.378	0.548	ND
Antimony	0.0015	ND	ND	ND	ND	0.0776	0.0696	0.0931	ND	0.0614	ND	0.109	ND	ND	ND	0.0963	ND
Arsenic	0.000045	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0111	ND	ND	ND	ND	ND	ND
Barium	0.26	3.7	3.3	ND	ND	1.86	2.39	1.21	ND	1.23	ND	1.29	ND	2.13	1.94	26.4	ND
Chromium	0.018	0.0108	0.0134	0.0123	0.0116	ND	ND	0.0334	ND	ND	ND	ND	ND	0.0138	ND	0.0149	ND
Cobalt	0.22	ND	ND	0.0691	0.0538	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Iron	1.1	0.187	ND	0.45	ND	ND	ND	ND	ND	428	ND	0.358	ND	0.129	ND	5.76	ND
Lead	0.015	ND	ND	ND	ND	ND	ND	ND	0.0444	0.0263	ND	ND	ND	ND	ND	ND	ND
Manganese	0.073	0.021	0.016	0.0475	0.025	0.0169	0.0272	10.3	ND	ND	ND	0.131	ND	0.0205	0.0165	0.173	ND
Mercury	0.0011	ND	ND	ND	0.00025	ND	ND	ND	ND	ND	ND	0.00024	ND	ND	ND	ND	ND
Nickel	0.073	ND	ND	0.0681	0.0535	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.026	0.0624	0.0563	ND	ND	ND	ND	0.382	0.14	ND	ND	ND	ND	ND	ND	0.0594	ND
Zinc	1.1	ND	0.0402	ND	0.026	0.0228	0.0228	0.0735	ND	ND	ND	0.0367	ND	0.03 J	ND	0.0243	ND
Cyanide (total)																	
Cyanide	na	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[a] RBC value in mg/L for groundwater.

[b] ND - Compound analyzed for but below detection limit (non-detect).

| 190 | Detected concentration exceeds or equals to RBC.

5.3 Hydraulic Connection Between Two Water-Bearing Zones

The overburden water-bearing zone lies directly on top of the bedrock across the site. During monitoring well installation, no significant layer with low permeability that would retard downward flow was encountered. Comparison between the two water level contour maps (Figures 5-1 and 5-2) shows that the water level elevations of the bedrock wells are generally lower than those observed in the overburden wells, indicating a possible downward flow component. This is consistent with the conclusion made by D&M in their GWI report (D&M, 1996). However, in some portions of the site, the overburden materials may not contain any water when the water levels are lower than the bottom elevation of the soil, suggesting that the downward flow from overburden zone to the bedrock zone occurs only seasonally. There is also another possibility that groundwater in the shallow water-bearing zone may move upward during the summer months due to evapotranspiration. It is estimated that approximately 70 percent of the annual precipitation in Ohio is returned to the atmosphere by evapotranspiration (Shindel, et al., 1990).

6.0 Conclusions and Recommendation

This section presents conclusions and recommendations from the GWI at the former PBOW based on the analytical results presented in Chapter 4.0 and hydrogeology discussed in Chapter 5.0. With the exception of groundwater flow condition, conclusions concerning groundwater quality are presented by geographic area and monitored water-bearing zone.

6.1 Conclusions

The following conclusions are derived from the results of the current GWI within the former PBOW.

6.1.1 Groundwater Flow

Groundwater across PBOW site exists in both overburden and bedrock water-bearing zones. The general groundwater flow direction in both water-bearing zones is to the north and northeast. However, local flow regime in the overburden may be different depending on soil thickness, topography, and surface water features and exhibits strong seasonal dependence. Some overburden wells may become dry at certain times of the year. The groundwater flow regime in the bedrock is believed to be influenced by solutionally enlarged fractures. The difference in water level elevations in both water-bearing zones indicates a predominantly downward flow, but water in the shallow depth can also move upward and be lost to evapotranspiration

6.1.2 West Area Red Water Ponds and TNT Area C

Eleven overburden and three bedrock wells were sampled in the vicinity of the WARWP and TNTC. Two (TNTC-MW03 and MK-MW10) of the 11 overburden wells exhibited low levels of VOCs, but did not exceed RBCs. Nitroaromatic compounds were detected under the SVOC analysis at concentrations exceeding the RBCs in IT-MW02 and WA-MW02; SVOCs were also detected in TNTC-MW03 but did not exceed the RBCs. Similarly, IT-MW02 and WA-MW02 both exhibited nitroaromatic compounds at concentrations exceeding the RBCs under the explosives analysis. Explosives were also detected in IT-MW06, but the concentrations did not exceed the RBCs. Each of the 11 overburden wells also exhibited inorganic compounds at concentrations exceeding the RBCs. RBC exceedances in overburden wells are summarized as follows:

- ***IT-MW06.*** Aluminum, arsenic, barium, chromium, iron, lead, and manganese
- ***IT-MW08.*** Manganese and vanadium

- ***IT-MW02.*** 1,3,5-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, 4,6-dinitro-2-methylphenol, RDX, iron, lead, and manganese

- ***WA-MW01.*** Iron and manganese

- ***WA-MW02.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 3-nitroaniline, 4-amino-2,6-DNT, aluminum, arsenic, chromium, iron, manganese, nickel, and vanadium

- ***MK-MW10.*** Aluminum, arsenic, chromium, iron, lead, and manganese

- ***MK-MW11.*** Iron, lead, and manganese

- ***TNTC-MW03.*** Aluminum, arsenic, barium, chromium, iron, lead, manganese, nickel, and vanadium

- ***TNTC-MW04.*** Aluminum, arsenic, chromium, iron, lead, manganese, and vanadium

- ***TNTC-MW05.*** Iron, lead, and manganese

- ***TNTC-MW06.*** Chromium, iron, and manganese

With the exception of nitroaromatic compounds and total cyanide (RBC not established) in IT-MW02 and WA-MW02, detected constituents exceeding RBC values were limited to inorganic compounds in the 11 overburden wells. Of the metals exceeding RBCs, only lead, manganese, nickel, and vanadium were detected in any of the wells at concentrations exceeding the RBCs in the dissolved phase; two of the wells (MK-MW10 and MK-MW11) did not exhibit dissolved metals at concentrations exceeding the RBCs.

Based on the analytical results for the overburden wells, it is evident that IT-MW02 and WA-MW02 have been impacted by nitroaromatic compounds by past site activities. In addition, nine wells (IT-MW06, IT-MW08, IT-MW02, WA-MW01, WA-MW02, TNTC-MW03, TNTC-MW04, TNTC-MW05, and TNTC-MW06) exhibit inorganic compounds at concentrations exceeding the RBCs in the dissolved phase, which may be due to site contamination or naturally occurring conditions; background levels for inorganic compounds in groundwater have not been established. Because dissolved metals were not detected in MK-MW10 and MK-MW11, the total metals RBC exceedances in these wells are attributed to suspended solids in the groundwater samples.

Two of the three sampled bedrock wells exhibited VOCs at concentrations exceeding the RBCs: BED-MW13 and BED-MW19. SVOCs were detected in each of the three wells, but only BED-MW13 exhibited an SVOC compound at a concentration exceeding the RBC. Nitroaromatic compounds exceeded the RBCs in BED-MW13 and BED-MW19. Although each of the three bedrock wells had detectable levels of inorganic compounds, only BED-MW13 and BED-MW19 had levels exceeding their respective RBCs. RBC exceedances in bedrock wells are summarized as follows:

- ***BED-MW13.*** Benzene, toluene, 2-methylnaphthalene, 4-amino-2,6-DNT, nitrobenzene, barium, and vanadium
- ***BED-MW14.*** None
- ***BED-MW19.*** Benzene, nitrobenzene, and barium.

Based on the analytical results from the three bedrock wells, it is evident that BED-MW13 and BED-MW19 have been impacted by explosives and organic contaminants from past site activities. BED-MW14 also exhibits impacts by these constituents, but at levels below the RBCs. Bedrock wells BED-MW13 and BED-MW19 also exhibit at least one inorganic compound exceeding the RBCs, but these levels are not necessarily attributable to site contamination as background levels have not been established. In addition, BED-MW13 exhibited strong H_2S gas that could be hazardous during well sampling.

In general, it is concluded that the overburden water-bearing zone in TNTC has not been impacted by organic compounds, nitroaromatic compounds, or pesticides and PCBs. A small number of metals have exceeded the RBCs in the dissolved phase, but further evaluation is needed to determine whether these detections are attributable to site contamination. The overburden water-bearing zone exhibits impacts by nitroaromatic compounds in the central portion of the WARWP area, while inorganic compounds are present at concentrations exceeding the RBCs throughout this area. However, as with TNTC, detected metals in groundwater in the WARWP area will require further evaluation to determine whether these are due to site contamination.

The bedrock water-bearing zone has been impacted by nitroaromatic and organic compounds in TNTC and north of the WARWP area, but does not exhibit impacts by any constituents in the central portion of the WARWP area. Inorganic compounds have also exceeded the RBCs in

TNTC and north of the WARWP area, but these exceedances will require further evaluation to determine their source.

6.1.3 Pentolite Road Red Water Pond Area

Four overburden and two bedrock wells were sampled in the vicinity of the Pentolite Road Red Water Pond area. None of the four overburden wells exhibited VOCs at concentrations exceeding the RBCs, although IT-MW05 had detectable concentrations of chlorobenzene and toluene. Nitroaromatic compounds exceeded the RBCs in PR-MW07, PR-MW08, and PR-MW09 under the SVOC and explosives analyses. SVOCs and explosives were not detected in IT-MW05. Inorganic compounds exceeded the RBCs in each of the four overburden wells. RBC exceedances in the four overburden wells are summarized as follows:

- ***IT-MW05.*** Arsenic, barium, iron, and manganese
- ***PR-MW07.*** 1,3,5-TNB, 1,3-DNB, 2,4,-DNT, 2,6-DNT, RDX, chromium, cobalt, copper, iron, manganese, nickel, and vanadium
- ***PR-MW08.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,4-DNT, 2,6-DNT, 4,6-dinitro-2-methylphenol, RDX, antimony, cadmium, chromium, cobalt, copper, iron, manganese, nickel, and vanadium
- ***PR-MW09.*** 1,3,5-TNB, 1,3-DNB, 2,4-DNT, 2,6-DNT, antimony, chromium, cobalt, copper, iron, manganese, nickel, and vanadium.

Based on the analytical results for the overburden wells, it is evident that PR-MW07, PR-MW08, and PR-MW09 have been impacted by nitroaromatic compounds by past site activities. Each of the four wells also exhibit inorganic compounds at concentrations exceeding the RBCs, with greater impacts evident in the PR-series wells. However, background concentrations have not been established for metals in groundwater at PBOW, and it is unclear whether these RBC exceedances are due to site contamination.

Both of the sampled bedrock wells exhibited VOCs and SVOCs at concentrations exceeding the RBCs. Both wells also exhibited nitroaromatic compounds, but only the detections in BED-MW15 exceeded the respective RBCs. Inorganic compounds were detected in each well at concentrations exceeding the RBCs. In addition, petroleum product was observed in BED-MW16. RBC exceedances in the two bedrock wells are summarized as follows:

- ***BED-MW15.*** Benzene, chloroform, ethyl benzene, toluene, bis(2-ethylhexyl)phthalate, 2-methylnaphthalene, 1,3,5-TNB, 1,3-DNB, RDX, antimony, and barium

- ***BED-MW16.*** Benzene, chloroform, ethyl benzene, toluene, total xylenes, 2-methylnaphthalene, antimony, barium, chromium, lead, manganese, and vanadium.

Based on the analytical results from the two bedrock wells, it is evident that BED-MW15 and BED-MW16 have been impacted by organic contaminants from past site activities. In addition, BED-MW15 also exhibits impacts by nitroaromatic compounds. Both wells also exhibit at least two inorganic compounds at concentrations exceeding the RBCs, but these levels are not necessarily attributable to site contamination as background levels have not been established. In addition, BED-MW16 also contained floating petroleum product that may be the source of dissolved benzene, toluene, ethyl benzene, and xylene (BTEX) detected in both bedrock wells in this area.

In general, it is concluded that the overburden water-bearing zone in the Pentolite Road Red Water Pond area has been impacted by nitroaromatic compounds, while the bedrock water-bearing zone exhibits impacts by BTEX, SVOCs, and nitroaromatic compounds. Although the Pentolite Road Red Water area water-bearing zones exhibit larger suites of inorganic compounds at concentrations exceeding the RBCs than other areas of PBOW, further evaluation is necessary to determine whether they are attributable to site contamination.

6.1.4 TNT Area A

Five overburden and two bedrock wells were sampled in the vicinity of TNTA. None of the five overburden wells exhibited concentrations of VOCs or SVOCs that exceeded the RBCs. Two wells had detectable levels of nitroaromatic compounds, but only MK-MW22 exhibited explosives at concentrations exceeding the RBCs. All of the overburden wells exhibited inorganic compounds at concentrations exceeding the RBCs. The RBC exceedances for each of the five wells is summarized as follows:

- ***TNTA-MW10.*** Arsenic, iron, and manganese
- ***TNTA-MW11.*** Arsenic, iron, and manganese
- ***MK-MW22.*** 1,3,5-TNB, 4-amino-2,6-DNT, nitrobenzene, iron, and manganese
- ***MK-MW23.*** Arsenic
- ***MK-MW24.*** Iron, lead, manganese, and vanadium.

Based on the analytical results for the overburden wells, it is evident that MK-MW22 has been impacted by nitroaromatic compounds from past site activities. Each of the five wells also exhibit at least one inorganic compound at concentrations exceeding the RBCs. However, background concentrations have not been established for metals in groundwater at PBOW, and it is unclear whether these RBC exceedances are due to site contamination.

VOCs were detected at concentrations exceeding the RBCs in both bedrock wells during the GWI, and SVOCs were detected but did not exceed RBCs. Nitroaromatic compounds were also detected at concentrations exceeding the RBCs in BED-MW17 and BED-MW18. Several inorganic compounds were detected at concentrations exceeding the RBCs in both wells. RBC exceedances in the two bedrock wells are summarized as follows:

- ***BED-MW17.*** Benzene, toluene, nitrobenzene, antimony, arsenic, barium, iron, and lead
- ***BED-MW18.*** Benzene, ethyl benzene, 4-amino-2,6-DNT, antimony, barium, and manganese.

The analytical results from the two monitoring wells indicate that both BED-MW17 and BED-MW18 have been impacted by organic and nitroaromatic compounds from past site activities. Although several metals were detected at concentrations exceeding the RBCs, only one (arsenic) was present in the dissolved sample and only in BED-MW17, which suggests that the other metals RBC exceedances are attributable to suspended solids in the unfiltered sample and are not necessarily due to site contamination. However, site background levels of inorganic compounds have not been developed for groundwater at PBOW. H_2S gas was detected in both bedrock wells, indicating a possible strong reducing environment in the bedrock zone.

It is concluded that the overburden water-bearing zone has been impacted by nitroaromatic contaminants in the vicinity of MK-MW22 in the western part of TNTA. The bedrock water-bearing zone exhibits impacts by BTEX and nitroaromatic compounds in the northeastern part of TNTA. Further evaluation is, however, necessary to determine whether detected inorganic in the two water-bearing zones are attributable to site contamination.

6.1.5 TNT Area B

Two overburden wells and one bedrock well were sampled in the vicinity of TNTB. Neither overburden well exhibited organic contaminants at concentrations exceeding the RBCs. Nitroaromatic compounds were not detected in MK-MW16, but exceeded RBCs in MK-MW17.

Several inorganic compounds also exceeded the RBCs in both wells. The RBC exceedances for each well are summarized as follows:

- ***MK-MW16.*** Aluminum, iron, lead, manganese, and nickel
- ***MK-MW17.*** 1,3,5-TNB, 1,3-DNB, 2,4,6-TNT, 2,6-DNT, 4-amino-2,6-DNT, arsenic, iron, manganese, and nickel.

Based on the analytical results from the two overburden wells, it is evident that MK-MW17 has been impacted by nitroaromatic compounds from past site activities. Although several metals exceeded the RBCs in both wells, only manganese and nickel exceeded the RBCs in the dissolved phase in MK-MW16. This indicates that the RBC exceedances of aluminum, iron, and lead in this well are attributable to suspended solids in the unfiltered sample. As background concentrations have not been established for metals in groundwater at PBOW, it is unclear whether the inorganic compounds detected at concentrations exceeding the RBCs are attributable to site contamination.

It is concluded that the overburden water-bearing zone has been impacted by nitroaromatic compounds downgradient of TNTB. Further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions

6.1.6 PB-BED-MW20

The upgradient bedrock well, BED-MW20, was sampled during the GWI. Analytical results from this well indicate that it has not been impacted by organic or explosive compounds from past activities. Five metals did exceed RBCs from this well, but only vanadium was detected in both the total and dissolved samples. Therefore, the RBC exceedances of total antimony, barium, iron, and manganese are attributed to suspended solids in the unfiltered sample. Because background concentrations of metals have not been established for groundwater at PBOW, the RBC exceedance of vanadium requires further evaluation to determine whether it is due to natural conditions.

It is, therefore, concluded that the bedrock water-bearing zone upgradient in relation to other bedrock wells at PBOW does not exhibit impacts by organic or nitroaromatic compounds. However, further evaluation is necessary to determine whether detected inorganic compounds are attributable to site contamination or natural conditions

6.2 Recommendations

Based on the analytical results and conclusions of the sitewide GWI, the following recommendations are made:

- Installation and sampling of additional monitoring wells at various locations are recommended to more accurately define the nature and extent of contaminants in groundwater in the overburden and bedrock water-bearing zones. Specifically, additional overburden and bedrock wells are recommended as follows:

  Bedrock Wells

  - One at the G-8 Burning Ground (corner of Campbell Street and Patrol Road) to provide water quality data upgradient of the WARWP and TNTC.

  - One near MK-MW16 (TNTB) to provide upgradient water quality data for TNTB and one near MK-MW17 (TNTB) to provide downgradient water quality data for TNTB.

  - One in the Maintenance Area to provide upgradient water quality data for the Pentolite Road Red Water Pond area.

  - One each (three total) in Acid Areas 1, 2, and 3 to provide bedrock water-bearing zone water quality data in these areas.

  - One in the Additional Burn Ground (intersection of Fox Road and Snake Road) to provide groundwater quality data upgradient of TNTA, the Pentolite Road Area, and the Maintenance Area.

  Overburden Wells

  - One each (three total) in Acid Areas 1, 2, and 3 to provide overburden water-bearing zone water quality data in these areas. These wells should be placed close to the proposed bedrock well in each area to form a well pair so that appropriate test can be performed to determine the vertical hydraulic gradient.

  - One in the Additional Burn Ground (intersection of Fox Road and Snake Road) to provide groundwater quality data upgradient of TNTA, the Pentolite Road Red Water Pond area, and the Maintenance Area. This well should also be placed close to the bedrock well as a well cluster.

- Groundwater level measurements should be collected from all PBOW wells on a quarterly basis for a period of 1 year to determine groundwater gradient variations.

- Selected monitoring wells should be sampled once during the wet season and once during the dry season to determine possible impacts on contaminant migration at the site.

- Existing and new monitoring wells should be evaluated to determine their suitability as background wells; once selected, analytical data from background wells shall be statistically evaluated to determine naturally occurring background concentrations for inorganic compounds so that metals in groundwater samples can be fully evaluated

- All future groundwater data shall be collected in order to support (1) sitewide groundwater flow and transport modeling and (2) a human health risk assessment.

The outlined recommendations will be addressed during the sitewide groundwater level investigation recently contracted to IT. Data collected from the upcoming investigation will be combined with data collected during this GWI and previous GWIs conducted by others in order to provide a comprehensive sitewide groundwater quality evaluation. In addition, the following recommendations should be considered in scoping future studies at the PBOW site:

- Additional groundwater sampling of the overburden water-bearing zone in the vicinity of the two red water pond areas to delineate the lateral extent of nitroaromatic contamination. Hydropunch is the recommended methodology for this additional sampling effort.

- Geochemical evaluation of bedrock chemical data to determine the source of the H_2S gas detected in the bedrock water-bearing zone and possible impact on contaminant migration.

7.0 References

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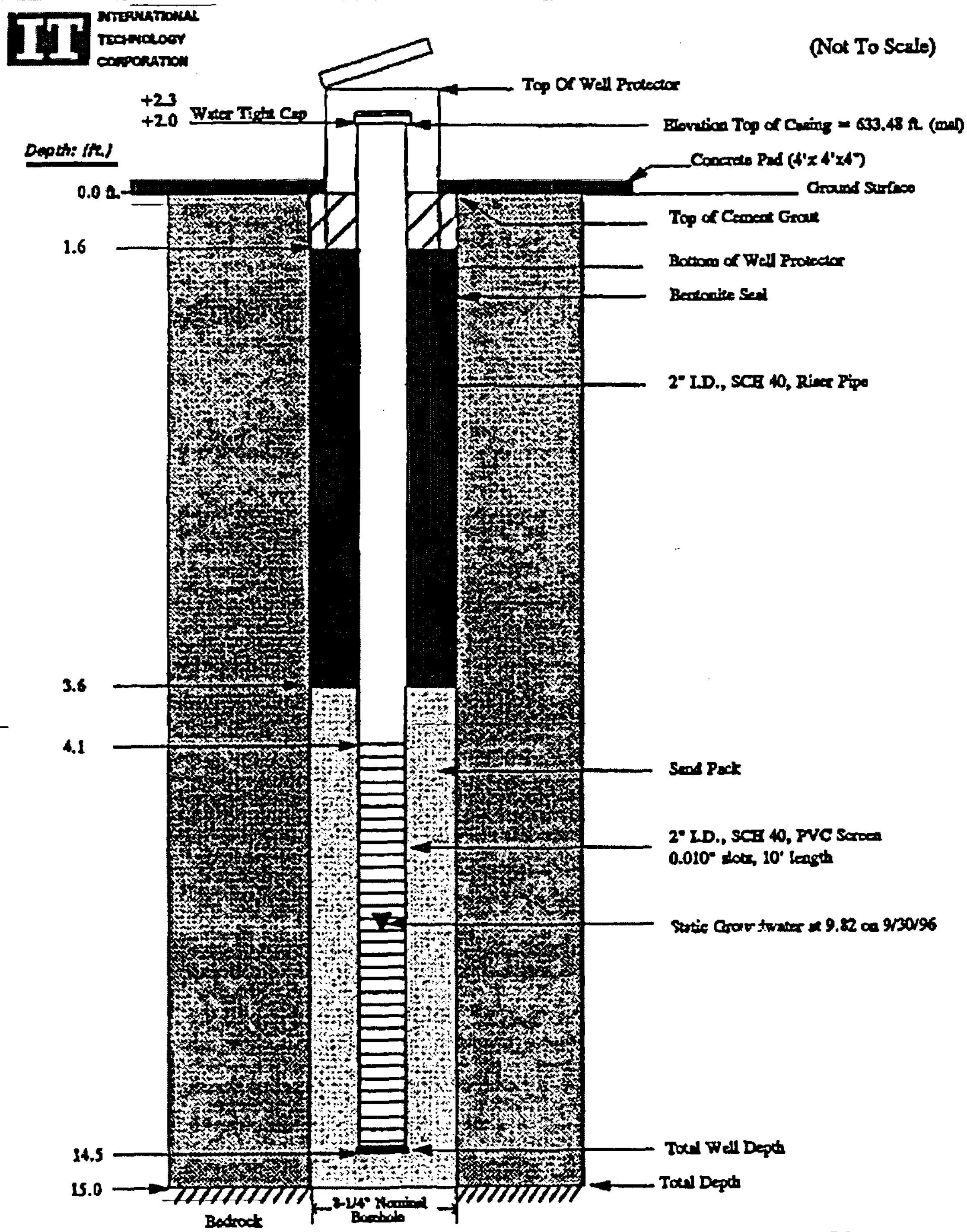
APPENDIX A

DRILL LOGS, GEOTECHNICAL DATA, AND WELL CONSTRUCTION DIAGRAM



Well Construction Diagram
prepared for:
USACE - NASHVILLE
PLUM BROOK ORDNANCE WORKS

Notes:

Well No.: IT-MW8
Date Installed: 9/27/96
Elevation Top of Casing*:
* Based on Mean Sea Level (MSL)

HTRW DRILLING LOG

HTRW DRILLING LOG	DISTRICT: Nashville	HOLE NUMBER: IT-MW8
1. COMPANY NAME: IT Corporation	2. DRILL SUBCONTRACTOR: Alliance	SHEET 1 OF 3 SHEETS

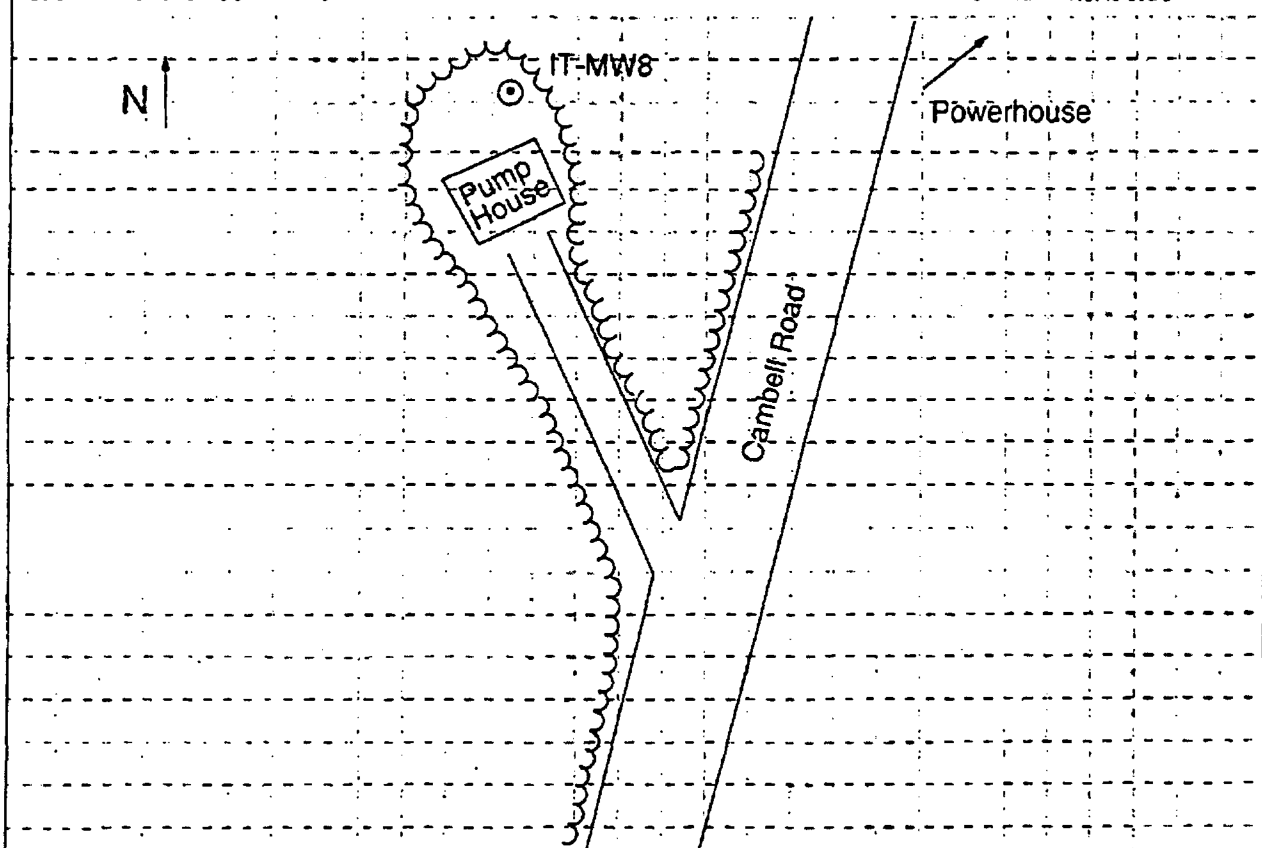
3. PROJECT: PBOW	4. LOCATION: Erie County, Ohio
5. NAME OF DRILLER: Paul D. McAdams	6. MANUFACTURER'S DESIGNATION OF DRILL: Dietrich D-50
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 2" Split Spoons, 8-1/2" O.D. Augers	8. HOLE LOCATION: Near Old Pump House by Powerhouse #2
	9. SURFACE ELEVATION: 630.92 feet (MSL)
	10. DATE STARTED: 9/25/96 — 11. DATE COMPLETED: 9/27/96
12. OVERBURDEN THICKNESS: 10.4 ft.	15. DEPTH GROUNDWATER ENCOUNTERED
13. DEPTH DRILLED INTO ROCK: 4.6 ft.	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 9.82 ft./5 days
14. TOTAL DEPTH OF HOLE: 15.0 ft.	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): NA

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
X	X		

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
NA						%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Wesley White

LOCATION SKETCH/COMMENTS — SCALE: Not to scale



PROJECT	HOLE NO.
PBOW	IT-MW8

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW8

PROJECT: PBOW | INSPECTOR: W. White | SHEET 2 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	0–2.2	Stiff to hard, dark gray (10 YR 4/1) clayey SILT, medium to low plasticity, low dry strength, trace organics (roots), moist 2.2	0.0	S-1	ML	2,3 5,6	
	2.2–4.2	Hard, brown (10 YR 5/3), clayey SILT, trace very fine sand, low to medium plasticity, low dry strength, dry to moist (well below plastic limit) 4.2	0.0	S-2 Geotechnical Sample	ML	6,7 9,11	
	4.2–5.75	Dense, strong brown (7.5 YR 5/6) mottled with pinkish gray (7.5 YR 7/2), silty very fine SAND, well sorted, poorly graded, well rounded, dry to moist 5.75	0.0	S-3 Geotechnical Sample	SP	6,5 4,4	
	5.75–6.3	Hard, gray (10 YR 5/1), very fine sandy SILT, low plasticity, low dry strength, dry to moist 6.3			ML		
	6.3–8.0	Very stiff to hard, grayish brown (10 YR 5/2) CLAY, medium to high plasticity, moist 8.0	0.0	S-4 Geotechnical Sample	CL/CH	4,5 5,10	
	8.0–9.6	Hard, grayish brown (10 YR 5/2) sitly CLAY, trace medium to coarse sand, medium plasticity, moist 9.6	0.0	S-5	CL	5,11 14,17	
	9.6–10	Very stiff to hard, silty CLAY and weathered shale, bluish gray (5 PB 6/1), low			CL		

Project: PBOW | Hole No. IT-MW8

PBOW/BORINGS/MW-8A.DRW/rd/11-12-95

INTERNATIONAL TECHNOLOGY CORPORATION

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW8

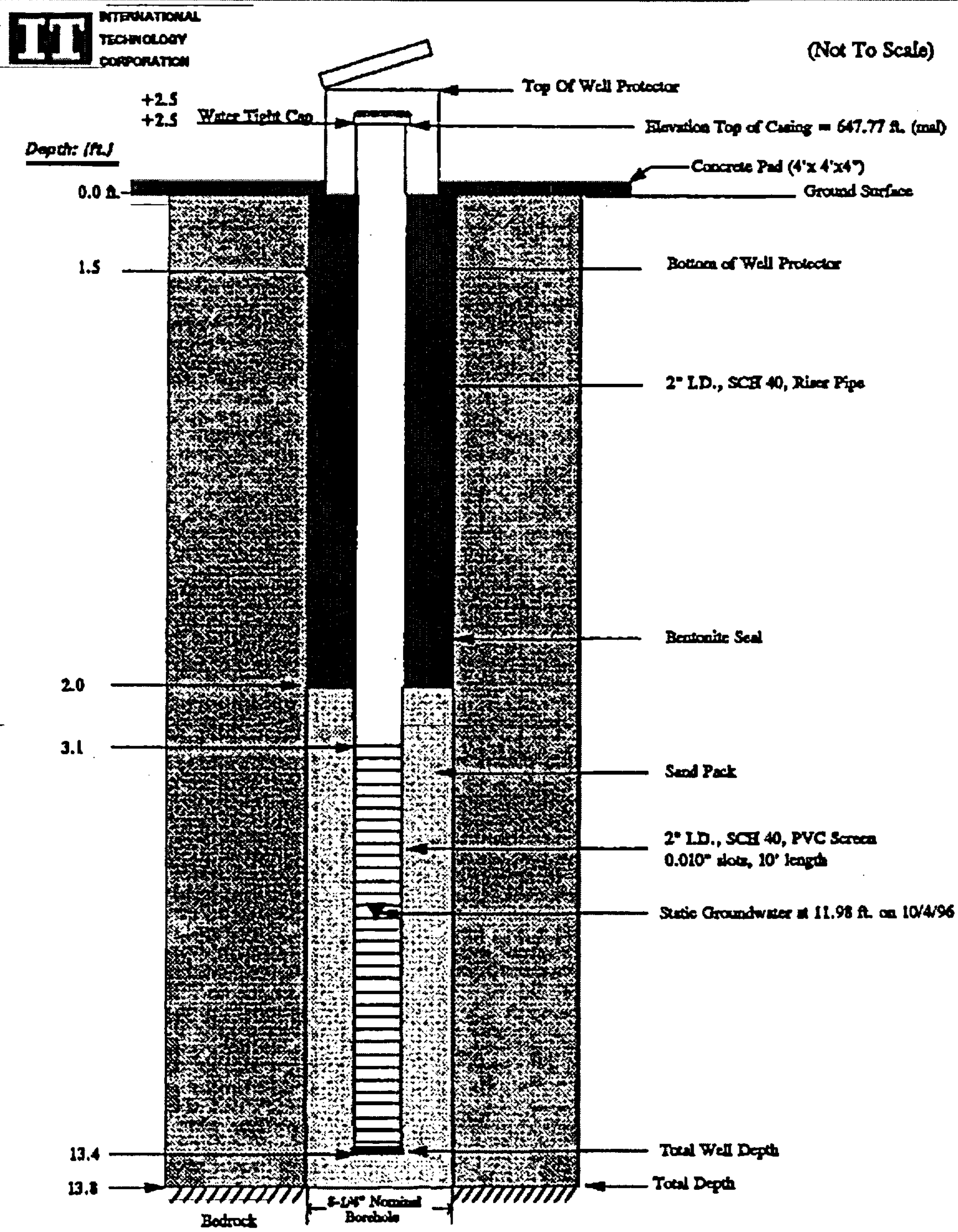
PROJECT: PBOW | INSPECTOR: W. White | SHEET 3 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	10	10.4			CL		
		Very hard, bluish gray (10 B 6/1), shale, dry 10.8	0.0	S-6		10,12 13,16	
	11	Weathered shale zone, bluish gray (5 PB 6/1), moist 11.3					
		Very hard, bluish gray (10 B 6/1), shale, dry 12.0					
	12	Weathered shale zone, bluish gray (5 PB 6/1), moist 12.8	0.0	S-7		7,14 80-6	
	13	Very hard, bluish gray (10 B 6/1), shale, dry					
	14	15.0					Augered down 1 ft. hard
	15	Total Depth = 15.0 Ft.					Hit refusal at 15 ft.
	16						
	17						
	18						
	19						
	20						

Project: PBOW | Hole No. IT-MW8

PBOW/BORINGS/MW-8B.DRW/mo/11-12-96

IT INTERNATIONAL TECHNOLOGY CORPORATION



Well Construction Diagram
prepared for:
USACE - NASHVILLE
PLUM BROOK ORDNANCE WORKS

Notes:

Well No.: IT-MW9

Date Installed: 9/26/96

Elevation Top of Casing*:

* Based on Mean Sea Level (MSL)

HTRW DRILLING LOG

HTRW DRILLING LOG	DISTRICT Nashville	HOLE NUMBER IT-MW9
1. COMPANY NAME IT Corporation	2. DRILL SUBCONTRACTOR Alliance	SHEET 1 OF 3 SHEETS

3. PROJECT PBOW	4. LOCATION Erie County, Ohio
5. NAME OF DRILLER Paul D. McAdams	6. MANUFACTURER'S DESIGNATION OF DRILL Dietrich D-50
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 2" Split Spoons, 8-1/2" O.D. Augers	8. HOLE LOCATION North at TOT Area C
	9. SURFACE ELEVATION 645.72 feet (MSL)
	10. DATE STARTED 9/25/96 / 11. DATE COMPLETED 9/27/96
12. OVERBURDEN THICKNESS 9.0 ft.	15. DEPTH GROUNDWATER ENCOUNTERED
13. DEPTH DRILLED INTO ROCK 6.0 ft.	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED 12.2 ft./5 days
14. TOTAL DEPTH OF HOLE 15.0 ft.	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY) NA

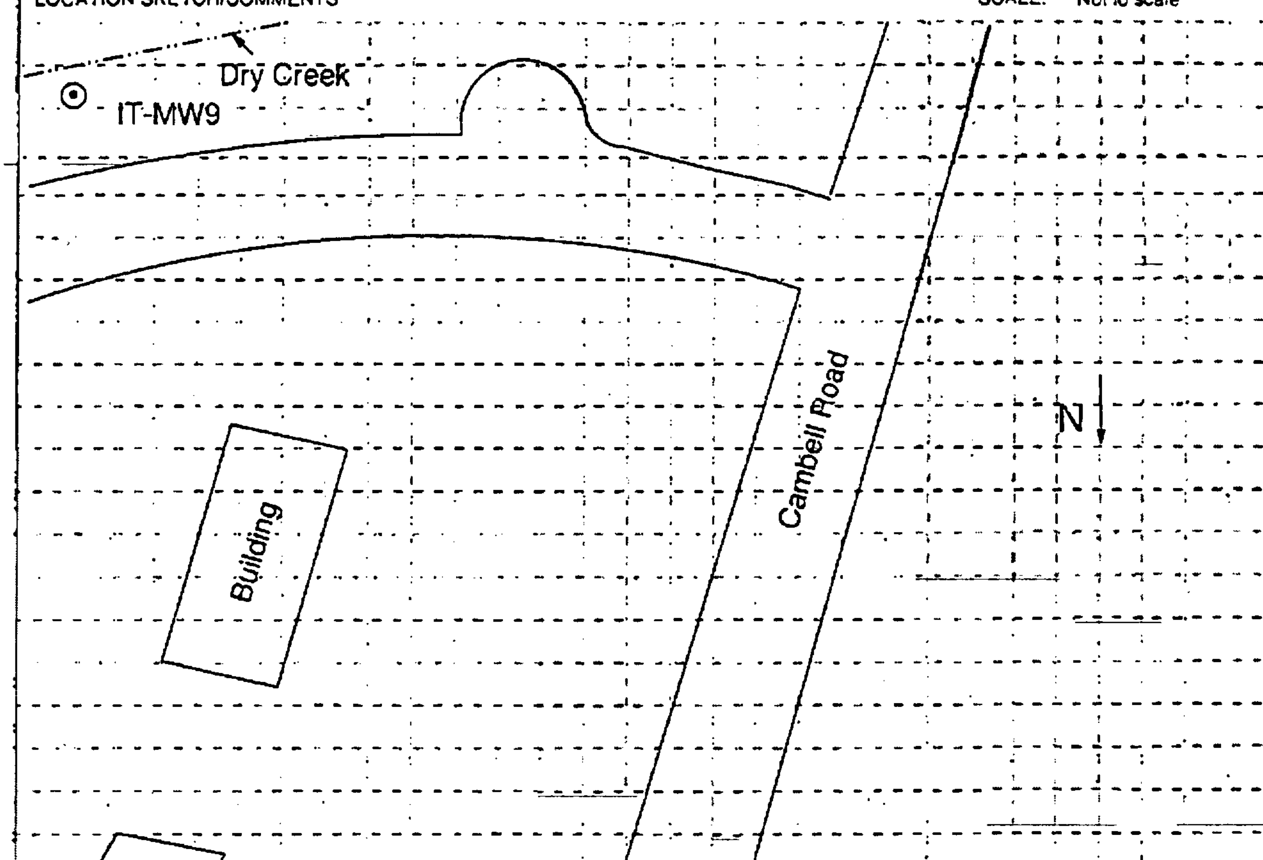
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
X	X		

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
NA						%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Wesley White

LOCATION SKETCH/COMMENTS

SCALE: Not to scale



PROJECT	HOLE NO.
PBOW	IT-MW9

PEOW/BORINGS/MW-9.DRW/MC/11-12-96

INTERNATIONAL TECHNOLOGY CORPORATION

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW9

PROJECT: PBOW | INSPECTOR: W. White | SHEET 2 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	0–2.0	Firm to hard, dark grayish brown (10 YR 4/2), silty CLAY, medium plasticity, blocky, dry to moist (near the plastic limit) 2.0	0.0	S-1	CL	1,3 6,8	
	2.0–4	Hard to very hard, brown (10 YR 5/3) silty CLAY, medium plasticity, blocky, trace medium sand, dry to moist (below plastic limit)	0.0	S-2 Geotechnical Sample	CL	7,10 14,21	
	4–6	10% fine to medium SAND, trace fine gravel and coarse sand size shale fragments	0.0	S-3 Geotechnical Sample	CL	8,15 21,25	
	6–7.25	7.25	0.0	S-4 Geotechnical Sample	CL	12,19 25,20	
	7.25–8.2	Hard, dark grayish brown (10 YR 4/2) silty CLAY, 25% sand of various sizes, medium plasticity, trace fine gravel, blocky, dry to moist 8.2			CL		
	8.2–9.0	Hard to very hard, bluish gray (10 B 5/1) silty CLAY, medium plasticity, blocky to platey, trace medium sand, dry to moist 9.0	0.0	S-5	CL	9,14 19,29	
	9.0–10	Weathered shale, platey					

Project: PBOW | Hole No. IT-MW9

PBOW\BORINGS\MW-5A.DRW\mc/11-12-96

INTERNATIONAL TECHNOLOGY CORPORATION

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW9

PROJECT: PBOW | INSPECTOR: W. White | SHEET 3 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	10	Very hard, buish gray (10 B 6/1) shale, dry					Shale broke up easily
	11		0.0	S-6		29,44 59, 50=3-1/2	
	12						
	13		0.0	S-7		23,5 100:5	
	14						Augered down to 15 ft.
	15	15.0					
		Total Depth = 15.0 Ft.					
	16						
	17						
	18						
	19						
	20						

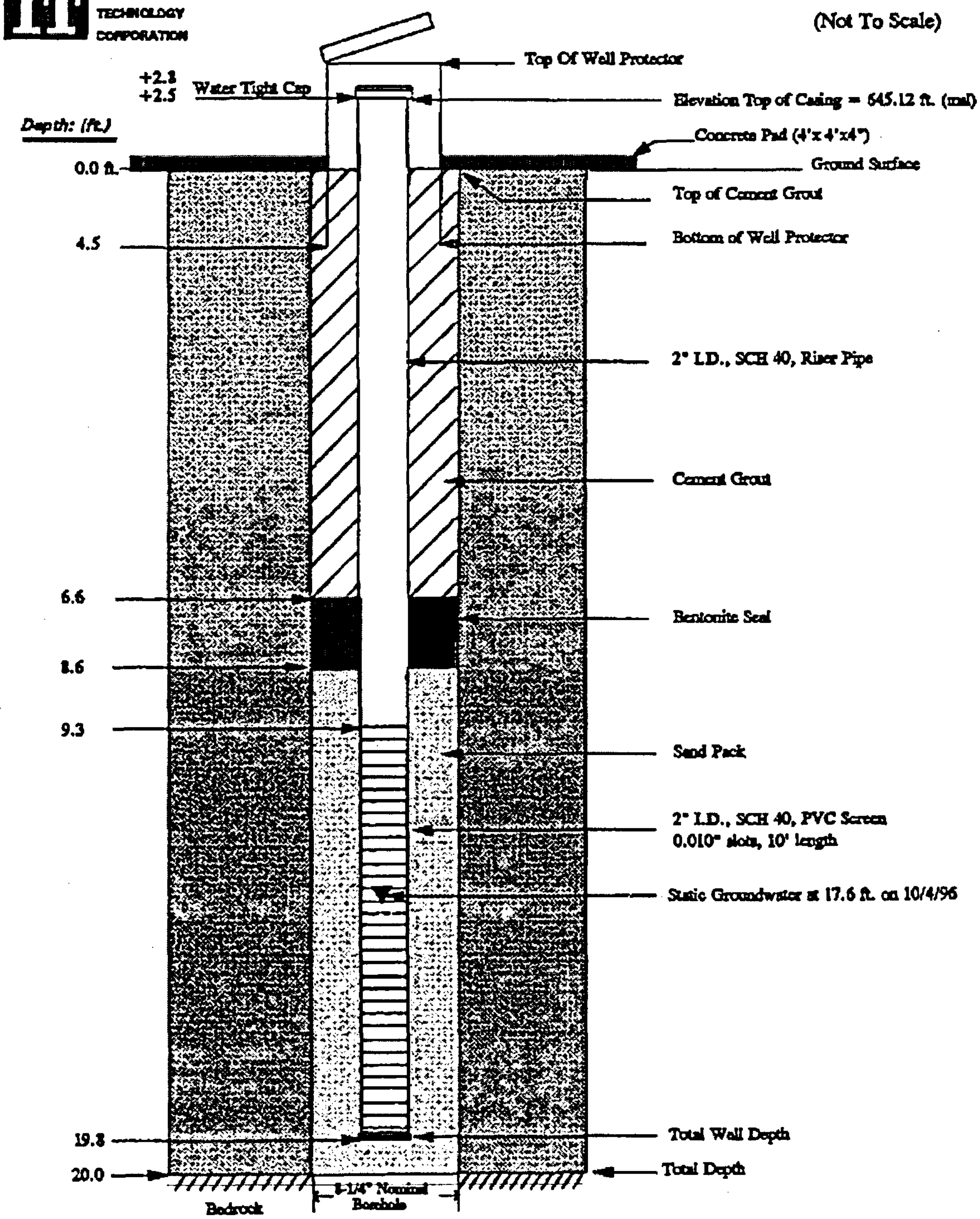
Project: PBOW | Hole No. IT-MW9

PBOW/BORINGS/MW-9B.DRW/ms/11-12-95

INTERNATIONAL TECHNOLOGY CORPORATION

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Well Construction Diagram
prepared for:
USACE - NASHVILLE
PLUM BROOK ORDNANCE WORKS

Notes:

Well No.: IT-MW10
Date Installed: 9/26/96
Elevation Top of Casing*:
* Based on Mean Sea Level (MSL)

HTRW DRILLING LOG

DISTRICT: Nashville

HOLE NUMBER: IT-MW10

1. COMPANY NAME: IT Corporation
2. DRILL SUBCONTRACTOR: Alliance

SHEET 1 OF 3 SHEETS

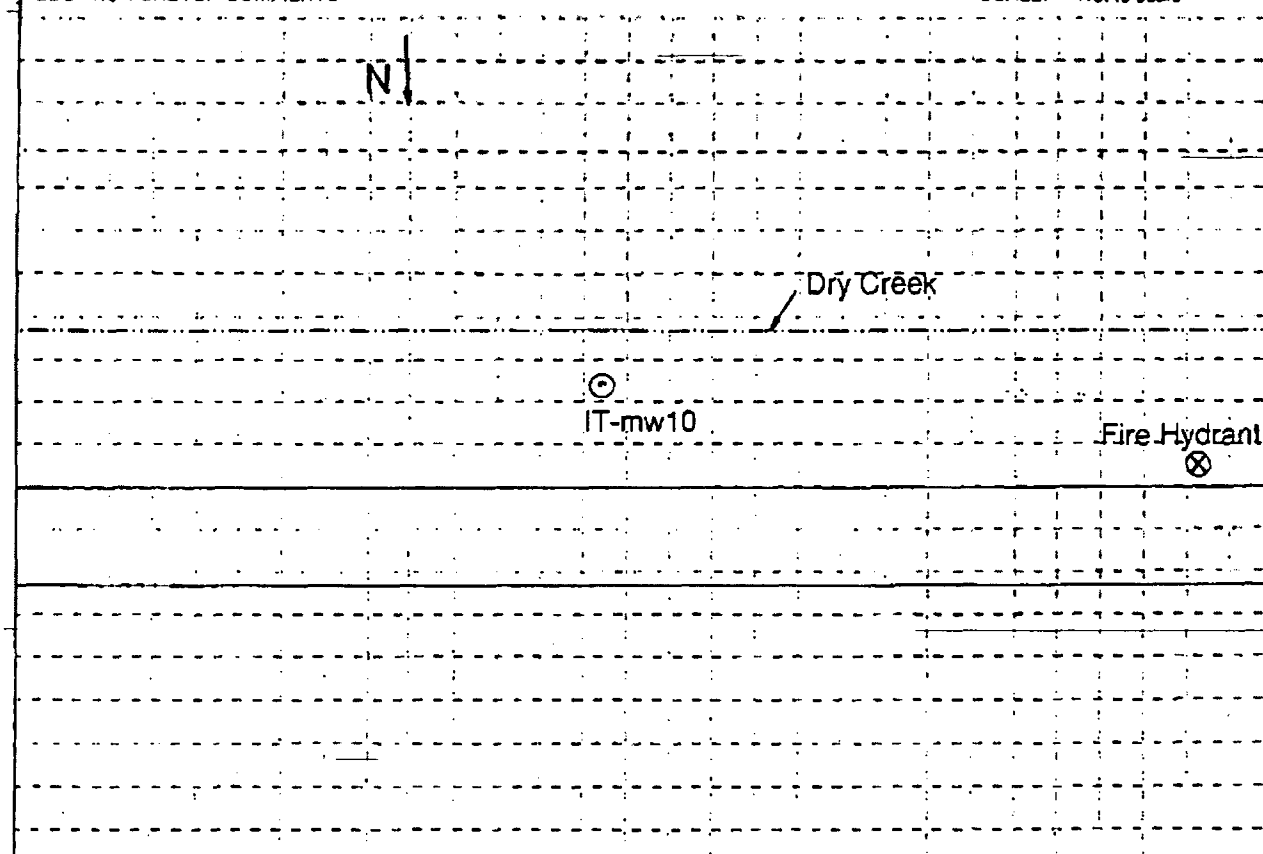
3. PROJECT: PBOW
4. LOCATION: Erie County, Ohio
5. NAME OF DRILLER: Paul D. McAdams
6. MANUFACTURER'S DESIGNATION OF DRILL: Dietrich D-50
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 2" Split Spoons, 8-1/2" O.D. Augers
8. HOLE LOCATION: Northwest of Redwater Pond
9. SURFACE ELEVATION: 642.51 feet (MSL)
10. DATE STARTED: 9/26/96
11. DATE COMPLETED: 9/27/96
12. OVERBURDEN THICKNESS: 19.5 ft.
13. DEPTH DRILLED INTO ROCK: 0.5 ft.
14. TOTAL DEPTH OF HOLE: 20.0 ft.
15. DEPTH GROUNDWATER ENCOUNTERED: NA
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 17.9 ft./5 days
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): NA

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
X	X		

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
NA				Pest/PCBs	Nitro	NA %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
		X		Wesley White/

LOCATION SKETCH/COMMENTS — SCALE: Not to scale



PROJECT: PBOW

HOLE NO.: IT-MW10

PBOW/BORINGS/MW-8.DRW/MC/11-11-96

INTERNATIONAL TECHNOLOGY CORPORATION

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW10

PROJECT: PBOW | INSPECTOR: W. White | SHEET 2 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	0–2	Firm, dark gray (10 YR 4/1) mottled with pale brown (10 YR 6/3) silty CLAY, medium plasticity, moist, roots	0.0	S-1	CL	1,3 3,5	
	2–4	Hard, very pale brown (10 YR 7/4), clayey SILT, low to medium plasticity, moderately low dry strength, dry to moist (below plastic limit)	0.0	S-2	ML	4,4 5,6	
	4–6	Firm, very pale brown (10 YR 7/3) clayey SILT to SILT, low plasticity, low dry strength, dry	0.0	S-3 Geotechnical Sample		7,8 11,15	
	6–8	Firm to soft, gray (10 YR 5/1), interbedded silty CLAY and SILT, medium to low plasticity, silts are dilatent, silty clays are moist to wet, silts are moist to dry	0.0	S-4	ML/CL	5,6 7,9	
	8–10	Silts are becoming moist to wet Fewer clay beds (predominant silts)	0.0	S-5	ML	3,3 4,4	

Project: PBOW | Hole No. IT-MW10

PBOW/BORINGS MW-6A.DRW/ng/11-12-95

INTERNATIONAL TECHNOLOGY CORPORATION

HTRW DRILLING LOG (CONTINUATION SHEET)

HOLE NO. IT-MW10

PROJECT: PBOW | INSPECTOR: W. White | SHEET 3 OF 3 SHEETS

ELEV. a	DEPTH b	DESCRIPTION OF MATERIALS c	FIELD SCREENING RESULTS d	GEOTECH SAMPLE OR CORE BOX NO. e	USCS f	BLOW COUNTS g	REMARKS h
	10–12		0.0	S-6		3,2 3,4	
	12–14		0.0	S-7	ML	1,3 4,4	
	14–16		0.0	S-8 Geotechnical Sample		1,3 3,3	
	16–18		0.0	S-9 Geotechnical Sample		2,3 3,4	
	18–19.5	Hard, dark bluish gray (5PB 4/1) clayey SILT, trace gravel and sand, low to medium plasticity, moist to dry, limestone float (19.5)	0.0	S-10	ML	8,11 50, 50=1/2"	
	19.5–20.0	Limestone (20.0)					

Project: PBOW | Hole No. IT-MW10

PBOW\BORINGS\MW-03.DRW/mr 7/11-12-95

INTERNATIONAL TECHNOLOGY CORPORATION

ALLIANCE
ENVIRONMENTAL, INC.

10/29/96

IT Corporation
312 Directors Drive
Knoxville, TN 37923

Attention: Mr. Wesley White

RE: ***Laboratory Results for Plum Brook Ordnance Works***

Dear Mr. White:

Enclosed is the laboratory results for the samples submitted for the above referenced project.

If we can help you with your drilling needs or you need additional information just give a call. I can be reached either at 1.614.373.2190 extension 128.

Sincerely,

ALLIANCE ENVIRONMENTAL, INC.

Paul D. McAdams, CWD
Project Manager

enclosures
Laboratory Results

Goyle
Engineering, Inc.
115 Rauch Drive, Marietta
Ohio 45750
614 374-5607

R.K.Goyle,M.S.C.E.,P.E.

Registration:
Ohio
West Virginia
Kentucky
Pennsylvania
Indiana
Wisconsin
South Carolina
North Carolina

RECEIV

October 25, 1996

Job No: 96-186

Client: Alliance Environmental, Inc.

Laboratory Soil Testing

Test Boring No. MW-6:

Depth	%Moisture	Soil Description(Classification)
4'-6'	17.9	Very moist, brown sandy silt (Non-Plastic) Can not be rolled into 1/8" thread(-#40)
14'-16'	25.6	Very moist gray clayey silt, silty clay CL-ML, LL = 26.1, PL = 20.4, PI = 5.7
16'-18'	27.1	Very moist, gray, silty clay, clayey silt CL-ML, LL = 27.2, PL = 20.5, PI = 6.7

Test Boring No. MW-8:

Depth	%Moisture	Soil Description(Classification)
2'-4'	14.4	Moist, brown sandy, clayey silt SM-ML, LL = 24.8, PL = 21.1, PI = 3.7
4.2'-5.7'	11.8	Moist, brown silty sand (Non-Plastic)
6'-8'	28.4	Very moist, gray clayey silt ML, LL = 43.6, PL = 27.2, PI = 16.4

Test Boring No. MW-9:

Depth	%Moisture	Soil Description(Classification)
2'-4'	16.3	Moist, brown clayey silt ML, LL = 34.2, PL = 24.1, PI = 10.1
4'-6'	13.4	Moist, brown silty clay CL, LL = 34.1, PL = 23.2, PI = 10.9
6'-8'	11.2	Moist, brown silty clay CL, LL = 30.9, PL = 20.3, PI = 10.6

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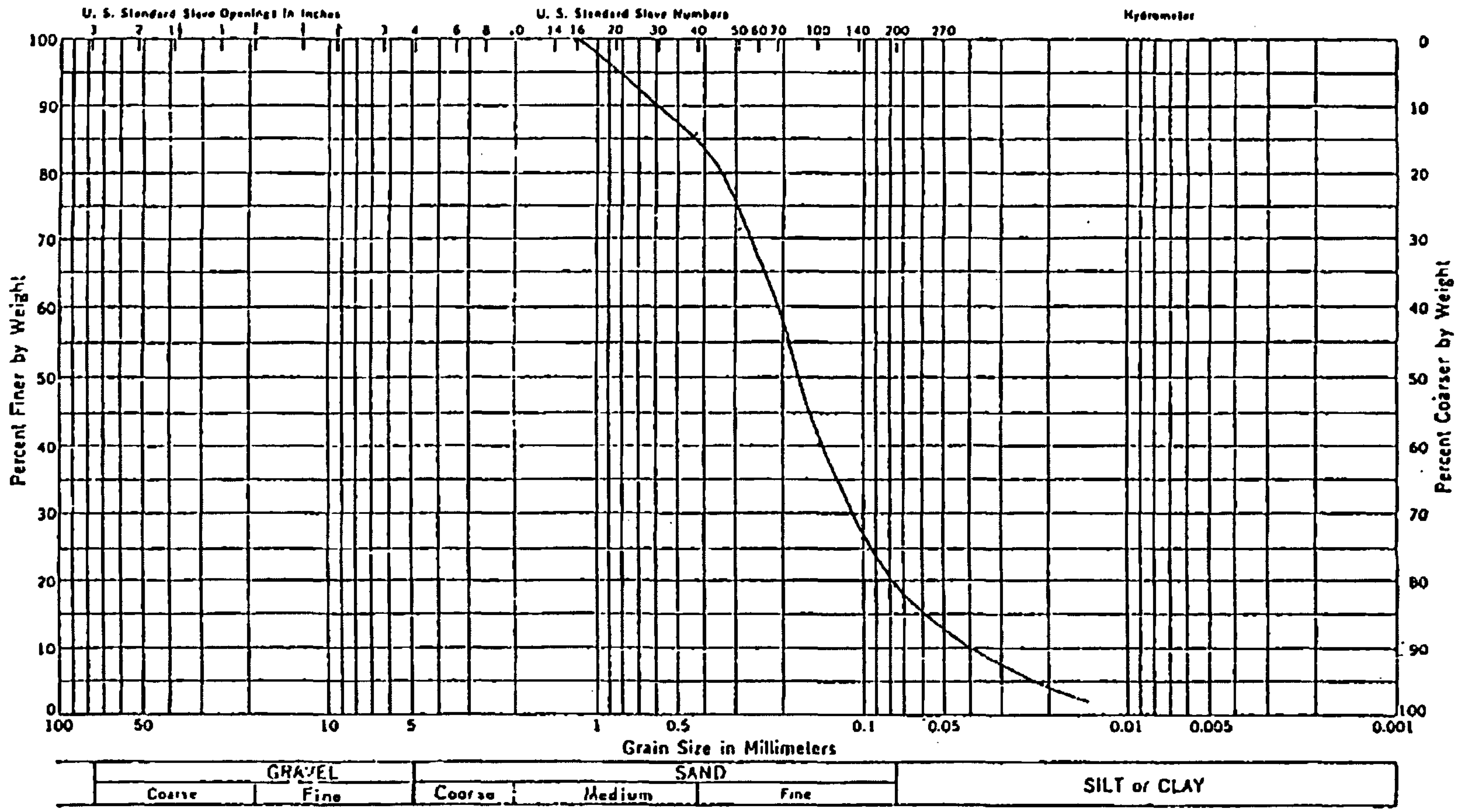
Note: Sample received October 16, 1996



HOLE NO.	SAMPLE NO.	DEPTH	M.C		CLASSIFICATION
MW-8		4.5'-7'	11.8%		Moist, brown silty sand "SM"

Client: Alliance Environmental, Inc.
Job No: 96-186
Project: Laboratory Soil Testing

Goyle Engineering, Inc.
October, 1996

APPENDIX C

LAND SURVEY DATA

NEW MONITORING WELLS (NASA PBS COORDINATES)

PT #	Y	X	ELEV	WELL #
252	29982.500	13987.892	632.640	MW7GND
251	29982.504	13987.790	635.350	MW7CAS
227	30437.005	15248.293	630.920	MW8GND
228	30435.170	15247.906	633.480	MW8CAS
233	28884.946	14852.186	645.720	MW9GND
234	28882.831	14852.220	647.770	MW9CAS
248	30926.420	13587.695	642.510	MW10GND
246	30924.244	13587.828	645.120	MW10CAS

NEW MONITORING WELLS (OHIO STATE COORDINATES)

PT #	Y	X	ELEVATION (ground)	ELEVATION (casing)	WELL #
251	622075.676	1909861.839	632.300	635.030	IT-MW7*
225	622497.939	1911132.383	630.600	633.160	IT-MW8
231	620955.600	1910699.468	645.400	647.450	IT-MW9
245	623026.644	1909484.655	642.200	644.800	IT-MW10

* - temporary piezometer

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:XISTING MONITORING WELLS (OHIO STATE COORDINATES)

PT #	Y	X	ELEVATION	WELL	POSITION
1100	624339.440	1923776.407	637.730	MK-MW22	CAS
1101	624339.661	1923775.783	635.240	MK-MW22	GND
1102	624656.620	1925353.648	639.110	MK-MW23	CAS
1103	624655.534	1925353.894	636.630	MK-MW23	GND
1104	622263.851	1923302.327	656.800	MK-MW24	CAS
1105	622264.944	1923301.968	654.120	MK-MW24	GND
1106	623863.520	1923399.445	639.860	PB-TNTA-MW10	CAS
1107	623861.382	1923398.533	637.180	PB-TNTA-MW10	GND
1108	623517.575	1922744.173	640.180	PB-TNTA-MW11	CAS
1109	623515.418	1922744.065	937.540	PB-TNTA-MW11	GND
1200	616833.696	1918010.497	674.000	MK-MW16	CAS
1201	616834.747	1918009.976	671.010	MK-MW16	GND
1202	618572.482	1917812.572	664.320	MK-MW17	CAS
1203	618572.092	1917811.385	660.650	MK-MW17	GND
1300	621464.997	1911390.720	645.090	PB-TNTC-MW3	CAS
1301	621465.147	1911392.442	642.250	PB-TNTC-MW3	GND
1302	620412.716	1910470.087	654.110	PB-TNTC-MW4	CAS
1303	620410.329	1910469.141	651.570	PB-TNTC-MW4	GND
1304	620691.637	1911811.188	651.490	PB-TNTC-MW5	CAS
1305	620691.916	1911813.344	648.750	PB-TNTC-MW5	GND
1306	620428.714	1913006.304	659.080	PB-TNTC-MW6	CAS
1307	620430.320	1913004.737	656.500	PB-TNTC-MW6	GND
1400	622512.007	1910264.705	639.280	IT-MW002	CAS
1401	622511.675	1910264.431	636.370	IT-MW002	GND
1402	622511.924	1910264.557	639.310	IT-MW002	MEASU.
1403	623859.687	1910564.322	640.570	MK-MW10	CAS
1404	623860.782	1910563.734	637.740	MK-MW10	GND
1405	623859.687	1910564.322	637.360	MK-MW11	CAS
1406	623828.580	1911843.397	634.390	MK-MW11	GND
1407	622640.734	1909947.711	644.110	PB-WA-MW-1	CAS
1408	622640.619	1909948.210	642.000	PB-WA-MW-1	GND
1409	622123.895	1910176.458	633.330	PB-WA-MW-2	CAS
1410	622124.533	1910176.535	630.840	PB-WA-MW-2	GND
1500	624996.059	1919020.828	633.670	PB-PR-MW7	CAS
1501	624995.842	1919020.879	631.180	PB-PR-MW7	GND
1502	624888.805	1919308.729	634.700	PB-PR-MW8	CAS
1503	624888.942	1919308.382	632.180	PB-PR-MW8	GND
1504	625091.706	1919510.083	633.380	PB-PR-MW9	CAS
1505	625089.087	1919513.212	630.380	PB-PR-MW9	GND
1506	625345.617	1919475.123	634.670	IT-MW05	CAS
1507	625344.046	1919473.379	631.590	IT-MW05	GND
1600	621044.151	1912174.521	647.950	PB-BED-MW13	CAS
1601	621042.117	1912174.539	645.490	PB-BED-MW13	GND

1602	622719.990	1910457.060	645.720	PB-BED-MW14	CAS
1603	622719.740	1910454.570	642.730	PB-BED-MW14	GND
1604	626178.959	1919282.558	631.310	PB-BED-MW15	CAS
1605	626178.892	1919284.779	628.760	PB-BED-MW15	GND
1606	623298.550	1920593.533	635.700	PB-BED-MW16	CAS
1607	623296.570	1920593.727	633.360	PB-BED-MW16	GND
1608	625417.226	1924121.493	629.650	PB-BED-MW17	CAS
1609	625419.121	1924122.212	627.020	PB-BED-MW17	GND
1610	623848.512	1925483.197	651.180	PB-BED-MW18	CAS
1611	623846.215	1925482.960	648.510	PB-BED-MW18	GND
1612	623869.017	1910173.785	642.750	PB-BED-MW19	CAS
1613	623866.980	1910173.474	640.190	PB-BED-MW19	GND
1614	612423.248	1922951.545	676.010	PB-BED-MW20	CAS
1615	612421.674	1922950.501	673.250	PB-BED-MW20	GND
1616	626773.634	1917983.404	629.800	REACTOR1	CAS
1617	626773.771	1917983.396	631.890	REACTOR1	GND
1618	626660.982	1918003.256	630.360	REACTOR2	CAS
1619	626661.200	1918003.208	630.400	REACTOR2	GND
1620	626685.067	1918148.350	630.560	REACTOR3	CAS
1621	626685.072	1918148.453	630.410	REACTOR3	GND
1622	626630.217	1918146.484	630.830	REACTOR4	CAS
1623	626630.259	1918146.510	630.440	REACTOR4	GND

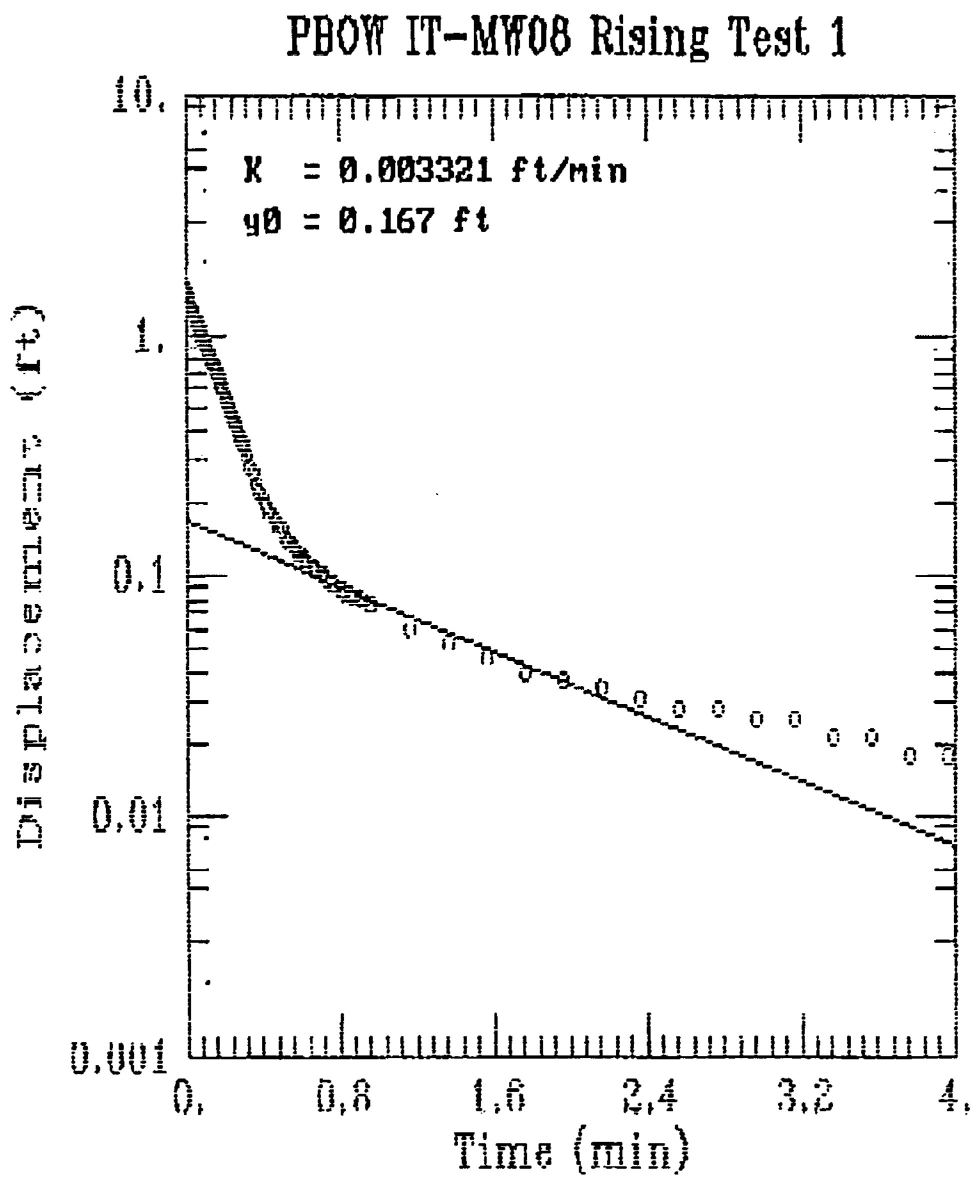
EXISTING MONITORING WELLS (NASA PBS COORDINATES)

PT #	Y	X	ELEVATION	WELL	POSITION
1000	32580.157	27844.966	638.050	MK-MW22	CAS
1001	32580.363	27844.337	635.560	MK-MW22	GND
1002	32935.171	29414.244	639.430	MK-MW23	CAS
1003	32934.091	29414.516	636.950	MK-MW23	GND
1004	30493.623	27420.866	657.120	MK-MW24	CAS
1005	30494.707	27420.481	654.440	MK-MW24	GND
1006	32095.281	27479.522	640.180	PB-TNTA-MW10	CAS
1007	32093.121	27478.661	637.500	PB-TNTA-MW10	GND
1008	31733.664	26832.705	640.500	PB-TNTA-MW11	CAS
1009	31731.505	26832.648	937.860	PB-TNTA-MW11	GND
2000	24937.473	22260.669	674.320	MK-MW16	CAS
2001	24938.512	22260.123	671.330	MK-MW16	GND
2002	26671.128	22021.002	664.640	MK-MW17	CAS
2003	26670.709	22019.825	660.970	MK-MW17	GND
3000	29408.697	15531.026	645.410	PB-TNTC-MW3	CAS
3001	29408.888	15532.745	642.570	PB-TNTC-MW3	GND
3002	28334.519	14635.879	654.430	PB-TNTC-MW4	CAS
3003	28332.110	14634.991	651.890	PB-TNTC-MW4	GND
3004	28645.608	15969.988	651.810	PB-TNTC-MW5	CAS
3005	28645.938	15972.137	649.070	PB-TNTC-MW5	GND
3006	28411.461	17171.165	659.400	PB-TNTC-MW6	CAS
3007	28413.029	17169.559	656.820	PB-TNTC-MW6	GND

4000	30428.422	14380.094	639.600	IT-MW002	CAS
4001	30428.083	14379.828	636.690	IT-MW002	GND
4002	30428.335	14379.948	639.630	IT-MW002	MEASU.P
4003	31783.011	14647.261	640.890	MK-MW10	CAS
4004	31784.092	14646.646	638.060	MK-MW10	GND
4005	31783.011	14647.261	637.680	MK-MW11	CAS
4006	31782.648	15926.807	634.710	MK-MW11	GND
4007	30549.503	14060.075	644.430	PB-WA-MW-1	CAS
4008	30549.400	14060.577	642.320	PB-WA-MW-1	GND
4009	30038.273	14301.193	633.650	PB-WA-MW-2	CAS
4010	30038.913	14301.254	631.160	PB-WA-MW-2	GND
5000	33122.354	23074.634	633.990	PB-PR-MW7	CAS
5001	33122.138	23074.690	631.500	PB-PR-MW7	GND
5002	33022.042	23365.050	635.020	PB-PR-MW8	CAS
5003	33022.170	23364.700	632.500	PB-PR-MW8	GND
5004	33229.738	23561.485	633.700	PB-PR-MW9	CAS
5005	33227.194	23564.676	630.700	PB-PR-MW9	GND
5006	33482.754	23520.431	634.990	IT-MW05	CAS
5007	33481.141	23518.725	631.910	IT-MW05	GND
6000	29006.777	16324.772	648.270	PB-BED-MW13	CAS
6001	29004.744	16324.838	645.810	PB-BED-MW13	GND
6002	30640.982	14567.410	646.040	PB-BED-MW14	CAS
6003	30640.673	14564.926	643.050	PB-BED-MW14	GND
6004	34311.288	23307.881	631.630	PB-BED-MW15	CAS
6005	34311.275	23310.104	629.080	PB-BED-MW15	GND
6006	31463.005	24687.792	636.020	PB-BED-MW16	CAS
6007	31461.030	24688.033	633.680	PB-BED-MW16	GND
6008	33666.003	28164.077	629.970	PB-BED-MW17	CAS
6009	33667.915	28164.751	627.340	PB-BED-MW17	GND
6010	32130.350	29563.185	651.500	PB-BED-MW18	CAS
6011	32123.048	29563.003	648.830	PB-BED-MW18	GND
6012	31782.954	14256.584	643.070	PB-BED-MW19	CAS
6013	31780.910	14256.322	640.510	PB-BED-MW19	GND
6014	20646.714	27306.637	676.330	PB-BED-MW20	CAS
6015	20645.115	27305.631	673.570	PB-BED-MW20	GND
6016	34874.615	21994.717	630.120	REACTOR1	CAS
6017	34874.752	21994.706	632.210	REACTOR1	GND
6018	34762.465	22017.272	630.680	REACTOR2	CAS
6019	34762.682	22017.219	630.720	REACTOR2	GND
6020	34790.031	22161.756	630.880	REACTOR3	CAS
6021	34790.039	22161.859	630.730	REACTOR3	GND
6022	34735.148	22161.209	631.150	REACTOR4	CAS
6023	34735.191	22161.233	630.760	REACTOR4	GND

APPENDIX G

HYDRAULIC CONDUCTIVITY TEST



PBOW IT-MW08 Rising Test 1
K = 0.003321 ft/min
y0 = 0.167 ft
10.
1.
0.1
0.01
0.001
Displacement (ft)
0.
0.8
1.6
2.4
3.2
4.
Time (min)

IT-MW08 Slug Test 1
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0	1.547
0.0033	1.472
0.0066	1.456
0.01	1.406
0.0133	1.413
0.0166	1.366
0.02	1.366
0.0233	1.341
0.0266	1.315
0.03	1.294
0.0333	1.268
0.0366	1.24
0.04	1.237
0.0433	1.212
0.0466	1.221
0.05	1.171
0.0533	1.162
0.0566	1.153
0.06	1.124
0.0633	1.112
0.0666	1.077
0.07	1.052
0.0733	1.055
0.0766	1.037
0.08	1.024
0.0833	1.008
0.0866	0.993
0.09	0.977
0.0933	0.961
0.0966	0.949
0.1	0.921
0.1033	0.918
0.1066	0.877
0.11	0.889
0.1133	0.867
0.1166	0.855
0.12	0.842
0.1233	0.833
0.1266	0.82
0.13	0.808
0.1333	0.792
0.1366	0.78
0.14	0.767
0.1433	0.755
0.1466	0.742
0.15	0.733
0.1533	0.72
0.1566	0.708
0.16	0.698

IT-MW08 Slug Test 1
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0.1633	0.686
0.1666	0.683
0.17	0.676
0.1733	0.667
0.1766	0.664
0.18	0.632
0.1833	0.62
0.1866	0.61
0.19	0.601
0.1933	0.592
0.1966	0.582
0.2	0.573
0.2033	0.564
0.2066	0.554
0.21	0.545
0.2133	0.535
0.2166	0.526
0.22	0.517
0.2233	0.51
0.2266	0.482
0.23	0.491
0.2333	0.482
0.2366	0.476
0.24	0.466
0.2433	0.46
0.2466	0.451
0.25	0.444
0.2533	0.438
0.2566	0.429
0.26	0.423
0.2633	0.416
0.2666	0.407
0.27	0.401
0.2733	0.394
0.2766	0.388
0.28	0.382
0.2833	0.375
0.2866	0.369
0.29	0.363
0.2933	0.357
0.2966	0.35
0.3	0.344
0.3033	0.338
0.32	0.31
0.3366	0.285
0.3533	0.263
0.37	0.241
0.3866	0.225
0.4033	0.209

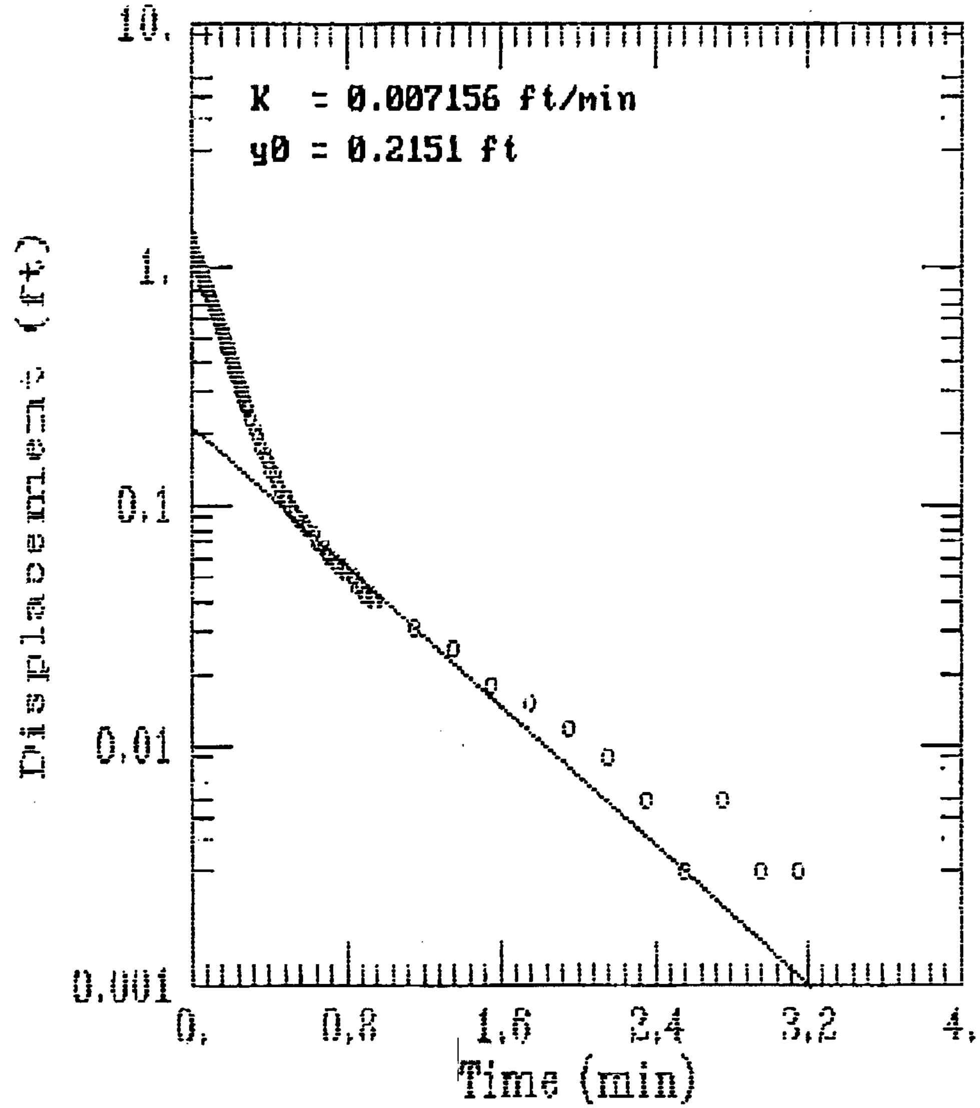
IT-MW08 Slug Test 1
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0.42	0.197
0.4366	0.184
0.4533	0.175
0.47	0.166
0.4866	0.156
0.5033	0.15
0.52	0.144
0.5366	0.137
0.5533	0.134
0.57	0.128
0.5866	0.122
0.6033	0.119
0.62	0.115
0.6366	0.112
0.6533	0.109
0.67	0.106
0.6866	0.103
0.7033	0.1
0.72	0.1
0.7366	0.097
0.7533	0.094
0.77	0.094
0.7866	0.09
0.8033	0.087
0.82	0.087
0.8366	0.084
0.8533	0.084
0.87	0.081
0.8866	0.081
0.9033	0.081
0.92	0.078
0.9366	0.078
0.9533	0.075
0.97	0.075
1.17	0.059
1.37	0.053
1.57	0.046
1.77	0.04
1.97	0.037
2.17	0.034
2.37	0.031
2.57	0.028
2.77	0.028
2.97	0.025
3.17	0.025
3.37	0.021
3.57	0.021
3.77	0.018
3.97	0.018

IT-MW08 Slug Test 1
PBOW, Groundwater Investigation

Elapsed Time	Input 1
4.17	0.015
4.37	0.018
4.57	0.015
4.77	0.015
4.97	0.015
5.17	0.012
5.37	0.012
5.57	0.012
5.77	0.012
5.97	0.012
6.17	0.009
6.37	0.012
6.57	0.009
6.77	0.009
6.97	0.009
7.17	0.009
7.37	0.009
7.57	0.009
7.77	0.009
7.97	0.006
8.17	0.006
8.37	0.006
8.57	0.006
8.77	0.006
8.97	0.006
9.17	0.006
9.37	0.006
9.57	0.006
9.77	0.006
9.97	0.003

PBOW IT-MW08 Rising Test 2



IT-MW08 Slug Test 2
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0	1.3
0.0033	1.272
0.0066	1.225
0.01	1.209
0.0133	1.178
0.0166	1.159
0.02	1.14
0.0233	1.124
0.0266	1.068
0.03	1.096
0.0333	1.068
0.0366	1.049
0.04	1.046
0.0433	1.012
0.0466	0.98
0.05	0.958
0.0533	0.98
0.0566	0.933
0.06	0.933
0.0633	0.918
0.0666	0.892
0.07	0.877
0.0733	0.858
0.0766	0.811
0.08	0.833
0.0833	0.82
0.0866	0.808
0.09	0.792
0.0933	0.78
0.0966	0.764
0.1	0.752
0.1033	0.739
0.1066	0.73
0.11	0.714
0.1133	0.701
0.1166	0.692
0.12	0.676
0.1233	0.664
0.1266	0.651
0.13	0.642
0.1333	0.629
0.1366	0.617
0.14	0.607
0.1433	0.595
0.1466	0.585
0.15	0.573
0.1533	0.564
0.1566	0.554
0.16	0.542

IT-MW08 Slug Test 2
PBOW, Groundwater Investigation

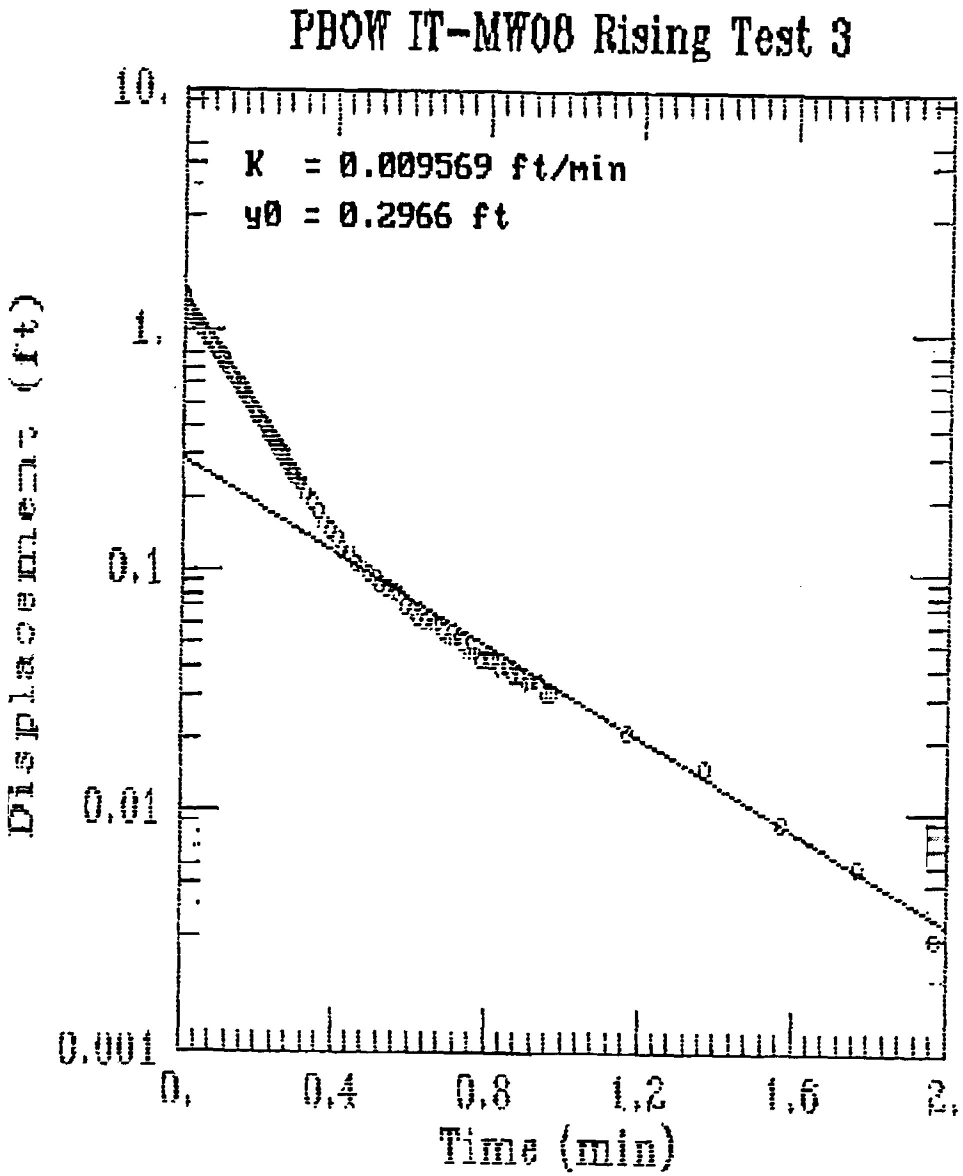
Elapsed Time	Input 1
0.1633	0.532
0.1666	0.523
0.17	0.513
0.1733	0.504
0.1766	0.495
0.18	0.485
0.1833	0.476
0.1866	0.466
0.19	0.457
0.1933	0.448
0.1966	0.441
0.2	0.432
0.2033	0.426
0.2066	0.416
0.21	0.41
0.2133	0.401
0.2166	0.394
0.22	0.385
0.2233	0.379
0.2266	0.372
0.23	0.363
0.2333	0.357
0.2366	0.35
0.24	0.344
0.2433	0.335
0.2466	0.332
0.25	0.322
0.2533	0.316
0.2566	0.31
0.26	0.307
0.2633	0.3
0.2666	0.294
0.27	0.288
0.2733	0.285
0.2766	0.278
0.28	0.272
0.2833	0.269
0.2866	0.263
0.29	0.256
0.2933	0.253
0.31	0.231
0.3266	0.209
0.3433	0.191
0.36	0.175
0.3766	0.162
0.3933	0.15
0.41	0.14
0.4266	0.131
0.4433	0.125
0.46	0.115

IT-MW08 Slug Test 2
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0.4766	0.109
0.4933	0.106
0.51	0.1
0.5266	0.094
0.5433	0.09
0.56	0.087
0.5766	0.084
0.5933	0.081
0.61	0.078
0.6266	0.075
0.6433	0.072
0.66	0.068
0.6766	0.068
0.6933	0.065
0.71	0.062
0.7266	0.059
0.7433	0.059
0.76	0.056
0.7766	0.056
0.7933	0.053
0.81	0.053
0.8266	0.05
0.8433	0.05
0.86	0.046
0.8766	0.046
0.8933	0.043
0.91	0.043
0.9266	0.043
0.9433	0.04
0.96	0.04
1.16	0.031
1.36	0.025
1.56	0.018
1.76	0.015
1.96	0.012
2.16	0.009
2.36	0.006
2.56	0.003
2.76	0.006
2.96	0.003
3.16	0.003
3.36	0
3.56	0
3.76	0
3.96	-0.003
4.16	-0.003
4.36	-0.003
4.56	-0.003
4.76	-0.003
4.96	-0.003

IT-MW08 Slug Test 2
PBOW, Groundwater Investigation

Elapsed Time	Input 1
5.16	-0.006
5.36	-0.006
5.56	-0.006
5.76	-0.006
5.96	-0.006
6.16	-0.006
6.36	-0.009
6.56	-0.009
6.76	-0.009
6.96	-0.009
7.16	-0.009
7.36	-0.009
7.56	-0.009
7.76	-0.009
7.96	-0.009
8.16	-0.012
8.36	-0.012
8.56	-0.009
8.76	-0.012
8.96	-0.012
9.16	-0.012
9.36	-0.012
9.56	-0.012
9.76	-0.012
9.96	-0.012


PBOW IT-MW08 Rising Test 3
K = 0.009569 ft/min
y0 = 0.2966 ft
10.
1.
0.1
0.01
0.001
Displacement (ft)
0.
0.4
0.8
1.2
1.6
2.
Time (min)

IT-MW08 Slug Test 3
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0	1.375
0.0034	1.353
0.0067	1.237
0.01	1.228
0.0134	1.2
0.0167	1.178
0.02	1.153
0.0234	1.165
0.0267	1.102
0.03	1.102
0.0334	1.08
0.0367	1.062
0.04	1.055
0.0434	1.018
0.0467	1.024
0.05	0.987
0.0534	0.974
0.0567	0.958
0.06	0.93
0.0634	0.927
0.0667	0.905
0.07	0.886
0.0734	0.871
0.0767	0.864
0.08	0.846
0.0834	0.833
0.0867	0.814
0.09	0.802
0.0934	0.786
0.0967	0.78
0.1	0.761
0.1034	0.748
0.1067	0.733
0.11	0.72
0.1134	0.704
0.1167	0.695
0.12	0.683
0.1234	0.67
0.1267	0.657
0.13	0.648
0.1334	0.636
0.1367	0.623
0.14	0.614
0.1434	0.601
0.1467	0.589
0.15	0.579
0.1534	0.57
0.1567	0.557
0.16	0.548

IT-MW08 Slug Test 3
PBOW, Groundwater Investigation

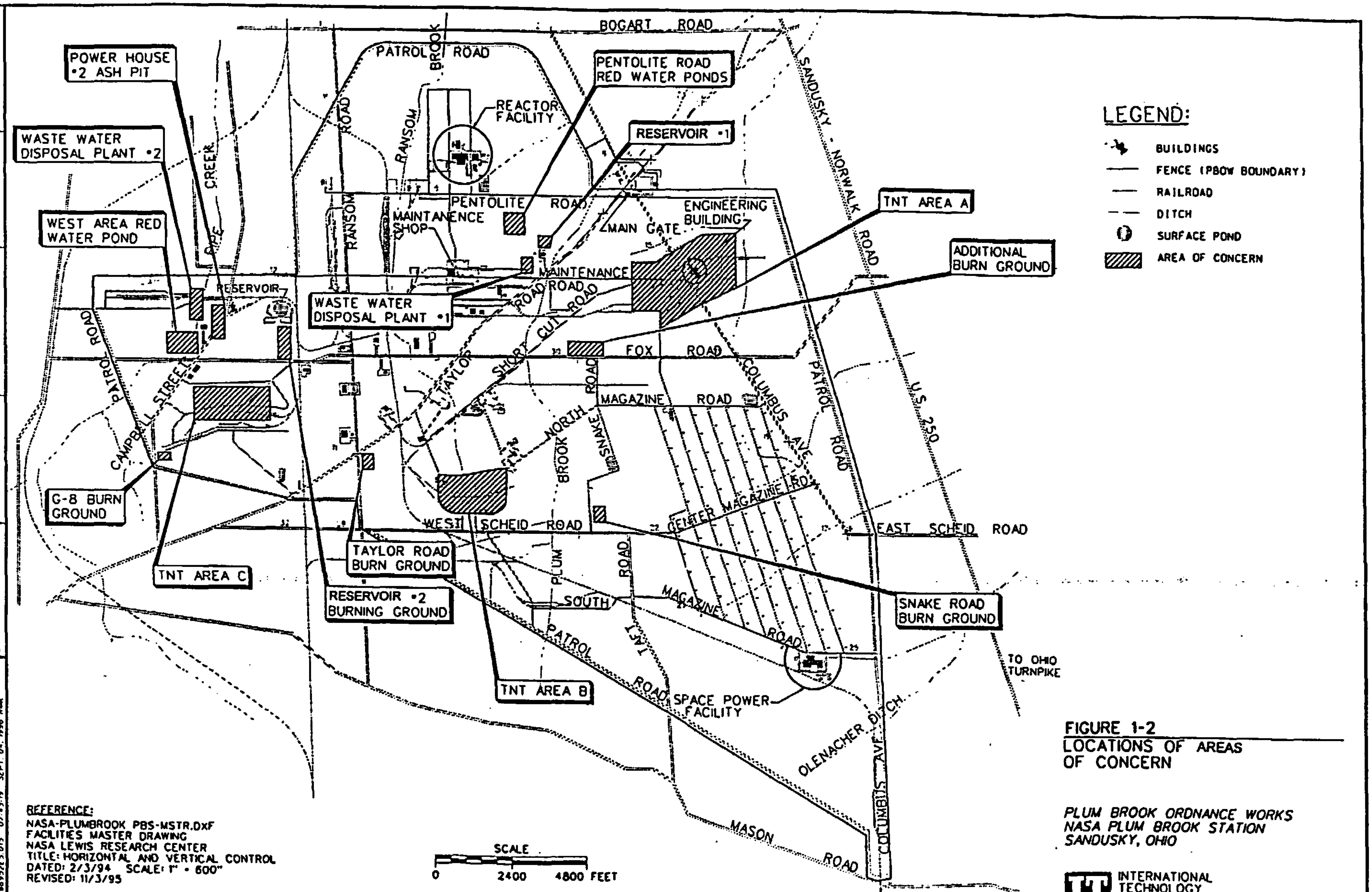
Elapsed Time	Input 1
0.1634	0.535
0.1667	0.526
0.17	0.517
0.1734	0.507
0.1767	0.498
0.18	0.488
0.1834	0.479
0.1867	0.469
0.19	0.46
0.1934	0.451
0.1967	0.444
0.2	0.435
0.2034	0.426
0.2067	0.419
0.21	0.41
0.2134	0.401
0.2167	0.394
0.22	0.388
0.2234	0.379
0.2267	0.372
0.23	0.363
0.2334	0.357
0.2367	0.35
0.24	0.344
0.2434	0.338
0.2467	0.329
0.25	0.325
0.2534	0.316
0.2567	0.31
0.26	0.307
0.2634	0.3
0.2667	0.294
0.27	0.288
0.2734	0.281
0.2767	0.275
0.28	0.272
0.2834	0.266
0.2867	0.26
0.29	0.256
0.2934	0.25
0.2967	0.244
0.3	0.241
0.3034	0.235
0.3067	0.231
0.3234	0.209
0.34	0.191
0.3567	0.172
0.3734	0.159
0.39	0.147
0.4067	0.137

IT-MW08 Slug Test 3
PBOW, Groundwater Investigation

Elapsed Time	Input 1
0.4234	0.125
0.44	0.119
0.4567	0.109
0.4734	0.103
0.49	0.097
0.5067	0.094
0.5234	0.087
0.54	0.084
0.5567	0.081
0.5734	0.078
0.59	0.072
0.6067	0.068
0.6234	0.065
0.64	0.062
0.6567	0.059
0.6734	0.059
0.69	0.056
0.7067	0.053
0.7234	0.053
0.74	0.05
0.7567	0.046
0.7734	0.046
0.79	0.043
0.8067	0.043
0.8234	0.043
0.84	0.04
0.8567	0.04
0.8734	0.037
0.89	0.037
0.9067	0.034
0.9234	0.034
0.94	0.034
0.9567	0.031
0.9734	0.031
1.1734	0.021
1.3734	0.015
1.5734	0.009
1.7734	0.006
1.9734	0.003
2.1734	0
2.3734	0
2.5734	-0.006
2.7734	-0.006
2.9734	-0.006
3.1734	-0.009
3.3734	-0.009
3.5734	-0.009
3.7734	-0.012
3.9734	-0.012
4.1734	-0.012

IT-MW08 Slug Test 3
PBOW, Groundwater Investigation

Elapsed Time	Input 1
4.3734	-0.012
4.5734	-0.015
4.7734	-0.015
4.9734	-0.015
5.1734	-0.015
5.3734	-0.015
5.5734	-0.018
5.7734	-0.015
5.9734	-0.018
6.1734	-0.018
6.3734	-0.018
6.5734	-0.018
6.7734	-0.018
6.9734	-0.018
7.1734	-0.018
7.3734	-0.021
7.5734	-0.021
7.7734	-0.021
7.9734	-0.021
8.1734	-0.021
8.3734	-0.021
8.5734	-0.021
8.7734	-0.021
8.9734	-0.021
9.1734	-0.021
9.3734	-0.025
9.5734	-0.021
9.7734	-0.025
9.9734	-0.021



REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

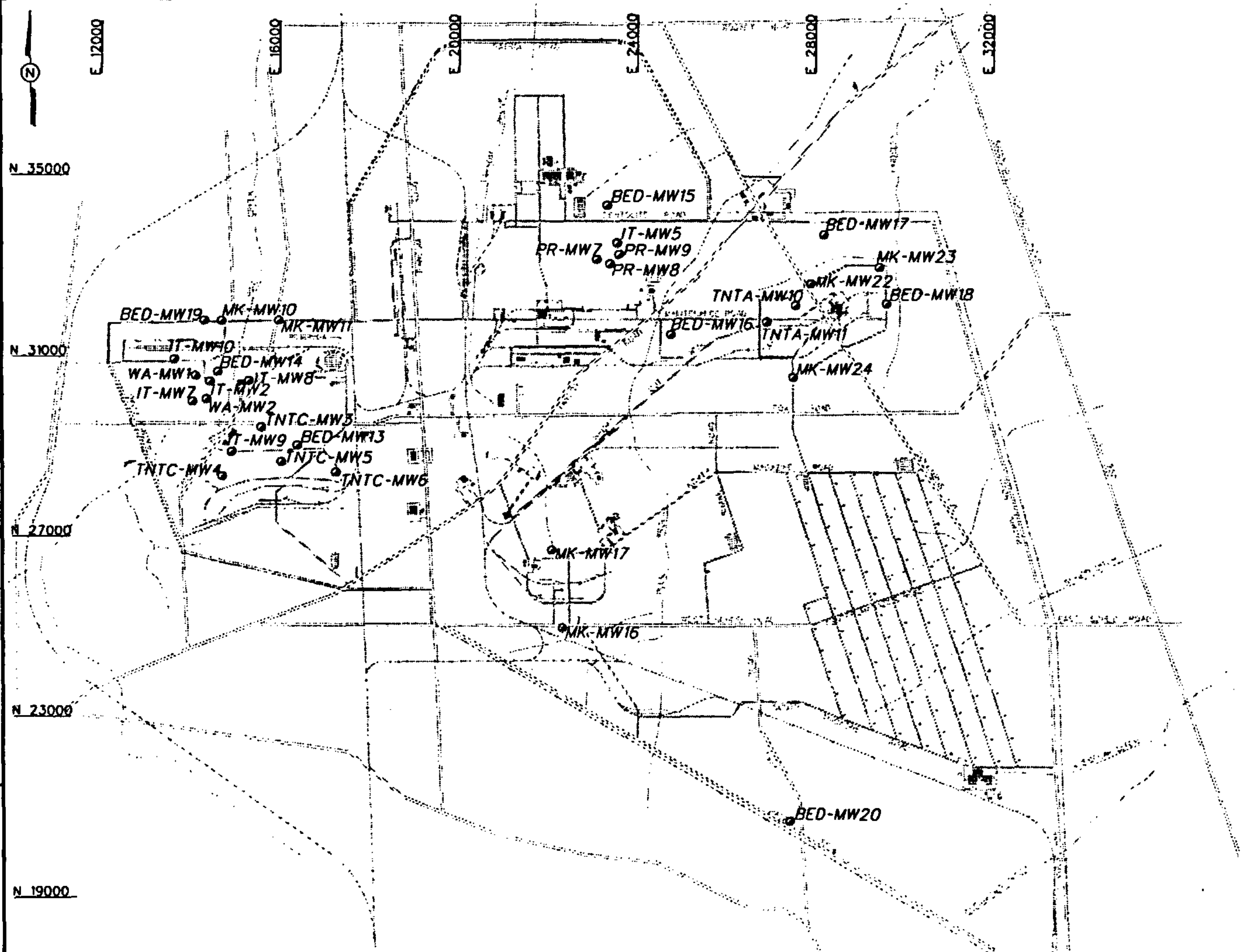
FIGURE 1-2
LOCATIONS OF AREAS OF CONCERN

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

STARTING DATE: 09/04/96 | DATE LAST: | DRAFT. CHCK. BY: R. KNIGHT | INITIATOR: G. YU | DWG. NO.: .ES.015
DRAWN BY: R. KNIGHT | DRAWN BY: | ENGR. CHCK. BY: G. YU | PROJ. MGR.: D. BURTON | PROJ. NO.: 766952

766952ES.015 07:45:19 SEPT. 04, 1996 RMK



LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600'
REVISED: 11/3/95

DWG. NO.: ...766952es.028 | PROJ. NO.: 766952
INITIATOR: G. YU | PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU
DATE LAST REV.: | DRAWN BY:
STARTING DATE: 3/11/97 | DRAWN BY: R. KNIGHT
23 SEP 97 15:33:19

FIGURE 2-1
MONITORING WELLS SAMPLED DURING THE GROUNDWATER INVESTIGATION

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

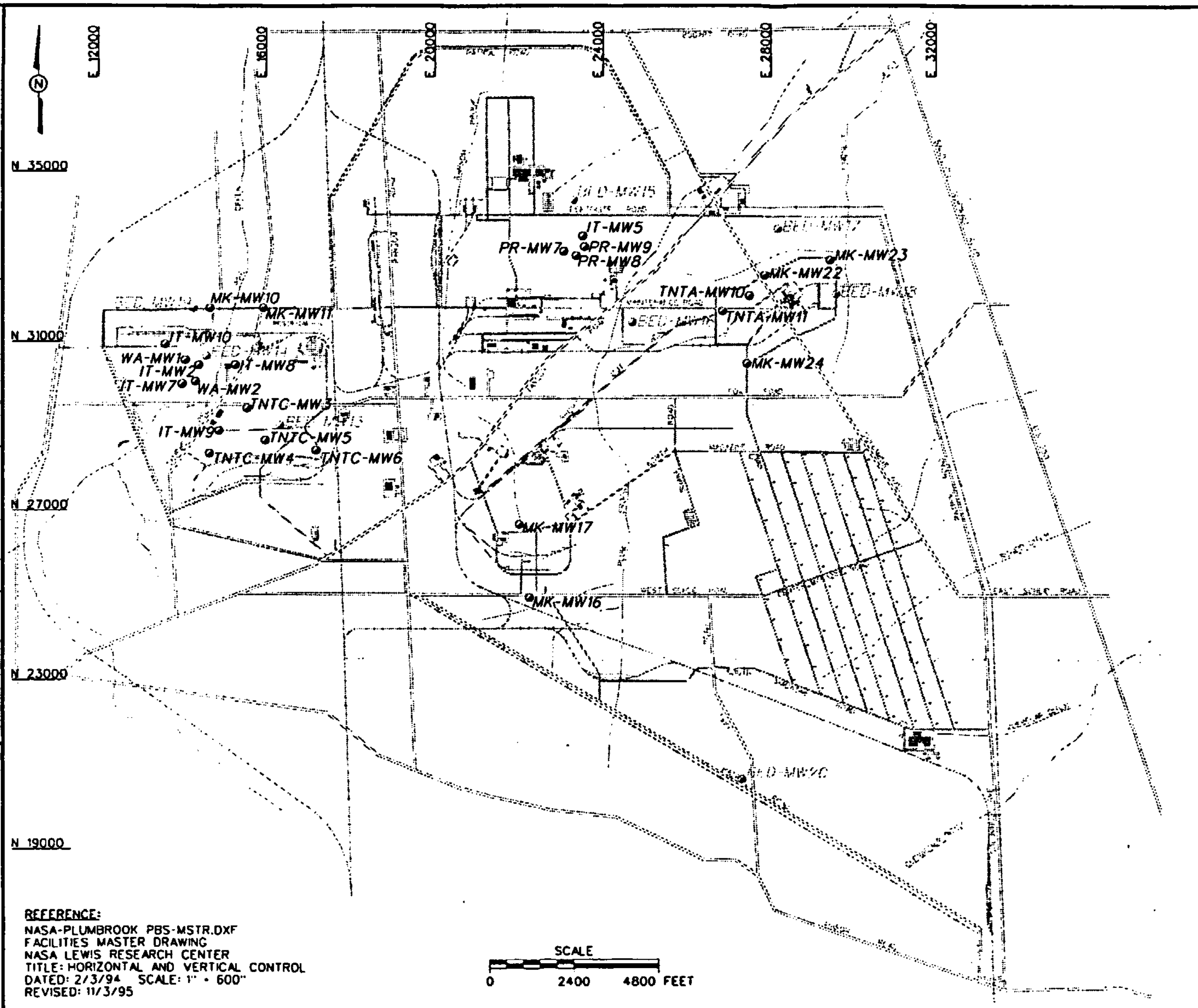


FIGURE 4-1
SITE WIDE OVERBURDEN
MONITORING WELL LOCATION MAP

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

DWG. NO.: 766952es 033
PROJ. NO.: 766952
INITIATOR: G. YU
PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT
ENGR. CHCK. BY: G. YU
DATE LAST REV.:
DRAWN BY:
STARTING DATE: 3/13/97
DRAWN BY: R. KNIGHT
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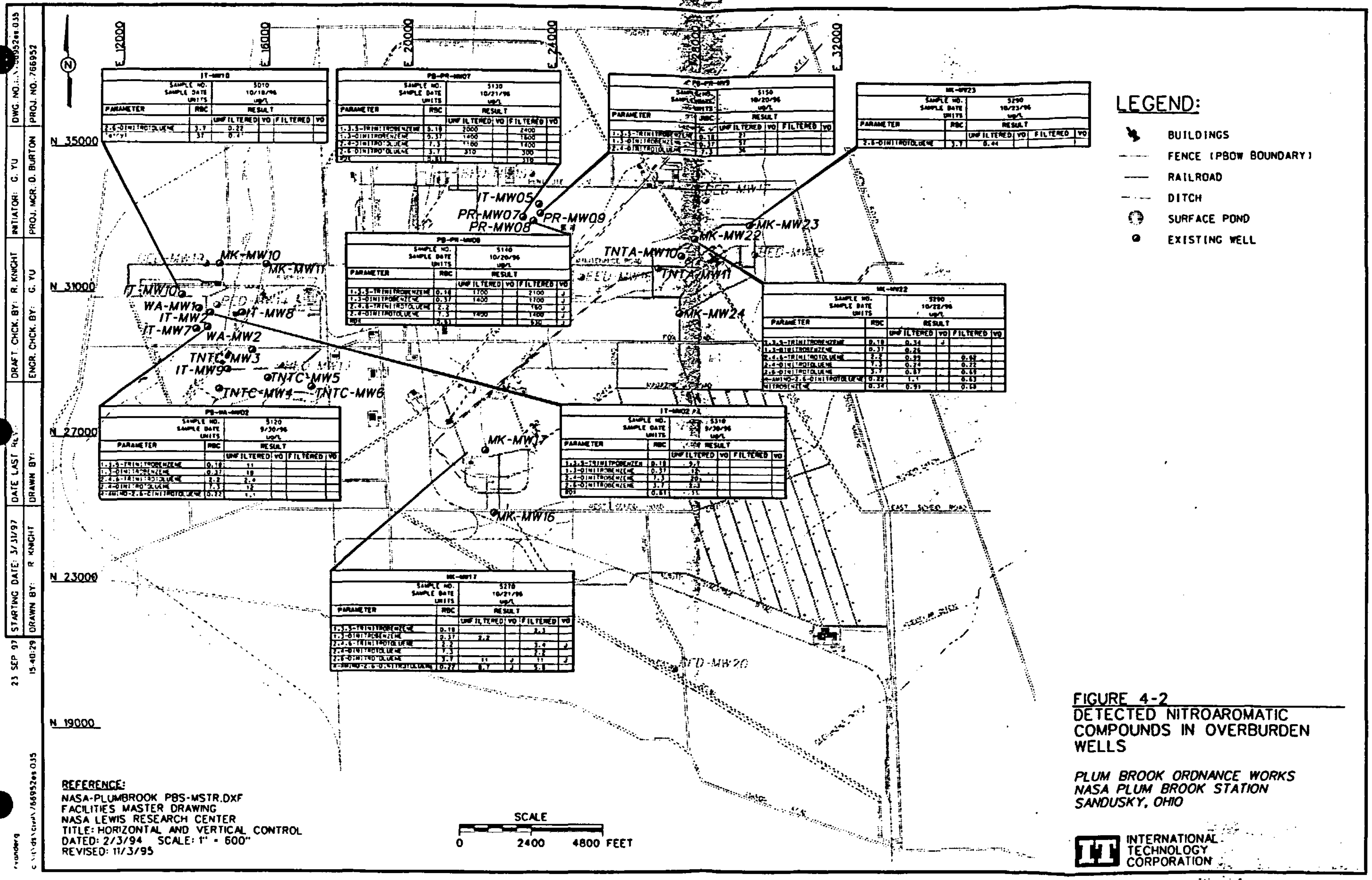
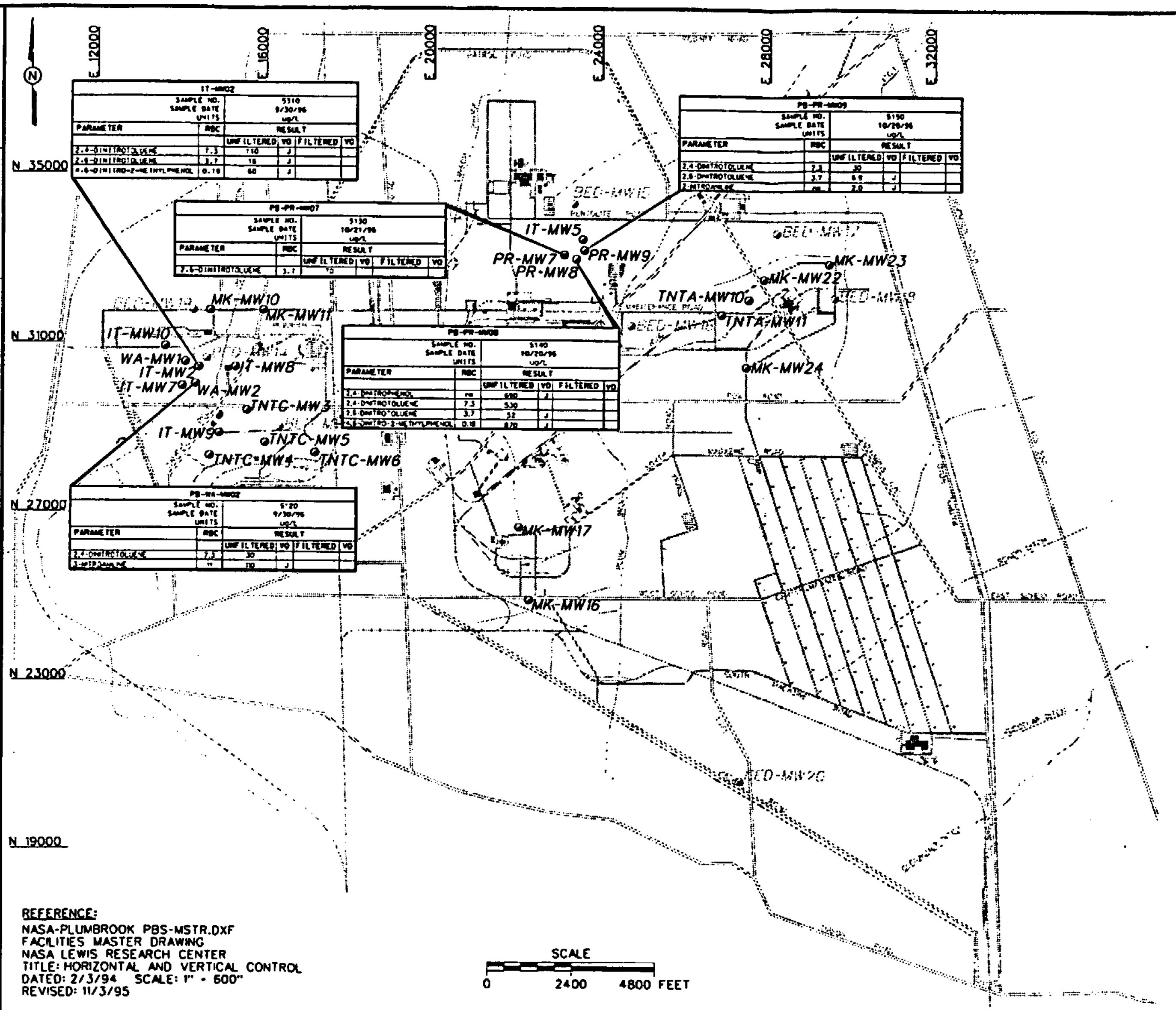


FIGURE 4-2
DETECTED NITROAROMATIC COMPOUNDS IN OVERBURDEN WELLS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO



IT-MW02					
SAMPLE NO.		5310			
SAMPLE DATE		9/30/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,4-DINITROTOLUENE	7.3	110	J		
2,6-DINITROTOLUENE	3.7	16	J		
4,6-DINITRO-2-METHYLPHENOL	0.18	60	J		

PB-PR-MW07					
SAMPLE NO.		5130			
SAMPLE DATE		10/21/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,6-DINITROTOLUENE	3.7	70			

PB-PR-MW09					
SAMPLE NO.		5150			
SAMPLE DATE		10/20/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,4-DINITROTOLUENE	7.3	30			
2,6-DINITROTOLUENE	3.7	6.8	J		
2-NITROANILINE	[illegible]	2.0	J		

PB-PR-MW08					
SAMPLE NO.		5140			
SAMPLE DATE		10/20/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,4-DINITROPHENOL	[illegible]	690	J		
2,4-DINITROTOLUENE	7.3	530			
2,6-DINITROTOLUENE	3.7	52	J		
4,6-DINITRO-2-METHYLPHENOL	0.18	870	J		

PB-WA-MW02					
SAMPLE NO.		5120			
SAMPLE DATE		9/30/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,4-DINITROTOLUENE	7.3	30			
3-NITROANILINE	[illegible]	110	J		

LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

SCALE
0 2400 4800 FEET

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

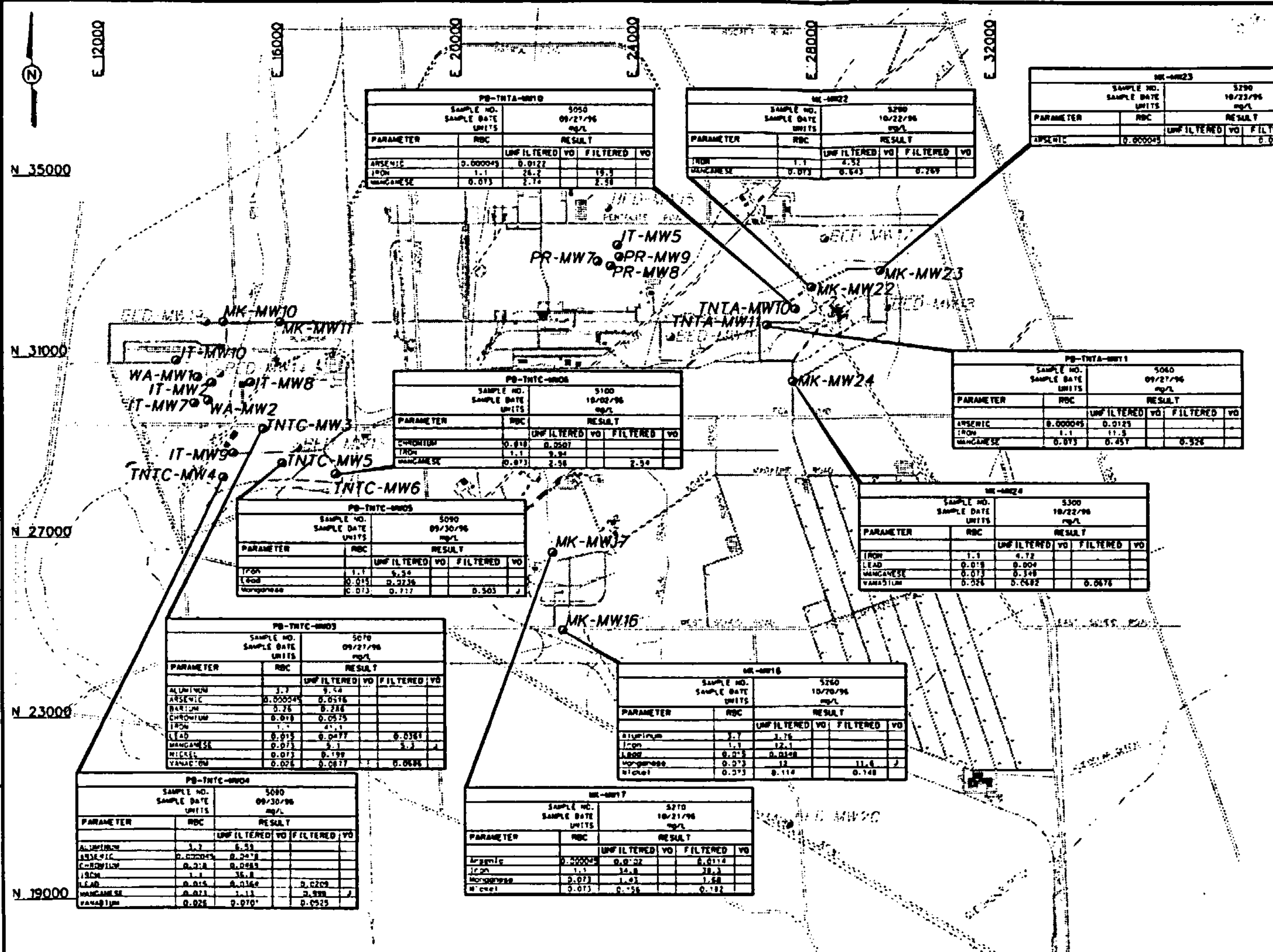
FIGURE 4-3
DETECTED ORGANIC COMPOUNDS ABOVE RBCs IN OVERBURDEN WELLS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

DWG. NO.: 766952es 036	PROJ. NO.: 766952
INITIATOR: G. YU	PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT	ENGR. CHCK. BY: G. YU
DATE LAST REV.:	DRAWN BY:
STARTING DATE: 3/31/97	DRAWN BY: R. KNIGHT

23 SEP 97 15:51:55



PB-TNTA-MW10					
SAMPLE NO. / SAMPLE DATE / UNITS		5050 / 09/27/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ARSENIC	0.000045	0.0122			
IRON	1.1	26.2		19.5	
MANGANESE	0.073	2.74		2.58	

MK-MW22					
SAMPLE NO. / SAMPLE DATE / UNITS		5280 / 10/22/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
IRON	1.1	4.52			
MANGANESE	0.073	0.643		0.269	

MK-MW23					
SAMPLE NO. / SAMPLE DATE / UNITS		5290 / 10/23/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ARSENIC	0.000045			0.0104	

LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

PB-TNTA-MW11					
SAMPLE NO. / SAMPLE DATE / UNITS		5060 / 09/27/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ARSENIC	0.000045	0.0125			
IRON	1.1	11.5			
MANGANESE	0.073	0.457		0.526	

PB-TNTC-MW06					
SAMPLE NO. / SAMPLE DATE / UNITS		5100 / 10/02/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
CHROMIUM	0.018	0.0507			
IRON	1.1	9.94			
MANGANESE	0.073	2.58		2.54	

PB-TNTC-MW05					
SAMPLE NO. / SAMPLE DATE / UNITS		5090 / 09/30/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
Iron	1.1	5.54			
Lead	0.015	0.2736			
Manganese	0.073	0.717		0.503	J

MK-MW24					
SAMPLE NO. / SAMPLE DATE / UNITS		5300 / 10/22/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
IRON	1.1	4.72			
LEAD	0.015	0.004			
MANGANESE	0.073	0.348			
VANADIUM	0.026	0.0682		0.0676	

PB-TNTC-MW03					
SAMPLE NO. / SAMPLE DATE / UNITS		5070 / 09/27/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ALUMINUM	3.7	9.54			
ARSENIC	0.000045	0.0516			
BARIUM	0.26	0.286			
CHROMIUM	0.018	0.0575			
IRON	1.1	41.1			
LEAD	0.015	0.0477		0.0361	
MANGANESE	0.073	5.1		5.1	J
NICKEL	0.073	0.199			
VANADIUM	0.026	0.0817		0.0686	

MK-MW16					
SAMPLE NO. / SAMPLE DATE / UNITS		5260 / 10/20/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
Aluminum	3.7	3.76			
Iron	1.1	12.1			
Lead	0.015	0.0148			
Manganese	0.073	12		11.6	J
Nickel	0.073	0.114		0.148	

PB-TNTC-MW04					
SAMPLE NO. / SAMPLE DATE / UNITS		5080 / 09/30/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ALUMINUM	3.7	6.55			
ARSENIC	0.000045	0.0278			
CHROMIUM	0.018	0.0483			
IRON	1.1	35.8			
LEAD	0.015	0.0364		0.0209	
MANGANESE	0.073	1.13		0.998	J
VANADIUM	0.026	0.0701		0.0525	

MK-MW17					
SAMPLE NO. / SAMPLE DATE / UNITS		5270 / 10/21/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
Arsenic	0.000045	0.0132		0.0114	
Iron	1.1	34.8		38.3	
Manganese	0.073	1.43		1.68	
Nickel	0.073	0.156		0.182	

FIGURE 4-4
DETECTED INORGANIC ANALYTES ABOVE RBCs, OVERBURDEN WELLS TNT MANUFACTURING AREAS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

SCALE
0 2400 4800 FEET

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

DWG. NO.: 766952es.037 | PROJ. NO.: 766952 | INITIATOR: G. YU | PROJ. MGR.: D. BURTON | DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU | DATE LAST REV.: | DRAWN BY: | STARTING DATE: 3/31/97 | DRAWN BY: R. KNIGHT

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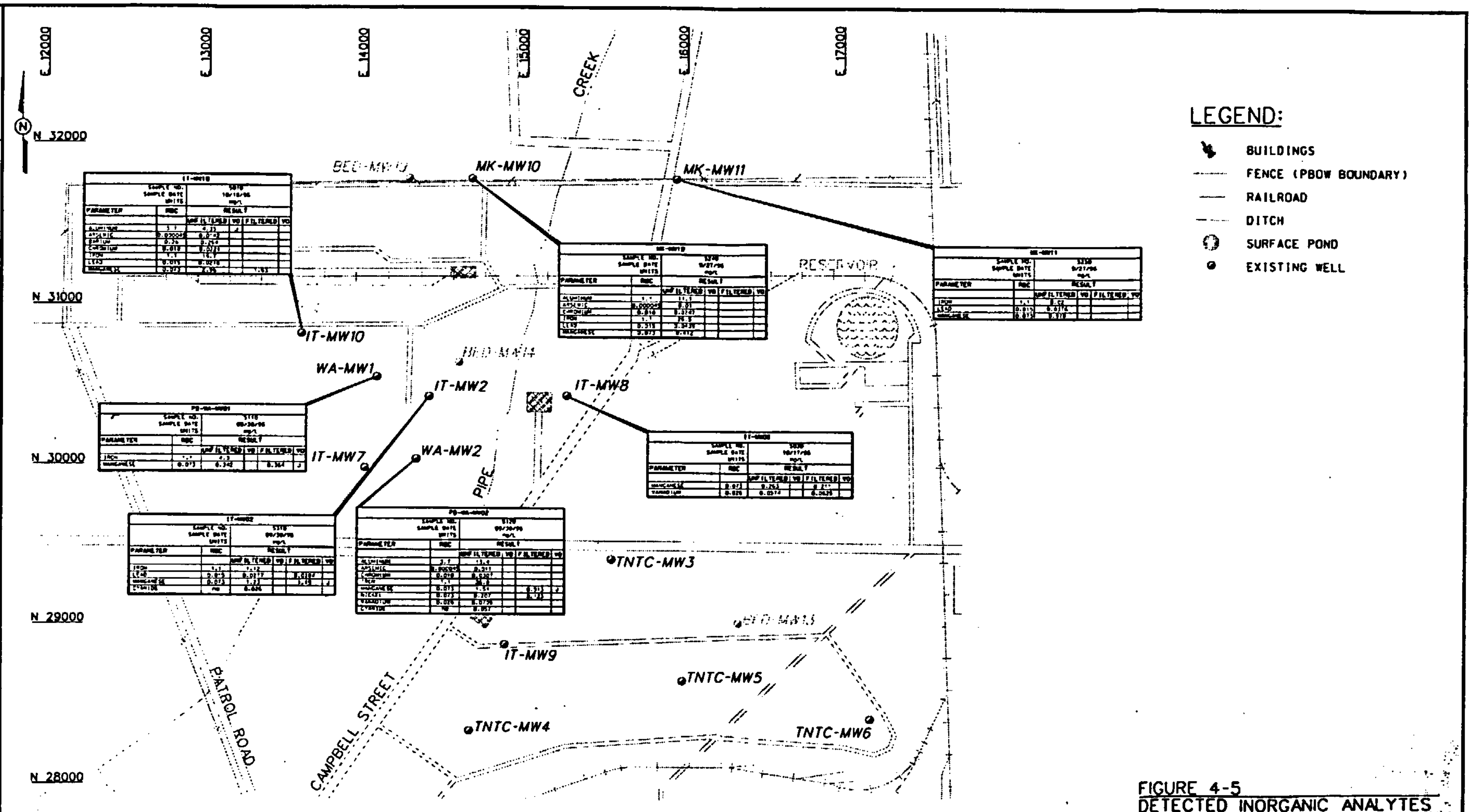

FIGURE 4-5
DETECTED INORGANIC ANALYTES ABOVE RBCs IN WEST AREA REDWATER PONDS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" - 600"
REVISED: 11/3/95

DWG. NO.: ...52es.038
PROJ. NO.: 766952
INITIATOR: G. YU
PROJ. MGR. D. BURTON
DRAFT. CHCK. BY: R. KNIGHT
ENGR. CHCK. BY: G. YU
DATE LAST REV.
DRAWN BY:
STARTING DATE 4/1/97
DRAWN BY: R. KNIGHT
23 SEP 97 15:55:10
rvonderg
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DWG NO.: ...56952es 039 | PROJ. NO.: 756952
INITIATOR: G. YU | PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU
DATE LAST REV.: | DRAWN BY:
STARTING DATE: 4/1/97 | DRAWN BY: R. KNIGHT
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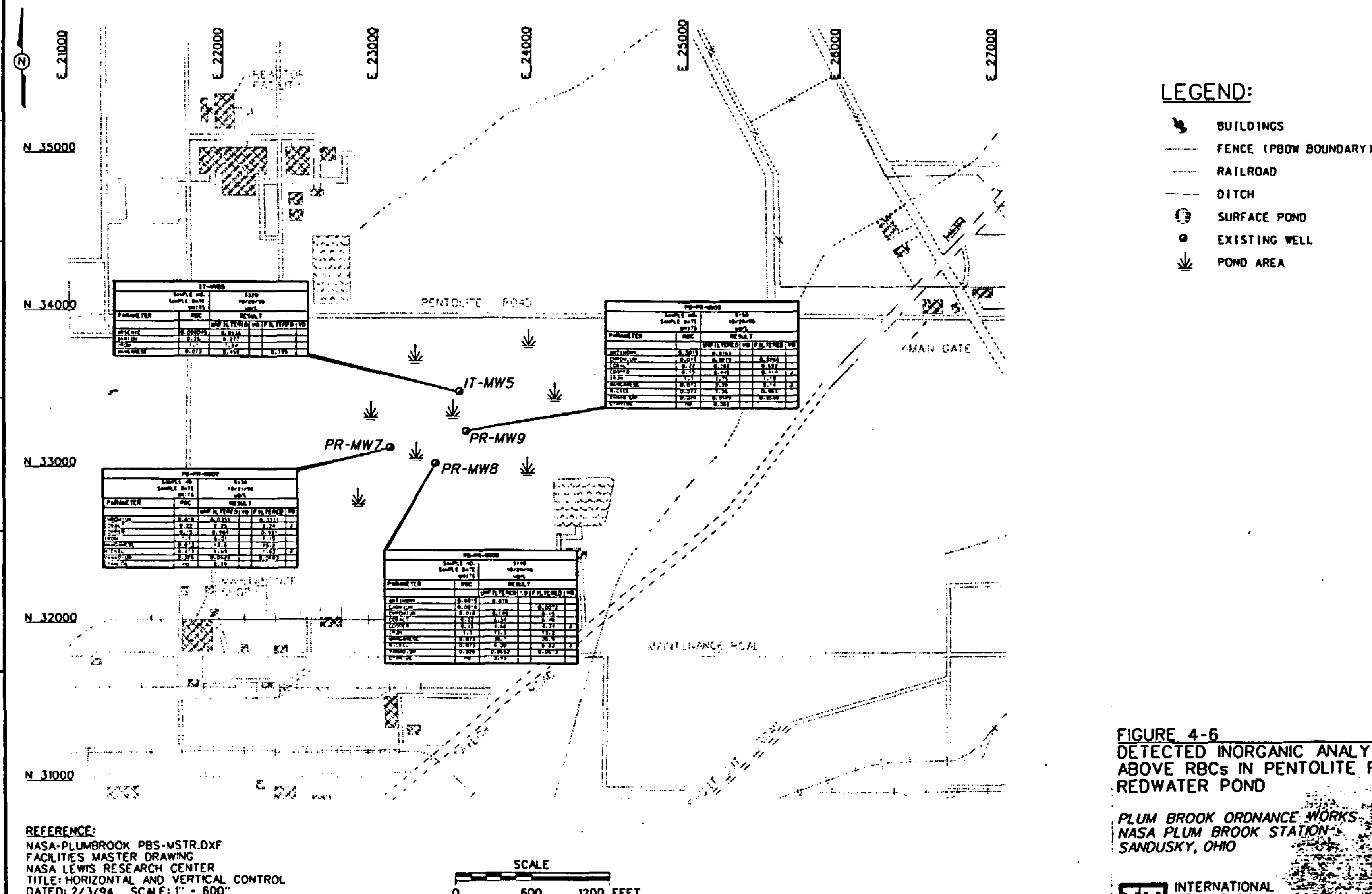
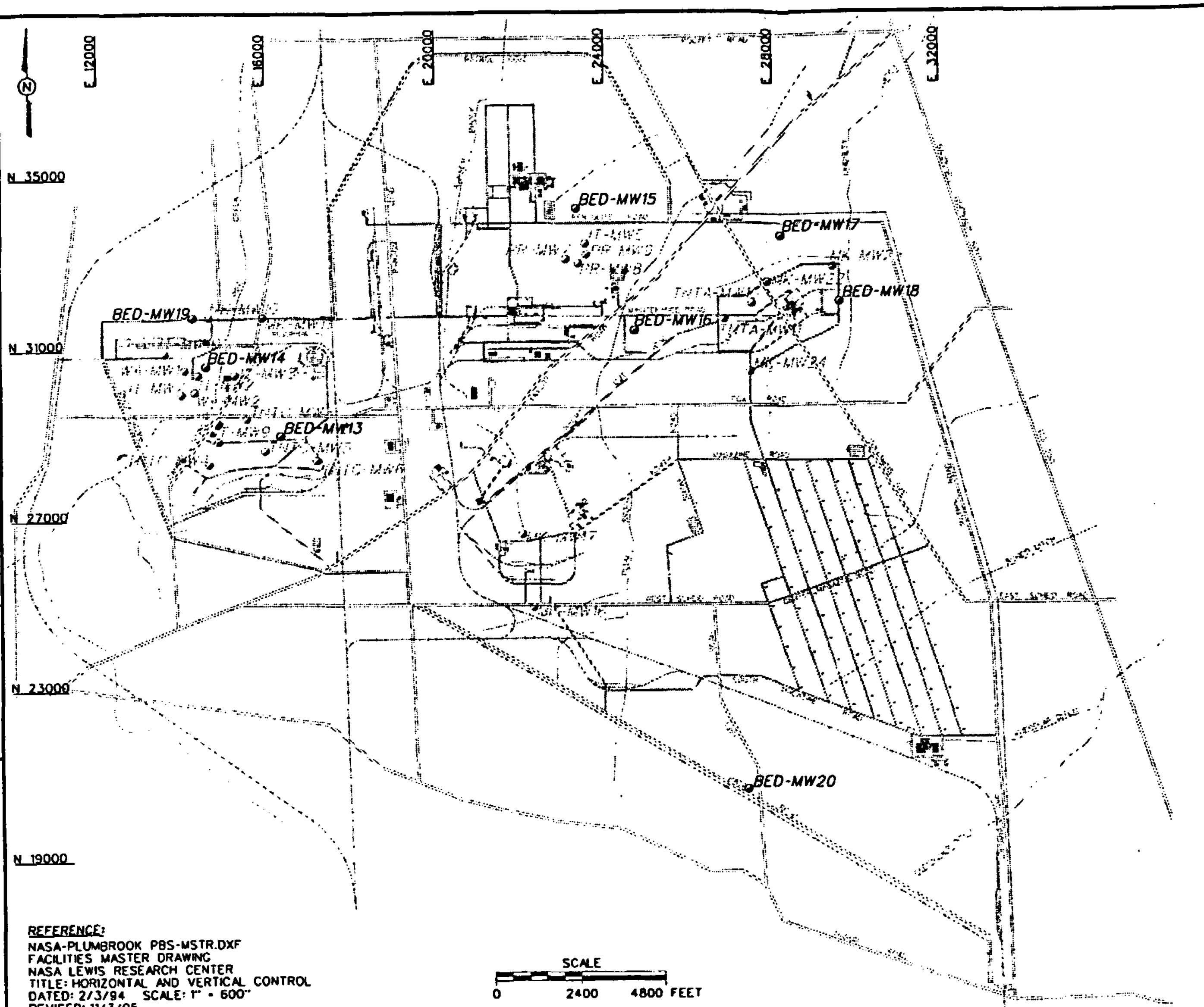


FIGURE 4-6
DETECTED INORGANIC ANALYTES ABOVE RBCs IN PENTOLITE ROAD REDWATER POND

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600'
REVISED: 11/3/95



LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

SCALE
0 2400 4800 FEET

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

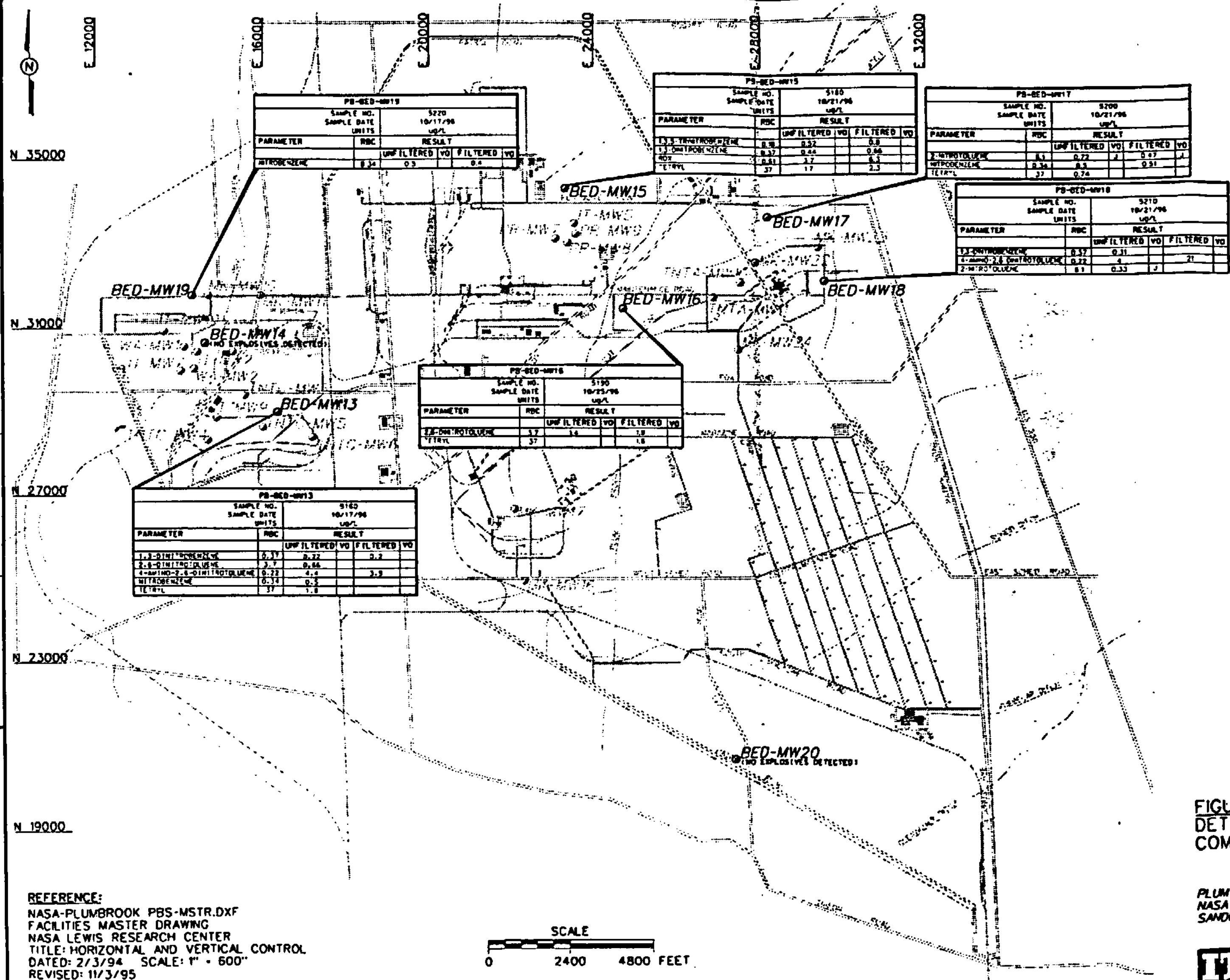
FIGURE 4-7
SITE WIDE BEDROCK MONITORING WELL LOCATION MAP

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

STARTING DATE: 3/13/97 | DATE LAST REV.: | DRAFT CHCK. BY: R. KNIGHT | INITIATOR: G. YU | DWG. NO.: ...952es.032
DRAWN BY: R. KNIGHT | DRAWN BY: | ENGR. CHCK. BY: G. YU | PROJ. MGR.: D. BURTON | PROJ. NO.: 766952

23 SEP 97 15:36:49



PB-BED-MW19						
SAMPLE NO.		5220				
SAMPLE DATE		10/17/96				
UNITS		ug/L				
PARAMETER	RBC	RESULT				
		UNFILTERED	VQ	FILTERED	VQ	
NITROBENZENE	0.34	0.3		0.4		

PB-BED-MW15					
SAMPLE NO.		5180			
SAMPLE DATE		10/21/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
1,3,5-TRINITROBENZENE	0.18	0.52		0.8	
1,3-DINITROBENZENE	0.37	0.44		0.46	
RDX	0.61	3.7		6.3	
TETRYL	37	17		2.3	

PB-BED-MW17					
SAMPLE NO.		5200			
SAMPLE DATE		10/21/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2-NITROTOLUENE	6.1	0.72	J	0.47	J
NITROBENZENE	0.34	0.5		0.51	
TETRYL	37	0.74			

PB-BED-MW18					
SAMPLE NO.		5210			
SAMPLE DATE		10/21/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
1,3-DINITROBENZENE	0.37	0.31			
4-AMINO-2,6-DINITROTOLUENE	0.22	4		21	
2-NITROTOLUENE	6.1	0.33	J		

PB-BED-MW16					
SAMPLE NO.		5190			
SAMPLE DATE		10/25/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
2,6-DINITROTOLUENE	3.7	1.4		1.8	
TETRYL	37			1.6	

PB-BED-MW13					
SAMPLE NO.		5160			
SAMPLE DATE		10/17/96			
UNITS		ug/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
1,3-DINITROBENZENE	0.37	0.22		0.2	
2,6-DINITROTOLUENE	3.7	0.66			
4-AMINO-2,6-DINITROTOLUENE	0.22	4.4		3.9	
NITROBENZENE	0.34	0.5			
TETRYL	37	1.8			

LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

SCALE
0 2400 4800 FEET

FIGURE 4-8
DETECTED NITROAROMATIC COMPOUNDS IN BEDROCK WELLS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

DWG. NO.: 766952es.040 | PROJ. NO.: 766952 | INITIATOR: G. YU | PROJ. MGR.: D. BURTON | DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU | DATE LAST REV.: | DRAWN BY: | STARTING DATE: 4/1/97 | DRAWN BY: R. KNIGHT

23 SEP 97 15:57:46

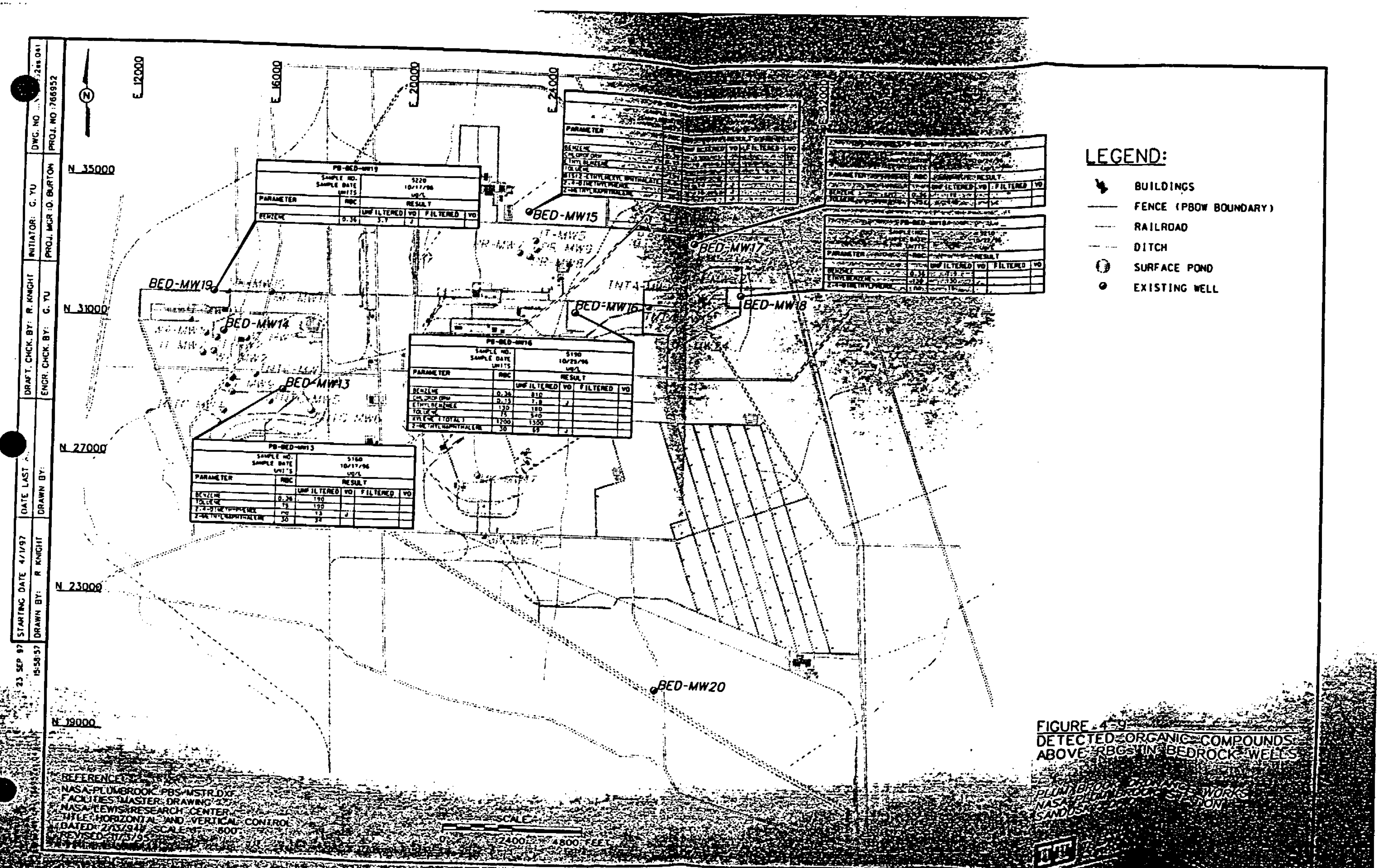
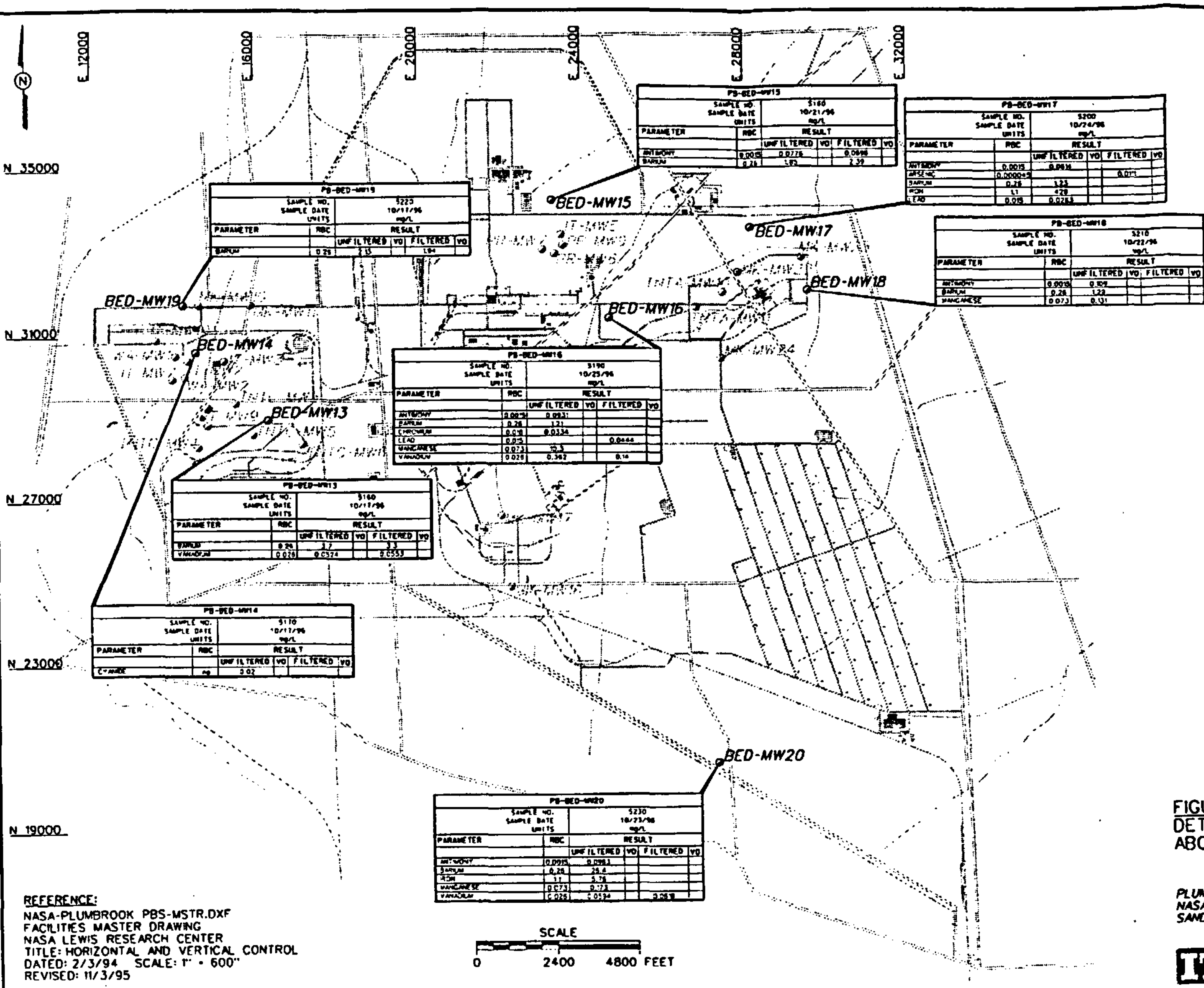


FIGURE 4-9
DETECTED ORGANIC COMPOUNDS ABOVE RBCs IN BEDROCK WELLS
PLUM BROOK ... WORKS
NASA PLUM BROOK STATION
SANDUSKY



PB-BED-MW15					
SAMPLE NO. / SAMPLE DATE / UNITS		5160 / 10/21/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ANTIMONY	0.0015	0.0776		0.0696	
BARIUM	0.26	1.85		2.39	

PB-BED-MW17					
SAMPLE NO. / SAMPLE DATE / UNITS		5200 / 10/24/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ANTIMONY	0.0015	0.0614			
ARSENIC	0.000045			0.011	
BARIUM	0.26	1.23			
IRON	1.1	428			
LEAD	0.015	0.0263			

PB-BED-MW19					
SAMPLE NO. / SAMPLE DATE / UNITS		5220 / 10/17/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
BARIUM	0.26	2.15		1.94	

PB-BED-MW18					
SAMPLE NO. / SAMPLE DATE / UNITS		5210 / 10/22/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ANTIMONY	0.0015	0.109			
BARIUM	0.26	1.22			
MANGANESE	0.073	0.131			

PB-BED-MW16					
SAMPLE NO. / SAMPLE DATE / UNITS		5190 / 10/25/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ANTIMONY	0.0015	0.0931			
BARIUM	0.26	1.21			
CHROMIUM	0.018	0.0334			
LEAD	0.015			0.0444	
MANGANESE	0.073	10.3			
VANADIUM	0.026	0.362		0.14	

PB-BED-MW13					
SAMPLE NO. / SAMPLE DATE / UNITS		5180 / 10/17/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
BARIUM	0.26	3.7		3.3	
VANADIUM	0.026	0.0374		0.0553	

PB-BED-MW14					
SAMPLE NO. / SAMPLE DATE / UNITS		5170 / 10/17/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
CYANIDE	ng	0.02			

PB-BED-MW20					
SAMPLE NO. / SAMPLE DATE / UNITS		5230 / 10/23/96 / mg/L			
PARAMETER	RBC	RESULT			
		UNFILTERED	VQ	FILTERED	VQ
ANTIMONY	0.0015	0.0983			
BARIUM	0.26	25.4			
IRON	1.1	5.76			
MANGANESE	0.073	0.173			
VANADIUM	0.026	0.0594		0.0618	

LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL

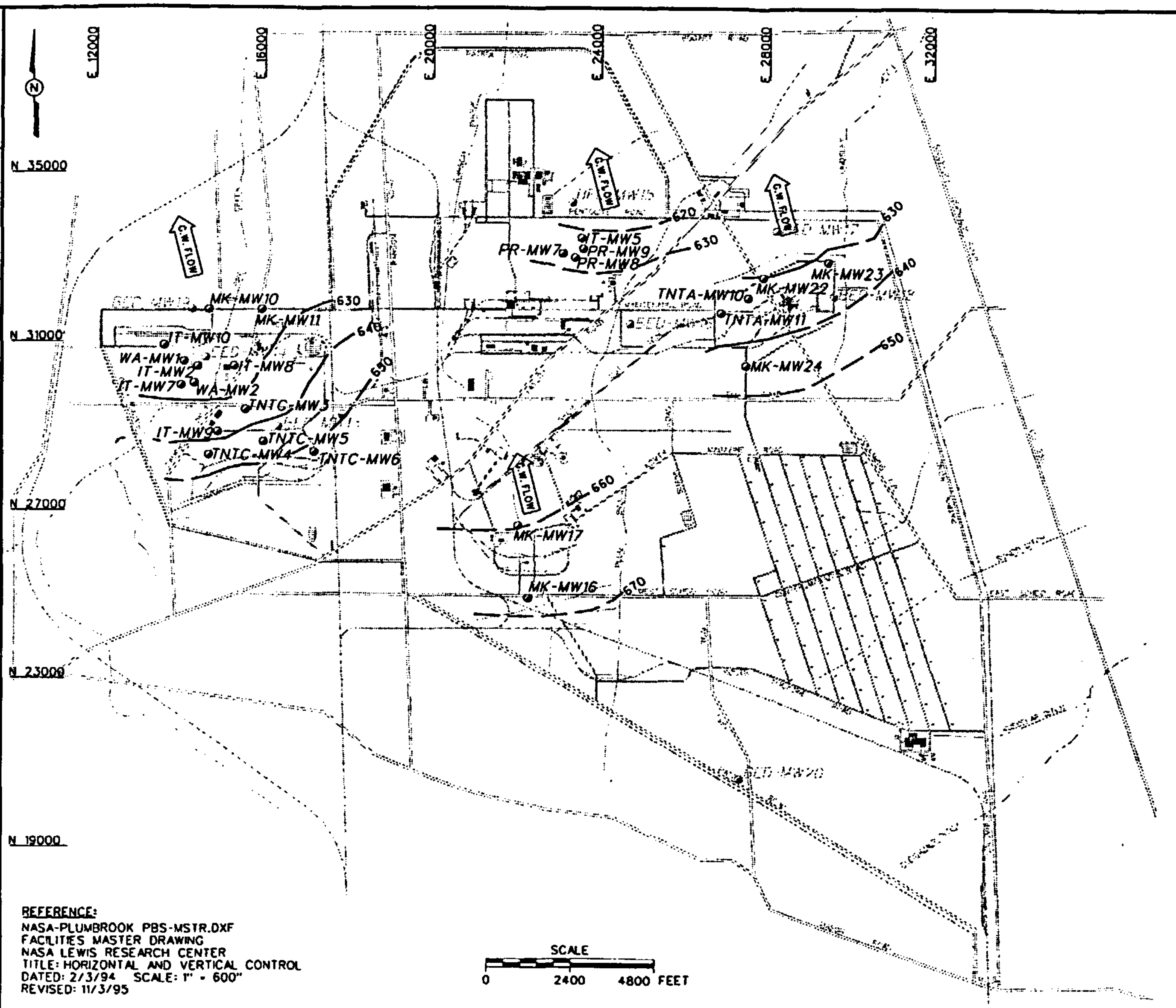
REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

FIGURE 4-10
DETECTED INORGANIC ANALYTES ABOVE RBCs IN BEDROCK WELLS

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

DWG. NO.: ...2es.042 | PROJ. NO.: 766952
INITIATOR: G. YU | PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU
DATE LAST REV.: | DRAWN BY:
STARTING DATE: 4/1/97 | DRAWN BY: R. KNIGHT
23 SEP 97 15:59:56
c:\...\766952es.042



LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL
- G.W. FLOW — INTERPRETED GROUNDWATER FLOW DIRECTION
- GROUNDWATER ELEVATION CONTOUR ELEVATION LINE (DASHED WHERE INFERED)

NOTES:

CONTOUR INTERVAL IS 10 FEET

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" = 600"
REVISED: 11/3/95

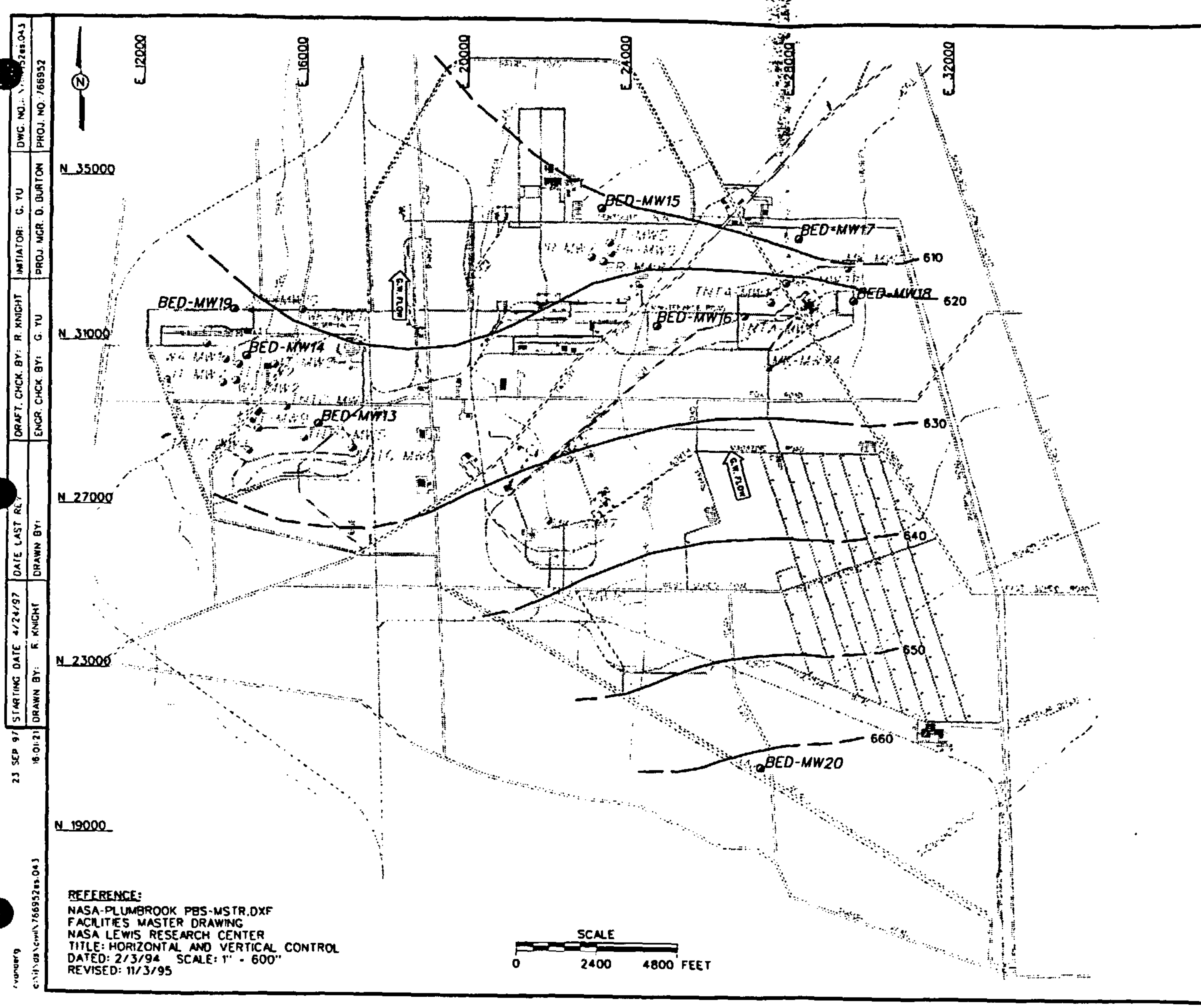
SCALE
0 2400 4800 FEET

FIGURE 5-1
GROUNDWATER ELEVATION CONTOUR MAP OVERBURDEN WATER BEARING ZONE (OCTOBER, 1996)

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

DWG NO.: 766952es.044 | PROJ. NO.: 766952
INITIATOR: G. YU | PROJ. MGR.: D. BURTON
DRAFT. CHCK. BY: R. KNIGHT | ENGR. CHCK. BY: G. YU
DATE LAST REV.: | DRAWN BY:
STARTING DATE: 4/24/97 | DRAWN BY: R. KNIGHT
23 SEP 97 18:02:31



LEGEND:

- BUILDINGS
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- EXISTING WELL
- GROUNDWATER FLOW DIRECTION
- WATER LEVEL ELEVATION CONTOUR LINE (DASHED WHERE INFERED)

NOTES:

CONTOUR INTERVAL IS 10 FEET

FIGURE 5-2
BEDROCK GROUNDWATER ELEVATION CONTOUR MAP (OCTOBER, 1996)

PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

INTERNATIONAL TECHNOLOGY CORPORATION

REFERENCE:
NASA-PLUMBROOK PBS-MSTR.DXF
FACILITIES MASTER DRAWING
NASA LEWIS RESEARCH CENTER
TITLE: HORIZONTAL AND VERTICAL CONTROL
DATED: 2/3/94 SCALE: 1" - 600"
REVISED: 11/3/95

APPENDIX A

SECTION 11

1999 Summary Report, Site-Wide Groundwater Monitoring, 1997-1998

(IT, June 1999)

Final
Summary Report
Site-Wide Groundwater Monitoring (1997-1998)
Former Plum Brook Ordnance Works, Sandusky, Ohio

Volume I
Text, Tables, and Figures

Submitted to:

Commander
U.S. Army Corps of Engineers
Nashville District
P. O. Box 1070
Nashville, Tennessee 37202-1070

Prepared by:

IT Corporation
312 Directors Drive
Knoxville, Tennessee 37923

Project Number 771481

June 1999

Revision 1

KN/4379/COV/06/28/99(9:26 AM)

Draft
Summary Report
Site-Wide Groundwater Monitoring (1997-1998)
Former Plum Brook Ordnance Works, Sandusky, Ohio

Supplement I
Sample Collection Logs

Submitted to:

Commander
U.S. Army Corps of Engineers
Nashville District
P. O. Box 1070
Nashville, Tennessee 37202-1070

Prepared by:

IT Corporation
312 Directors Drive
Knoxville, Tennessee 37923

Project Number 771481

June 1999

Revision 1

KN/4379/COV/06/25/99(11:16 AM)

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List of Figures

List of Figures (Continued)

List of Acronyms

AA1	Acid Area 1
AA2	Acid Area 2
AA3	Acid Area 3
ABG	Additional Burning Ground
BG8	G-8 Burning Ground
bgs	below ground surface
BNA	base neutral/acid extractable compound
BTEX	benzene, toluene, ethyl benzene, and xylene
COPC	chemical(s) of potential concern
CRQL	contract-required quantitation limit
D&M	Dames and Moore, Inc.
DCE	dichloroethene
DERP	Defense Environmental Restoration Program
DI	dionized water
DNB	dinitrobenzene
DNT	dinitrotoluene
DO	dissolved oxygen
DOD	U.S. Department of Defense
DQE	data quality evaluation
DQO	data quality objective
Eh	oxidation-reduction potential
EPA	U.S. Environmental Protection Agency
ft/day	feet per day
ft/ft	foot per foot
FUDS	Formerly Used Defense Sites
gpm	gallons per minute
GSA	General Services Administration
GWI	groundwater investigation
HI	hazard index
HRS	Hazard Ranking System
HSA	hollow-stem auger
ICI	International Consultants, Inc.
ID	inside diameter
IDL	instrument detection limit

List of Acronyms (Continued)

IT	IT Corporation
µg/L	micrograms per liter
µm	micrometer
MK	Morrison Knudsen Group
MNTA	Maintenance Shop Area
msl	mean sea level
NASA	National Aeronautics and Space Administration
NCP	National Contingency Plan
NGVD	National Geodetic Vertical Datum
OD	outside diameter
ODNR	Ohio Department of Natural Resources
OEPA	Ohio Environmental Protection Agency
PBOW	Plum Brook Ordnance Works
PBS	Plum Brook Station
PCB	polychlorinated biphenyl
PID	photoionization detector
PRRWP	Pentolite Road Red Water Ponds
PVC	polyvinyl chloride
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RA	risk assessment
RBC	risk-based concentration
RME	reasonable maximum exposure
RRF	relative response factor
SAIC	Science Applications International Corporation
SAP	sampling and analysis plan
SCEM	site conceptual exposure model
SCS	Soil Conservation Service
SVOC	semivolatile organic compound
TCA	trichloroethane
TNB	trinitrobenzene
TNT	trinitrotoluene
TNTA	TNT Area A

List of Acronyms (Continued)

TNTB	TNT Area B
TNTC	TNT Area C
TOC	top of casing
VOC	volatile organic compound
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WARWP	West Area Red Water Ponds

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Executive Summary

Site Description. The Former Plum Brook Ordnance Works (PBOW) was build tin early 1941 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite. Production of explosives began in December 1941 and continued until 1945. It is estimated that more than one billion pounds of explosives were manufactured during the 4-year operation period.

After the plant was shut down, decontamination of TNT, acid, pentolite, and DNT processing lines began and were completed during the last quarter of 1945. The property was initially transferred to the Ordnance Department, then to the War Assets Administration after it was certified by the U.S. Army to be decontaminated. In 1949, PBOW was transferred to the General Services Administration (GSA).

The National Aeronautics and Space Administration (NASA) acquired the PBOW on March 15, 1963 and is presently utilizing the site. On April 18, 1978, NASA declared approximately 2,152 acres of land as excess. The Perkins Township Board of Education acquired 46 acres of the excess and uses this area as a bus transportation center. GSA retains the remaining acreage and currently has a use agreement with the Ohio National Guard for 604 acres of the land. NASA presently controls about 6,400 acres and is using the site to conduct space research as a satellite operation of NASA's LERC in Cleveland Ohio. The details of these land transactions are listed in the site management plan and can be found at the NASA PBS.

Historical Activities. Previous investigations of site hydrogeology and groundwater contamination were documented in the Contamination Evaluation Report (IT, 1991), the Site Inspection Report (MK, 1994), the Site Management Plan (ICI, 1995), the Site-Wide Groundwater Investigation Draft Report (D&M, 1996) and the Site-Wide Groundwater Investigation Report (IT, 1996).

In 1989, IT conducted the contamination evaluation focusing on areas associated with past DOD operations at PBOW. As part of the investigation, four groundwater monitoring wells were installed in the overburden water-bearing zone.

A site inspection was conducted at PBOW by MK from June through July 1993. The purpose of the site inspection was to collect information concerning conditions to assess the threat posed to human health and the environment and to determine the need for any addition investigation. A total of 13 monitoring wells were installed in the overburden water-bearing zone in multiple areas.

From May to June of 1995, D&M conducted a groundwater investigation of the overburden and bedrock water-bearing zones. The objectives of the D&M investigation were as follows:

- Evaluate groundwater occurrence and flow conditions in the overburden and bedrock water-bearing zones;
- Assess the groundwater quality in the overburden water-bearing zone and at the Red Water Ponds and TNT Manufacturing Areas;
- Investigate on a sitewide based the baseline groundwater quality of the bedrock water-bearing zone;
- Evaluate the necessity of additional work at PBOW.

A total of 11 monitoring wells were installed in the bedrock water-bearing zone and 8 wells were placed in the bedrock water-bearing zone. Groundwater samples were also collected from 25 wells.

In September 1995, ICI issued a site management plan for PBOW. The objectives were to describe the regulatory framework, site setting, site investigations and results, and management objectives of the PBOW.

IT conducted a site-wide groundwater investigation at the former PBOW from September through October 1996. This work included installation of overburden monitoring wells, redevelopment of the existing monitoring wells, and collection and analysis of groundwater samples to acquire supplementary data of site-wide groundwater levels and contaminants to add to an existing database, and to fill in existing data gaps in groundwater levels and contamination in the western portion of PBOW.

Current Status of Overburden Water-Bearing Zone. The overburden water-bearing zone at PBOW has been impacted by organic and/or explosive contaminants to different extents by past site activities. Nitroaromatic compounds, explosive residues, and SVOCs have significantly impacted the West Area Red Water Pond and the Pentolite Road Red Water Pond areas. Lesser impacts by nitroaromatic compounds are evident at TNTA and TNTB, with bis(2-

ethylhexyl)phthalate also exceeding RBCs at TNTA. Two areas, the Upper Toluene Area and the Maintenance Area, have exhibited impacts by non-explosive organic contaminants at levels well above the RBCs. Lower levels of organic contaminants are evident at TNTC, AA2, the ABG, the Snake Road Burning Grounds, at the Lower Toluene Area. Analytical results from sampled overburden monitoring wells indicated that AA1, AA3 and the Reactor Building do not show organic or explosives contaminants at levels that would pose unacceptable risk to human health.

Five areas, TNTC, AA3, the ABG, the Snake Road Burning Ground and the Upper Toluene Tanks Area, exhibited only dissolved iron, manganese and/or nickel at concentrations exceeding RBCs. Dissolved iron and manganese were detected at concentrations exceeding the RBCs at AA1 and the Lower Toluene Area. Larger suites of inorganic compounds were detected in wells from the West Area Red Water Pond, the Pentolite Road Red Water Pond, TNTA, and TNTB. The overburden water-bearing zone did not exhibit dissolved inorganic compounds exceeding RBCs for three areas; AA2, the Maintenance Area, and the Reactor Facility. Many total metals were determined to exceed RBCs in overburden wells; however, many of these metals were due to suspended solids in the unfiltered sample and were therefore not attributable to site contamination.

Overburden Geologic and Hydrogeological Conclusions. Groundwater flow in the overburden is predominantly to the north-northeast. The general flow direction in the overburden aquifer largely mirrors the surface topography and is strongly correspondent to the topography of the top of the bedrock; thus, groundwater on the western side of the site flows toward a groundwater low. Groundwater elevation fluctuations are very similar among overburden wells which may imply a high degree of connectivity between the site wells. Another possibility is that the overburden water-bearing zone has a higher vertical hydraulic conductivity than assumed and the water levels in the overburden are directly influenced by changes in the bedrock water-bearing zone water levels. Slug test results reveal significant variability in the overburden water-bearing zone hydraulic conductivities across the site, possibly implying the water-bearing zone is not a single hydrogeologic unit.

Current Status of Bedrock Water-Bearing Zone. The bedrock water-bearing zone at PBOW has been impacted by organic and/or explosive contaminants to different extents by past site activities, although to a lesser degree than the overburden. Nitroaromatic compounds and SVOCs have impacted the WARWP, while VOCs have impacted the bedrock wells at the

PRRWP. Lesser impacts by nitroaromatic compounds are evident at TNTA, AA1, AA2 and the Maintenance Area. VOCs have also impacted the bedrock water-bearing zone at TNTC, AA2, and the Upper Toluene Tanks Area; SVOCs also exhibit impacts on water quality at the upper Toluene Tanks Area. Two areas, the ABG and BG8, did not exhibit organics or explosives at concentrations exceeding RBCs.

Dissolved concentrations of barium and manganese were commonly detected at concentrations exceeding RBCs in most areas of PBOW. Other less frequently detected metals exceeding RBCs in the bedrock water -bearing zone include arsenic, iron, thallium, and vanadium. Only two areas, the WARWP and AA3, lacked any detected dissolved inorganic compound at concentrations exceeding RBCs.

Bedrock Geologic and Hydrogelogical Conclusions. Groundwater flow in the bedrock is predominantly to the north-northeast. Little groundwater elevation fluctuation occurred over time in the wells monitoring the Ohio Shale and the Olentangy Shale; however, wells monitoring the Delaware Limestone showed significant variability. There is a similar groundwater elevation fluctuation between wells REACTOR 1, 2, 3, and PB-BED-MW13 located on the west side of PBOW along a bedrock low coming from the Reactor Building Area.

Slug tests revealed that the Ohio Shale had the highest hydraulic conductivity of the three bedrock units tested at approximately 20 ft/day. The Delaware Limestone and Olentangy Shale had hydraulic conductivities of three orders of magnitude lower.

Quarries mining the Delaware Limestone in the vicinity of PBOW have some minor natural hydrocarbon. This is evident in PBOW wells monitoring the bedrock based on drilling notes, H_2S readings, and BTEX compounds detected in the groundwater.

In general, there is a downward vertical gradient from the overburden to the bedrock in the western and northern portions of the site. The greatest groundwater elevation difference was 25 feet in overburden/Delaware Limestone pair IT-AA1-GW002/IT-AA1-BED-GW001 located in the north central portion of the site. In contrast, the central and southern portions of the site showed very similar groundwater elevations in overburden/Ohio Shale pairs. This may indicate a high degree of connectivity between groundwater in the overburden and Ohio Shale.

Peaks in calculated recharge rates appear to correlate with groundwater highs taking into account a lag time. Similarly, lows in recharge rates correspond somewhat (taking into account the lag time) with lows in the groundwater.

Recommendations. The following additional investigations are recommended:

- Determination of the site-specific reference levels for VOC constituents (benzene, toluene, ethyl benzene and xylenes) and background concentrations for metals in the bedrock water-bearing zone.
- Investigation of bedrock water-bearing zone at the Middle Toluene Tank Area.
- Completion of a three-dimensional groundwater fate and transport model utilizing data generated during the site-wide groundwater investigation as well as pertinent historical data to aid in bedrock groundwater monitoring.
- Completion of a human-health risk assessment for site-wide groundwater to define contaminants of concern and to aid in determining whether additional sampling or remedial actions are warranted.
- Complete a residential/agricultural well survey to determine potential off-site receptors; sampling of downgradient off-site wells within proximity of the site should be considered.

1.0 Introduction

The U.S. Army is conducting studies of the environmental impact of suspected hazardous waste sites at properties previously owned by the U.S. Department of Defense (DOD). This work is being pursued by the U.S. Army Corps of Engineers (USACE) under the Defense Environmental Restoration Program (DERP) Formerly Used Defense Sites (FUDS). The former Plum Brook Ordnance Works (PBOW), located in Sandusky, Erie County, Ohio, is an Army DERP FUDS project and is being managed and technically overseen by the USACE-Nashville District Office (CELRN). Figure 1-1 shows the geographical location of the former PBOW site. IT Corporation (IT) was contracted by the CELRN to conduct a Site-Wide Groundwater Investigation (GWI) at PBOW under Delivery Order 0023 of Contract Number DACA62-94-D-0030. Field activities associated with the GWI were conducted between August 1997 and May 1998.

This summary report assimilates data generated during four quarterly monitoring events. Results of the first three quarterly events were previously presented in:

- *First Quarterly Groundwater Level Measurement Report* (October 1997).
- *Second Quarterly Groundwater Level Measurements and First Semi-Annual Groundwater Sampling Event* (May 1998).
- *Third Quarterly Groundwater Level Measurements* (September 1998).

1.1 Objectives and Scope of Work

The objectives of this investigation included the following:

- Determine if there are hazardous substances present at the site at concentrations that may constitute unacceptable risk to human health or the environment.
- Define site physical features and characteristics.
- Collect, evaluate, and tabulate groundwater data to facilitate a scope of work to be written for a groundwater modeling effort at the site.
- Determine current and future routes of exposure.

The scope of the groundwater investigation included a site visit and records review, the preparation of site-specific work plans, monitoring well installations, groundwater sampling, land surveying, analytical work, and report preparation. This report presents the information presented in three prior quarterly (seasonal) reports, as well as new data obtained as part of the fourth quarterly investigation. This information, in conjunction with recently acquired and interpreted soil, geological, hydrogeological, and climatological information, was then used to more accurately define the site conceptual model.

A major portion of this investigation effort consisted of the collection and interpretation of water level measurements. The purpose for the collection of the quarterly groundwater level measurements was to provide temporal as well as spatial data for evaluating the groundwater flow regime in both overburden and bedrock water-bearing zones. The quarterly water level measurement data help to determine the seasonal fluctuation of groundwater levels and the hydraulic connectivity between the two water-bearing zones.

Another important aspect of this investigation consisted of the collection and interpretation of groundwater samples from a select group of site wells. These two semi-annual groundwater sampling events were conducted to acquire chemical analytical data for constituents such as nitroaromatics, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), metals, etc. and water quality data (sulfate, alkalinity, etc.) on a sitewide basis. Chemical analytical data were collected to determine if there are hazardous substances present at the site in a manner that constitutes unacceptable risk to human health. Ecological risk is addressed at PBOW on a site-specific basis. Ecological risk assessments are currently in progress at TNT Area B (TNTB) and both the Pentolite Road Red Water Ponds (PRRWP) and the West Area Red Water Pond (WARWP) Areas. Risk-based concentrations (RBC) are used to determine human health chemicals of potential concern (COPC) at PBOW as presented in the site-specific sampling and analysis plan (SSAP) approved by the Ohio Environmental Protection Agency (OEPA). Both the chemical analytical data and the water quality data collected as part of this investigation will also support contaminant fate and transport calculations, groundwater modeling efforts, and/or assessment of remedial activities.

1.2 Facility Location and Description

The former PBOW site is currently owned by the National Aeronautics and Space Administration (NASA) and is operated as the Plum Brook Station (PBS) of the NASA John Glenn Research Center at Lewis Field based in Cleveland, Ohio. Most of the aerospace testing facilities built in the 1960s at the site are in standby or inactive status. The site is located approximately 4 miles south of Sandusky, Ohio and 59 miles west of Cleveland (Figure 1-2). Although primarily in Perkins and Oxford Townships, the eastern edge of the site extends into Huron and Milan Townships. PBOW is bounded on the north by Bogart Road, on the south by

Mason Road, on the west by County Road 43, and on the east by U.S Highway 250. The areas surrounding PBOW are mostly agricultural and residential.

Public access is restricted at PBOW except during the annual deer hunting season.

1.3 Site History and Potential for Contamination

The 9,009-acre PBOW site was built in early 1941 as a manufacturing plant for 2,4,6-trinitrotoluene (TNT), dinitrotoluene (DNT), and pentolite. Production of explosives began on December 16, 1941 and continued until 1945. It is estimated that more than one billion pounds of explosives were manufactured during the 4-year operating period.

After the plant was shut down, decontamination of TNT, acid, pentolite, and DNT processing lines began and was completed during the last quarter of 1945. The property was initially transferred to the Ordnance Department, then to the War Assets Administration after it was certified by the U.S. Army to be decontaminated. In 1949, PBOW was transferred to the General Services Administration (GSA).

NASA acquired the PBOW on March 15, 1963 and is presently utilizing the site. On April 18, 1978, NASA declared approximately 2,152 acres of land as excess. The Perkins Township Board of Education acquired 46 acres of the excess and uses this area as a bus transportation center. GSA retains the remaining acreage and currently has a use agreement with the Ohio National Guard for 604 acres of the land. NASA presently controls about 6,400 acres and is using the site to conduct space research as a satellite operation of NASA's John Glenn Research Center at Lewis Field in Cleveland, Ohio. The details of these land transactions are listed in the site management plan and can be found at the NASA PBS.

Potential contaminants in the groundwater at PBOW, based on review of historical use of the site and findings of previous investigations, may include nitroaromatic compounds, VOCs, SVOCs, cyanide, and metals.

2.0 Physical Setting

2.1 Geography, Topography, and Surface Drainage

PBOW is located within the Eastern Lake Region of the Central Lowland Province (Soil Conservation Service [SCS], 1971). Erie County is overlain by lake, glacial outwash, and glacial till sediment. The surface is a plain with a slight slope to the north-northeast toward Lake Erie at approximately 25 feet per mile (Figure 1-2). Elevations at the site range from 680 feet above mean sea level (msl) at the intersection of Taylor Road and Patrol Road on the western side of the site to 625 feet msl at the northern portion of the installation. In general, the topography of PBOW is characterized by a flat ground surface with occasional low hummocks influenced primarily by glacial scouring and deposition. A low escarpment trends from the western to the northeastern portion of the site.

PBOW lies in the eastern region of the Pickeral Creek-Pipe Creek Basin, which is part of the St. Lawrence River drainage basin (Dames and Moore, Inc. [D&M], 1997). Eleven streams exist within the site and flow north-northeast toward Lake Erie, which is located approximately 3.5 miles north of the site. The three main streams at the site, Plum Brook, Ransom Brook, and Pipe Creek, are being monitored by NASA PBS. The site is part of four drainage areas: (1) Sawmill Creek (southern PBOW); (2) Plum Brook (central PBOW); (3) Pipe Creek (western PBOW); and (4) Storrs-Hemminger Ditch, all of which flow into Sandusky Bay (D&M, 1997). The drainage pattern is dendritic where streams are incised into bedrock and poorly developed where they have not yet downcut to the bedrock. In addition to streams seventeen isolated ponds and reservoirs and former red water ponds are located at PBOW (IT, 1996a; D&M, 1997).

2.2 Geology and Soils

2.2.1 Regional Geology

The bedrock in northern Ohio consists of Devonian and Silurian carbonates (limestone and dolomite) and clastics (shale, siltstone, and sandstone). These units unconformably overlie older sedimentary sequences of Ordovician and Cambrian Age rocks which in turn unconformably overlie Pre-Cambrian basement rocks (D&M, 1997). The local bedrock is situated on the eastern flank of the Findlay Arch. Beds in the vicinity of PBOW dip to the southeast at an angle of approximately 10 to 30 feet per mile. In the Devonian and Silurian carbonate of northern and western Erie County weathering of the carbonates has produced cavernous porosity and karst topography.

2.2.2 Local Geology

Three formations, all of Devonian Age, are shown on the regional geologic map (Figure 2-2). Each of the units discussed below were encountered in the upper 100 feet of the bedrock at PBOW along the lines of section presented in Figure 2-2, and on cross-sections shown on Figures 2-3 through 2-7, respectively. The top of bedrock elevation map is presented on Figure 2-8.

The Delaware Limestone is the lowermost formation screened by site wells. It is characterized as a hard, dense, finely crystalline limestone and dolomite. Dissolution of this unit has been described which has produced solution channels along bedding planes and joints, and has even produced caverns in some areas. The unit is typically buff colored and usually is described as fossiliferous. In the vicinity of PBOW, quarries mine limestone from the Delaware. Traces of natural petroleum-derived benzene, toluene, ethyl benzene, and xylene (BTEX) and hydrogen sulfide (H_2S) are common in area quarries (BTEX in Quarry Teleconference, Appendix A). Overlying the Delaware Limestone is the Olentangy Shale. Two members of the Olentangy Shale have been characterized at the site, the Plum Brook Shale and the overlying Prout Limestone. The Plum Brook Shale is interpreted to consist of approximately 35 feet of bluish-gray, soft, fossiliferous shale containing thin layers of dark, hard, fossiliferous limestone. The Prout Limestone has been described as a 15 feet thick unit which occasionally outcrops in a 1,000 to 2,000 foot-wide, northeast striking band across the middle portion of PBOW. It has been described as a dark-gray to blue, very hard, siliceous, fossiliferous limestone or dolomitic mudstone. The uppermost formation at the site is the Ohio Shale. Only one member of the Ohio Shale is present in the PBOW area – the Huron Shale. This unit has been described as black, thinly bedded, with abundant carbonaceous matter. Some large pyrite/carbonate concretions are also present in the Huron Shale with some as large as 6 feet in diameter (D&M, 1997).

2.2.3 Local Soils

The bedrock overburden in Erie County is predominantly glacial till, glacial outwash, or glacial lacustrine (lake) deposits. In the vicinity of PBOW, the soil has been interpreted to be lacustrine. In many areas, the overburden also consists of highly weathered bedrock. The thickness of the overburden ranges from 1 to greater than 25 feet. As shown on Figure 2-9, the overburden is thickest on the northern portion of the site in the vicinity of the Reactor Building Area where it has filled in the bedrock low that is located in the same area.

The 1971 SCS Soil Survey of Erie County mapped four soil associations on PBOW (in the order of areal percentage) as the Prout, Arkport-Galen, Del Rey-Lenawee, and the Lewisburg (SCS, 1971). More recently, the Ohio Department of Natural Resources revised the soil associations in the county which also changed the soil associations at PBOW. The revised survey is not ready for publication, but a document called the Progress Report was issued in 1994 (Ohio Department of Natural Resources [ODNR], 1994). As shown in the 1994 report, the soil in the northwest portion of the site is now placed within the Kibbie-Elnora-Tuscola-Colwood Association which is described as nearly level to gently sloping. The drainage ability of the soil is presented as somewhat poorly drained, moderately well drained, and very poorly drained soils formed in outwash, lacustrine, and deltaic sediments. Along a strip from west to northeast across the site is the Castalia-Millsdale-Milton-Ritchey Association. It is described as a shallow to moderately deep, nearly level to moderately steep, well-drained and very-poorly drained soils formed in glacial till, lacustrine sediments, and limestone residuum. Across much of the central portion of the site is the Hornell-Fries-Colwood Association. It is described as moderately deep to deep, nearly level to gently sloping, somewhat poorly drained to very poorly drained soils formed in glacial till and lacustrine sediments over shale bedrock. At the extreme southeast portion of PBOW is the Pewamo-Bennington Association. It is described as nearly level, to gently sloping, very-poorly drained, and somewhat poorly- drained soils formed from glacial till and lacustrine sediments.

2.2.4 Hydrogeology

2.2.4.1 Current Groundwater Usage

The majority of residents in Erie County receive water from public utilities which receive most of their water from surface water sources. Residences to the north and east of PBOW are connected to city, county, or rural services. Five percent of the county residents obtain groundwater from private wells. Erie County's primary groundwater source is the limestone and dolomite found in the western end of the county. Groundwater wells in the central and eastern portions of the county tap lower yielding shale and sandy zones in the overburden (D&M, 1997). Some wells surrounding PBOW are used for agricultural purposes including irrigation, which could have an effect on drawdown near the site (International Consultants, Inc. [ICI], 1995). A few wells in the vicinity of PBOW were determined to be used for private and public consumption (Science Applications International Corporation [SAIC], 1991); however, none are used within the facility boundary.

2.2.4.2 Regional Hydrogeology

Regional groundwater flow is to the north-northeast towards Lake Erie, although local flow may vary due to local topography. The water in the limestone typically occurs in joints and along bedding planes or in solutionally enlarged openings. Although some limestones in the middle of the county provide well yields of up to 500 gallons per minute (gpm), the overburden and the majority of the other formations can sustain groundwater pumping of only 10 gpm or less (D&M, 1997). A hydrogeological study by the U.S. Geological Survey (USGS) conducted on the glacial deposits in Sandusky in 1990 reported a horizontal hydraulic conductivity of 0.046 foot/day and a vertical hydraulic conductivity of 1.2 feet per day (IT, 1996a).

2.2.4.3 General Site Hydrogeology

At PBOW, the groundwater has been divided into three zones based on location and yield. Zone one occurs in the north and northwestern portion of PBOW. It has been characterized as yielding from 100 to 500 gpm from karst limestone approximately 100 feet below grade. Zone two is in the northern portion of PBOW and has yields of 15 gpm or less from limestone approximately 300 feet below grade. Zone three has the lowest yields and is located in the eastern and southern portion of the site in predominantly shale bedrock. In addition to being found in the shale, groundwater is located in thin sand and gravel horizons interbedded with silt and clay depositions. Most of the Zone three wells are poor yielding with many of them providing less than 3 gpm (D&M, 1997).

The two main water-bearing zones at PBOW are the overburden and the bedrock. The general flow direction in the overburden aquifer is to the north-northeast largely mirroring the surface topography. The flow is also somewhat correspondent to the topography of the top of the bedrock. Some of the groundwater overburden wells become dry at certain times of the year (IT, 1997c). In contrast, the bedrock water-bearing zone is saturated year-round. The conceptual model of the site is that the groundwater flow in the bedrock water-bearing zone migrates and is influenced by the frequency, orientation, density, and connectivity of the fractures. Similar to the overburden flow direction, groundwater in the bedrock flows to the north-northeast. A more detailed discussion of the hydrogeological information obtained as part of the four quarterly investigations is presented in Section 6.0.

2.3 Climatological Setting

The climate for Erie County is continental with cold and cloudy winters and warm, humid summers. The county's first freezing temperature is typically in October, and its last freezing temperature is typically in April. Average annual precipitation for Sandusky from 1961 to 1990 was 34.05 inches. Within that time period, February had the lowest mean monthly rainfall average with 1.65 inches, whereas July had a high of 3.70 inches. The weather changes every few days as cold fronts move through the region. Wind is from the southwest 55 percent of the time (Morrison Knudsen Group [MK], 1994; D&M, 1997). A discussion of more recent climatological data obtained as part of this investigation are presented in Section 6.1.4.

3.0 Summary of Previous Environmental Studies

Previous investigations of site hydrogeology and groundwater contamination were documented in the Contamination Evaluation Report (IT, 1991), the Site Inspection Report (MK, 1994), the Site Management Plan (ICI, 1995), the Site-Wide Groundwater Investigation Draft Report (D&M, 1996), and the Site-Wide Groundwater Investigation Report (IT, 1997c).

In 1989, IT conducted the contamination evaluation focusing on areas associated with past DOD operations at PBOW while under contract for the CELRN. The objective of this preliminary evaluation was to confirm or deny the presence of residual chemical contamination from operational activities conducted at the site during DOD operations. As part of the investigation, four groundwater monitoring wells were installed in the overburden water-bearing zone at locations shown on Figure 2-2. IT-MW01 was placed at the intersection of West Scheid Road and Patrol Road to monitor the quality of groundwater entering the site. IT-MW02 and IT-MW05 were installed in the presumed downgradient locations close to Waste Disposal Areas 2 (also known as West Area Red Water Ponds) and 1 (also known as Pentolite Road Red Water Ponds), respectively. IT-MW06 was located near the northern perimeter of the site and monitors the quality of groundwater exiting the site. Groundwater samples were collected and analyzed for VOCs, SVOCs, nitroaromatic compounds, nitrates, sulfates, and metals. Analytical results indicated that several VOCs, SVOCs, and nitroaromatics were present at concentrations in the low parts per billion range, including acetone, carbon disulfide, 2,6-DNT, and 2,4-DNT. Chromium, manganese, and sulfate were also detected in some groundwater samples at elevated concentrations. The contamination evaluation concluded that these detected organic and inorganic compounds in groundwater represented groundwater contamination from past activities at the facility. The Hazard Ranking System (HRS) score was calculated for the site based on the results of this evaluation. The HRS score was zero because there were no target users of impacted groundwater or surface water within 3 miles of the site.

A site inspection was conducted at PBOW by MK from June through July of 1993 under contract to NASA. The purpose of the site inspection was to collect information concerning conditions at the PBS facility sufficient to assess the threat posed to human health and the environment and to determine the need for any additional investigation. A total of 13 monitoring wells were installed in the overburden water-bearing zone by MK in multiple areas. The MK investigation identified limited contamination by nitroaromatics and metals in groundwater at PBOW. One of the monitoring wells, the only one slated for the Middle Toluene Tank Area, was unable to be installed.

In 1994 and 1995, D&M conducted a groundwater investigation under contract to the Nashville and Huntington Corps of Engineers districts. The objectives of the D&M investigation were as follows: to evaluate groundwater occurrence and flow conditions in the overburden and bedrock water-bearing zones; to assess the groundwater quality in the overburden water-bearing zone and at the Red Water Ponds and TNT Manufacturing Areas; to investigate on a site-wide basis the baseline groundwater quality of the bedrock water-bearing zone; and to evaluate the necessity of additional work at PBOW. A total of 11 monitoring wells were installed in the overburden water-bearing zone and 8 wells were placed in the limestone bedrock. The general 1997 groundwater flow directions in both water-bearing zones as indicated on the contour maps in the D&M report were to the north, eventually toward Lake Erie. However, the investigation also found that the groundwater flow in the overburden exhibited a strong downward vertical component across most of the site and the presence of groundwater in the overburden water-bearing zone was seasonally dependent. Groundwater samples were collected from 25 wells and analyzed for nitroaromatics, nitrates, and metals. Samples from bedrock wells were also analyzed for VOCs and base neutral/acid extractable compounds (BNA). The analytical results indicated that significant levels of explosive residues (including 1,3,5-trinitrobenzene [TNB], 1,3-dinitrobenzene [DNB], and 2,4-DNT) were present in the groundwater in the overburden aquifer near both Red Water Pond areas. However, away from the ponds, the levels of detected explosives in groundwater decreased. Low levels of explosives were also reported in some overburden wells placed in TNT Area A (TNTA), TNTB, and in several bedrock wells at both Red Water Ponds and TNT Area C (TNTC). Several VOCs and BNAs were detected in the bedrock water-bearing zone, including hydrocarbon compounds with benzene concentrations in seven of the nine bedrock wells at or above the regulatory action level. In addition, eleven metals were detected in groundwater samples in a few limited areas with concentrations of copper, manganese, nickel, and thallium occasionally exceeding their respective regulatory action levels (D&M, 1997).

In September 1995, ICI issued a site management plan under contract with USACE-Huntington District. The objectives were to describe the regulatory framework, site setting, site investigations and results, and management objectives of the PBOW. As part of their site recommendations they stated that at least one additional well should be installed at the G8 Burn Grounds, the Waste Lagoons Area, the Middle Toluene Tank Area, Rail Car Unloading Area, TNT A B, and C, WARWP, and the PRRWP Areas (ICI, 1995).

IT conducted a site-wide GWI at the former PBOW from September through October 1996 under contract to the USACE-Nashville District (IT, 1997c). This work included installation of overburden monitoring wells, redevelopment of existing monitoring wells, and collection and analysis of groundwater samples to acquire supplementary data of site-wide groundwater levels and contaminants to add to an existing database, and to fill in existing data gaps in groundwater levels and contamination in the western portion of PBOW. IT reported that the overburden water-bearing zone had been impacted by nitroaromatic compounds in all areas except at TNTC. Nitroaromatic compounds were also detected in six of the eight bedrock wells sampled, indicating that nitroaromatic contamination is evident in both water-bearing zones. Organic compounds (VOCs and SVOCs) at concentrations exceeding the RBCs were present exclusively in overburden water-bearing zones in the two red water pond areas. At least one BTEX compound was present in all the bedrock wells except BED-MW14 and -MW20. Free product was found in BED-MW16 located near the upper toluene tank area. A variety of metals were present in groundwater samples from both water-bearing zones, with some exceeding RBCs. Hydrogen sulfide (H_2S) gas was encountered in three bedrock wells indicating a possible reducing environment in the bedrock zone. Pesticides/polychlorinated biphenyls (PCB) were not detected in any of the sampled wells. Groundwater samples collected from five overburden wells and one bedrock well contained cyanide. However, the presence of cyanide in water samples was attributed to suspended solids as cyanide was not detected in filtered samples. Based on the GWI, additional sampling efforts were recommended, including additional well installations, quarterly water level measurements, seasonal groundwater sampling, delineation of the lateral extent of contamination in the two Red Water Pond areas, and a geochemical study of bedrock water quality to determine the source of the H_2S.

4.0 Summary of Groundwater Investigation Field Activities

4.1 New Monitoring Well Installation

Three new overburden wells and eight bedrock wells were installed as part of the GWI following the first quarterly groundwater level measurement event. In addition, one piezometer was also installed in place of monitoring well IT-AA2-GW-002 because the borehole was dry at the time of well completion. One well cluster consisting of one overburden (piezometer at AA2) and one bedrock well was placed in each of three Acid Areas and in the Additional Burning Ground (ABG).

Monitoring wells were installed in accordance with guidelines specified in the USACE Engineering Manual EM-1110-1-4000 (USACE, 1994) and following procedures established in the site-wide sampling and analysis plan (SAP) (IT, 1996a). Specifically, monitoring wells were installed as described below.

A Dietrich D-50 truck mounted rotary drill rig was used to drill boreholes in the overburden soil for well installation. The boring was advanced by using 8.25-inch outside diameter (OD) (4.25-inch inside diameter [ID]) hollow-stem auger (HSA) to the depth of auger refusal. Soil core samples were collected continuously from the ground surface to the terminating depth using a 2-foot long and 2-inch diameter stainless-steel split spoon. Soil core samples were visually examined by an IT field geologist and documented on the drilling logs (Appendix B). Well completion in each borehole was accomplished using 2-inch-diameter polyvinyl chloride (PVC) Schedule 40 riser pipe and a 10-foot section of factory slotted screen. Three discrete soil samples were collected from each borehole for geotechnical testing. At least one of the three geotechnical samples was collected from the depth interval of the well screen to allow selection of proper size of filter materials. Soil samples were also scanned for the presence of organic vapor using a photoionization detector (PID). The terminating depths for the overburden well boreholes were all at the top of the bedrock with AA1-GW-002 at 22 feet below ground surface (bgs), AA2-GW-002 (piezometer) at 18.5 feet bgs, AA3-GW-002 at 16 feet bgs, and ABG-GW-002 at 6.75 feet bgs, respectively.

A Dietrich D-120 truck mounted rotary drill rig was used to drill boreholes for bedrock well installation. The bedrock wells were installed as double-cased wells. Initially, 14-inch OD (8.25-inch ID) HSA were used to drill through and hold back the overburden materials. Following the overburden drilling, a 10-inch OD roller cone bit was used to cut several feet into competent bedrock for placement of steel surface casing. The surface casing was made of 10-inch, low carbon steel. The surface casing was placed in the borehole through the augers and pressure grouted into the bedrock. The grout was allowed to cure for at least 48 hours. After the grout was cured and the overburden zone completely sealed, a 3-inch OD, 10-foot long core barrel was used to advance the borehole into the bedrock through the center of the surface casing. Rock cores were visually examined and a lithology description prepared. After the desired depth had been drilled, the core barrel assembly was removed and the borehole was reamed with a 6-inch OD roller cone bit. Bedrock well completion in each borehole was accomplished using 2-inch-diameter, Schedule 40 PVC riser pipe and a 15-foot section of factory slotted screen.

The monitoring well construction details for monitoring wells at the site are summarized in Table 4-1. Drilling logs and monitoring well construction diagrams are included in Appendix B and geotechnical testing results are included in Appendix C.

4.1.1 Monitoring Well Development

All newly constructed monitoring wells were developed after completion of well construction. Well development was performed by surging and bailing or by pumping using a Grundfos™ submersible pump or a Whale™ pump. The method of development chosen depended upon groundwater yield in the well. A well development log was completed for each well to document well development progress, field parameters, and other pertinent information. Photographs of development water and well development logs are included in Appendix B.

In addition to development of new monitoring wells, existing overburden wells that had not been sampled with the previous 12 months at the time of the sampling were redeveloped prior to collecting groundwater samples for chemical analysis, following procedures specified in the SAP (IT, 1996a). Redevelopment was performed to remove the stagnant water column inside the well casing and in the filter pack to allow collection of representative water samples. Redevelopment was performed using a bailer or a submersible pump. During redevelopment, field measurements of pH, oxidation-reduction potential (Eh), temperature, dissolved oxygen (DO), turbidity, and conductivity were collected periodically to monitor changes in water quality and to assess the effectiveness of development.

4.1.2 Hydraulic Conductivity Testing

Rising head slug tests were performed at each newly installed monitoring well to acquire information on the hydraulic conductivity of each water-bearing zone. A slug test was not conducted in the temporary piezometer (AA2-GW-002). Equipment used in the test included:

- Ten pounds per square inch pressure transducer equipped with an atmospheric pressure compensation tube
- HERMIT 1000C Environmental Data Logger
- Five-foot-long, 1.5-inch-diameter PVC slug.

The slug test was set up by lowering the pressure transducer more than 5 feet below the static water level to a point above which the PVC slug could be fully immersed in the well water without interfering with the transducer. The data logger allows water level changes be recorded at desired time intervals. The slug was inserted in the well and the water level allowed to return to static level. The rising test was started by initializing the data logger and removing the slug from the well. The water level recovery versus elapsed time was recorded for later analysis. The test was considered completed when the water column above the pressure transducer had returned to 95 percent of the original level. Following the test, the data recorded by the data logger was recovered and stored on diskette. The raw data were inspected in the field for consistency and completeness. The slug test data were analyzed using the computer program Aquifer Test (Waterloo Hydrogeologic, 1995). The hydraulic conductivity testing data are included in Appendix D, along with a description of the method used in the data analysis.

4.2 Quarterly Groundwater Level Measurements

Four quarterly groundwater level measurement events were completed as part of the GWI. Each groundwater level measurement was completed within one 12-hour period as required by the statement of work. The measurements were collected on August 27 and November 12, 1997, and on February 24, and May 5, 1998.

Reconnaissance of the wells to be measured before each quarterly groundwater level measurement event was performed to determine the accessibility and condition of each well. This included locating wells that were in remote areas, clearing and flagging paths to wells, and identifying any potential health and safety hazards near the wells. All inoperable (rusted) locks were cut off and replaced with special-ordered, keyed-alike padlocks during the first quarterly event. Construction details of each existing well including well identification, well depth, well diameter, the year of completion, and available survey coordinates as well as previously measured depth to water data were tabulated and provided to each field group. A specially designed water level measurement form was used for data collection.

Upon opening the well cap, real-time air monitoring was conducted using a PID for the overburden wells and a PID and a hydrogen sulfide (H_2S) detector for the bedrock wells. The purpose of the air monitoring was to protect field personnel from organic vapor and H_2S exposure and to document the quality of trapped air in each well for future monitoring and sampling use. Organic vapor had been detected in several overburden wells and H_2S was encountered in bedrock wells during previous groundwater investigations (D&M, 1997; IT, 1997c).

Water level indicators and oil/water interface probes were decontaminated before the first use, between each use, and after the final use in order to prevent possible cross contamination per the procedures outlined in Section 4.2 of the PBOW site-wide quality assurance project plan (QAPP) (IT, 1996b). Field testing and monitoring equipment were inspected and calibrated as specified in Section 6.0 of the PBOW Site-Wide QAPP (IT, 1996b) and according to the manufacturers' specifications. To further minimize the possibility of cross contamination, water level measurements began with the least contaminated well and progressed in sequence to the most contaminated well as determined by the degree of known contaminant concentrations.

The static water level in each well was measured using an electronic water level indicator or an oil/water interface probe to the nearest 0.01 foot. The depth from the marked point on the rim of the inner PVC casing of the well to the water table was recorded. When a marked point was not found, the highest point on the rim of the inner casing was marked as a datum for current and future reference, and depth to water level was measured from that point. A discussion of the results of these four quarterly measurements and a table showing the elevations measured is presented in Section 6.1. Water level measurement forms are included in Appendix B.

4.2.1 First Quarterly Groundwater Level Measurements

On August 27, 1997, groundwater level measurements were completed over a single 11½ hour period (0800 to 1930). No significant precipitation was recorded in the Sandusky area for at least 3 days prior to water level measurements. The first quarterly event measured 73 monitoring wells that were known to exist, including 13 bedrock wells, 59 overburden wells, and 1 temporary overburden piezometer.

4.2.2 Second Quarterly Groundwater Level Measurements

The second quarterly event included 79 monitoring wells/piezometers (19 bedrock wells, 58 overburden wells, and 2 temporary piezometers). Twelve newly installed wells (including one temporary piezometer) were included for the first time in this measurement event. Four overburden wells (PB-MW01, -MW02, -MW03, and -MW04) were eliminated from further measurements due to a lack of adequate well construction and survey data and two bedrock wells (Reactor 4 and 5) were dropped because of their reported connection to sumps within the NASA Reactor Building. Field measurements of static water levels began at 0800 and were completed at 1730 on November 12, 1997. No significant precipitation was recorded in the Sandusky area for at least 3 days prior to the water level measurements.

4.2.3 Third Quarterly Groundwater Level Measurements

The third quarterly event included the same 79 monitoring wells/piezometers as the second quarterly measurements. Two of the wells were dry. Field measurements of static water levels began at 0800 and were completed at 1500 on February 24, 1998. No significant precipitation was recorded in the Sandusky Area for at least 2 days before the water level measurements.

4.2.4 Fourth Quarterly Groundwater Level Measurements

Seventy-nine monitoring wells were measured during the fourth quarterly measurement event on May 5, 1998. Field measurements of static water levels began at 0730 and were completed at 1600. The Sandusky Area had a combined total of 0.16-inches of rain from May 3 through May 5.

4.3 Semi-Annual Groundwater Sampling

Two semi-annual groundwater sampling events were conducted under the GWI at PBOW. The first sampling event was conducted in November 1997 and the second in May/June 1998. Groundwater samples were analyzed for VOCs, SVOCs, nitroaromatic explosives, metals (total and dissolved), cyanide, and water quality parameters alkalinity, chloride, hardness, sulfate, nitrate, total dissolved solids, total organic carbon, and total suspended solids. However, because of an insufficient quantity of water, Reactor 1 was not analyzed for nitrate during the November 1997 event and MK-MW23 was not analyzed for any of the water quality parameters or for PCBs during the May/June 1998 event.

Prior to collecting groundwater samples, monitoring wells were purged to remove standing water in the well casing and screen including water stored in the filter pack voids. The three to five well volumes requiring removal from the wells were calculated based on the static water level and well construction data, assuming a 30 percent porosity of the filter material. During purging, field measurements of pH, specific conductance, temperature, DO, turbidity, and Eh were made and recorded. Purging was considered completed when the required volume was removed and the field parameters listed above were stabilized for three consecutive readings, following procedures stated in the site-wide QAPP (IT, 1996b). In the case of low yield wells, purging ceased after the well had been purged dry.

The majority of overburden wells were sampled using low-flow techniques with a peristaltic pump equipped with disposable Tygon™ tubing. Sampling tubing was discarded after each use to avoid possible cross-contamination. Dedicated Teflon™ bailers fitted with a bottom-emptying device were used for collection of groundwater samples from bedrock wells. Groundwater samples collected using the peristaltic pump were filtered in the field using in-line 0.45 micrometer (µm) size filters for metal analysis. Samples collected by bailer for metal analysis were filtered using filtration apparatus through 0.45 µm filter paper at the site office as soon as possible following sample collection. All groundwater sample bottles were prelabeled and were placed in coolers packed with ice before being preserved and packed for shipment. Sample filtration, preservation, packing, and shipment were performed in accordance with Section 5.4 of the site-wide QAPP (IT, 1996b).

4.3.1 First Semi-Annual Groundwater Sampling Event

The first semi-annual groundwater sampling event was conducted from November 13 through 24, 1997, following the second quarterly water level measurement event. In the SAP (IT, 1996a), 59 primary groundwater samples were to be collected. Well REACTOR 2 could not be sampled due to the low yield of the well. Well REACTOR 3 could not be sampled because it was dry. Two piezometers, IT-MW07 and AA2-GW-002 were dry. Therefore, samples were collected from 55 wells listed in Table 4-2. Field measurements of groundwater samples are presented in Table 4-3.

4.3.2 Second Semi-Annual Groundwater Sampling Event

The second semi-annual groundwater sampling event was conducted from May 12 through June 1, 1998, following the fourth quarterly water level measurement event. Primary groundwater samples were attempted to be collected from the same group of 57 wells attempted during the first semi-annual event. Two piezometers (IT-MW07 and AA2-GW-002) were dry at the time of sampling and could not be sampled. Therefore, samples were collected from the 55 wells listed in Table 4-4.

4.4 Land Survey

Newly installed monitoring wells (11 monitoring wells and 1 piezometer installed in October 1997) were surveyed in November 1997 by an Ohio-registered professional land surveyor. In addition, a total of 35 existing monitoring wells were re-surveyed in February 1998 in order to bring the surveyed coordinates of these wells in line with other wells and to collect top-of-casing (TOC) data that were missing from most of these wells. At each well location, the horizontal coordinates (northing and easting) were surveyed in reference to the Ohio State Plane Coordinate system (north zone) while the elevation was surveyed at the ground surface and at the top of the inner casing to the closest 0.01 foot, referenced to the 1927 National Geodetic Vertical Datum (NGVD). The complete land survey data are included in Appendix E.

4.5 Decontamination Procedures

Decontamination of drill rigs, downhole tools, and sampling equipment was performed in accordance with Section 4.4.3 of the SAP (IT, 1996a). Specifically, drill rigs, rods, drill bits, and augers were cleaned at the decontamination pad using high pressure hot water from a steam-cleaner before entering the drilling site, between sites, and after completion of the last borehole. Other equipment, including water level indicators, slug, and transducer were decontaminated by rinsing in sequence with soapy water, deionized (DI) water, methanol, and a final rinse with DI water. Each were then air dried before use. Submersible pumps were decontaminated by running approximately 5 gallons of soapy water and 5 gallons DI water through the pump head and tubing. Equipment rinsate samples were collected and analyzed for the same parameters as the primary sample. The results of the equipment rinsate samples exhibited no detectable chemicals, confirming the effectiveness of the decontamination process.

5.0 Analytical Program

All groundwater samples were analyzed by Quanterra Environmental Services, Knoxville, Tennessee. Analyses for water quality parameters were provided by Quanterra's Tampa laboratory. Data validation was performed by E & I Technologies, an independent third party contractor, located in Oak Ridge, Tennessee. The validation summaries are provided in Appendix F. The analytical results are summarized in Appendix G. Detected hits tables that exclude "B" qualified data are included in Appendix H. The groundwater analytical data were compared to RBCs. A definition of RBC is presented in Section 5.4. The RBC tables (Section 6.2) include only compounds detected above the RBC screening concentrations or those compounds without RBCs. "B" qualified data were not included in the RBC comparison.

5.1 Analytical Program and Methodologies

Chemical analyses for the investigation were performed in accordance with the guidelines detailed in the U.S. Environmental Protection Agency (EPA) *Test Methods for Evaluating Solid Waste* (SW-846), Physical/Chemical Methods, Third Edition, September 1986 (EPA, 1986) and subsequent revisions. The groundwater samples and associated quality assurance/quality control (QA/QC) samples were analyzed for volatile organics, semivolatile organics, PCBs, metals, explosives, and several water quality parameters. Methods used for analysis are summarized in Table 5-1.

All analytical samples collected for the generation of definitive data were reported in EPA Level IV CLP-like data packages. A 100 percent Level III data validation was performed using EPA guidelines presented in the EPA *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA, 1994a) and *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* dated February 1994 (EPA, 1994b). After validation, the data were reevaluated for blank contamination and revisions were made to the original validation results. The revisions consisted of assigning "B" qualifiers to the analytical results when necessary. The criteria for blank evaluation were based on those detailed in *Region III Modifications to National Functional Guidelines for Organic Data Review* (September 1994) (EPA, 1994c) and *Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses* (EPA, 1993). The procedure is outlined in Section 5.3.

5.2 Data Quality Evaluation

The reliability of the sampling and analytical procedures used during the investigation was demonstrated by implementing the project-specific QA procedures specified in the site-wide SAP (IT, 1996a) and QAPP (IT, 1996b) and its site-specific attachments. Successful execution of these procedures provides strong supporting evidence that the data are representative of the areas under investigation.

The data quality objectives (DQO) for this project were to produce scientifically valid data of known accuracy and precision, which were complete with respect to identified critical samples, comparable with similar data types and representative of the media sampled so as to be useful for the cited purposes. Evaluation of the data using the DQOs and the data validation process resulted in the determination that most of the data set is valid and of sufficient quality to meet the objectives of the investigation. In both sampling events, acetone, 2-butanone, and 2-hexanone were rejected in several samples due to low relative response factors (RRF) in the initial and continuing calibrations. Only non-detects were rejected. Detects were qualified "J", estimated. In the second sampling event, semivolatile compounds associated with the internal standard perylene-d12 in samples 5685 (WAMW2), 5905R (BEDMW14), 5695 (PRMW7), 5696 (PRMW7), 5705 (PRMW8), and 5715 (PRMW9) were rejected. Compounds associated with acenaphthene-d10 and phenanthrene-d10 in sample 5695 were qualified as "NJ" for detects and"R" for non-detects because of low area counts. The samples were not reanalyzed. A complete evaluation of the procedures implemented in the investigations is discussed in the data quality evaluation (DQE) found in its entirety in Appendix I.

5.3 Blank Evaluation

The purpose of blank analysis is to determine the existence of contamination resulting from laboratory and field activities. Blank evaluation involves qualification of data based on the results of associated field blanks, trip blanks, equipment rinsates, and laboratory method blanks. The criteria for blank evaluation are as follows:

- If a parameter is found in a blank but not detected in the sample, no action is taken.
- For organics, if the sample result is greater than the Contract Required Quantitation Limit (CRQL), but is less than the 5X or 10X multiple of the blank result, the sample result is qualified "B".

- For organics, if the sample result is less than the CRQL and less than the 5X or 10X multiple of the blank result, the sample result is qualified "B". The "J" qualifier is not used.

- For inorganics, if the sample result is greater than the instrument detection limit (IDL) but less than the 5X multiple of the blank result, the sample result is qualified "B".

- If the sample result is greater than the 5X or 10X multiple of the blank result, the sample result is not qualified.

In instances where more than one blank is associated with a given sample, qualification is based upon a comparison with the associated blank having the highest concentration of a contaminant. Blank results are not subtracted from sample concentrations.

5.4 Screening Criteria

The analytical data were screened against RBC screening concentrations derived from the published EPA Region 3 tables (EPA, 1998). RBCs are media-specific contaminant levels used to reduce the list of site-related chemicals carried through all the steps of the COPC selection and quantitative risk assessment. RBCs have been conservatively derived by assuming a residential receptor, applying high-end values for most of the exposure variables, and setting the target cancer risk at 10^{-6} and the target hazard index (HI) at 0.1. The cancer risk of 10^{-6} reflects the lower end of the target risk range as defined in the National Contingency Plan (NCP) (EPA, 1990). The HI of 0.1 provides additional protection from noncancer effects arising from exposure to multiple chemicals. Chemicals present in environmental media at concentrations below the RBCs will not contribute significantly to total site risk.

RBCs were obtained preferentially from the EPA Region III tables compiled for this purpose (EPA, 1998). No attempt was made to develop RBCs for ubiquitous, nutritionally essential elements unlikely to be toxic at concentrations ordinarily found in environmental media and for which toxicity values are unavailable (i.e., calcium, magnesium, potassium, and sodium). RBCs used in the screening of groundwater investigation data are presented in Section 6.0 tables. RBCs for tap water were used to screen contaminants in groundwater. It was assumed that household use of groundwater results in the most restrictive contamination levels.

6.0 Investigation Results

6.1 Geologic and Hydrogeologic Investigation Results

This section presents the geologic and hydrogeologic data and interpretations of the data collected as part of this groundwater investigation. Table 6-1 shows the lithologic units monitored by each of the site wells and headspace in these wells. All the groundwater elevation measurements for site wells measured during the four quarters and those measured since 1994 are shown in Table 6-2. Hydraulic conductivity results for this investigation are shown on Table 6-3. Contours of the water level elevations in the overburden for the four quarters measured are presented in Figures 6-1 through 6-4. Contours of the water level elevations in the bedrock for the four quarters measured are presented in Figures 6-5 through 6-8.

6.1.1 Hydrogeology of Overburden Water-Bearing Zone

Groundwater in the overburden water-bearing zone fluctuated less than 3 feet in the four water level measurements collected as part of this investigation. Groundwater flow in the overburden is predominantly to the north-northeast. The general flow direction in the overburden aquifer largely mirrors the surface topography and is correspondent to the topography of the top of the bedrock. This is demonstrated by comparing the top of the bedrock map (Figure 2-8) with the overburden groundwater elevation contour maps. In the southeastern portion of the site the groundwater has a relatively constant flow to the north-northeast for each of the four dates. However, on the northwest side of the site, the flow is toward a groundwater low located southwest of the Reactor Building Area. Figure 6-9 shows flow in both the overburden and bedrock water-bearing zones in the vicinity of the Reactor Building Area for November 1997 and Figure 6-10 shows the same information for May 1998. A distinct southwestern flow is present in the overburden in that area toward the reactor buildings, possibly as the result of active sump pumps believed to be pumping within and at the base of the overburden there.

Hydraulic gradients were calculated for three transects across the site for the four dates measured. The location of these three transects and the calculations for them are presented in Appendix D. Flow along the western side of the site is toward the north-northwest to a groundwater low at a gradient ranging from 0.0086 foot per foot (ft/ft) to 0.011 ft/ft. Flow at the center of the site was to the north with a very consistent gradient over time ranging from 0.0044 ft/ft to 0.0053 ft/ft. Groundwater on the east-central portion of the site flowed to the northeast at a gradient ranging from 0.0049 ft/ft to 0.0060 ft/ft. Hydraulic conductivities of the overburden water-bearing zone measured by slug tests performed in the site wells range from 0.74 feet per day (ft/day) to 211.68 ft/day as shown in Table 6-3. All slug test data and hydraulic gradient calculations are presented in Appendix D.

Correspondent seasonal groundwater elevation fluctuations have occurred in the overburden, irrespective of the area of the site. Figure 6-11 demonstrates this similarity between four select overburden wells. Similar fluctuations in overburden wells may imply a significant horizontal connectivity across the overburden water-bearing zone. However, these levels in the overburden may be influenced by changes in water levels in the bedrock water-bearing zone, possibly indicating higher vertical than horizontal hydraulic conductivity in the overburden.

6.1.2 Geology and Hydrogeology of Bedrock Water-Bearing Zone

The bedrock at the site has been largely discussed as one unit in previous reports. In this report, the formations within the bedrock have been differentiated to explain enigmatic groundwater levels and fluctuations over time in many of the site wells. After comparing the geologic plan view map (by the ODNR) with the five cross-sections (discussed in Section 2.0), the bedrock will be discussed as a whole and as three separate units (the Ohio Shale, Olentangy Shale, and the Delaware Limestone) where appropriate.

Horizontal hydraulic gradients were calculated for three transects across the site for the four dates measured. The locations of these three transects and the calculations for them are presented in Appendix D. Flow along the western side of site is toward the north-northeast with a gradient of 0.004 ft/ft to 0.0286 ft/ft. Flow in the center of the site was predominantly to the north-northeast with a gradient ranging from 0.0038 ft/ft to 0.0110 ft/ft. At the east-central portion of the site, flow is to the northeast with a gradient ranging from 0.0023 ft/ft to 0.0038 ft/ft. Groundwater elevation in the bedrock water-bearing zone typically had little fluctuation in the wells monitoring the Ohio Shale and the Olentangy Shale (Figures 6-12 and 6-13, respectively); however, wells monitoring the Delaware Limestone showed significant elevation fluctuations over time (Figure 6-14). Wells constructed in the Delaware Limestone which are located in the Reactor Building Area wells (REACTOR 1, 2, and 3) showed the greatest variation over time with water levels fluctuating as much as 25 feet (Figure 6-15). Another well shown on Figure 6-15, PB-BED-MW13, fluctuated very similarly to those of Reactor Building Area (REACTOR 1, 2, and 3). PB-BED-MW13, which monitors the Delaware Limestone, is located along a bedrock low which trends along the west side of the site to the Reactor Building Area. The very similar extreme fluctuations in these wells indicates that there is a hydraulic connection between these two areas. Eight sump pumps are present in the Reactor Building Area at the locations shown on Figures 6-9 and 6-10. The frequency and rate that these wells pump is unknown. However, it is possible that these wells may draw a significant amount of water from the top of the bedrock low, causing drawdown as far as PB-BED-MW13 and possibly causing flow from the overburden water-bearing zone to the Reactor Building Area as shown on both Figures 6-9 and 6-10.

Hydraulic conductivities in the bedrock measured by slug tests performed in the site wells shows that the range is from a minimum of 0.03 ft/day to 22.18 ft/day. This range also demonstrates the variability in the hydraulic conductivity of the bedrock across the site. Of the eight wells tested, the Ohio Shale was shown to have the highest hydraulic conductivities at 22.18 ft/day in IT-ABG-BEDGW-001 and 17.9 ft/day in IT-TNTB-BEDGW-002 as shown on Table 6-3. In contrast, the hydraulic conductivities in the other six wells (installed in the Delaware Limestone and the Olentangy Shale) had conductivites two to three orders of magnitude lower.

Some of the lithologic units at the site have had the presence of natural petroleum and H_2S, a byproduct of anaerobic petroleum degradation. After evaluating the boring logs that had petroleum noted during drilling and the wells with H_2S detected by monitoring equipment, it is apparent that petroleum (and H_2S) is naturally occurring at the site to a significant degree only in the Delaware Limestone.

6.1.3 Hydraulic Connection Between Zones

Vertical hydraulic gradients, calculated for five well pairs, revealed two general trends across the site (Table 6-4). Well pairs on the western and northern portions of the site showed a strong downward gradient from the overburden to the bedrock. The greatest difference in water levels occurred in the overburden/Delaware Limestone well pair IT-AA1-GW002/IT-AA1-BED-GW001 with approximately 25 feet of difference in the water levels and an average vertical gradient over time of 0.6 foot/foot downward from the overburden to the bedrock. In contrast, the central and southern portions of the site showed very similar groundwater elevations in the overburden and the bedrock, particularly in well pair ABG-GW002/ABG-BED-GW001. This may indicate that the groundwater in the overburden and the Ohio Shale located on that portion of the site have a high degree of connectivity.

6.1.4 Influence of Precipitation on Water Levels

Although previous investigations have indicated that there is a strong connection between precipitation and water level elevations, no clear correlation exists between monthly precipitation rates and water level elevations in site wells. Figure 6-16 shows the precipitation rates in Sandusky, Ohio from January 1994 to May 1998. However, when comparing the limited number of seasonal groundwater elevation measurements collected from the site shown in Table 6-2 with aquifer recharge (Figure 6-17), a seasonal correlation appears to be present. Recharge at PBOW was obtained by subtracting potential evapotranspiration rates (from Cleveland, Ohio) and calculated runoff rates from rainfall. Appendix J shows the calculations and reference information required for this calculation.

Figure 6-17 demonstrates that there is a strong correlation between seasons of the year and calculated monthly aquifer recharge rates at PBOW. Recharge to the overburden is calculated to be highest in January for 3 of the 5 years shown. A lag time should, however, occur from the time the rain infiltrates the soil to the time it reaches the water table. This lag time at PBOW should be weeks from the time of precipitation. The lag time depends largely upon the infiltration capacity of the soil, the thickness of the overburden in the areas of recharge, and in the winter, frozen ground. Thus, the groundwater elevations should typically be highest in February or March. Although Figure 6-16 shows that the highest rainfall occurs in summer months, Figure 6-17 shows that recharge rates are actually lower during that season. This is caused by evapotranspiration, which is highest in the mid to late summer in north-central Ohio. Similar to the lag time for the groundwater high, a lag time in the groundwater low should also occur. Thus, groundwater elevations should be lowest in early fall.

Figures 6-16 and 6-17 show that both precipitation and recharge rates were similar for most of the years measured. However, in 1994 the annual precipitation was approximately 25 percent lower than the average annual rate in Sandusky. Correspondingly, the lowest water levels measured in site wells occurred in December 1994. This reveals that significant fluctuation in groundwater wells can occur during drought conditions such as 1994.

6.2 Analytical Results

IT conducted two semi-annual groundwater sampling events of overburden and bedrock monitoring wells as part of the groundwater investigation at PBOW. Specifically, 38 overburden and 17 bedrock wells were sampled in November 1997 and May 1998. The following sections present the blank-corrected results of these two sampling events by monitored water-bearing zone and geographic location within the site. Site-specific RBCs have been used to evaluate the detected constituents. Only analytes exceeding RBCs are shown on figures. Analytes detected below the RBCs are not discussed in detail or shown on figures but are presented in the referenced data tables. All analytical data is presented in Appendices G and H.

6.2.1 Overburden Water-Bearing Zone

A total of 38 overburden wells were sampled under the GWI. Specific locations of these wells are as follows:

- Five at the WARWP Area
- Four at the PRRWP Area
- Five at TNTA
- Two at TNTB
- Six at TNTC
- Two at Acid Area 1 (AA1)
- Three at Acid Area 2 (AA2)
- One at Acid Area 3 (AA3)
- Five at various Burning Grounds
- Two at the Lower Toluene Tank Area
- One at the Upper Toluene Tank Area
- One at the Reactor Facility
- One upgradient of the PBOW (background).

Note that results from the upgradient background well are included in background wells, Section 6.2.3.

6.2.1.1 West Area Red Water Ponds Area

Five existing overburden monitoring wells were sampled during the two semi-annual sampling events at the WARWP as shown in Figure 6-18. These wells include IT-MW02, IT-MW08, IT-MW10, PB-WA-MW01, and PB-WA-MW02. One of these, PB-WA-MW02, is located south and upgradient of the former Red Water Ponds, while the remaining four wells are located downgradient or sidegradient of the ponds. All wells were analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.1.1 First Semi-Annual Sampling Event

One VOC (carbon disulfide) was detected in IT-MW10 in November 1997; however, this constituent did not exceed the RBC (Table 6-5). At least one SVOC was detected in IT-MW02, IT-MW10, and PB-WA-MW01. Four SVOCs exceeded the RBCs in IT-MW02, including 2,4-DNT, 2,6-DNT, 2-nitroaniline, and 4,6-dinitro-2-methylphenol. In IT-MW10, only bis(2-

ethylhexyl)phthalate exceeded the RBC while PB-WA-MW10 exhibited di-n-octyl phthalate at a concentration below the RBC. Of the sampled wells, only IT-MW02 exhibited detectable concentrations of nitroaromatic compounds, consistent with detections under the SVOC analysis. Of the four detected explosives, three (1,3-DNB, 2,4-DNT, and 2,6-DNT) exceeded the respective RBCs; 1,3,5-TNB did not exceed its RBC.

Several metals were detected in each of the five sampled wells at the WARWP in November 1997 (Table 6-5). Manganese exceeded the RBC in each of the sampled wells in both total and dissolved samples. Total iron also exceeded the RBC in IT-MW10, PB-WA-MW01, and PB-WA-MW02, but was not detected in the filtered samples, indicating that the RBC exceedances were due to suspended solids in the unfiltered samples. Similarly, total aluminum and nickel exceeded the RBCs in PB-WA-MW02 but were not detected in the dissolved phase. Cyanide was only detected in PB-WA-MW02 at a concentration of 79 micrograms per liter (μg/L), slightly above the RBC of 73 μg/L.

Water quality parameters are also presented on Table 6-5. Of these, only nitrate has an established RBC, which was exceeded in PB-WA-MW02 at an estimated concentration of 80,000 μg/L.

6.2.1.1.2 Second Semi-Annual Sampling Event

VOCs were not detected in any well during the May 1998 sampling event (Table 6-5). SVOCs were detected in IT-MW02 and PB-WA-MW02, with the largest suite evident in PB-WA-MW02. In IT-MW02, three of four detected SVOCs exceeded RBCs including 2,4-DNT, 2,6-DNT, and 2-nitroaniline. PB-WA-MW02 exhibited six detected SVOCs, of which 2,4-dinitrophenol, 2,4-DNT, 3-nitroaniline, and nitrobenzene exceeded the respective RBCs.

Explosives were detected in IT-MW02 and PB-WA-MW02 during the May 1998 sampling event, consistent with the constituents detected under the SVOC analyses. In IT-MW02, six of seven detected nitroaromatic compounds exceeded the corresponding RBCs, including 1,3-DNB, 2,4-DNT, 2,6-DNT, 3-nitrotoluene, nitrobenzene, and RDX, while PB-WA-MW02 exhibited 1,3-DNB, 2,4-DNT, and 2,6-DNT at concentrations above the RBCs.

Consistent with the November 1997 sampling event, several metals were detected in each of the five sampled wells at the WARWP in May 1998 (Table 6-5). Manganese exceeded the RBC in each of the sampled wells in both total and dissolved samples. Total iron also exceeded the RBC in IT-MW10 and PB-WA-MW02 but was not detected in the filtered samples, indicating that the RBC exceedances were due to suspended solids in the unfiltered samples. IT-MW10 also exhibited total aluminum, arsenic, barium, chromium, lead, and vanadium at concentrations above the RBCs; however, these metals were not detected in the dissolved phase, indicating that their presence in the unfiltered sample was due to suspended solids. PB-WA-MW02 exhibited total aluminum and nickel at concentrations exceeding the RBCs, of which nickel also exceeded the RBC in the dissolved phase. Cyanide and nitrate again exceeded the respective RBCs in PB-WA-MW02 at levels comparable to those observed in November 1997.

6.2.1.1.3 Summary of Sampling Events

Results from the two sampling events at the WARWP area indicate that the overburden water-bearing zone has been impacted by nitroaromatic explosives and, to a lesser extent, SVOCs in the immediate vicinity of the former Red Water Ponds (IT-MW02 and PB-WA-MW02). Cyanide also appears to have impacted groundwater on the south side of the ponds (PB-WA-MW02), a location also noted for exhibiting red water in the well. Metals have exceeded RBCs, but dissolved RBC exceedances are limited to manganese and nickel. Further evaluation is needed to determine whether these are due to site contamination.

6.2.1.2 Pentolite Road Red Water Ponds Area

Four existing overburden monitoring wells were sampled during the two semi-annual sampling events at the PRRWP at the locations shown on Figure 6-19. These wells include IT-MW05, PB-PR-MW07, PB-PR-MW08, and PB-PR-MW09. All wells were analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.2.1 First Semi-Annual Sampling Event

Two VOCs (acetone and carbon disulfide) were detected in IT-MW05 in November 1997; however, neither constituent exceeded the RBCs (Table 6-6). SVOCs were not detected in IT-MW05, but at least three SVOCs were detected in PB-PR-MW07, PB-PR-MW08, and PB-PR-MW09 at concentrations exceeding the RBCs. In PB-PR-MW07, three SVOCs (2,4-DNT, 2,6-DNT, and 4,6-dinitro-2-methylphenol) exceeded the respective RBCs by several orders of magnitude, while five SVOCs (2,4-dinitrophenol, 2,4-DNT, 2,6-DNT, 3-nitroaniline, and 4,6-dinitro-2-methylphenol) were also well above RBCs in PB-PR-MW08. Monitoring well PB-PR-MW09 exhibited 2,4-dinitrophenol, 2,4-DNT, and 3-nitroaniline at concentrations above the RBCs.

Consistent with the SVOC results, the three PB-PR-series wells exhibited detectable concentrations of nitroaromatic explosives that were also well above the respective RBCs. The highest concentrations were observed in PB-PR-MW07 and PB-PR-MW08, where 1,3,5-TNB, 1,3-DNB, and 2,4-DNT exceeded the RBCs. Lesser concentrations were reported for PB-PR-MW09, but 1,3-DNB and 2,4-DNT did exceed the RBCs.

Several metals were detected in each of the four sampled wells at the PRRWP in November 1997 (Table 6-6). Manganese exceeded the RBC in each of the sampled wells in both total and dissolved samples. In IT-MW05, arsenic and iron also exceeded the RBCs, while aluminum exceeded the RBC only in the unfiltered sample. Significantly higher metals concentrations were observed in PB-PR-MW07 and PB-PR-MW08 where total and dissolved cobalt, copper, iron, manganese, and nickel were well above the corresponding RBCs. Cyanide was detected in PB-PR-MW07, PB-PR-MW08, and PB-PR-MW09, exceeding the RBC in each case; reported concentrations of cyanide were highest in PB-PR-MW07 and PB-PR-MW08. Water quality parameters are also presented on Table 6-6. Of these, only nitrate has an established RBC, which was exceeded in PB-PR-MW08 in November 1997.

6.2.1.2.2 Second Semi-Annual Sampling Event

VOCs were detected in each of the four PRRWP wells during the May 1998 sampling event (Table 6-6). However, only bromodichloromethane in PB-PR-MW08 and benzene in PB-PR-MW09 were detected at concentrations exceeding the respective RBCs. SVOCs were not detected in IT-MW05 but were detected in the remaining wells at concentrations above the RBCs, with the highest concentrations evident in PB-PR-MW07 and PB-PR-MW08. PB-PR-MW07 exhibited 2,4-DNT, 4,6-dinitro-2-methylphenol, and nitrobenzene at concentrations well above the RBCs. Similarly, 2,4-dinitrophenol, 2,4-DNT, 4,6-dinitro-2-methylphenol, 4-nitrophenol, dibenzofuran, and nitrobenzene were detected at concentrations well above RBCs in PB-PR-MW08. In PB-PR-MW09, only two SVOCs (2,4-DNT and 4,6-dinitro-2-methylphenol) exceeded the RBCs and at concentrations well below those observed in the other two PB-PR-series wells.

Explosives were detected in the three PB-PR-series wells during the May 1998 sampling event, consistent with the constituents detected under the SVOC analyses and the November sampling event. Three explosives compounds (1,3,5-TNB, 1,3-DNB, and 2,4-DNT) were detected at concentrations several orders of magnitude above the RBCs in PB-PR-MW07 and PB-PR-

MW08, while PB-PR-MW09 exhibited 1,3-DNB and 2,4-DNT at concentrations above the RBCs but well below those observed in the former wells (Table 6-6).

As with the November 1997 sampling event, several metals were detected in each of the four sampled wells at the PRRWP in May 1998 (Table 6-6). Although several total metals exceeded the RBCs in IT-MW05, only manganese exceeded the RBC in the dissolved phase indicating that the remaining RBC exceedances were due to suspended solids in the unfiltered sample. The three PB-PR-series wells exhibited a larger suite of dissolved metals with concentrations well above the RBCs. Dissolved cobalt, copper, iron, manganese, and nickel each surpassed the RBCs in PB-PR-MW07 and PB-PR-MW08. PB-PR-MW09 exhibited dissolved cobalt, copper, manganese, and nickel at concentrations above the RBCs, but these concentrations were well below those observed in PB-PR-MW07 and PB-PR-MW08. Cyanide was again detected at concentrations above the RBC in each of the three PB-PR-series wells.

Water quality parameters are also presented on Table 6-6. Nitrate exceeded the RBC in PB-PR-MW07, PB-PR-MW08, and PB-PR-MW09.

6.2.1.2.3 Summary of Sampling Events

Results from the two sampling events at the PRRWP area indicate that the overburden water-bearing zone has been impacted by VOCs, SVOCs, and nitroaromatic explosives near the former Red Water Ponds. Cyanide has also impacted groundwater in the PB-PR-series wells, two of which (PB-PR-MW07 and –MW08) are also noted for exhibiting red water. Metals have exceeded the RBCs, and detected concentrations in the PB-PR-series wells appear elevated and are considered to be due to site contamination.

6.2.1.3 TNT Manufacturing Area A

Five overburden monitoring wells were sampled during the two semi-annual sampling events at TNT Area A (TNTA) as shown in Figure 6-20. These wells include MK-MW22, MK-MW23, MK-MW24, PB-TNTA-MW10 and PB-TNTA-MW11. All wells were analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.3.1 First Semi-Annual Sampling Event

Two VOCs (acetone and carbon disulfide) were detected in MK-MW23 in November 1997 while only acetone was detected in PB-TNTA-MW10; however, none of the detected VOCs exceeded the RBCs (Table 6-7). One SVOC (di-n-octyl phthalate) was detected in MK-MW23 but at a concentration below the RBC; the remaining four wells did not exhibit detectable concentrations of SVOCs in November 1997.

Only one of the sampled TNTA wells (MK-MW22) exhibited detectable concentrations of nitroaromatic compounds (Table 6-7). Of the five detected explosive constituents in downgradient well MK-MW22, only 4-amino-2,6-DNT exceeded the RBC.
Several metals were detected in each of the five sampled wells at TNTA in November 1997 (Table 6-7). Although up to eight total metals exceeded the respective RBCs, only arsenic, barium, iron, manganese, and vanadium were detected at concentrations above the RBCs in the filtered samples. Dissolved manganese exceeded the RBC in each of the sampled wells, dissolved iron in MK-MW24 and PB-TNTA-MW10, dissolved arsenic in MK-MW23 only, dissolved barium in PB-TNTA-MW10 only, and dissolved vanadium in MK-MW24 only. Cyanide was not detected in any of the overburden wells sampled at TNTA.

Water quality parameters are also presented on Table 6-7; however, none of the detected parameters exceeded RBCs.

6.2.1.3.2 Second Semi-Annual Sampling Event

VOCs, including acetone, carbon disulfide, and toluene, were detected in four of the sampled wells in May 1998; VOCs were not detected in PB-TNTA-MW11. None of the detected VOCs exceeded the RBCs (Table 6-7). One SVOC (bis(2-ethylhexyl)phthalate) was detected in MK-MW23 at a concentration well above the RBC; consistent with the November sampling event, the remaining four wells did not exhibit detectable concentrations of SVOCs in May 1998.

Only one of the sampled TNTA wells (MK-MW22) exhibited detectable concentrations of nitroaromatic compounds (Table 6-7). Of the six detected explosive constituents in MK-MW22, only 4-amino-2,6-DNT exceeded the RBC.

Several metals were detected in each of the five sampled wells at TNTA in May 1998 (Table 6-7). Although up to eleven total metals (MK-MW23) exceeded the respective RBCs, only iron and manganese were detected at concentrations above the RBCs in the filtered samples. Dissolved manganese exceeded the RBC in each of the sampled wells, while dissolved iron exceeded the RBC in MK-MW24 and PB-TNTA-MW10 only. Cyanide was not detected in any of the overburden wells sampled at TNTA in May 1998.

Water quality parameters are also presented on Table 6-7; however, none of the detected parameters exceeded RBCs. Well MK-MW23 was not analyzed for water quality parameters because of an insufficient water volume.

6.2.1.3.3 Summary of Sampling Events

Results from the two sampling events at TNTA indicate that the overburden water-bearing zone has been impacted by nitroaromatic explosives at MK-MW22 and SVOCs at MK-MW23, located downgradient and sidegradient, respectively, of TNTA. Metals have exceeded RBCs, but dissolved RBC exceedances are limited to arsenic, barium, iron, manganese, and vanadium. Further evaluation is needed to determine whether these inorganic constituents are due to site contamination.

6.2.1.4 TNT Manufacturing Area B

Two overburden monitoring wells (MK-MW16 and MK-MW17) were sampled during the two semi-annual sampling events at TNT Area B (TNTB) as shown in Figure 6-21. Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.4.1 First Semi-Annual Sampling Event

VOCs were not detected in the two TNTB overburden wells in November 1997. One SVOC (bis(2-ethylhexyl)phthalate) was detected in MK-MW16 but at a concentration below the RBC; the remaining well did not exhibit detectable concentrations of SVOCs in November 1997 (Table 6-8).

Only one of the sampled TNTB wells (MK-MW17) exhibited detectable concentrations of nitroaromatic compounds (Table 6-8). One nitroaromatic compound, 4-amino-2,6-DNT, was detected and exceeded the RBC. MK-MW17 is located north and downgradient of TNTB.

Of the detected metals in the two TNTB wells, total aluminum, arsenic, iron, manganese, and nickel were present at concentrations above the RBCs in at least one of the two wells. In the dissolved phase, iron and manganese exceeded the RBCs in MK-MW16 and iron, manganese, and nickel exceeded the RBCs in MK-MW17 (Table 6-8). Cyanide was not detected in any of the overburden wells sampled at TNTB.

Water quality parameters are also presented on Table 6-8; however, none of the detected parameters exceeded RBCs.

6.2.1.4.2 Second Semi-Annual Sampling Event

One VOC (acetone) was detected in MK-MW16 in May 1998 but at a concentration below the RBC; VOCs were not detected in MK-MW17 (Table 6-8). One SVOC (2,4-DNT) was detected in MK-MW17 at a concentration below the RBC; MK-MW16 did not exhibit detectable concentrations of SVOCs in May 1998.

Only one of the sampled TNTB wells (MK-MW17) exhibited detectable concentrations of nitroaromatic compounds (Table 6-8). Of the three detected explosive constituents in MK-MW17, only 4-amino-2,6-DNT exceeded the RBC.

Of the detected metals in the two TNTB wells, total aluminum, arsenic, iron, lead, manganese, and nickel were present at concentrations above the RBCs in at least one of the two wells. In the dissolved phase, iron, manganese, and nickel exceeded the RBCs in MK-MW16, while aluminum, arsenic, iron, lead, manganese, and nickel exceeded the RBCs MK-MW17 (Table 6-8). Cyanide was not detected in any of the overburden wells sampled at TNTB.

Water quality parameters are also presented on Table 6-8; however, none of the detected parameters exceeded RBCs.

6.2.1.4.3 Summary of Sampling Events

Results from the two sampling events at TNTB indicate that the overburden water-bearing zone exhibits limited impacts from nitroaromatic explosives at MK-MW17, located north and downgradient of TNTB. Metals have also exceeded RBCs, but further evaluation is needed to determine whether these inorganic constituents are due to site contamination.

6.2.1.5 TNT Manufacturing Area C

Six overburden monitoring wells (IT-MW09, MK-MW12, PB-TNTC-MW03, PB-TNTC-MW04, PB-TNTC-MW05, and PB-TNTC-MW06) were sampled during the two semi-annual sampling events in the vicinity of TNTC as shown on Figure 6-22. Note that MK-MW12 is located several thousand feet northwest and downgradient of TNTC and may be more appropriately considered a background well; however, it is included here due to its geographic location. Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.5.1 First Semi-Annual Sampling Event

One VOC (chlorobenzene) was detected in IT-MW09 during the November 1997 sampling event at a concentration well below the RBC; VOCs were not detected in the remaining five TNTC wells. One SVOC (bis(2-ethylhexyl)phthalate) was detected in MK-MW12 and PB-TNTC-MW06 at concentrations above the RBC; the remaining wells did not exhibit detectable concentrations of SVOCs in November 1997 (Table 6-9). Explosives were not detected in any of the six TNTC overburden wells in November 1997.

Several total (unfiltered) metals were detected in the five TNTC overburden wells (Table 6-9). Of these, six (aluminum, arsenic, chromium, iron, manganese, and nickel) exceeded the RBC in at least one of the sampled wells. However, in the dissolved phase (filtered samples), manganese exceeded the RBC in each well, nickel exceeded the RBC in PB-TNTC-MW03, and iron exceeded the RBC in PB-TNTC-MW06.

Water quality parameters are also presented on Table 6-9. Nitrate exceeded the RBC in IT-MW09 and PB-TNTC-MW04.

6.2.1.5.2 Second Semi-Annual Sampling Event

Two VOCs (benzene and toluene) were detected at concentrations below the RBC in IT-MW09 during the May 1998 sampling event. Toluene was also detected below the RBC in PB-TNTC-MW06. SVOCs and nitroaromatic compounds were not detected in the five sampled wells in May 1998.

Of the detected metals in the five TNTC wells, total aluminum, arsenic, chromium, iron, lead, and manganese were present at concentrations above the RBCs in at least one of the two wells. However, in the dissolved phase, only manganese exceeded the RBCs; none of the dissolved metals detected in IT-MW09 exceeded RBCs (Table 6-9). Cyanide was not detected in any of the overburden wells sampled at TNTC.

Water quality parameters are also presented on Table 6-9; however, none of the detected parameters exceeded the RBCs during the May 1998 sampling event.

6.2.1.5.3 Summary of Sampling Events

Results from the two sampling events at TNTC indicate that the overburden water-bearing zone has not significantly been impacted by past site activities. Although low levels of VOCs were detected, these detections were limited to two wells and were sporadic in nature. Similarly, only one SVOC (bis[2-ethylhexyl]phthalate) was detected and only in two wells. A limited number of metals exceeded RBCs, but further evaluation is needed to determine whether these inorganic constituents are due to site contamination.

6.2.1.6 Acid Areas and Maintenance Shop Area

Six overburden monitoring wells were sampled during the two semi-annual sampling events in the vicinity of three acid areas. Of these, one (IT-AA1-GW002) is located at AA1 as shown on Figure 6-23, three (MK-MW09, MK-MW10, and MK-MW11) are located at AA2 as shown on Figure 6-24, one (IT-AA3-GW002) is located at AA3 as shown on Figure 6-25, and one (MK-MW19) is located in the Maintenance Shop Area (MNTA) north of AA1 (Figure 6-23). Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.6.1 First Semi-Annual Sampling Event

At AA1 (IT-AA1-GW002), detected parameters were limited to total and dissolved metals (Table 6-10). Of these constituents, only total and dissolved iron, and manganese were detected at concentrations exceeding RBCs. VOCs, SVOCs, cyanide, and explosives were not detected at AA1.

Of the three sampled wells at AA2, only MK-MW10 and MK-MW11 exhibited detected constituents above RBCs. In MK-MW10, one SVOC (bis[2-ethylhexyl]phthalate) and two total metals (iron and manganese) exceeded RBCs; however, dissolved metals did not exceed RBCs indicating that the total metals exceeding RBCs are due to suspended solids. In MK-MW11, one VOC (carbon disulfide) was detected at a concentration below the RBC, while three total metals (aluminum, iron, and manganese) exceeded the RBCs. However, dissolved metals were not detected in MK-MW11, indicating that the total metals were due to suspended solids in the unfiltered sample. Explosives and cyanide were not detected in the three wells at AA2.

VOCs, SVOCs, cyanide, and nitroaromatic compounds were not detected at AA3. Six of eight detected total metals exceeded the respective RBCs in IT-AA3-GW002, including aluminum, arsenic, chromium, iron, lead, and manganese (Table 6-10). However, in the dissolved phase only manganese exceeded the RBC, indicating that the other total metals were due to suspended solids.

Monitoring well MK-MW19, located at MNTA, exhibited detectable concentrations of VOCs and metals during the November 1997 sampling event. Of these detections, only two VOCs (1,1,1-trichloroethane [TCA]and 1,1-dichloroethene [DCE]) were detected at concentrations exceeding the respective RBCs (Table 6-10).

Water quality parameters for the wells sampled at the three acid areas and the MNTA are also presented on Table 6-10.

6.2.1.6.2 Second Semi-Annual Sampling Event

During the May 1998 sampling event, IT-AA1-GW002 (AA1) exhibited one VOC (carbon disulfide) and metals (Table 6-10). Of these detections, only total and dissolved iron and manganese were detected at concentrations exceeding the respective RBCs. SVOCs, cyanide, and explosives were not detected at AA1.

As with the November 1997 sampling event, only MK-MW10 and MK-MW11 exhibited detected constituents above RBCs at AA2 in May 1998. MK-MW10 exhibited one VOC (chloroform) at a concentration exceeding the RBC; the only other detected constituent (dissolved iron) did not exceed the RBC. In MK-MW11, three total metals (aluminum, iron, and manganese) exceeded the RBCs, but dissolved metals were not detected, indicating that the total metals were due to suspended solids in the unfiltered sample. Explosives, cyanide, and SVOCs were not detected in the three wells at AA2 in May 1998.

Consistent with the first sampling event, VOCs, SVOCs, cyanide, and nitroaromatic compounds were not detected in IT-AA3-GW002 (AA3) in May 1998. One metal (manganese) was detected in the filtered and unfiltered samples at similar concentrations exceeding the RBC (Table 6-10).

At the MNTA, MK-MW19 again exhibited detectable concentrations of VOCs and metals during the May 1998 sampling event. However, only one VOC (1,1-DCE) exceeded the RBC while seven total metals exceeded their respective RBCs. Two dissolved metals were detected (lead and manganese) at concentrations below the respective RBCs (Table 6-10), indicating that the total metals exceeding RBCs were due to suspended solids in the unfiltered sample.

Water quality parameters from the May 1998 sampling event for the wells sampled at the three acid areas and the MNTA are also presented on Table 6-10.

6.2.1.6.3 Summary of Sampling Events

Results from the two sampling events at AA1 suggest that the overburden water-bearing zone has not been significantly impacted by past site activities. Two dissolved metals (iron and manganese) have exceeded the RBCs at concentrations that appear to be elevated in comparison to metals detected in other areas of PBOW. Therefore, metals in the overburden water-bearing zone at AA1 warrant additional evaluation.

Overburden groundwater at AA2 exhibits limited VOC and SVOC contaminants in one well (MK-MW10) located downgradient of the site. However, these detections have been sporadic and further study is needed to determine whether these constituents are site related. While several total metals have exceeded RBCs, the lack of RBC exceedances in the dissolved phase indicates that these metals are due to suspended solids and are not considered site contaminants.

Results from the sampling events at AA3 indicate that the overburden water-bearing zone has not been impacted by past site activities. Only one inorganic constituent (manganese) has exceeded the RBC in the dissolved phase; however, concentrations have been low compared to other PBOW areas and manganese is not believed to be a site-related contaminant.

In the MNTA, the overburden water-bearing zone exhibits impacts from VOCs likely due to past site activities. Dissolved metals have not exceeded RBCs and metals are, therefore, not considered site-related contaminants.

6.2.1.7 Burning Ground Areas

Five overburden monitoring wells were sampled during the two semi-annual sampling events in the vicinity of two former burning grounds areas. Of these, one (IT-ABG-GW002) is located at the ABG (Figure 6-26) and four (GCL-MW01, GCL-MW02A, GCL-MW02B, and GCL-MW03) are located near Snake Road Burning Ground (Figure 6-27). Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.7.1 First Semi-Annual Sampling Event

Groundwater in the overburden water-bearing zone at the ABG exhibited detectable concentrations of VOCs and metals in November 1997; SVOCs, cyanide, and explosives were not detected (Table 6-11). Of the detected VOCs, only benzene was detected at a concentration exceeding the RBC. Although ten total metals exceeded the respective RBCs, only two dissolved metals (iron and manganese) exceeded the RBCs, indicating that the total metals exceedances are due to suspended solids.

At the Snake Road Burning Ground Area, GCL-MW02A exhibited one detected VOC (carbon disulfide) at a concentration well below the RBC (Table 6-11). SVOCs were detected in two wells; bis(2-ethylhexyl)phthalate exceeded the RBC in GCL-MW01 while diethyl phthalate was detected at a concentration well below the RBC in GCL-MW02B. Explosives and cyanide were not detected in any of the four sampled GCL-series wells.

Up to ten total metals were detected in at least one of the four GCL-series wells, of which up to seven exceeded the respective RBCs (Table 6-11). However, only two dissolved (filtered samples) inorganic constituents were detected at concentrations above the RBC indicating that most of the total metals were due to suspended solids. Dissolved manganese exceeded the RBC in each of the four wells while dissolved iron was detected in each well but exceeded the RBC only in GCL-MW01 and GCL-MW02B.

Water quality parameters for the sampled burning grounds wells are also shown on Table 6-11; however, none of these parameters exceeded RBCs.

6.2.1.7.2 Second Semi-Annual Sampling Event

During the May 1998 sampling event, IT-ABG-GW002 (ABG) again exhibited one VOC (benzene) at a concentration exceeding the RBC (Table 6-11); SVOCs, cyanide, and explosives were not detected. Comparable to the November 1997 sampling event, a suite of nine total metals exceeded the RBCs in this well in May 1998. However, only two dissolved metals were detected, indicating that most total metals exceeding the RBCs were due to suspended solids. In the dissolved phase, iron and manganese again exceeded the RBCs during the May 1998 sampling event.

Each of the four GCL-series wells exhibited detectable concentrations of VOCs in May 1998, but none of the detected concentrations exceeded RBCs. SVOCs were detected in only one well

(GCL-MW03); however, the detected concentration of phenol was well below the RBC (Table 6-11). Cyanide and explosives were not detected in any of the Snake Road Burning Ground Area wells in May 1998.

As with the November 1997 sampling event, several total metals were detected at concentrations exceeding the RBCs in the GCL-series wells in May 1998 (Table 6-11). However, filtered samples from these wells indicated the presence of only two dissolved metals at concentrations exceeding the RBCs. Dissolved manganese exceeded the RBC in each of the four wells, and while dissolved iron was detected in each well it exceeded the RBC in only three of the four wells (excluding GCL-MW02A).

Water quality parameters from the May 1998 sampling event for the wells sampled at the burning grounds are also presented on Table 6-11.

6.2.1.7.3 Summary of Sampling Events

Results from the two sampling events at the ABG suggest that the overburden water-bearing zone has been impacted to a limited extent by VOCs (benzene) at concentrations slightly above the RBCs. Two dissolved metals (iron and manganese) have exceeded the RBCs at concentrations that appear to be consistent with those observed in other areas of PBOW. Therefore, these RBC exceedances are suspected to be naturally occurring but will require further evaluation.

Overburden groundwater at the Snake Road Burning Ground Area exhibits limited impacts by VOCs and SVOCs, generally at concentrations below the RBCs. However, these constituents have been detected sporadically over the two sampling events and further study is warranted to determine whether they are due to site contamination. As with the ABG results, only two dissolved metals (iron and manganese) have exceeded RBCs but at concentrations comparable to those in other areas of PBOW.

6.2.1.8 Lower Toluene Tanks Area

Two overburden monitoring wells (MK-MW14 and MK-MW15) were sampled during the two semi-annual sampling events in the vicinity of the lower toluene tanks area (Figure 6-30). Note that these wells were discussed in previous IT reports as part of TNT Area B. Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.8.1 First Semi-Annual Sampling Event

One VOC (carbon disulfide) and one SVOC (bis(2-ethylhexyl)phthalate) were detected in the two overburden water-bearing zone wells sampled at the lower toluene tanks area in November 1997. However, with the exception of bis(2-ethylhexyl)phthalate in MK-MW15, these detections were below the RBCs (Table 6-12). Explosives and cyanide were not detected in either well.

Up to five total metals were detected in the two wells during the November 1997 sampling event, of which two (iron and manganese) exceeded the RBCs in both wells (Table 6-12). These two metals also exceeded the RBCs in the dissolved phase at concentrations similar to those reported for the unfiltered sample, an indication that these metals are present primarily in the dissolved phase in the two wells.

Water quality parameters for the two wells sampled at the lower toluene tank area are also shown on Table 6-12; however, none of these parameters exceeded RBCs.

6.2.1.8.2 Second Semi-Annual Sampling Event

VOCs, SVOCs, and explosive compounds were not detected in the two lower toluene tank area wells during the May 1998 sampling event. Cyanide was detected in MK-MW14 but at a concentration below the RBC (Table 6-12). A suite of three total metals (aluminum, iron, and manganese) exceeded the RBCs in both wells in May 1998. However, only two dissolved metals were detected in the two wells (iron and manganese), and exceeded the RBCs only in MK-MW14. Detected concentrations of these dissolved metals in MK-MW15 were significantly lower than those observed during the November 1997 sampling event.

Water quality parameters from the May 1998 sampling event for the wells sampled at the lower toluene tanks area are also presented on Table 6-12.

6.2.1.8.3 Summary of Sampling Events

Analytical results from the two sampling events at the lower toluene tanks area indicates that the overburden water-bearing zone has not been impacted by past site activities. Two dissolved metals (iron and manganese) have exceeded the RBCs at concentrations that appear to be consistent with those observed in other areas of PBOW. Therefore, these RBC exceedances are suspected to be naturally occurring but will require further evaluation.

6.2.1.9 Upper Toluene Tanks Area

One monitoring well (MK-MW20) has been sampled during the two semi-annual sampling events at the upper toluene tanks area (Figure 6-29). This well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.9.1 First Semi-Annual Sampling Event

One VOC (toluene) and three SVOCs (2-methylphenol, 4-methylphenol, and bis(2-ethylhexyl)phthalate) were detected at concentrations well above the respective RBCs in the overburden water-bearing zone well at the upper toluene tanks area in November 1997 (Table 6-13). In addition, phenol was detected in MK-MW20 at a concentration well below the RBC. Explosives and cyanide were not detected in the sampled well.

Seven total metals were detected in MK-MW20 at concentrations exceeding the RBCs during the November 1997 sampling event (Table 6-13). However, only two metals (iron and manganese) were detected in the dissolved phase, neither of which exceeded the RBC; this indicates that the total metals exceedances were due to suspended solids in the unfiltered sample.

Water quality parameters for MK-MW20 are also shown on Table 6-13.

6.2.1.9.2 Second Semi-Annual Sampling Event

Confirming results from the November 1997 sampling event, one VOC (toluene) and two SVOCs (2-methylphenol and 4-methylphenol) were detected at concentrations above the RBCs in MK-MW20 during the May 1998 sampling event (Table 6-13). Phenol was also detected, but again at a concentration below the RBC. Explosive compounds and cyanide were not detected. Two total and dissolved metals (iron and manganese) were also detected at concentrations exceeding the RBCs (Table 6-13).

Water quality parameters from the May 1998 sampling event for the well sampled at the upper toluene tanks area are also presented on Table 6-13.

6.2.1.9.3 Summary of Sampling Events

Analytical results from the two sampling events at the upper toluene tanks area indicates that the overburden water-bearing zone has been impacted by toluene and SVOCs from past site activities. Two dissolved metals (iron and manganese) have exceeded the RBCs at concentrations that appear to be consistent with those observed in other areas of PBOW. It should be noted that although these dissolved metals did not exceed the RBCs in November 1997, the reported concentrations for the two sampling events are comparable and are slightly below or slightly above the RBCs, respectively (Table 6-13). These inorganic RBC exceedances are suspected to be naturally occurring but will require further evaluation.

6.2.1.10 Reactor Building Area

One monitoring well (IT-MW06) has been sampled during the two semi-annual sampling events near the Reactor Building (Figure 6-31). This well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.1.10.1 First Semi-Annual Sampling Event

One VOC (toluene) was detected in IT-MW06 in November 1997, but at a concentration well below the RBC (Table 6-14). SVOCs, cyanide, and explosives were not detected.

Two total metals (iron and manganese) were detected at concentrations exceeding the RBCs during the November 1997 sampling event (Table 6-14). However, neither metal was detected in the dissolved phase, indicating that the total metals exceedances were due to suspended solids in the unfiltered sample.

Water quality parameters for IT-MW06 are also shown on Table 6-14.

6.2.1.10.2 Second Semi-Annual Sampling Event

VOCs, SVOCs, explosive compounds, and cyanide were not detected in IT-MW06 during the May 1998 sampling event. Two total metals (iron and manganese) were detected at concentrations exceeding the RBCs (Table 6-14); however, none of the detected dissolved metals exceeded the RBCs.

Water quality parameters from the May 1998 sampling event for IT-MW06 near the Reactor Building are also presented on Table 6-14.

6.2.1.10.3 Summary of Sampling Events

Analytical results from the two sampling events at the Reactor Building indicates that the overburden water-bearing zone in this area has not been impacted by past site activities.

6.2.2 Bedrock Water-Bearing Zone

A total of 17 bedrock wells were sampled under the annual GWI. Specific locations of these wells are as follows:

- One at the WARWP Area
- One at the PRRWP Area
- Two at TNTA
- Two at TNTB
- One at TNTC
- Two at AA1
- Two at AA2
- One at AA3
- Two at various Burning Grounds
- One at the Upper Toluene Tank Area
- One at the Reactor Facility
- One upgradient of the PBOW (background).

Note that results from sampling of the upgradient background well are included in background wells, Section 6.2.3.

6.2.2.1 West Area Red Water Ponds Area

One bedrock monitoring well (PB-BED-MW14) was sampled during the two semi-annual sampling events at the WARWP at the locations shown on Figure 6-18. This well is located northeast and downgradient of the former Red Water Ponds, and was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.1.1 First Semi-Annual Sampling Event

Four VOCs (benzene, carbon disulfide, ethyl benzene, and total xylenes) were detected in PB-BED-MW14 in November 1997. Of these detected VOCs, only benzene exceeded the RBC (Table 6-15). SVOCs and explosives were not detected in this well in November 1997.

Several metals (total and dissolved) were detected in PB-BED-MW14 but none exceeded the respective RBCs (Table 6-15). Similarly, cyanide was detected but at a concentration below the RBC. Water quality parameters are also presented on Table 6-15.

6.2.2.1.2 Second Semi-Annual Sampling Event

One VOC (carbon disulfide) was detected in PB-BED-MW14 during the May 1998 sampling event, but at a concentration well below the RBC (Table 6-15). However, four SVOCs (2,4-dinitrophenol, 2,4-DNT, 4,6-dinitro-2-methylphenol, and nitrobenzene) were detected at concentrations in excess of calculated RBCs. These explosive compounds were not detected under the nitroaromatic analysis.

As observed during the November 1997 sampling event, several metals (total and dissolved) were detected in PB-BED-MW14 in May 1998 but none exceeded the respective RBCs (Table 6-15). Cyanide was again detected but at a concentration below the RBC. Water quality parameters are also presented on Table 6-15; nitrate exceeded the RBC during the May 1998 sampling event.

6.2.2.1.3 Summary of Sampling Events

Results from the two sampling events at the WARWP area indicate that the bedrock water-bearing zone exhibits impacts from low levels of VOCs, primarily BTEX constituents. Nitroaromatic explosives also appear to have impacted the bedrock water-bearing zone based on the May 1998 SVOC sample results.

6.2.2.2 Pentolite Road Red Water Ponds Area

One bedrock monitoring well (PB-BED-MW15) was sampled during the two semi-annual sampling events at PRRWP (Figure 6-19). This well is located north and downgradient of the former red water ponds and was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.2.1 First Semi-Annual Sampling Event

The four BTEX constituents were detected in PB-BED-MW15 in November 1997, including benzene, ethyl benzene, and toluene at concentrations exceeding the RBCs (Table 6-16). Ten SVOCs were also detected, but only bis(2-ethylhexyl)phthalate exceeded the RBC. Explosives and cyanide were not detected in PB-BED-MW15 in November 1997. Of the detected total and dissolved metals, only barium (total and dissolved) exceeded the RBC (Table 6-16). Water quality parameters are also presented on Table 6-16.

6.2.2.2.2 Second Semi-Annual Sampling Event

VOCs, including BTEX, 1,1,2-TCA, and chlorobenzene, were detected in PB-BED-MW15 during the May 1998 sampling event (Table 6-16). Of these, 1,1,2-TCA, benzene, chlorobenzene, ethyl benzene, and toluene exceeded the respective RBCs. Eight SVOCs were also detected in PB-BED-MW15 in May 1998, but none exceeded the RBCs. Two explosives (2,4-DNT and 2,6-DNT) were detected at concentrations well below the RBCs. Cyanide was not detected in this well in May 1998.

Several total metals, including five (barium, chromium, iron, manganese, and thallium) exceeding RBCs, were detected in PB-BED-MW15 in May 1998 (Table 6-16). However, in the dissolved phase, only barium and thallium were detected at concentrations exceeding the RBCs. Water quality parameters for PB-BED-MW15 are also presented on Table 6-16.

6.2.2.2.3 Summary of Sampling Events

Results from the two sampling events at the PRRWP area indicate that the bedrock water-bearing zone has been impacted by VOCs and bis(2-ethylhexyl)phthalate near the former Red Water Ponds. Metals have also exceeded the RBCs, but detected concentrations require further evaluation to determine whether they are due to site contamination.

6.2.2.3 TNT Manufacturing Area A

Two bedrock monitoring wells (PB-BED-MW17 and PB-BED-MW18) were sampled during the two semi-annual sampling events at TNTA (Figure 6-20). PB-BED-MW17 is located north and downgradient of TNTA, while PB-BED-MW18 east and sidegradient of TNTA. Both wells were analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide. and water quality parameters as previously discussed.

6.2.2.3.1 First Semi-Annual Sampling Event

VOCs, including BTEX and carbon disulfide, were detected in both PB-BED-MW17 and PB-BED-MW18 in November 1997. Of these detected VOCs, benzene exceeded the RBC in both wells, while toluene exceeded the RBC only in PB-BED-MW17 (Table 6-17). Several SVOCs were detected in PB-BED-MW18 but at concentrations below the RBCs; PB-BED-MW17 did not exhibit detectable concentrations of SVOCs in November 1997.

Both of the sampled TNTA bedrock wells exhibited detectable concentrations of nitroaromatic compounds (Table 6-17). Of the three detected explosive constituents in downgradient well PB-

BED-MW18, only 1,3-DNB and nitrobenzene exceeded the RBCs. In PB-BED-MW17, nitrobenzene was detected but at a concentration below the RBC.

Several metals were detected in each of the TNTA bedrock wells in November 1997 (Table 6-17). Although three total metals exceeded the respective RBCs in PB-BED-MW17, only barium was detected at a concentration above the RBC in the filtered sample. In PB-BED-MW18, RBCs were exceeded only by total and dissolved barium. Cyanide was only detected in PB-BED-MW17 but at a concentration well above the RBC.

Water quality parameters are also presented on Table 6-17; however, none of the detected parameters exceeded RBCs.

6.2.2.3.2 Second Semi-Annual Sampling Event

VOCs, including BTEX, acetone, and carbon disulfide were detected in at least one of the two bedrock wells in May 1998. None of the VOCs detected in PB-BED-MW17 exceeded the RBCs, while benzene exceeded the RBC in PB-BED-MW18 (Table 6-17). Several SVOCs were also detected in the two bedrock wells, but at concentrations below the RBCs. Only one of the sampled TNTA wells (PB-BED-MW18) exhibited detectable concentrations of nitroaromatic compounds (Table 6-17); however, neither detected explosive compound exceeded the RBC.

Several metals were detected in each of the sampled bedrock wells at TNTA in May 1998 (Table 6-17). Three total metals were detected in both wells, with barium exceeding the RBC in each case and manganese exceeding the RBC in PB-BED-MW18. In the dissolved phase, arsenic and barium exceeded the RBC in PB-BED-MW17 while barium and manganese exceeded the RBC in PB-BED-MW18. Cyanide was not detected in either bedrock well sampled at TNTA in May 1998. Water quality parameters are also presented on Table 6-17; however, none of the detected parameters exceeded RBCs.

6.2.2.3.3 Summary of Sampling Events

Based on results from the two sampling events at TNTA, the bedrock water-bearing zone exhibits impacts from VOCs, SVOCs, and nitroaromatic explosives. Metals have exceeded RBCs, but dissolved RBC exceedances are limited to arsenic, barium, and manganese. Further evaluation is needed to determine whether these inorganic constituents are due to site contamination.

6.2.2.4 TNT Manufacturing Area B

Two bedrock monitoring wells (IT-TNTB-BED-GW001 and IT-TNTB-BED-GW002) were sampled during the two semi-annual sampling events at TNTB (Figure 6-21). IT-TNTB-BED-GW001 is located northwest and downgradient of TNTB while IT-TNTB-BED-GW002 is located south and upgradient of the site. Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.4.1 First Semi-Annual Sampling Event

VOCs and SVOCs were detected in both bedrock wells sampled at TNTB in November 1997 (Table 6-18). However, of these detected constituents, only one VOC (benzene) was detected at a concentration above the RBC and only in the upgradient well, IT-TNTB-BED-GW002. Explosives and cyanide were not detected in either well.

IT-TNTB-BED-GW001 exhibited detectable concentrations of seven total metals, of which only iron and manganese exceeded the RBC (Table 6-18). In the dissolved phase, only iron and manganese were detected, exceeding the RBCs for each. Six total metals were detected in IT-TNTB-GW002 of which barium and manganese exceeded the RBCs. The filtered sample exhibited four dissolved metals, of which only barium exceeded the RBC. Water quality parameters are also presented on Table 6-18; however, none of the detected parameters exceeded RBCs.

6.2.2.4.2 Second Semi-Annual Sampling Event

Two VOCs (1,1-dichloroethane [DCA] and carbon disulfide) were detected in IT-TNTB-BED-GW001 in May 1998 but at concentrations below the RBCs; VOCs were not detected in IT-TNTB-BED-GW002 (Table 6-18). SVOCs, explosives, and cyanide were not detected in the two TNTB bedrock wells in May 1998.

IT-TNTB-BED-GW001 exhibited detectable concentrations of eight total metals of which arsenic, barium, iron, and manganese exceeded the RBCs (Table 6-18). However, of three detected dissolved metals, only barium and manganese exceeded the RBCs. Four total metals were detected in IT-TNTB-GW002, of which only barium exceeded the RBCs. The filtered sample exhibited two dissolved metals, of which only barium exceeded the RBC.

Water quality parameters are also presented on Table 6-18; however, none of the detected parameters exceeded RBCs.

6.2.2.4.3 Summary of Sampling Events

Results from the two sampling events at TNTB indicate that the bedrock water-bearing zone exhibits limited impacts from organic constituents at concentrations generally below the RBCs. Metals have also exceeded RBCs, but further evaluation is needed to determine whether these inorganic constituents are due to site contamination.

6.2.2.5 TNT Manufacturing Area C

One bedrock monitoring well (PB-BED-MW13) has been sampled during the two semi-annual sampling events near TNTC (Figure 6-22). PB-BED-MW13 is located on the north side and downgradient of TNTC and was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.5.1 First Semi-Annual Sampling Event

Five VOCs (BTEX and carbon disulfide) were detected in PB-BED-MW13 during the November 1997 sampling event; of these detections, benzene and toluene exceeded the respective RBCs (Table 6-19). A suite of seven SVOCs was also detected in this well, but only one (bis(2-ethylhexyl)phthalate) exceeded the RBCs. Explosives and cyanide were not detected in the TNTC bedrock well in November 1997.

Three total metals (barium, manganese, and zinc) were detected in PB-BED-MW13 in November 1997 (Table 6-19). Of these, only barium exceeded the RBC. In the dissolved phase (filtered samples), barium again exceeded the RBC while zinc was detected at a concentration well below the RBC. Water quality parameters are also presented on Table 6-19.

6.2.2.5.2 Second Semi-Annual Sampling Event

Four VOCs (BTEX) were detected in PB-BED-MW13 during the May 1998 sampling event (Table 6-19). Of these VOCs, benzene and toluene exhibited concentrations above the RBCs. Similar to the November results, eight SVOCs were detected in this bedrock well in May 1998; however, bis(2-ethylhexyl)phthalate was the only SVOC detected at concentrations above the RBCs. Nitroaromatic compounds and cyanide were not detected in PB-BED-MW13 in May 1998.

Two total metals (iron and manganese) and two dissolved metals (barium and manganese) were detected in PB-BED-MW13 in May 1998 (Table 6-19). However, none of these inorganic constituents were present at concentrations exceeding the RBCs. Water quality parameters are also presented on Table 6-19.

6.2.2.5.3 Summary of Sampling Events

Based on results from the two sampling events at TNTC, the bedrock water-bearing zone exhibits impacts by organic constituents, of which benzene, toluene, and bis(2-ethylhexyl)phthalate have exceeded RBCs. One metal (barium) also exceeded the RBC, but further evaluation is needed to determine whether this inorganic constituent is due to site contamination.

6.2.2.6 Acid Areas and Maintenance Shop Area

Five bedrock monitoring wells were sampled during the two semi-annual sampling events in the vicinity of three acid areas. Of these, one (IT-AA1-BED-GW001) is located at AA1 (Figure 6-23), two (IT-AA2-BED-GW001 and PB-BED-MW19) are located at AA2 (Figure 6-24), one (IT-AA3-BED-GW001) is located at AA3 (Figure 6-25), and one (IT-MNTA-BED-GW001) is located in the MNTA north of AA1 (Figure 6-23). Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.6.1 First Semi-Annual Sampling Event

At AA1, IT-AA1-BED-GW001 exhibited detectable concentrations of VOCs and SVOCs during the November 1997 sampling event (Table 6-20). Of the detected organic parameters, benzene and bis(2-ethylhexyl)phthalate exceeded the RBCs. Explosives and cyanide were not detected in this well in November 1997. Several total and dissolved metals were also detected in IT-AA1-BED-GW001. Although four total metals (arsenic, barium, iron, and manganese) exceeded the RBCs, only two dissolved metals (barium and manganese) exceeded the RBCs (Table 6-20).

Both of the two sampled bedrock wells at AA2 exhibited detectable concentrations of VOCs and SVOCs during the November 1997 sampling event. In IT-AA2-BED-GW001, RBCs were exceeded by benzene and chlorobenzene, while PB-BED-MW19 exhibited benzene and bis(2-ethylhexyl)phthalate at concentrations above the RBCs. Nitroaromatic compounds were detected in PB-BED-MW19 but did not exceed the RBCs. Of the detected metals in IT-AA2-BED-GW001, only total iron, total manganese, and dissolved manganese were present at concentrations above the RBCs. In PB-BED-MW19, inorganic constituents exceeding the RBCs were limited to total and dissolved barium (Table 6-20). Cyanide was detected in PB-BED-MW19 but did not exceed the RBC.

Two VOCs and two SVOCs were detected in IT-AA3-BED-GW001; however, only bis(2-ethylhexyl)phthalate exceeded the RBCs. Explosives and cyanide were not detected in this well in November 1997. Detected inorganic constituents in IT-AA3-BED-GW001 were limited to total and dissolved manganese and zinc; of these, only total manganese exceeded the RBC (Table 6-20).

Monitoring well IT-MNTA-BED-GW001, located at MNTA, exhibited detectable concentrations of VOCs, SVOCs, and metals during the November 1997 sampling event. None of the detected VOCs and SVOCs exceeded RBCs (Table 6-20). Of the detected metals, barium (total and dissolved), iron (total), and manganese (total and dissolved) exceeded the RBCs.

Water quality parameters for the sampled bedrock wells at the three acid areas and the MNTA are also presented on Table 6-20.

6.2.2.6.2 Second Semi-Annual Sampling Event

During the May 1998 sampling event, IT-AA1-BED-GW001 exhibited detectable concentrations of VOCs, SVOCs, and explosives. Of these organic compounds, one VOC (benzene) and one explosive (RDX) exceeded the respective RBCs (Table 6-20). Five total metals and three dissolved metals were also detected in this well; four of the five total metals (arsenic, barium, iron, and manganese) and all of the dissolved metals (arsenic, barium, and manganese) exceeded the RBCs. Cyanide was not detected in IT-AA1-BED-GW001 in May 1998.

Both of the AA2 bedrock wells exhibited VOCs, SVOCs, and explosives during the May 1998 sampling event. In IT-AA2-BED-GW001, benzene and 1,3-DNB exceeded the RBCs, while only benzene exceeded the RBC in PB-BED-MW19 (Table 6-20). A large suite of nine total metals exceeded the RBCs in IT-AA2-BED-GW001 in May 1998; however, only barium and manganese exceeded the RBC in the dissolved phase, indicating that the total metals exceedances were due primarily to suspended solids in the unfiltered sample. In PB-BED-MW19, only total and dissolved barium exceeded the RBC. Cyanide was also detected in PB-BED-MW19 but did not exceed the RBC.

VOCs, SVOCs, cyanide, and nitroaromatic compounds were not detected in IT-AA3-BED-GW001 in May 1998. Three total metals and one dissolved metal were detected in this well, but RBC exceedances were limited to total manganese (Table 6-20).

At the MNTA, IT-MNTA-BED-GW001 again exhibited detectable concentrations of VOCs, SVOCs, and metals during the May 1998 sampling event. One VOC (benzene) exceeded the RBC while total and dissolved barium and manganese exceeded their respective RBCs. In addition, this well exhibited three explosive compounds in May 1998 of which 1,3-DNB exceeded the RBC (Table 6-20). Cyanide was not detected in IT-MNTA-BED-GW001 in May 1998.

Water quality parameters from the May 1998 sampling event for the wells sampled at the three acid areas and the MNTA are also presented on Table 6-20.

6.2.2.6.3 Summary of Sampling Events

Results from the two sampling events at AA1 indicate that the bedrock water-bearing zone has been impacted by low levels of VOCs, SVOCs, and explosives. It is suspected that BTEX constituents there may be related to the Middle Toluene Tanks Area located approximately 2,400 feet upgradient. Monitoring wells have not been installed at the Middle Toluene Tanks Area. Other organic constituents are likely due to past activities at AA1. Three dissolved metals (arsenic, barium, and manganese) have exceeded the RBCs, but at concentrations that appear to be similar to other areas of PBOW.

Bedrock groundwater at AA2 exhibits impacts by VOCs, SVOCs, and explosives, all of which are considered to be site related. While several metals have exceeded RBCs, further study is needed to determine whether these constituents are site related.

Results from the sampling events at AA3 indicate that the bedrock water-bearing zone has not been impacted by past site activities. Sporadic detections of low levels of VOCs and SVOCs are not considered site-related contaminants. None of the inorganic constituents have exceeded the RBCs in the dissolved phase and metals are not considered contaminants of concern at AA3.

In the MNTA, the bedrock water-bearing zone exhibits impacts from low levels of VOCs, SVOCs, and explosives. Two dissolved metals have exceeded RBCs and further study is needed to determine whether these constituents are site-related contaminants.

6.2.2.7 Burning Ground Areas

Two bedrock monitoring wells were sampled during the two semi-annual sampling events in the vicinity of two former burning grounds areas. Of these, one (IT-ABG-BED-GW001) is located at the ABG (Figure 6-26) and one (IT-BG8-BED-GW001) is located at the G-8 Burning Ground (BG8) (Figure 6-27). Each well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.7.1 First Semi-Annual Sampling Event

Groundwater in the bedrock water-bearing zone at the ABG exhibited detectable concentrations of VOCs and metals in November 1997; SVOCs, cyanide, and explosives were not detected (Table 6-21). The detected VOC (trichloroethene) did not exceed the RBC. Although four total metals exceeded the respective RBCs, only two dissolved metals (iron and manganese) exceeded the RBCs.

At the BG8, bedrock groundwater exhibited detectable levels of VOCs, SVOCs, and metals during the November 1997 sampling event. The detected VOC and SVOC constituents did not exceed RBCs. Explosives and cyanide were not detected in either sampled well. Nine total metals were detected in IT-BG8-BED-GW001 of which seven exceeded the respective RBCs (Table 6-21). However, only two dissolved inorganic constituents (barium and manganese) were detected at concentrations above the RBC, indicating that most of the total metals were due to suspended solids.

Water quality parameters for the sampled burning grounds wells are also shown on Table 6-21; however, none of these parameters exceeded RBCs in November 1997.

6.2.2.7.2 Second Semi-Annual Sampling Event

During the May 1998 sampling event, IT-ABG-BED-GW001 again exhibited one VOC (carbon disulfide) at a concentration below the RBC (Table 6-21); SVOCs, cyanide, and explosives were not detected. Three total metals (iron, lead, and manganese) exceeded the RBCs in this well in May 1998. However, only two dissolved metals exceeded the RBC (iron and manganese).

VOCs, SVOCs, explosives, and cyanide were not detected in IT-BG8-BED-GW001 during the May 1998 sampling event (Table 6-21). Two total metals (iron and manganese) were detected at concentrations exceeding the RBCs, but the filtered sample indicated the presence of only manganese at a concentration exceeding the RBC.

Water quality parameters from the May 1998 sampling event for the wells sampled at the burning grounds are also presented on Table 6-18. Of these parameters, one (nitrate) exceeded the RBC in IT-BG8-BED-GW001.

6.2.2.7.3 Summary of Sampling Events

Results from the two sampling events at the ABG and BG8 suggest that the bedrock water-bearing zone in these areas has not been impacted by past site activities. Three dissolved metals (barium, iron, and manganese) have exceeded the RBCs at concentrations that appear to be consistent with those observed in other areas of PBOW. Therefore, these RBC exceedances are suspected to be naturally occurring but will require further evaluation.

Because of its location and lack of contaminants, IT-BG8-BED-GW001 appears to be a potential background well.

6.2.2.8 Lower Toluene Tanks Area

Bedrock monitoring wells have not been installed in the lower toluene tanks area and this water-bearing zone has not been monitored under the GWI.

6.2.2.9 Upper Toluene Tanks Area

One bedrock monitoring well (PB-BED-MW16) has been sampled during the two semi-annual sampling events at the upper toluene tanks area (Figure 6-28). This well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.9.1 First Semi-Annual Sampling Event

Three VOCs (benzene, ethyl benzene, and toluene) and one SVOC (bis[2-ethylhexyl]phthalate) were detected at concentrations well above the respective RBCs in the bedrock water-bearing zone well at the upper toluene tanks area in November 1997 (Table 6-22). In addition, total xylene was detected in PB-BED-MW16 at a concentration slightly below the RBC. Explosives and cyanide were not detected in the sampled well.

Five total metals were detected in PB-BED-MW16 at concentrations exceeding the RBCs during the November 1997 sampling event (Table 6-22). However, only two metals (barium and vanadium) exceeded the RBC in the dissolved phase. Water quality parameters for PB-BED-MW16 are also shown on Table 6-22.

6.2.2.9.2 Second Semi-Annual Sampling Event

Confirming results from the November 1997 sampling event, three VOCs (benzene, ethyl benzene, and toluene) and one SVOC (1,3-dichlorobenzene) were detected at concentrations above the RBCs in PB-BED-MW16 during the May/June 1998 sampling event (Table 6-22). Total xylene was also detected, again at a concentration slightly below the RBC. Explosive compounds and cyanide were not detected. Eight total metals but only three dissolved metals (barium, thallium, and vanadium) exceeded the RBCs, indicating that most of the total metals were due to suspended solids in the unfiltered sample (Table 6-22).

Water quality parameters from the May/June 1998 sampling event for the bedrock well sampled at the upper toluene tanks area are also presented on Table 6-22.

6.2.2.9.3 Summary of Sampling Events

Analytical results from the two sampling events at the upper toluene tanks area indicates that the bedrock water-bearing zone has been impacted by BTEX and SVOCs from past site activities. Three dissolved metals (barium, thallium, and vanadium) have exceeded the RBCs. These inorganic RBC exceedances will require further evaluation to determine whether they are naturally occurring.

6.2.2.10 Reactor Building Area

One bedrock monitoring well (REACTOR 1) has been sampled during the two semi-annual sampling events near the Reactor Building (Figure 6-30). This well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.2.10.1 First Semi-Annual Sampling Event

Two VOCs (benzene and total xylene) were detected in REACTOR 1 in November 1997; benzene exceeded the RBC while total xylene was detected at a concentration well below the RBC (Table 6-23). One SVOC, bis(2-ethylhexyl)phthalate, was detected at a concentration well above the RBC. Cyanide and explosives were not detected.

Four total metals (barium, iron, lead, and manganese) were detected at concentrations exceeding the RBCs during the November 1997 sampling event (Table 6-23). However, only barium and manganese exceeded the RBCs in the filtered sample.

Water quality parameters for REACTOR 1 are also shown on Table 6-23.

6.2.2.10.2 Second Semi-Annual Sampling Event

Six VOCs were detected in REACTOR 1 during the May 1998 sampling event, with benzene exhibiting a concentration above the RBC (Table 6-23). SVOCs, explosive compounds, and cyanide were not detected. Two metals (iron and manganese) were detected at concentrations exceeding the RBCs in both total and dissolved phases (Table 6-23).

Water quality parameters from the May 1998 sampling event for REACTOR 1 are also presented on Table 6-23.

6.2.2.10.3 Summary of Sampling Events

Analytical results from the two sampling events at the Reactor Building indicates that the bedrock water-bearing zone in this area exhibits low levels of VOC and SVOC constituents, predominantly below the RBCs. Three dissolved metals (barium, iron, and manganese) have exceeded the RBCs at concentrations that appear to be consistent with those observed in other areas of PBOW. These inorganic RBC exceedances are suspected to be naturally occurring but will require further evaluation.

6.2.3 Background Monitoring Wells

6.2.3.1 Overburden Background Monitoring Wells

One monitoring well (IT-MW01) located near the intersection of West Scheid Road and Patrol Road in the south central portion of PBOW (Figure 6-31) has been sampled during the two semi-annual sampling events. IT-MW01 is located upgradient of PBOW and is considered a background well. This well was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.3.1.1 First Semi-Annual Sampling Event

VOCs, SVOCs, cyanide, and explosives were not detected in IT-MW01 during the November 1997 sampling event. Four total metals (iron, manganese, mercury, and zinc) were detected, of which iron and manganese exceeded the RBCs (Table 6-24). In the dissolved phase, iron, manganese, and zinc were detected, of which only manganese exceeded the RBC. Water quality parameters for IT-MW01 are also shown on Table 6-24.

6.2.3.1.2 Second Semi-Annual Sampling Event

SVOCs, explosive compounds, and cyanide were not detected in IT-MW01 during the May 1998 sampling event. However, one VOC (toluene) was detected at a concentration below the RBC. Three total metals (iron, manganese, and zinc) were detected of which iron and manganese exceeded the RBCs (Table 6-24). In the dissolved phase, aluminum, iron, and manganese were detected, with manganese and iron exceeding the RBCs. Water quality parameters are also presented on Table 6-24.

6.2.3.1.3 Summary of Sampling Events

Analytical results from IT-MW01 over the two sampling events indicate that this well has not been impacted by past site activities and is suitable for use as a background monitoring well. However, the existing data set is insufficient for the determination of background concentrations in the overburden water-bearing zone.

6.2.3.2 Bedrock Background Monitoring Well

One bedrock monitoring well (PB-BED-MW20) located near the intersection of Taft Road and Patrol Road in the southern portion of PBOW (Figure 6-31) has been sampled during the two semi-annual sampling events; this well is located upgradient of PBOW and is considered a background well. PB-BED-MW20 was analyzed for VOCs, SVOCs, nitroaromatic explosives, PCBs, metals (total and dissolved), cyanide, and water quality parameters as previously discussed.

6.2.3.2.1 First Semi-Annual Sampling Event

Three BTEX constituents and one SVOC were detected in PB-BED-MW20 during the November 1997 sampling event; of these detections, only benzene exhibited a concentration above the RBC (Table 6-24). Explosives and cyanide were not detected. Six total metals (aluminum, barium, copper, iron, manganese, and zinc) were detected, of which barium, iron, and manganese exceeded the RBCs (Table 6-24). In the dissolved phase, barium, iron, and manganese were detected and exceeded the RBCs. Water quality parameters for PB-BED-MW20 are also shown on Table 6-24.

6.2.3.2.2 Second Semi-Annual Sampling Event

SVOCs, explosive compounds, and cyanide were not detected in PB-BED-MW20 during the May 1998 sampling event. However, three VOCs (benzene, carbon disulfide, and total xylene) were detected, of which only benzene exceeded the RBC. Four total metals (barium, iron, manganese, and mercury) were detected of which barium, iron, and manganese exceeded the RBCs (Table 6-24). In the dissolved phase, barium, iron, manganese, and mercury were detected, with barium and iron exceeding the RBCs. Water quality parameters are also presented on Table 6-24.

6.2.3.2.3 Summary of Sampling Events

Analytical results from PB-BED-MW20 over the two sampling events indicate that the bedrock water-bearing zone in this area exhibits low levels of VOCs and SVOCs which may be naturally occurring; however, further evaluation is necessary to confirm this. Up to three metals have exceeded RBCs in this well; however, the existing data set is insufficient for the determination of background concentrations in the bedrock water-bearing zone.

7.0 Site Conceptual Exposure Model

Exposure is the actual or potential for contact of a receptor with a chemical or physical agent through an identifiable pathway in the environment. An exposure assessment estimates the type and magnitude of potential exposure of a receptor to COPC found at or migrating from a site (EPA, 1989). An exposure assessment includes the following steps:

- Characterize the physical setting.
- Identify the contaminant sources, release mechanisms, and migration pathways.
- Identify the potentially exposed receptors.
- Identify the potential exposure pathways.

The site conceptual exposure model (SCEM) provides the basis for identifying and evaluating the potential risks to human health in a future baseline risk assessment (RA). Two SCEMs are provided for this report. The first is a generalized SCEM which includes the receptors appropriate to all plausible land-use scenarios, and the potential exposure pathways (Figure 7-1). The second is an SCEM limited to groundwater pathways, transport mechanisms, and receptors (Figure 7-2). Figure 7-2 applies to the data contained in this report.

Graphically presenting all possible pathways by which a potential receptor may be exposed, including all sources, release and transport pathways, and exposure routes, facilitates consistent and comprehensive evaluation of risk to human health, and helps ensure that potential pathways are not overlooked. The elements of an SCEM include:

- Source (i.e., initially contaminated environmental media)
- Contaminant release mechanisms
- Contaminant transport pathways
- Intermediate or transport media
- Exposure media
- Receptors
- Routes of exposure.

Contaminant release mechanisms and transport pathways are not required for direct receptor contact with a contaminated source medium.

The receptors and pathways in Figure 7-1 reflect plausible scenarios developed from information regarding site background and history, topography, climate, and site usage as presented in the scope of work and the site-wide GWI (IT, 1997c). Asterisks identify exposure pathways that are complete and addressed in the RA. Justification for exclusion of other pathways is provided in the footnotes on the figure.

Contaminant Sources, Release Mechanisms, and Migration Pathways. The sources of DOD related groundwater contamination on site are TNT and related nitroaromatic compounds produced as part of the manufacturing process of TNT. Nitroaromatics were released directly to surface water ponds as part of the manufacturing process of TNT. Some of the pond water contaminants were sorbed into pond sediment or were precipitated out of solution and deposited onto the sediment. In addition, above- and below-ground process lines leaked or broke releasing nitroaromatics to the surface and/or subsurface soil. Over-land flow and runoff have spread soil-bound contamination over the surrounding soil, some of which may have reached surface water streams or ponds. Infiltration of contamination from the soil or sediment to the underlying groundwater also occurred. In turn, this contaminated groundwater migrated downgradient, some of which was released into streams, ponds, or marshy areas.

Receptors and Exposure Pathways. Receptors are selected to represent the upper bound on exposure from all plausibly exposed groups of people at the site. Most RA are based on a reasonable maximum exposure (RME) assumption. The intent of the RME assumption is to estimate the highest exposure level that could reasonably be expected to occur, but not necessarily the worst possible case (EPA, 1989, 1991). It is interpreted as reflecting the 90th to 95th percentile on exposure.

Three receptors provide the most plausible potential for human exposure to groundwater:

- On-Site Worker (current and future, including the construction worker and
- trainee)

- Sportsman (current and future, including the hunter and fisherman)

- On-Site Resident (future).

Although Plum Brook is not active, exposure potential exists for workers frequenting contaminated areas particularly, if they drink site groundwater for an extended period of time. A future on-site resident, using an on-site well, is proposed as a plausible scenario under future land use scenarios. Sportsmen may be exposed by direct exposure to site chemicals or by ingestion of contaminated fish or venison. These animals can bioaccumulate certain chemicals obtained through their food and will be evaluated as potential exposure pathways. The construction worker scenario is included within the on-site worker receptor scenario. However, it is not relevant to Figure 7-2 because its principal exposure is subsurface soil rather than groundwater. Sufficiently frequent access to the site by a trespasser is considered unlikely and this scenario is not included.

8.0 Conclusions

IT has completed two semi-annual groundwater sampling events and four quarterly groundwater level measurement events of overburden and bedrock monitoring wells under the GWI at PBOW. Previous chapters of this report have presented results from these sampling and measurement events as well as hydrogeologic interpretations and conceptual site models developed as part of the site-wide GWI. Figure 8-1 is a compilation of overburden and bedrock monitoring wells that had groundwater samples exhibiting organics above EPA Region 3 RBCs. The following sections present conclusions of the GWI based on the data and interpretations previously presented.

8.1 Overburden Water-Bearing Zone

A total of 38 overburden wells were sampled on a semi-annual basis while groundwater levels were measured in 58 overburden wells on a quarterly basis under the 1997-1998 GWI.

8.1.1 Groundwater Sampling Results

8.1.1.1 Organic and Explosives Constituents

As presented on Table 8-1, analytical results from sampled overburden monitoring wells indicate that several areas of PBOW do not exhibit impacts of organic or explosive compounds from past site activities. Specifically, wells sampled at AA1, AA3, and the Reactor Building do not show organic or explosives contaminants at levels that would be considered to pose unacceptable risk to human health. While not presented on this table, the background well (IT-MW01) shows a similar absence of organic and explosives contaminants consistent with its stated purpose as an overburden background well.

A small suite of organic contaminants exceeding RBCs are evident in wells sampled at TNTC, AA2, the Maintenance Area, the ABG, the Snake Road Burning Ground, and the Lower Toluene Area (Table 8-1). At TNTC, bis(2-ethylhexyl)phthalate was detected in two wells at concentrations of 7.3 µg/L and 28 µg/L, well below the maximum detected concentration of this compound (Table 8-2). One well (MK-MW10) at Acid Area 2 exhibited chloroform (0.45 µg/L) and bis(2-ethylhexyl)phthalate (11 µg/L). The Maintenance Area Well (MK-MW19) exhibited consistent detections of 1,1,1-TCA and 1,1-DCA at concentrations near or above the RBCs; note that these constituents were not detected in other overburden wells (Table 8-2). At the ABG, benzene was detected at concentrations slightly above the RBCs during both sampling events, while one well (GCL-MW01) at the Snake Road Burning Grounds exhibited bis(2-ethylhexyl)phthalate at 100 µg/L during the second sampling event which is well above the RBC. With the exception of results from the Maintenance Area, these detections have not been consistent over the two sampling events and are not necessarily attributable to site contamination. However, it is concluded that the overburden water-bearing zone at the Maintenance Area has been impacted by VOCs from past site activities.

TNTA exhibited one SVOC (bis(2-ethylhexyl)phthalate) and one nitroaromatic compound (4-amino-2,6-DNT) at concentrations exceeding the RBC. Of these, bis(2-ethylhexyl)phthalate was detected in May 1998 in MK-MW23 at a concentration of 890 µg/L, well above the RBC and is the maximum detected concentration at PBOW over the two sampling events. However, this compound was not detected in November 1997. 4-Amino-2,6-DNT was detected in MK-MW22 at concentrations exceeding the RBC during both sampling events; this well also exhibited other explosives at concentrations below the RBC during both sampling events. These results suggest that while the overburden water-bearing zone has been impacted by low levels of explosives in the north-central portion of TNTA, bis(2-ethylhexyl)phthalate warrants further evaluation to determine whether it is due to site contamination.

TNTB exhibited 4-amino-2,6-DNT at concentrations exceeding the RBC during both sampling events in MK-MW17 (3.6 to 5.7 µg/L). It is concluded that the overburden water-bearing zone on the north side of TNT Area B has been impacted by explosives from past site activities.

The Upper Toluene Area has exhibited a larger suite of organic contaminants than other sites exceeding RBCs, including toluene, 2-methylphenol, 4-methylphenol, and bis(2-ethylhexyl)phthalate (Table 8-1). The detected concentrations of these compounds have been well above the RBCs and have been detected during both sampling events, clearly indicating that the overburden water-bearing zone in this area has been impacted by organic contaminants from past site activities.

Two areas of PBOW have exhibited the largest suites of organic and explosive contaminants in the overburden water-bearing zone; the WARWP, and the PRRWP (Table 8-1). Although a slightly larger set of contaminants have exceeded RBCs at the WARWP, the highest concentrations of contaminants have been documented at the PRRWP. However, both areas exhibit significant impacts from past site activities, primarily because of their role as wastewater disposal areas. In addition, groundwater from several overburden wells in these areas have been documented to contain red water, consistent with the high levels of nitroaromatic compounds.

In summary, the overburden water-bearing zone at PBOW has been impacted by organic and/or explosive contaminants to different extents by past site activities. Nitroaromatic compounds, explosives residues, and SVOCs have significantly impacted the PRRWP and the WARWP areas. Lesser impacts by nitroaromatic compounds are evident at TNTA and TNTB, with bis(2-ethylhexyl)phthalate also exceeding RBCs at TNTA. Two areas, the Upper Toluene Area and the Maintenance Area, have exhibited impacts by non-explosive organic contaminants at levels well above the RBCs. Lower levels of organic contaminants are evident at TNTC, AA2, the ABG, the Snake Road Burning Grounds, and the Lower Toluene Area. Three areas, AA1, AA3, and the Reactor Building Area, have not been impacted by past site activities.

8.1.1.2 Inorganic Constituents

As presented on Table 8-3, many total metals were determined to exceed the corresponding RBCs in overburden wells sampled across PBOW. However, as discussed in previous sections, many of these total metals were due to suspended solids in the unfiltered sample and were therefore not attributable to site groundwater contamination. Therefore, the following discussion focuses on dissolved metals except for total cyanide and nitrate.

The overburden water-bearing zone within three geographic areas did not exhibit dissolved inorganic compounds at concentrations above the RBCs; AA2, the Maintenance Area, and the Reactor Facility. Five areas (TNTC, AA3, the ABG, the Snake Road Burning Ground, and the Upper Toluene Area) exhibited only dissolved iron, manganese, and/or nickel at concentrations exceeding the RBCs (Table 8-3). Detected concentrations in these five areas were between 684 to 9,240 µg/L for dissolved iron, between 36.4 to 4,020 µg/L for dissolved manganese, and between 56.8 to 77.1 µg/L for dissolved nickel. Comparing these concentrations to site-wide detections (Table 8-4), it is evident that all were at least one order of magnitude below the maximum detected concentration. However, since background concentrations have not been established for metals in groundwater at PBOW, these metals will require further evaluation.

Two dissolved metals (iron and manganese) were detected at concentrations exceeding the RBCs at AA1 and the Lower Toluene Area. Detected concentrations ranged from 226 to 39,100 µg/L for iron and from 30.7 to 5,550 µg/L for manganese. Although dissolved manganese appears to be well within the range of detected concentrations across PBOW (Table 8-4), the dissolved iron concentrations at the two sites may be elevated and warrant additional evaluation.

Larger suites of inorganic compounds were detected in wells from the WARWP, PRRWP, TNTA, and TNTB (Table 8-3). Although not necessarily attributable to site contamination, many of these metals were detected infrequently in the overburden water-bearing zone across PBOW (Table 8-4). The range in concentration of naturally occurring metals in PBOW overburden and bedrock water-bearing zones is not currently known. Once the range of background metals concentrations has been determined, the metals detected above RBCs should be re-evaluated to determine if they are site-related.

8.1.2 Overburden Geologic and Hydrogeological Conclusions

Groundwater flow in the overburden is predominantly to the north-northeast. The general flow direction in the overburden aquifer largely mirrors the surface topography and is strongly correspondent to the topography of the top of the bedrock; thus, groundwater on the western side of the site flows toward a groundwater low. Groundwater elevation fluctuations are very similar among overburden wells which may imply a high degree of connectivity between the site wells. Another possibility is that the overburden water-bearing zone has a higher vertical hydraulic conductivity than assumed and the water levels in the overburden are directly influenced by changes in the bedrock water-bearing zone water levels. Slug test results reveal significant variability in the overburden water-bearing zone hydraulic conductivities across the site, possibly implying the water-bearing zone is not a single hydrogeologic unit.

8.2 Bedrock Water-Bearing Zone

A total of 17 bedrock wells were sampled on a semi-annual basis while groundwater levels were measured in 19 bedrock wells on a quarterly basis under the 1997-1998 GWI.

8.2.1 Groundwater Sampling Results

8.2.1.1 Organic and Explosives Constituents

As presented on Table 8-5, two of the areas sampled under the site-wide groundwater investigation failed to exhibit any organic or explosive contaminants at levels exceeding RBCs. The bedrock water-bearing zone in these areas (ABG and BG8) along with the background well (PB-BED-MW20) are therefore interpreted to not have been impacted by past site activities. VOCs have impacted the bedrock water-bearing zone in ten areas of the site. The most common

VOC exceeding RBCs was benzene, with detected concentrations ranging from 0.14 µg/L to 780 µg/L (Table 8-6). This constituent was detected in 23 of the 34 samples analyzed for VOCs, and it is known to occur naturally within the Delaware Limestone. However, maximum detected benzene concentrations at the PRRWP (780 µg/L), TNTC (130 µg/L), AA2 (130 µg/L), and Upper Toluene Tanks Area (490 µg/L) are well above levels seen in other areas (including background well PB-BED-MW20) and are considered site-related contaminants (Figure 8-1). Toluene was also detected at concentrations above RBCs in several areas (Table 8-5), with detected concentrations of this VOC ranging from 1.3 to 550 µg/L (Table 8-6). As with benzene, toluene is a naturally occurring BTEX constituent in the Delaware Limestone. However, the maximum detected concentrations at the PRRWP (550 µg/L), TNTA (140 µg/L), TNTC (170 µg/L), and the Upper Toluene Tanks Area (390 µg/L) are well above levels seen in other areas and are considered site-related contaminants (Figure 8-2). Another location which is likely to have site-related BTEX compounds at high concentrations is the area upgradient of AA1. The tanks at the Middle Toluene Tank Area are possible sources for the toluene (50 µg/L) and xylene (500 µg/L) found 2,400 feet downgradient at the AA1 well IT-AA1-BED-GW001. Presently, no wells have been installed in the vicinity of the Middle Toluene Tank Area. Other detected VOCs exceeding RBCs at the PRRWP (1,1,2-TCA, chlorobenzene, and ethylbenzene), AA2 (chlorobenzene), and the Upper Toluene Tank Area (ethyl benzene) are considered to be site-related contaminants.

Several SVOCs have also been detected at levels exceeding the RBCs in the bedrock wells. Of these, bis(2-ethylhexyl)phthalate was detected at concentrations exceeding the RBC most frequently (Table 8-5). Detected concentrations ranged from 1.7 to 920 µg/L (Table 8-6). This compound was detected sporadically and further evaluation will be needed to determine whether it is a site-related contaminant or a sampling artifact in the affected areas. Two areas (WARWP and Upper Toluene Tank Area) exhibited two or more SVOCs at concentrations exceeding the RBCs. At the WARWP, 2,4-dinitrophenol, 2,4-DNT, 4,6-dinitro-2-methylphenol, and nitrobenzene have impacted the bedrock water-bearing zone because of past site activities. The Upper Toluene Tank Area exhibits impacts from 1,3-dichlorobenzene and bis(2-ethylhexyl)phthalate.

Three nitroaromatic compounds (1,3-DNB, nitrobenzene, and RDX) were detected at concentrations exceeding the RBCs at TNTA, AA1, AA2, and/or the Maintenance Area; note that explosives also exceeded RBCs at the WARWP under the SVOC analysis. At TNTA, the bedrock wells have been impacted by low levels of explosives from past site activities. AA1 and

AA2 as well as the Maintenance Area have also been impacted by low levels of nitroaromatic compounds from past site activities.

In summary, the bedrock water-bearing zone at PBOW has been impacted by organic and/or explosive contaminants to different extents by past site activities, although to a lesser degree than the overburden. Nitroaromatic compounds and SVOCs have impacted the WARWP, while VOCs have impacted the bedrock wells at the PRRWP. Lesser impacts by nitroaromatic compounds are evident at TNTA and AA1 and AA2 and the Maintenance Area. VOCs have also impacted the bedrock water-bearing zone at TNTC, AA2, and the Upper Toluene Tanks Area; SVOCs also exhibit impacts on water quality at the Upper Toluene Tanks Area.

8.2.1.2 Inorganic Constituents

As presented on Table 8-7, many total metals were determined to exceed the respective RBCs in bedrock wells sampled across PBOW. However, as discussed in previous sections, many of these total metals were due to suspended solids in the unfiltered sample and were therefore not attributable to site groundwater contamination. Therefore, the following discussion focuses on dissolved metals except for total cyanide.

Only two areas (WARWP and AA3) lacked any detected dissolved inorganic compound at a concentration exceeding the RBC. However, cyanide did exceed the RBC at the WARWP. Two dissolved metals (barium and manganese) were commonly detected in the bedrock wells at concentrations exceeding the RBCs in most areas of PBOW (Table 8-7). Detected concentrations exhibited a wide range (Table 8-8), suggesting that some detections may be due to site contamination. However, these metals will require further evaluation once background has been established.

Other less frequently detected dissolved metals at concentrations exceeding RBCs in the bedrock water-bearing zone include arsenic, iron, thallium, and vanadium (Table 8-7). The frequency of detection, as well as range of concentrations, for these metals is presented on Table 8-8. However, further evaluation of these metals is required once background is established to determine whether they are due to site contamination.

8.2.2 Bedrock Geologic and Hydrogelogical Conclusions

Groundwater flow in the bedrock is predominantly to the north-northeast. Little groundwater elevation fluctuation occurred over time in the wells monitoring the Ohio Shale and the

Olentangy Shale; however, wells monitoring the Delaware Limestone showed significant variability. There is a similar groundwater elevation fluctuation between wells REACTOR 1, 2, 3, and PB-BED-MW13 located on the west side of PBOW along a bedrock low coming from the Reactor Building Area.

Slug tests revealed that the Ohio Shale had the highest hydraulic conductivity of the three bedrock units tested at approximately 20 ft/day. The Delaware Limestone and Olentangy Shale had hydraulic conductivities of three orders of magnitude lower.

Quarries mining the Delaware Limestone in the vicinity of PBOW have some minor natural hydrocarbon. This is evident in PBOW wells monitoring the bedrock based on drilling notes, H_2S readings, and BTEX compounds detected in the groundwater.

In general, there is a downward vertical gradient from the overburden to the bedrock in the western and northern portions of the site. The greatest groundwater elevation difference was 25 feet in overburden/Delaware Limestone pair IT-AA1-GW002/IT-AA1-BED-GW001 located in the north central portion of the site. In contrast, the central and southern portions of the site showed very similar groundwater elevations in overburden/Ohio Shale pairs. This may indicate a high degree of connectivity between groundwater in the overburden and Ohio Shale.

Peaks in calculated recharge rates appear to correlate with groundwater highs taking into account a lag time. Similarly, lows in recharge rates correspond somewhat (taking into account the lag time) with lows in the groundwater.

9.0 Recommendations

- As presented in Section 8.0, Conclusions, the two water-bearing zones at PBOW have exhibited inorganic, organic, and nitroaromatic constituents at concentrations that have exceeded their respective RBCs. It is recommended that additional investigations be performed as follows:

- Determination of site-specific reference levels for VOC constituents and background concentrations for metals in the bedrock water-bearing zone
- Investigation of bedrock groundwater at the Middle Toluene Tank Area
- Completion of a three-dimensional groundwater fate and transport model utilizing data generated during the site-wide groundwater investigation as well as pertinent historical data to aid in bedrock groundwater monitoring
- Completion of a human-health risk assessment for site-wide bedrock groundwater to define contaminants of concern and to aid in determining whether additional sampling or remedial actions are warranted
- Complete a residential/agricultural well survey to determine potential off-site receptors; sampling of downgradient off-site wells within proximity of the site should be considered.

Further investigation and monitoring of the overburden water-bearing zone is not recommended under current and anticipated future land use scenarios for the following reasons:

- There are no identified receptors for groundwater from the overburden water-bearing zone
- The State of Ohio (DERR) has indicated that the overburden water-bearing zone is not considered a potable water source
- The overburden water-bearing zone is not likely to be used as a drinking water source now or in the future due to low permeability.

Contaminant migration issues between the overburden and bedrock water-bearing zones can be addressed through monitoring of bedrock wells. Bedrock monitoring should consist of selected wells within the bedrock contaminant plumes (and/or beneath overburden plumes), bedrock wells downgradient of plumes and near the facility boundary, and any residential/agricultural wells deemed appropriate for this purpose. The target analytes for future monitoring of bedrock wells should be based on previous analytical results for upgradient areas.

Should facility usage change in the future to allow for public reuse, additional monitoring and/or evaluation of the overburden water-bearing zone may be necessary.

The following paragraphs provide additional detail regarding the scope of recommended actions.

9.1 Background Determination

Site-specific reference levels for VOC constituents and background concentrations for metals should be determined for the bedrock water-bearing zone. Analytical concentrations of site chemicals will be compared with background levels to determine whether their concentrations reflect site-related activities. These background chemicals, assumed to be present from natural conditions, are eliminated from the list of total site chemicals. For PBOW, background chemicals will include metals and naturally occurring organics (i.e., BTEX). The arithmetic mean and the range of the site concentrations of each metal are compared with the arithmetic mean and the range of the background concentration. It is recommended that two existing bedrock wells (PB-BED-MW20 and IT-BG8-BED-GW001) be used for this determination along with three new bedrock wells. Background wells should be sampled on a quarterly basis for 1 year; wells should be analyzed for metals (total and dissolved) and VOCs.

It is recommended that the specific locations of new background wells, sampling frequency, analytical parameters, and statistical approach be developed by CELRN and IT. The specifics of background determination should then be proposed to OEPA and NASA, potentially during a site visit and team meeting at the Plum Brook Station.

9.2 Groundwater Investigation

Additional DOD areas of concern are scheduled for investigation in the near future. These investigations will primarily evaluate soils in each area of concern, but results may suggest that additional wells be installed in order to evaluate potential impacts on the groundwater.

Monitoring wells have not been successfully installed at the Middle Toluene Tanks Area, located approximately 1,500 feet southwest of the intersection of Fox Road and Taylor Road. Based on the results from the Upper and Lower Toluene Tanks Areas, consideration should also be given to the installation of bedrock water-bearing zone wells in this area.

9.3 Groundwater Modeling

A three-dimensional groundwater model should be completed to provide a basis for determining the effectiveness of any chosen remedial actions or groundwater-monitoring program at PBOW. This model should be based largely on the refined conceptual site model developed herein. The groundwater modeling effort should be supported with pump tests or dye trace studies to augment the current understanding of local water-bearing zones. Additional well clusters may also be necessary to understand vertical hydraulic gradients between the overburden and the bedrock. In addition, approximate pumping rates of the sump pumps at the Reactor Area should be obtained and utilized to understand the effect that these wells have on drawdown of local groundwater.

9.4 Risk Assessment

In addition to metals determined to exceed background concentrations, COPC identified herein should be carried forward to appropriate human health risk assessments for the bedrock water-bearing zone:

- WARWP - nitroaromatics, SVOCs, and cyanide
- Pentolite Road Area - BTEX compounds
- TNTA - BTEX and nitroaromatics
- TNTC - BTEX compounds
- AA1 - nitroaromatics
- AA2 - VOCs and nitroaromatics
- Maintenance Area - nitroaromatics
- Upper Toluene Tanks Area - BTEX compounds and SVOCs.

The site-wide bedrock water-bearing zone risk assessments should be conducted following completion of the pending site investigations to ensure that any groundwater concerns identified during these investigations are adequately addressed. If additional wells and groundwater samples are deemed necessary to assess the potential impact of these sites on groundwater quality, then that data should be collected and evaluated prior to the risk assessment.

Results of the risk assessment should then be used to determine (1) the need for additional groundwater monitoring and; (2) the need for remedial action.

10.0 References

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TABLES

Table 4-1

Monitoring Well Construction Details
Former Plumbrook Ordnance Works, Sandusky, Ohio

Well ID	Well Depth (feet bgs)	Date Installed	Casing Type	Casing Diameter (inches)	Borehole Diameter (inches)	Screen Interval (feet bgs)	Top of Filter Pack (feet bgs)	Top of Casing Elevation (feet msl)	Ground Elevation (feet msl)	Well Location
Overburden Monitoring Wells										
AA1-GW-002	22	9/19/97	PVC (40)	2"	8.25"	6.75-21.75	6	640.85	638.6	AA1 area, S of tracks, N of road
AA2-GW-002	18.5	9/22/97	PVC (40)	2"	8.25"	8.25-18.25	5.5	643.95	641.5	N of road at AA2 area
AA3-GW-002	16.0	9/18/97	PVC (40)	2"	8.25"	5.75-15.75	3.0	636.11	634.1	NE of Ransom/Maintenance Rd intersection.
ABG-GW-002	8.75	9/11/97	PVC (40)	2"	8.25"	2.50-8.50	2.0	661.08	658.2	W of Snake/Fox Rd intersection
EB-GM-01	27	1990	NA	NA	NA	NA	NA	640.45	637.70	NE of Bldg.9210
EB-GM-02	29	1990	NA	NA	NA	NA	NA	637.52	634.90	N of Bldg 7131
EB-GM-03	18	1990	NA	NA	NA	NA	NA	638.90	636.20	Behind Bldg 7131
EB-GM-04	18	1990	NA	NA	NA	NA	NA	636.34	633.60	SW of Bldg.7122
EB-GM-05	18	1990	NA	NA	NA	NA	NA	639.70	637.00	NE corner of Bldg.7121
EB-GM-06	18	1990	NA	NA	NA	NA	NA	639.61	637.00	SE corner of Bldg.7121
EB-PS-02	18	1990	NA	NA	NA	NA	NA	638.53	635.70	NW of Bldg 8133
EB-PS-03	18	1990	NA	NA	NA	NA	NA	637.15	634.40	NE of Bldg.8133
EB-PS-04	18	1990	NA	NA	NA	NA	NA	637.87	635.40	N of Bldg.8133
EB-RA-01	16	12/4/90	Stainless	2	8	5.5 - 15.5	4	633.97	631.40	Pentolite Rd at PBRF
EB-RA-02	20	12/13/90	Stainless	2	8	7.75 - 17.75	6	633.95	631.30	NE of Bldg.1134
EB-RA-03	22	12/13/90	Stainless	2	8	6.75 - 21.75	5	633.63	630.90	W of Bldg.1131
EB-RA-04	10	1990	Stainless	2	8	4.75 - 9.75	2.75	633.54	630.70	S W of Bldg.1131
EB-RA-05	10	1990	Stainless	2	8	4.75 - 9.75	2.75	633.34	630.60	S of Bldg.1131
EB-RA-06	10	1990	Stainless	2	8	3.7 - 6.7	3.4	632.64	630.10	S of Bldg.1153
EB-SP-01	9.5	1990	NA	NA	8	NA	NA	655.07	652.30	S of Bldg.9115
EB-SP-03	9.5	1990	NA	NA	8	NA	NA	657.73	655.10	N of Bldg.1461
EB-SP-04	9.5	1990	NA	NA	8	NA	NA	658.02	655.25	W of Bldg 1411 Boiler Room
EB-SP-05	9.5	1990	NA	NA	8	NA	NA	657.00	654.50	SW of Bldg.1411 Boiler Room
EB-SP-06	9	1990	NA	NA	8	NA	NA	658.25	655.40	S of Bldg 1411
GCL-MW01	11.03	3/12/92	Stainless	1	8	5.99 - 10.97	4	674.81	671.4	SE of the Snake Rd burn pit
GCL-MW02A	22.15	3/11/92	Stainless	1	8	12.09 - 22.09	9.9	672.96	669.7	N of the Snake Rd burn pit
GCL-MW02B	9.83	3/12/92	Stainless	1	8	4.82 - 9.82	3.75	673.42	669.8	N of the Snake Rd burn pit
GCL-MW03	10.6	3/12/92	Stainless	1	8	4.56 - 9.45	3	672.57	669.55	W of the Snake Rd burn pit
IT-MW01	9.5	1989	PVC	2	8	4.0 - 9.0	2	678.19	674.5	Scheid Road Burn Ground
IT-MW02	18.3	1989	PVC	2	8	6.0 - 16.0	3.8	639.28	636.37	West Area RWP
IT-MW05	21	1989	PVC	2	8	8.5 - 18.5	6.5	634.67	631.59	Pentolite Road RWP
IT-MW06	18.5	1989	PVC	2	8	6.0 - 16.0	4.4	631.70	628.5	Reactor Facility / PRA
IT-MW07	5.5	1996	PVC	2	4.25	0.5 - 5.5	none	635.03	632.3	West Area RWP, temporary
IT-MW08	13.4	1996	PVC	2	8.25	3.1 - 13.1	3.6	633.16	630.6	West Area RWP
IT-MW09	14.5	1996	PVC	2	8.25	4.1 - 14.1	2	647.45	645.4	TNT Area C
IT-MW10	19.6	1996	PVC	2	8.25	9.3 - 19.3	6.6	644.80	642.2	West Area RWP

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MK-MW09	15	1993	PVC	2	10	5.0 - 15.0	3	645.61	642.95	West Area RWP
MK-MW10	14	1993	PVC	2	10	4.0 - 14.0	2	640.67	637.74	West Area RWP
MK-MW11	13	1993	PVC	2	10	3.0 - 13.0	2	637.36	634.39	West Area RWP
MK-MW12	13	1993	PVC	2	10	3.0 - 13.0	2	640.93	638.1	Pipe Creek
MK-MW14	11.5	1993	PVC	2	10	4.0 - 9.0	2	681.26	678.6	Toluene Tank No. 645
MK-MW15	9	1993	PVC	2	10	4.0 - 9.0	2	680.63	677.8	Toluene Tank No. 655
MK-MW16	8	1993	PVC	2	10	2.0 - 7.0	1	674	671.01	TNT Area B
MK-MW17	6	1993	PVC	2	10	2.0 - 6.0	1	664.32	660.65	TNT Area B
MK-MW19	13	1993	PVC	2	10	3.0 - 13.0	2	639.13	636.2	Garage Maintenance Area
MK-MW20	23	1993	PVC	2	10	5.0 - 20.0	3	637.51	634.3	Toluene Tank No. 265
MK-MW22	9.5	1993	PVC	2	10	2.5 - 7.5	1.5	637.73	635.24	TNT Area A
MK-MW23	16	1993	PVC	2	10	6.0 - 16.0	4	639.11	636.63	TNT Area A
MK-MW24	9.5	1993	PVC	2	10	4.5 - 9.5	2.5	656.80	654.12	TNT Area A
PB-MW01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NE of Bldg.9206
PB-MW02	NA	NA	NA	NA	NA	NA	NA	NA	NA	NW of Bldg.9206
PB-MW03	NA	NA	NA	NA	NA	NA	NA	NA	NA	SE of Bldg.9206
PB-MW04	NA	NA	NA	NA	NA	NA	NA	NA	NA	SW of Bldg.9206
PR-MW07	22.3	1994	PVC	2	8	4.3 - 22.3	3	633.67	631.18	Pentolite Road RWP
PR-MW08	27.5	1994	PVC	2	8	5.0 - 27.5	4	634.7	632.18	Pentolite Road RWP
PR-MW09	19	1994	PVC	2	8	4.0 - 19.0	3	633.38	630.38	Pentolite Road RWP
TNTA-MW10	11	1994	PVC	2	8	3.0 - 11.0	2.5	639.68	637.18	TNT Area A
TNTA-MW11	11.4	1994	PVC	2	8	3.4 - 11.4	2.5	640.18	637.54	TNT Area A
TNTC-MW03	14	1994	PVC	2	8	5.0 - 14.0	3.2	645.09	642.25	TNT Area C
TNTC-MW04	18.8	1994	PVC	2	8	8.8 - 18.8	6	654.11	651.57	TNT Area C
TNTC-MW05	29.7	1994	PVC	2	8	4.7 - 29.7	3.7	651.49	648.75	TNT Area C
TNTC-MW06	12.2	1994	PVC	2	8	3.2 - 12.2	2.5	659.08	656.5	TNT Area C
WA-MW01	22.3	1994	PVC	2	8	4.3 - 22.3	3.7	644.11	642	West Area RWP
WA-MW02	13	1994	PVC	2	8	3.0 - 12.0	2.5	633.33	630.84	West Area RWP
Bedrock Monitoring Wells										
AA1-BEDGW-001	65.0	9/24/97	Steel to 27', PVC (40) to 65'	10" to 27', 2" to 65'	14.25" to 27', 6" to 66'	49.75-64.75	45	641.04	638.8	S of storage yd, N of RR tracks
AA2-BEDGW-001	43.0	10/2/97	Steel to 20', PVC (40) to 43'	10" to 20', 2" to 43'	14.25" to 20', 6" to 44'	27.75-42.75	23	644.06	641.6	AA2 area in woods, 70' N of road
AA3-BEDGW-001	53.0	10/5/97	Steel to 28', PVC (40) to 53'	10" to 28', 2" to 53'	14.25" to 28', 6" to 54'	37.75-52.75	33.0	638.43	634.1	NE of Ransom/Maintenance Rd intersection
ABG-BEDGW-001	21.0	9/10/97	Steel to 7', PVC (40) to 21'	10" to 7', 2" to 21'	14.25" to 7', 6" to 22'	10.75-20.75	9.0	660.59	658.2	SW of Snake/Fox Rd intersection

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BG8-BEDGW-001	20.0	9/20/97	Steel to 4', PVC (40) to 20'	10" to 4', 2" to 20'	14.25" to 4', 6" to 21'	4.75-19.75	4	676.56	673.7	NW of Campbell/ Patrol Rd intersection
MNTA-BEDGW-001	64.0	9/22/97	Steel to 31', PVC (40) to 64'	10" to 31', 2" to 64'	14.25" to 31', 6" to 65'	48.75-63.75	44	638.40	636.05	90 ft E of Bldg 7123, 15 ft west of ditch
PB-BED-MW13	75.5	1994	PVC	4	3 (A)	29.5 (B)	none	647.95	645.49	TNT Area C
PB-BED-MW14	52.2	1994	PVC	4	3 (A)	23.2 (B)	none	645.72	642.73	West Area RWP
PB-BED-MW15	74.4	1994	PVC	4	3 (A)	42.9 (B)	none	631.31	628.76	Pentolite Road RWP
PB-BED-MW16	74	1994	PVC	4	3 (A)	24.8 (B)	none	635.7	633.38	Pentolite Road RWP
PB-BED-MW17	64.4	1994	PVC	4	3 (A)	19.4 (B)	none	629.65	627.02	TNT Area A
PB-BED-MW18	75.4	1994	PVC	4	3 (A)	24.4 (B)	none	651.16	648.51	TNT Area A
PB-BED-MW19	49.5	1994	PVC	4	3 (A)	17.5 (B)	none	642.75	640.19	West Area RWP
PB-BED-MW20	49.5	1994	PVC	4	3 (A)	14.5 (B)	none	676.01	673.25	BG Well - Southern PBS
REACTOR1	80	6/3/60	NA	NA	8	34.5 (B)	none	630.51	630.45	Reactor Facility / PRA
REACTOR2	40	5/24/60	NA	NA	8	33 (B)	none	631.05	631.0	Reactor Facility / PRA
REACTOR3	40	5/16/60	NA	NA	8	32 (B)	none	631.21	631.1	Reactor Facility / PRA
REACTOR4	50	5/19/60	NA	NA	8	32.5 (B)	none	638.83	630.44	Reactor Facility / PRA
REACTOR5	65	9/22/58	NA	NA	5.6	35.5 (B)	none	NA	NA	Reactor Facility / PRA
TNTB-BEDGW-001	24.0	9/31/97	Steel to 9', PVC (40) to 24'	10" to 9', 2" to 24'	14.25" to 9', 6" to 25'	8.75-23.75	7.5	662.43	659.8	48 ft S of Emergency B Rd
TNTB-BEDGW-002	24.2	9/24/97	Steel to 8', PVC (40) to 24.2'	10" to 8', 2" to 24.2'	14.25" to 8', 6" to 25.2'	13.95-23.95	11.2	673.35	670.1	S of Scheid Rd, 40 ft E of MK-MW16

Elevations are with respect to North Geodetic Vertical Datum (NGVD), 1929.

bgs ---- Below ground surface.
A ---- 3-inch diameter open borehole into bedrock.
B ---- Depth at which PVC casing ends; remainder of well is open borehole in bedrock.
RWP ---- Red Water Ponds
PRA ---- Pentolite Road Area
BG ---- Background location
PBS ---- Plum Brook Station
NA ---- Information not available

Table 4-2

Summary of Primary Groundwater Samples Collected
First Semi-Annual Groundwater Sampling Event
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Sample Identification	Sampling Date	Laboratory Reference Number
IT-AA1-BEDGW-001	PBOW97-IT-AA1-BEDGW-001-GW-5450	11/16/97	5450
IT-AA1-GW-002	PBOW97-IT-AA1-GW-002-GW-5490	11/20/97	5490
IT-AA2-BEDGW-001	PBOW97-IT-AA2-BEDGW-001-GW-5460	11/20/97	5460
IT-AA2-GW-002	DRY (PIEZOMETER)	--	--
IT-AA3-BEDGW-001	PBOW97-IT-AA3-BEDGW-001-GW-5470	11/19/97	5470
IT-AA3-GW-002	PBOW97-IT-AA3-GW-002-GW-5510	11/19/97	5510
IT-ABG-GW-002	PBOW97-IT-ABG-GW-002-GW-5520	11/19/97	5520
IT-ABG-BEDGW-001	PBOW97-IT-ABG-BEDGW-001-GW-5480	11/13/97	5480
BED-MW13	PBOW97-PB-BED-MW13-GW-58990	11/13/97	5890
BED-MW14	PBOW97-PB-BED-MW14-GW-5900	11/18/97	5900
BED-MW15	PBOW97-PB-BED-MW15-GW-5910	11/18/97	5910
BED-MW16	PBOW97-PB-BED-MW16-GW-5920	11/24/97	5920
BED-MW17	PBOW97-PB-BED-MW17-GW-5930	11/20/97	5930
BED-MW18	PBOW97-PB-BED-MW-18-GW-5940	11/19/97	5940
BED-MW19	PBOW97-PB-BED-MW19-GW-5950	11/14/97	5950
BED-MW20	PBOW97-PB-BED-MW20-GW-5960	11/17/97	5960
IT-BG8-BEDGW-001	PBOW97-IT-BG8-BEDGW-001-GW-5410	11/17/97	5410
GCL-MW01	PBOW97-GCL-MW01-GW-5850	11/20/97	5850
GCL-MW02A	PBOW97-GCL-MW02A-GW-5860	11/20/97	5860
GCL-MW02B	PBOW97-GCL-MW02B-GW-5870	11/20/97	5870
GCL-MW03	PBOW97-GCL-MW03-GW-5880	11/20/97	5880
IT-MW01	PBOW97-IT-MW01-GW-5530	11/19/97	5530
IT-MW02	PBOW97-IT-MW02-GW-5540	11/21/97	5540
IT-MW05	PBOW97-IT-MW05-GW-5550	11/19/97	5550
IT-MW06	PBOW97-IT-MW06-GW-5560	11/19/97	5560
IT-MW07	DRY (PIEZOMETER)	--	--
IT-MW08	PBOW97-IT-MW08-GW-5580	11/19/97	5580
IT-MW09	PBOW97-IT-MW09-GW-5590	11/21/97	5590
IT-MW10	PBOW97-IT-MW10-GW-5600	11/14/97	5600
MK-MW09	PBOW97-MK-MW09-GW-5720	11/16/97	5720

Table 4-2

Summary of Primary Groundwater Samples Collected
First Semi-Annual Groundwater Sampling Event
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Sample Identification	Sampling Date	Laboratory Reference Number
MK-MW10	PBOW97-MK-MW10-GW-5730	11/14/97	5730
MK-MW11	PBOW97-MK-MW11-GW-5740	11/18/97	5740
MK-MW12	PBOW97-MK-MW12-GW-5750	11/17/97	5750
MK-MW14	PBOW97-MK-MW14-GW-5760	11/16/97	5760
MK-MW15	PBOW97-MK-MW15-GW-5770	11/16/97	5770
MK-MW16	PBOW97-MK-MW16-GW-5780	11/21/97	5780
MK-MW17	PBOW97-MK-MW17-GW-5790	11/21/97	5790
MK-MW19	PBOW97-MK-MK19-GW-5800	11/16/97	5800
MK-MW20	PBOW97-MK-MW20-GW-5810	11/16/97	5810
MK-MW22	PBOW97-MK-MW22-GW-5820	11/14/97	5820
MK-MW23	PBOW97-MK-MW23-GW-5830	11/16/97	5830
MK-MW24	PBOW97-MK-MW24-GW-5840	11/13/97	5840
IT-MNTA-BED-GW001	PBOW97-IT-MNTA-BEDGW-001-5440	11/20/97	5440
PR-MW7	PBOW97-PB-PR-MW7-GW-5690	11/17/97	5690
PR-MW8	PBOW97-PB-PR-MW8-GW-5700	11/17/97	5700
PR-MW9	PBOW97-PB-PR-MW9-GW-5710	11/17/97	5710
REACTOR 1	PBOW97-REACTOR1-GW-5970	11/21/97	5970
REACTOR 2	PURGED DRY	--	--
REACTOR 3	DRY	--	--
TNTA-MW10	PBOW97-PB-TNTA-MW10-GW-5610	11/19/97	5610
TNTA-MW11	PBOW97-PB-TNTA-MW11-GW-5620	11/18/97	5620
IT-TNTB-BED-GW001	PBOW97-IT-TNTB-BEDGW-001-GW-5420	11/17/97	5420
IT-TNTB-BED-GW002	PBOW97-IT-TNTB-BEDGW-002-GW-5430	11/16/97	5430
TNTC-MW3	PBOW97-PB-TNTC-MW3-GW-5630	11/21/97	5630
TNTC-MW4	PBOW97-PB-TNTC-MW4-GW-5640	11/24/97	5640
TNTC-MW5	PBOW97--PB-TNTC-MW5-GW-5650	11/21/97	5650
TNTC-MW6	PBOW97-PB-TNTC-MW6-GW-5660	11/20/97	5660
WA-MW1	PBOW97-PB-WA-MW1-GW-5670	11/21/97	5670
WA-MW2	PBOW97-PB-WA-MW2-GW-5680	11/23/97	5680

Table 4-3

Field Measurements of Groundwater Samples
First and Second Semi-Annual Groundwater Sampling Events
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Sample No.	Conductivity (mS/cm)	pH	Eh (mV)	Temperature (°C)	Turbidity (NTU)	Dissolved O_2 (mg/L)	Water Purged (gallons)
Overburden Wells									
GCL-MW01	11/20/97	5850	0.837	6.37	0	12.7	289	0.48	11
	5/17/98	5855	0.50	6.6	25	13	20	8.4	26.29
GCL-MW02A	11/20/97	5860	0.888	7.20	0	11.9	999	7.11	35
	5/17/98	5865	0.74	7.3	-58.6	14	27	7.8	58.66
GCL-MW02B	11/20/97	5870	0.933	6.82	-0.1	12.2	0	1.33	15
	5/17/98	5875	0.65	7.2	98.3	14	8	6.4	25
GCL-MW03	11/20/97	5880	0.524	6.91	118.4	11.9	137	-20	15
	5/17/98	5885	0.40	7.2	-55.8	15	23	7.7	25.82
IT-AA1-GW002	11/20/97	5490	3.34	6.21	-263.8	13.0	628	3.59	15
	5/13/98	5495	3.45	7.16	NM	10.8	624	5.51	9
IT-AA3-GW002	11/19/97	5510	1.02	7.10	-189.6	12.1	999	4.56	25
	5/14/98	5515	0.712	7.01	-2.2	11.5	-10	5.20	1.95
IT-ABG-GW002	11/19/97	5520	1.84	6.70	-15.2	9.5	>1000	10.89	1.5
	5/13/98	5525	1.51	7.22	8.4	14.6	-5	13.62	1
IT-MW01	11/19/97	5530	0.512	6.70	-58.2	9.6	1	10.57	6.5
	5/16/98	5535	0.447	6.23	57.3	14.2	0	13.13	8
IT-MW02	11/21/97	5540	1.25	6.60	NM	11.3	0	11.54	22
	5/15/98	5545	1.51	6.86	5	14	139	13.4	35
IT-MW05	11/19/97	5550	0.962	7.39	-81.9	11.7	78	-0.65	6
	5/28/98	5555	0.76	7.7	61.0	13	380	6.9	9.5
IT-MW06	11/19/97	5560	0.815	7.10	1.7	11.2	40	1.68	10
	5/28/98	5565	0.63	7.1	271.6	13	0	7.3	23
IT-MW08	11/19/97	5580	1.90	7.45	-5.2	10.7	0	9.76	7
	5/13/98	5585	2.17	6.72	NM	11.2	0	14.02	35
IT-MW09	11/21/97	5590	2.10	6.76	121.5	13.8	256	7.32	6
	5/19/98	5595	2.42	6.91	246.7	15.8	154	15.74	8
IT-MW10	11/13/97	5600	1.18	6.78	-155.4	8.6	1	9.59	11
	5/14/98	5605	1.2	7.20	2.87	11.5	999	15.80	9
MK-MW09	11/16/97	5720	0.602	6.96	152	10.0	2	8.84	35
	5/13/98	5725	0.522	7.16	NM	13.0	0	15.78	48

Table 4-3

Field Measurements of Groundwater Samples
First and Second Semi-Annual Groundwater Sampling Events
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Sample No.	Conductivity (mS/cm)	pH	Eh (mV)	Temperature (°C)	Turbidity (NTU)	Dissolved O_2 (mg/L)	Water Purged (gallons)
Overburden Wells									
MK-MW10	11/14/97	5730	0.581	6.99	377	11.0	12	8.97	10
	5/12/98	5735	0.485	6.82	NM	12.6	0	13.07	43
MK-MW11	11/18/97	5740	0.785	6.80	71.5	10.8	300	8.03	7
	5/13/98	5745	0.706	7.22	NM	10.5	999	13.98	6
MK-MW12	11/17/97	5750	0.762	6.93	67.4	9.5	2	8.66	10
	5/14/98	5755	0.573	6.24	204.3	13.5	0	13.74	5
MK-MW14	11/16/97	5760	0.946	6.53	-55.9	12.2	0	9.59	11
	5/14/98	5765	0.675	6.68	-39	14.8	0	14.45	25
MK-MW15	11/16/97	5770	0.556	6.81	-89.1	12.0	11	9.01	5.5
	5/14/98	5775	0.096	6.81	87.9	16.7	NM	16.70	25
MK-MW16	11/21/97	5780	NM	NM	NM	NM	NM	NM	1
	5/18/98	5785	1.1	7.40	NM	18.0	1	5.40	34.86
MK-MW17	11/21/97	5790	NM	NM	NM	NM	NM	NM	6
	5/27/98	5795	0.74	6.00	NM	17.0	14	4.90	15
MK-MW19	11/16/97	5800	1.14	7.11	38.5	11.7	223	9.74	25
	6/1/98	5805	0.889	7.54	NM	12.0	467	10.15	45
MK-MW20	11/16/97	5810	3.07	7.31	-251.8	10.5	999	9.87	20
	5/19/98	5815	2.53	7.05	-37.5	18.8	169	10.85	12.5
MK-MW22	11/14/97	5820	885	6.85	4.5	13.6	132	1.85	5
	5/18/98	5825	0.822	8.25	4.6	18.4	988	12.16	3.5
MK-MW23	11/16/97	5830	1.07	6.44	-55.5	14.0	602	0.01	NR
	5/29/98	5835	0.836	7.08	-133.4	15.4	154	13.50	8
MK-MW24	11/13/97	5840	2340	6.83	-53.1	13.8	137	1.70	3
	5/20/98	5845	2.19	7.05	-57.4	16.9	54	12.24	5
PR-MW07	11/17/97	5690	16.0	7.06	81.1	11.3	999	9.50	15
	5/20/98	5695	12.0	6.80	NM	20.0	3	6.40	18
PR-MW08	11/17/97	5700	43.1	7.07	88.5	8.4	999	4.25	25
	5/15/98	5705	3.6	6.80	NM	17.0	99	5.50	21.8
PR-MW09	11/17/97	5710	7.12	7.05	797.6	10.9	170	19.99	4
	5/20/98	5715	7	7.00	NM	21.0	9	6.20	15

Table 4-3

Field Measurements of Groundwater Samples
First and Second Semi-Annual Groundwater Sampling Events
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Sample No.	Conductivity (mS/cm)	pH	Eh (mV)	Temperature (°C)	Turbidity (NTU)	Dissolved O_2 (mg/L)	Water Purged (gallons)
Overburden Wells									
TNTA-MW10	11/18/97	5610	1.18	7.29	-170.5	11.2	246	-0.38	6
	5/29/98	5615	1.23	7.36	-109.7	14.8	260	7.17	11
TNTA-MW11	11/18/97	5620	1.54	6.49	-67.2	12.4	77	4.53	5
	5/29/98	5625	1.38	7.16	118.1	14.3	538	7.41	14
TNTC-MW03	11/21/97	5630	3.04	7.31	41.0	11.3	9	9.70	6
	5/18/98	5635	3.35	6.56	NM	13.8	999	15.78	NR
TNTC-MW04	11/20/97	5640	2.24	6.58	109.6	12.0	22	10.27	NM
	5/18/98	5645	2.22	6.80	282.6	14.6	999	14.72	11
TNTC-MW05	11/21/97	5650	1.52	6.97	22.9	10.0	25	11.45	24
	5/18/98	5655	NM	NM	NM	NM	NM	NM	11
TNTC-MW06	11/20/97	5660	1.00	6.71	33.6	11.0	6	11.66	13
	5/16/98	5665	0.983	6.91	179.3	13.5	3.0	14.08	21
WA-MW01	11/21/97	5670	0.96	7.08	4.3	10.0	0	11.65	8
	5/18/98	5675	0.931	8.16	143.8	14.7	0	16.30	16
WA-MW02	11/23/97	5680	5.54	6.52	65.0	10.9	300	10.82	30
	5/15/98	5685	5.42	6.85	168.4	13.7	999	15.19	30.5
Bedrock Wells									
Reactor1	11/21/97	5970	1.02	7.52	-266.8	11.8	90	9.89	243
	6/1/98	5975	0.137	7.86	NM	15.5	81	8.44	113
Reactor2	11/21/97	NS	0.445	8.14	-220.6	11.8	86	7.62	53
	NS	NS	NS	NS	NS	NS	NS	NS	NS
IT-AA1-BED-GW001	11/16/97	5450	5.37	6.99	-340.1	8.7	-10	2.62	49
	5/12/98	5455	7.33	6.91	NM	12.4	107	4.80	20
IT-AA2-BED-GW001	11/20/97	5460	1.28	7.08	-160	8.7	>1000	6.31	25
	5/12/98	5465	1.21	7.06	NM	13.5	999	8.02	20
IT-AA3-BED-GW001	11/19/97	5470	2.93	6.82	-297.2	10.6	595	6.51	42
	5/14/98	5475	2.79	6.81	8.7	13.7	26	NM	30.6
IT-BG8-BED-GW001	11/17/97	5410	3.31	7.21	-245.3	10.5	321	6.83	30
	5/15/98	5415	151	7.80	-36.2	13.0	10	8.00	27.73
IT-MNTA-BED-GW001	11/20/97	5440	9.50	6.78	-329.4	9.8	38	5.38	45
	5/28/98	5445	9.63	4.66	NM	17.2	79	0.74	37.5

Table 4-3

Field Measurements of Groundwater Samples
First and Second Semi-Annual Groundwater Sampling Events
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Date	Sample No.	Conductivity (mS/cm)	pH	Eh (mV)	Temperature (°C)	Turbidity (NTU)	Dissolved O_2 (mg/L)	Water Purged (gallons)
Bedrock Wells									
IT-TNTB-BED-GW001	11/17/97	5420	0.92	7.07	-190.4	9.8	99	4.48	33
	5/18/98	5425	3.2	7.20	NM	14.0	21	6.50	30.12
IT-TNTB-BED-GW002	11/16/97	5430	1.20	7.58	-294.5	10.2	-10	3.75	27
	5/18/98	5435	1.20	7.40	-327.2	13.0	1	6.20	34.59
IT-ABG-BED-GW001	11/13/97	5480	1.09	6.94	15.9	12.9	-10	7.35	25.5
	5/13/98	5485	0.85	7.18	NM	12.0	23	5.37	30
BED-MW13	11/13/97	5890	8.08	6.90	-317.9	9.6	284	4.93	24.5
	5/28/98	5895	0.755	6.98	NM	15.2	173	2.76	15.32
BED-MW14	11/18/97	5900	2.33	7.29	-85.3	8.7	269	4.66	13.5
	5/16/98	5905	2.4	7.70	-10.8	13.0	36	5.50	81.6
BED-MW15	11/18/97	5910	5.08	6.81	-298.3	8.9	71	3.17	15
	5/28/98	5915	6.94	6.91	-20	13.0	79	1.65	23.2
BED-MW16	11/24/97	5920	NM	NM	NM	NM	NM	NM	35
	6/1/98	5925	NM	NM	NM	NM	NM	NM	NR
BED-MW17	11/20/97	5930	4.70	7.00	322.2	8.9	318	7.46	23
	5/29/98	5935	4.21	6.70	NM	15.3	213	1.30	60
BED-MW18	11/19/97	5940	22.3	7.40	-311.6	9.2	109	5.22	27
	5/19/98	5945	2.8	7.20	-297.6	18.0	28	5.40	127.01
BED-MW19	11/14/97	5950	1.30	6.91	-318.1	9.4	108	5.58	14
	5/16/98	5955	1.80	6.70	17.8	16.0	17	6.00	82.5
BED-MW20	11/17/97	5960	48.5	6.74	-24.7	9.4	563	4.14	27
	5/28/98	5965	38.1	6.65	NM	13.0	999	12.80	58

mS/cm - Millisiemens per centimeter.
mV - Millivolts.
NTU - Nephelometric turbidity unit.
NM - Parameter was not measured either to save on limited water volume or because of an instrument malfunction.
NR - Not recorded.
NS - Not sampled.

Table 4-4

Summary of Primary Groundwater Samples
Second Semi-Annual Groundwater Sampling Event
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Sample Identification	Sampling Date	Laboratory Reference Number
IT-AA1-BEDGW-001	PBOW-98-GW-AA1-BEDGW-001-5455	5/12/98	5455
IT-AA1-GW-002	PBOW-98-GW-AA1-GW-002-5495	5/13/98	5495
IT-AA2-BEDGW-001	PBOW-98-GW-AA2-BEDGW-001-5465	5/12/98	5465
IT-AA2-GW-002	DRY (PIEZOMETER)	--	--
IT-AA3-BEDGW-001	PBOW-98-GW-AA3-BEDGW-001-5475	5/14/98	5475
IT-AA3-GW-002	PBOW-98-GW-AA3-GW-002-5515	5/14/98	5515
IT-ABG-BEDGW-01	PBOW-98-GW-ABG-BEDGW-001-5485	5/13/98	5485
IT-ABG-GW-002	PBOW-98-GW-ABG-GW-002-5525	5/13/98	5525
BED-MW13	PBOW-98-GW-BEDMW13-5895	5/29/98	5895
BED-MW14	PBOW-98-GW-BEDMW14-5905	5/16/98	5905
BED-MW14	PBOW-98-GW-BEDMW14-5905	5/18/98	5905R
BED-MW15	PBOW-98-GW-BEDMW15-5915	5/28/98	5915
BED-MW16	PBOW-98-GW-BEDMW16-5925	6/1/98	5925
BED-MW17	PBOW-98-GW-BEDMW17-5935	5/29/98	5935
BED-MW18	PBOW-98-GW-BEDMW18-5945	5/19/98	5945
BED-MW19	PBOW-98-GW-BEDMW19-5955	5/16/98	5955
BED-MW20	PBOW-98-GW-BEDMW20-5965	5/28/98	5965
IT-BG8-BEDGW-001	PBOW-98-GW-BG8-BEDGW-001-5415	5/15/98	5415
GCL-MW01	PBOW-98-GW-GCLMW01-5855	5/17/98	5855
GCL-MW02A	PBOW-98-GW-GCLMW02A-5865	5/17/98	5865
GCL-MW02B	PBOW-98-GW-GCLMW02B-5875	5/17/98	5875
GCL-MW03	PBOW-98-GW-GCLMW03-5885	5/17/98	5885
IT-MNTA-BEDGW-001	PBOW-98-GW-MNTA-BEDGW-001-5445	5/28/98	5445
IT-MW01	PBOW-98-GW-ITMW01-5535	5/16/98	5535
IT-MW01	PBOW-98-GW-ITMW01-5535	5/18/98	5535R
IT-MW02	PBOW-98-GW-ITMW02-5545	5/15/98	5545
IT-MW05	PBOW-98-GW-ITMW05-5555	5/28/98	5555
IT-MW06	PBOW-98-GW-ITMW06-5565	5/28/98	5565
IT-MW07	DRY (PIEZOMETER)	--	--
IT-MW08	PBOW-98-GW-ITMW08-5585	5/13/98	5585
IT-MW09	PBOW-98-GW-ITMW09-5595	5/19/98	5595
IT-MW10	PBOW-98-GW-ITMW10-5605	5/14/98	5605
MK-MW09	PBOW-98-GW-MKMW09-5725	5/13/98	5725
MK-MW10	PBOW-98-GW-MKMW10-5735	5/12/98	5735
MK-MW11	PBOW-98-GW-MKMW11-5745	5/13/98	5745
MK-MW12	PBOW-98-GW-MKMW12-5755	5/14/98	5755
MK-MW14	PBOW-98-GW-MKMW14-5765	5/14/98	5765
MK-MW15	PBOW-98-GW-MKMW15-5775	5/14/98	5775
MK-MW16	PBOW-98-GW-MKMW16-5785	5/18/98	5785
MK-MW17	PBOW-98-GW-MKMW17-5795	5/27/98	5795

Table 4-4

Summary of Primary Groundwater Samples
Second Semi-Annual Groundwater Sampling Event
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Sample Identification	Sampling Date	Laboratory Reference Number
MK-MW19	PBOW-98-GW-MKMW19-5805	6/1/98	5805
MK-MW20	PBOW-98-GW-MKMW20-5815	5/19/98	5815
MK-MW20	PBOW-98-GW-MKMW20-5815	5/27/98	5815R
MK-MW22	PBOW-98-GW-MKMW22-5825	5/18/98	5825
MK-MW23	PBOW-98-GW-MKMW23-5835	5/29/98	5835
MK-MW24	PBOW-98-GW-MKMW24-5845	5/20/98	5845
PR-MW7	PBOW-98-GW-PRMW7-5695	5/20/98	5695
PR-MW8	PBOW-98-GW-PRMW8-5705	5/20/98	5705
PR-MW9	PBOW-98-GW-PRMW9-5715	5/20/96	5715
REACTOR1	PBOW-98-GW-REACTOR1-5975	6/1/98	5975
REACTOR2	DRY	--	--
REACTOR3	DRY	--	--
REACTOR4	DRY	--	--
TNTA-MW10	PBOW-98-GW-TNTAMW10-5615	5/29/98	5615
TNTA-MW11	PBOW-98-GW-TNTAMW11-5625	5/29/98	5625
IT-TNTB-BEDGW-001	PBOW-98-GW-TNTB-BEDGW-001-5425	5/18/98	5425
IT-TNTB-BEDGW-002	PBOW-98-GW-TNTB-BEDGW-002-5435	5/18/98	5435
TNTC-MW3	PBOW-98-GW-TNTCMW3-5635	5/18/98	5635
TNTC-MW4	PBOW-98-GW-TNTCMW4-5645	5/18/98	5645
TNTC-MW5	PBOW-98-GW-TNTCMW5-5655	5/18/98	5655
TNTC-MW6	PBOW-98-GW-TNTCMW6-5665	5/16/98	5665
TNTC-MW6	PBOW-98-GW-TNTCMW6-5665	5/18/98	5665R
WA-MW1	PBOW-98-GW-WAMW1-5675	5/18/98	5675
WA-MW2	PBOW-98-GW-WAMW2-5685	5/15/98	5685

R - Additional sample volume collected at later date due to slow well recharge, shipping, or laboratory difficulties.

Table 5-1

Summary of Chemical Analyses and Methodologies
First and Second Semi-Annual Groundwater Sampling Events
Former Plum Brook Ordnance Works, Sandusky, Ohio

Matrix	Analytical Parameters	Analytical Method
Water	TCL Volatile Organic Compounds	SW-846 8260A[a]
	TCL Semivolatile Organic Compounds	SW-846 3520B/8270B[a]
	TAL Metals	SW-846 3050A/6010A[b] for Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Tl, V, Zn 7470A[a] for Hg
	PCBs	SW-846 3520B/8081[a]
	Nitroaromatic Compounds	SW-846/8330[c] (as modified)
	TOC, Total Cyanide Alkalinity, Chloride, TDS, TSS, Nitrate Sulfate	SW-846 9060, 9010A MCAWW[d] 310.1, 325.2 and 300.0 160.1, 160.2, 353.2 375.4

[a]U.S. Environmental Protection Agency (EPA), *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, Update II, September 1994.
[b]U.S. Environmental Protection Agency (EPA), *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, Update I, July 1992.
[c]U.S. Environmental Protection Agency (EPA), *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Third Edition, Revision 1, December 1990
[d]U.S. Environmental Protection Agency (EPA), *Methods for Chemical Analysis of Water and Wastes*, EPA- 600/4-79-020, March 1983 and subsequent revisions

TAL - Target analyte list.
TCL - Target compound list.
TDS - Total dissolved solids.
TOC - Total organic carbon.
TSS - Total suspended solids.

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
AA1-BEDGW-001	638.8	Delaware Limestone	5/5/98	6.0	1200	Burnt odor 3-4 ft, Hnu 2.0 ppm; Strong petroleum odor 52-59 ft; Rainbow sheen on surface; Petroleum odor at 61 ft, 2.5-4.2';
			2/24/98	0.0	1600	
			11/12/97	NM	1	
			8/27/97	NP	NP	
AA1-GW-002	638.6	Overburden	5/5/98	0.0	0	Black silt with trace of sand (burnt odor), Hnu = 4.5 ppm
			2/24/98	4.8	NM	
			11/12/97	0.2	NM	
			8/27/97	NP	NP	
AA2-BEDGW-001	641.6	Delaware Limestone	5/5/98	5.0	0	None
			2/24/98	5.0	NM	
			11/12/97	NM	0	
			8/27/97	NP	NP	
AA2-GW002	641.5	Overburden	5/5/98	0.0	0	None
			2/24/98	NM	NM	
			11/12/97	NM	0	
			8/27/97	NP	NP	
AA3-BEDGW-001	634.1	Delaware Limestone	5/5/98	9.0	10	None
			2/24/98	9.0	5	
			11/12/97	NM	0.04	
			8/27/97	NP	NP	
AA3-GW-002	634.1	Overburden	5/5/98	2.0	0	None
			2/24/98	0.8	NM	
			11/12/97	0.2	NM	
			8/27/97	NP	NP	
ABG-BEDGW-001	658.2	Ohio Shale	5/5/98	0.5	0	H_2S = 0.0 ppm at 11 ft.
			2/24/98	0.6	0	
			11/12/97	NM	0	
			8/27/97	NP	NP	
ABG-GW-002	658.2	Overburden	5/5/98	0.0	0	None
			2/24/98	0.7	NM	
			11/12/97	0.0	NM	
			8/27/97	NP	NP	
BED-MW13	645.49	Delaware Limestone	5/5/98	10.0	0	At 27 ft; odor from augers cutting shale - occasionally 3 ppm in breathing zone. At 57 ft; H_2S reading 1 ppm after coring. Oils on augers in Delaware Limestone
			2/24/98	14.0	NM	
			11/12/97	NM	6	
			8/27/97	0.4	0	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
BED-MW14	642.73	Olentangy Shale/Delaware Limestone	5/5/98	1.0	0	Very slight petroleum odor at 34 ft; small oil sheen on core at 48.5 ft.
			2/24/98	0.2	NM	
			11/12/97	NM	0	
			8/27/97	8.8	0	
BED-MW15	628.76	Delaware Limestone	5/5/98	30.0	150	Slight petroleum odor at 32 ft; black staining on core at 39 ft; 42.5 ft, and 46 ft.
			2/24/98	22.0	203	
			11/12/97	NM	122	
			8/27/97	0.0	0.12	
BED-MW16	633.36	Delaware Limestone	5/5/98	40.0	0	Petroleum odor, discoloration, and small amount of oil (on core) at 56 ft (HNu 16 ppm)
			2/24/98	114.0	0	
			11/12/97	260.0	0	
			8/27/97	220.0	0	
BED-MW17	627.02	Delaware Limestone	5/5/98	45.0	324	Petroleum odor at 45 ft.; black stain on core at 61.3 ft.
			2/24/98	54.0	828	
			11/12/97	NM	0	
			8/27/97	17.2	0	
BED-MW18	648.51	Olentangy Shale/Delaware Limestone	5/5/98	2.0	0	None
			2/24/98	5.4	0	
			11/12/97	NM	0	
			8/27/97	4.2	0	
BED-MW19	640.19	Delaware Limestone	5/5/98	2.0	0	H_2S odor 39.5 - 49.5 ft.
			2/24/98	6.0	NM	
			11/12/97	NM	0	
			8/27/97	9.8	0	
BED-MW20	673.25	Ohio Shale	5/5/98	0.0	0	Black stained shale 47.5 ft.
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	0.3	0	
BG8-BEDGW-001	673.7	Olentangy Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97			
EB-GM-01	637.70	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
EB-GM-02	634.90	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-GM-03	636.20	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-GM-04	633.60	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.5	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-GM-05	637.00	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-GM-06	637.00	Overburden	5/5/98	1.0	0	Unknown - borelog not available
			2/24/98	1.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-PS-02	635.70	Overburden	5/5/98	0.0	0	None
			2/24/98	0.6	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-PS-03	634.40	Overburden	5/5/98	0.0	0	None
			2/24/98	1.7	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-PS-04	635.30	Overburden	5/5/98	0.0	0	None
			2/24/98	7.6	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
EB-RA-01	631.40	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	NM	NM	
			8/27/97	0.4	0	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
EB-RA-02	631.30	Overburden	5/5/98	4.3	0	None
			2/24/98	13.8	NM	
			11/12/97	NM	0	
			8/27/97	0.4	0	
EB-RA-03	630.90	Overburden	5/5/98	0.0	0	None
			2/24/98	0.6	NM	
			11/12/97	NM	0	
			8/27/97	0.4	0	
EB-RA-04	630.70	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	0.4	0	
EB-RA-05	630.60	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	4.2	0	
EB-RA-06	630.1	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	0.4	0	
EB-SP-01	652.30	Overburden/Ohio Shale	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
EB-SP-03	655.10	Overburden/Ohio Shale	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
EB-SP-04	655.25	Overburden/Ohio Shale	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
EB-SP-05	654.50	Overburden/Ohio Shale	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
EB-SP-06	655.40	Overburden/Ohio Shale	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
GCL-MW01	671.40	Overburden/Ohio Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
GCL-MW02A	669.70	Ohio Shale	5/5/98	0.0	NM	None
			2/24/98	0.0	NM	
			11/12/97	0.3	0	
			8/27/97	0.0	0	
GCL-MW02B	669.60	Overburden/Ohio Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	
GCL-MW03	669.55	Overburden/Ohio Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	0	
			8/27/97	NM	NM	
IT-MW01	674.50	Olentangy Shale	5/5/98	4.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	
IT-MW02	636.37	Overburden	5/5/98	3.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.3	0	
			8/27/97	0.0	0	
IT-MW05	631.59	Overburden	5/5/98	0.0	0	None
			2/24/98	20.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
IT-MW06	628.50	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
IT-MW07	632.30	Overburden	5/5/98	0.0	0	Unknown - borelog not available
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	NM	NM	
IT-MW08	630.60	Overburden/Olentangy Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	1.1	0	
			8/27/97	0.0	NM	
IT-MW09	645.40	Overburden/Olentangy Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	0	
			8/27/97	0.0	NM	
IT-MW10	642.52	Overburden	5/5/98	2.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.3	0	
			8/27/97	0.0	NM	
MK-MW09	642.95	Overburden	5/5/98	0.0	NM	None
			2/24/98	0.0	NM	
			11/12/97	0.3	0	
			8/27/97	0.0	NM	
MK-MW10	637.74	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.3	0	
			8/27/97	0.0	NM	
MK-MW11	634.39	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	0.0	NM	
MK-MW12	638.10	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	
MK-MW14	678.50	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
MK-MW15	677.80	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	
MK-MW16	671.01	Overburden/Ohio Shale	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	NM	NM	
MK-MW17	660.65	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	60.0	NM	
MK-MW19	636.20	Overburden	5/5/98	0.5	0	None
			2/24/98	0.5	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	NM	
MK-MW20	634.30	Overburden	5/5/98	50.0	0	Chemical odors encountered at 6 ft. in gravel lens; strong chemical odor (toluene) 6-10 ft (PID = 4,000 ppm in borehole.
			2/24/98	50.0	NM	
			11/12/97	3.0	NM	
			8/27/97	0.2	NM	
MK-MW22	635.24	Overburden	5/5/98	42.0	0	None
			2/24/98	42.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
MK-MW23	636.63	Overburden	5/5/98	47.0	0	None
			2/24/98	47.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	0	
MK-MW24	654.12	Overburden	5/5/98	52.0	0	None
			2/24/98	52.0	NM	
			11/12/97	0.2	NM	
			8/27/97	NM	NM	
MNTA-BEDGW-001	636.05	Delaware Limestone	5/5/98	NM	1500	H_2S odor at 50 ft (7 ppm); H_2S 68 ppm at 55 ft; strong petroleum odor at 62 ft
			2/24/98	0.0	>1900	
			11/12/97	NM	1516	
			8/27/97	NM	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
PR-MW07	631.18	Overburden	5/5/98	0.0	0	None
			2/24/98	43.0	NM	
			11/12/97	0.0	NM	
			8/27/97	0.0	NM	
PR-MW08	632.18	Overburden/ Olentangy Shale	5/5/98	0.0	0	Dark brown stained sandy clay layer 7.8 - 8.0 ft. HNu = 3 ppm
			2/24/98	2.8	NM	
			11/12/97	0.0	NM	
			8/27/97	NM	NM	
PR-MW09	630.38	Overburden	5/5/98	0.0	0	Dark brown streaks in sandy clay 4 - 6 ft; HNu 2 ppm
			2/24/98	24.5	NM	
			11/12/97	0.8	NM	
			8/27/97	NM	NM	
REACTOR1	630.45	Delaware Limestone	5/5/98	0.0	0	None
			2/24/98	0.2	0	
			11/12/97	NM	0	
			8/27/97	0.4	0	
REACTOR2	631.00	Delaware Limestone	5/5/98	0.0	0	None
			2/24/98	0.5	0	
			11/12/97	NM	0	
			8/27/97	3.2	0	
REACTOR3	631.10	Delaware Limestone	5/5/98	0.0	0	None
			2/24/98	1.5	0	
			11/12/97	NM	0	
			8/27/97	0.4	0	
TNTA-MW10	637.18	Overburden/Ohio Shale	5/5/98	1.0	0	None
			2/24/98	52.0	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	0	
TNTA-MW11	637.54	Overburden/Ohio Shale	5/5/98	0.0	0	None
			2/24/98	0.3	NM	
			11/12/97	0.2	NM	
			8/27/97	0.0	0	
TNTB-BEDGW-001	659.8	Olentangy Shale	5/5/98	0.0	0	H_2S 1 ppm at well head when boring at 20 ft
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	NM	NM	

Table 6-1

Lithologic Units with Reported H_2S and Petroleum
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Ground Elevation (ft msl)	Unit Monitored	Date	HNu Reading During Ground-water Sampling (ppm)	H_2S Reading During Ground-Water Sampling (ppm)	Possible Petroleum Evidence During Well Installation
TNTB-BEDGW-002	670.1	Ohio Shale	5/5/98	0.0	0	H_2S odor at 16 ft
			2/24/98	0.0	NM	
			11/12/97	NM	0	
			8/27/97	NM	NM	
TNTC-MW03	642.25	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.6	0	
			8/27/97	0.0	NM	
TNTC-MW04	651.57	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.0	0	
			8/27/97	0.0	NM	
TNTC-MW05	648.75	Overburden/Olentangy Shale	5/5/98	0.0	NM	None
			2/24/98	0.0	NM	
			11/12/97	0.0	NM	
			8/27/97	0.0	NM	
TNTC-MW06	656.50	Overburden	5/5/98	0.0	0	Black stained sand 4-6; 6.0 - 7.5 ft, PID 1.0 ppm
			2/24/98	0.0	NM	
			11/12/97	0.2	0	
			8/27/97	0.0	NM	
WA-MW01	642.00	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	0	
			8/27/97	0.0	NM	
WA-MW02	630.84	Overburden	5/5/98	0.0	0	None
			2/24/98	0.0	NM	
			11/12/97	0.2	0	
			8/27/97	0.0	NM	

NM - Not measured.
NP - Not present.

Table 6-2

Summary of Groundwater Elevation Measurements
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Coordinates (Ohio Plane)[a] Easting x	Northing y	Top of Casing Elevation[a] (ft msl)	Ground Elevation[a] (ft msl)	Groundwater Elevation Measurements (feet above mean sea level [msl]) 12/1994[b]	03/1995[c]	10/1996[d]	8/27	8/27/1997[e]	11/12	11/12/1997[f]	2/24	02/24/1998[g]	5/5	05/05/1998[h]
IT-AA1-BEDGW-001	1917718	623069	641.04	638.8	--[i]	--	--	--	--	30.52	610.52	30.50	610.54	29.1	611.94
IT-AA1-GW002	1917728	623068	640.85	638.6	--	--	--	--	--	6.22	634.63	3.05	637.80	3.42	637.43
IT-AA2-BEDGW-001	1909553	623600	644.06	641.6	--	--	--	--	--	13.11	630.95	11.58	632.48	9.89	634.17
IT-AA2-GW-002[j]	1909481	623589	643.95	641.5	--	--	--	--	--	--	dry[k]	--	dry	--	dry
IT-AA3-BEDGW-001	1914957	625037	636.43	634.1	--	--	--	--	--	23.22	613.21	21.53	614.90	21.62	614.81
IT-AA3-GW-002	1914956	625028	636.11	634.1	--	--	--	--	--	6.30	629.81	3.88	632.23	3.97	632.14
IT-ABG-BEDGW-001	1921506	621580	660.59	658.2	--	--	--	--	--	6.09	654.50	3.55	657.04	5.60	654.99
IT-ABG-GW-002	1921516	621579	661.06	658.2	--	--	--	--	--	6.55	654.51	3.95	657.11	4.92	656.14
PB-BED-MW13	1912175	621044	647.95	645.49	607.85	619.29	621.79	27.80	620.15	27.08	620.87	48.47	599.48	41.40	606.55
PB-BED-MW14	1910457	622720	645.72	642.73	621.76	624.39	625.23	18.51	627.21	19.72	626.00	16.44	629.28	15.99	629.73
PB-BED-MW15	1919283	626179	631.31	628.76	603.54	598.91	610.22	29.95	601.36	21.12	610.19	20.34	610.97	19.79	611.52
PB-BED-MW16	1920594	623299	635.70	633.36	571.38	633.68	630.17	11.80	623.90	7.41	628.29	2.28	633.42	2.74	632.96
PB-BED-MW17	1924121	625417	629.65	627.02	602.57	602.90	602.76	26.48	603.17	27.75	601.90	26.85	602.80	26.40	603.25
PB-BED-MW18	1925483	623849	651.18	648.51	625.05	620.39	621.68	30.58	620.60	30.22	620.96	30.55	620.63	30.72	620.46
PB-BED-MW19	1910174	623869	642.75	640.19	621.07	623.52	622.92	19.85	622.90	20.55	622.20	19.00	623.75	18.45	624.30
PB-BED-MW20	1922952	612423	676.01	673.25	661.35	661.28	661.98	14.28	661.73	14.42	661.59	13.98	662.03	13.29	662.72
IT-BG8-BEDGW-001	1909857	616635	676.56	673.7	--	--	--	--	--	6.38	670.18	8.11	668.45	5.86	670.70
EB-GM-01	1918339	623563	640.45	637.70	--	--	--	8.77	631.68	9.29	631.16	7.35	633.10	7.97	632.48
EB-GM-02	1917622	624435	637.52	634.90	--	--	--	10.76	626.76	9.46	628.06	4.91	632.61	5.14	632.38
EB-GM-03	1917775	624131	638.90	636.20	--	--	--	6.28	632.62	7.38	631.52	5.81	633.09	5.99	632.91
EB-GM-04	1917442	624052	636.34	633.60	--	--	--	5.56	630.78	5.55	630.79	3.27	633.07	3.91	632.43
EB-GM-05	1917802	623872	639.70	637.00	--	--	--	6.24	633.46	7.57	632.13	5.80	633.90	dry	dry
EB-GM-06	1917799	623723	639.61	637.00	--	--	--	6.08	633.53	7.36	632.25	5.92	633.69	6.00	633.61
EB-PS-02	1920061	624344	638.53	635.70	--	--	--	5.97	632.56	5.87	632.66	4.81	633.72	4.90	633.63
EB-PS-03	1920187	624324	637.15	634.40	--	--	--	5.65	631.50	6.35	630.80	5.62	631.53	5.52	631.63
EB-PS-04	1920259	624298	637.87	635.30	--	--	--	8.87	629.00	9.00	628.87	7.30	630.57	5.26	632.61
EB-RA-01	1917783	625964	633.97	631.40	--	--	--	6.61	627.36	7.88	626.09	5.63	628.34	5.75	628.22
EB-RA-02	1918282	626944	633.95	631.30	--	--	--	8.10	625.85	8.72	625.43	6.52	627.43	6.72	627.23
EB-RA-03	1918346	626788	633.63	630.90	--	--	--	--	dry	--	dry	9.09	624.54	9.70	623.93
EB-RA-04	1918389	626731	633.54	630.70	--	--	--	8.07	625.47	10.36	623.18	7.12	626.42	7.53	626.01
EB-RA-05	1918492	626717	633.34	630.60	--	--	--	7.95	625.39	8.87	624.47	6.87	626.47	7.07	626.27
EB-RA-06	1918750	626748	632.64	630.10	--	--	--	8.65	623.99	7.86	624.78	5.20	627.44	4.49	628.15
EB-SP-01	1927550	613598	655.07	652.30	--	--	--	6.43	648.64	7.55	647.52	5.54	649.53	5.78	649.29
EB-SP-03	1926836	613398	657.73	655.10	--	--	--	5.26	652.47	6.94	650.79	4.26	653.47	4.21	653.52

Table 6-2

Summary of Groundwater Elevation Measurements
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Coordinates (Ohio Plane)[a] Easting x	Northing y	Top of Casing Elevation[a] (ft msl)	Ground Elevation[a] (ft msl)	Groundwater Elevation Measurements (feet above mean sea level (msl)) 12/1994[b]	03/1995[c]	10/1996[d]	8/27	8/27/1997[e]	11/12	11/12/1997[f]	2/24	02/24/1998[g]	5/5	05/05/1998[h]
EB-SP-04	1926937	613162	658.02	655.25	--	--	--	7.20	650.82	8.18	649.84	4.21	653.81	7.20	650.82
EB-SP-05	1926897	613051	657.00	654.50	--	--	--	5.08	651.92	6.17	650.83	4.92	652.08	4.96	652.04
EB-SP-06	1927074	613056	658.25	655.40	--	--	--	6.80	651.45	8.10	650.15	7.04	651.21	7.24	651.01
GCL-MW01	1921255	617560	674.81	671.40	--	--	--	8.32	666.49	8.81	666.00	4.57	670.24	4.98	669.83
GCL-MW02A	1920961	617937	672.96	669.70	--	--	--	7.57	665.39	7.79	665.17	4.65	668.31	4.85	668.11
GCL-MW02B	1920984	617941	673.42	669.60	--	--	--	8.32	665.10	8.41	665.01	4.59	668.83	5.00	668.42
GCL-MW03	1920777	617641	672.57	669.55	--	--	--	6.00	666.57	6.61	665.96	4.20	668.37	4.50	668.07
IT-MW01	1915525	616901	678.19	674.50	--	--	--	5.45	672.74	7.00	671.19	4.66	673.53	4.60	673.59
IT-MW02	1910265	622512	639.28	636.37	627.32	633.75	629.33	8.09	631.19	9.78	629.50	5.68	633.60	5.79	633.49
IT-MW05	1919475	625346	634.67	631.59	620.19	629.62	623.36	9.88	624.79	10.45	624.22	4.42	630.25	4.76	629.91
IT-MW06	1918768	628642	631.70	628.50	--	--	--	8.34	623.36	9.21	622.49	4.01	627.69	4.02	627.68
IT-MW07[i]	1909862	622076	635.03	632.30	--	--	--	--	dry	--	dry	--	dry	--	dry
IT-MW08	1911132	622498	633.16	630.60	--	--	619.96	8.22	624.94	10.72	622.44	2.91	630.25	3.12	630.04
IT-MW09	1910699	620956	647.45	645.40	--	--	dry	6.00	641.45	7.24	640.21	4.72	642.73	5.02	642.43
IT-MW10	1919485	623027	644.80	642.52	--	--	626.41	11.25	633.55	12.12	632.68	8.20	636.60	8.19	636.61
MK-MW09	1908872	623901	645.61	642.95	--	--	--	6.09	639.52	6.49	639.12	5.00	640.61	4.99	640.62
MK-MW10	1910564	623880	640.57	637.74	626.66	--	632.23	7.13	633.44	8.49	632.08	7.15	633.42	5.22	635.35
MK-MW11	1910564	623860	637.36	634.39	625.22	631.36	628.89	7.13	630.23	8.14	629.22	5.92	631.44	6.51	630.85
MK-MW12	1908764	621233	640.93	638.10	--	--	--	9.86	631.07	10.78	630.15	7.45	633.48	8.38	632.55
MK-MW14	1913325	618311	681.26	678.50	--	--	--	8.17	673.09	8.72	672.54	4.62	676.64	4.81	676.45
MK-MW15	1913304	618488	680.63	677.80	--	--	--	8.22	672.41	8.80	671.83	4.92	675.71	4.86	675.77
MK-MW16	1918011	616834	674.00	671.01	667.14	669.36	668.42	5.97	668.03	7.75	666.25	5.14	668.86	5.10	668.90
MK-MW17	1917813	618572	664.32	660.65	659.58	661.10	660.56	4.32	660.00	4.75	659.57	3.68	660.64	3.90	660.42
MK-MW19	1917535	623871	639.13	636.20	--	--	--	7.99	631.14	6.83	632.30	3.67	635.46	4.56	634.57
MK-MW20	1920539	622912	637.51	634.30	--	--	--	4.97	632.54	4.78	632.73	6.61	630.90	5.85	631.66
MK-MW22	1923776	624339	637.73	635.24	628.85	631.55	630.07	8.20	629.53	8.24	629.49	6.94	630.79	7.42	630.31
MK-MW23	1925354	624657	639.11	636.63	620.88	628.12	632.14	8.49	630.62	8.02	631.09	5.61	633.50	6.54	632.57
MK-MW24	1923302	622264	656.80	654.12	648.31	650.77	649.61	7.08	649.72	7.22	649.58	6.25	650.55	6.18	650.62
IT-MNTA-BEDGW-001	1918699	623808	638.40	636.05	--	--	--	--	--	28.04	610.36	27.05	611.35	25.60	612.80
PB-PR-MW07	1919021	624998	633.67	631.18	626.32	631.65	629.64	5.35	628.32	5.06	628.61	2.21	631.46	2.17	631.50
PB-PR-MW08	1919309	624889	634.70	632.18	624.55	629.98	627.56	6.66	628.04	7.72	626.98	4.90	629.80	4.37	630.33
PB-PR-MW09	1919510	625092	633.38	630.38	622.92	630.12	626.57	6.50	626.88	7.85	625.53	3.36	630.02	3.40	629.98
REACTOR1	1917983	626773	630.51	630.45	--	--	--	15.32	615.19	22.06	608.45	33.25	597.26	32.30	598.21
REACTOR2	1918003	626661	631.05	631.00	614.71	601.89	--	15.40	615.65	4.81	626.24	28.53	602.52	27.50	603.55

Table 6-2

Summary of Groundwater Elevation Measurements
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well Identification	Coordinates (Ohio Plane)[a]		Top of Casing Elevation[a] (ft msl)	Ground Elevation[a] (ft msl)	Groundwater Elevation Measurements (feet above mean sea level [msl])										
	Easting x	Northing y			12/1994[b]	03/1995[c]	10/1996[d]	8/27	8/27/1997[e]	11/12	11/12/1997[f]	2/24	02/24/1998[g]	5/5	05/05/1998[h]
REACTOR3	1918148	626685	631.21	631.10	--	--	--	14.60	616.61	22.17	609.04	37.45	593.76	37.08	594.13
PB-TNTA-MW10	1923399	623664	639.86	637.18	633.71	637.04	635.62	4.16	635.70	4.67	635.19	3.10	636.76	3.24	636.62
PB-TNTA-MW11	1922744	623518	640.18	637.54	630.50	632.82	633.56	5.49	634.69	5.16	635.02	4.78	635.40	4.34	635.84
IT-TNTB-BEDGW-001	1917218	618738	662.43	659.8	--	--	--	--	--	4.11	658.32	5.60	656.83	2.91	659.52
IT-TNTB-BEDGW-002	1918021	616835	673.35	670.1	--	--	--	--	--	6.91	666.44	2.89	670.46	7.67	665.68
PB-TNTC-MW03	1911391	621465	645.09	642.25	dry	639.20	635.01	8.07	637.02	9.27	635.82	3.80	641.29	4.95	640.14
PB-TNTC-MW04	1910470	620413	654.11	651.57	634.87	651.07	648.51	6.15	647.96	7.62	646.49	3.32	650.79	3.21	659.90
PB-TNTC-MW05	1911811	620692	651.49	648.75	628.01	647.62	643.28	5.62	645.87	5.60	645.89	3.02	648.47	3.10	648.39
PB-TNTC-MW06	1913006	620429	659.08	656.50	651.93	655.20	654.56	4.46	654.62	5.71	653.37	3.72	655.36	3.81	655.27
PB-WA-MW01	1909948	622641	644.11	642.00	--	--	--	14.00	630.11	16.15	627.96	4.09	640.02	4.70	639.41
PB-WA-MW02	1910176	622124	633.33	630.84	--	--	--	3.89	629.44	4.46	628.87	1.53	631.80	1.54	631.79

[a] Survey data are scaled to the Ohio State Plane Coordinate System (North Zone).
[b] Data from Dames & Moore, Sitewide Groundwater Investigation Final Report (4/97).
[c] Data from Dames & Moore, Sitewide Groundwater Investigation Final Report (4/97).
[d] Data from IT Corporation, Site-Wide Groundwater Investigation Report (9/97).
[e] Data from IT Corporation, 1st Quarterly Water Level Measurement Event Report (10/97).
[f] Data from IT Corporation, 2nd Quarterly Water Level Measurement and 1st Semi-Annual Groundwater Sampling Event Report (5/98).
[g] Data from IT Corporation, 3rd Quarterly Water Level Measurement Event Report (6/97).
[h] Data from IT Corporation, 4th Quarterly Water Level Measurement and 2nd Semi-Annual Groundwater Sampling Event Report (this volume).
[i] Symbol denotes data are not available.
[j] Temporary piezometer.
[k] Well was dry at the time of the measurement.

Table 6-3

Summary of Hydraulic Conductivity Testing Results
Former Plum Brook Ordnance Works, Sandusky, Ohio

Well ID	Test Type	Hydraulic Conductivities K (ft/min)	Hydraulic Conductivities K (cm/sec)	Hydraulic Conductivities K (ft/day)
Overburden Wells				
IT-MW-08	Rising	3.32E-03	1.69E-03	4.78E+00
	Rising	7.16E-03	3.64E-03	1.03E+01
	Rising	9.57E-03	4.86E-03	1.38E+01
IT-AA1-GW-002	Rising	5.13E-04	2.61E-04	7.39E-01
IT-AA2-GW-002	Dry	---	---	---
IT-AA3-GW-002	Rising	2.94E-03	1.49E-03	4.23E+00
IT-ABG-GW-002	Rising	1.47E-01	7.47E-02	2.12E+02
Maximum (K)		***1.47E-01***	***7.47E-02***	***2.12E+02***
Minimum (K)		***5.13E-04***	***2.61E-04***	***7.39E-01***
Geometric Mean (K)		***6.08E-03***	***3.09E-03***	***8.75E+00***
Standard Deviation (K)		***5.82E-02***	***2.96E-02***	***8.38E+01***
Bedrock Wells				
IT-AA1-BEDGW-001	Rising	5.17E-05	2.63E-05	7.44E-02
IT-AA2-BEDGW-001	Rising	2.26E-05	1.15E-05	3.25E-02
IT-BG8-BEDGW-001	Rising	2.39E-04	1.21E-04	3.44E-01
IT-ABG-BEDGW-001	Rising	1.54E-02	7.83E-03	2.22E+01
IT-TNTB-BEDGW-001	Rising	4.07E-05	2.07E-05	5.86E-02
IT-TNTB-BEDGW-002	Rising	1.24E-02	6.30E-03	1.79E+01
IT-MNTA-BEDGW-001	Rising	2.17E-05	1.10E-05	3.12E-02
IT-AA3-BEDGW-001	Rising	2.58E-04	1.31E-04	3.72E-01
Maximum (K)		***1.54E-02***	***7.83E-03***	***2.22E+01***
Minimum (K)		***2.17E-05***	***1.10E-05***	***3.12E-02***
Geometric Mean (K)		***2.43E-04***	***1.24E-04***	***3.50E-01***
Standard Deviation (K)		***6.44E-03***	***3.27E-03***	***9.27E+00***

Table 6-4

Well Pair Vertical Hydraulic Gradients
Former Plum Brook Ordnance Works, Sandusky, Ohio

	Well Name	Unit Monitored (ft below ground)	Well TD (ft below ground)	Depth of Monitored Zone (ft below ground)	Elevation of Ground Surface (ft)	Elevation of Center of Monitored Zone (ft)	Groundwater Elevation 8/27/97	Groundwater Elevation 11/12/97	Groundwater Elevation 2/24/98	Groundwater Elevation 5/5/98	Average Vertical Gradient (ft/ft)
Pair 1	IT-AA1-GW002	OB/OS	22	6.8-21.9	638.6	624.25	NA	634.63	637.80	637.43	
	IT-AA1-BED-GW001	DL	65.0	49.8-64	638.8	581.90	NA	610.52	610.54	611.94	
	Distance Between Center of Monitored Zones					42.35					
	Vertical Gradient						NA	0.563	0.637	0.596	0.599
Pair 2	IT-AA2-GW-002	OB/OLS	18.5	8.3-18.3	641.5	628.20	NA	DRY	DRY	643.95	
	IT-AA2-BED-GW001	DL	54	27.8-42.8	641.6	606.30	NA	630.95	632.48	634.17	
	Distance Between Center of Monitored Zones					21.90					
	Vertical Gradient						NA	NA	NA	0.447	0.447
Pair 3	AA3-GW002	OB	16	5.8-15.8	634.1	623.30	NA	629.81	632.23	622.14	
	AA3-BED-GW001	DL	53	37.8-52.8	634.1	588.80	NA	613.21	614.90	614.81	
	Distance Between Center of Monitored Zones					34.5					
	Vertical Gradient						NA	0.481	0.502	0.212	0.398
Pair 4	ABG-GW002	OB	6.8	2.5-6.5	658.2	653.70	NA	654.51	657.11	657.06	
	ABG-BED-GW001	OS	21	10.8-20.8	658.2	642.40	NA	654.50	657.04	656.99	
	Distance Between Center of Monitored Zones					11.30					
	Vertical Gradient	OB/OS					NA	0.001	0.006	0.006	0.004
Pair 5	MK-MW16	OB/OS	8	2-7	671.01	666.51	668.35	666.25	669.18	669.22	
	TNTB-BED-GW002	OS	24.2	14-24	670.10	651.10	NA	666.44	670.46	665.68	
	Distance Between Center of Monitored Zones					15.41					
	Vertical Gradient						NA	-0.012	-.081	0.223	0.044

OB - Overburden.
OS - Ohio Shale.
OLS - Olentangy Shale.
DL - Delaware Limestone.

Table 6-5

Blank Corrected Constituents in Overburden Monitoring Wells
West Area Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	IT-MW02				IT-MW08				IT-MW10			
		Sample No:	5540		5545		5580		5585		5605		5600	
		Sample Date:	21-Nov-97		15-May-98		19-Nov-97		13-May-98		14-Nov-97		14-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
Carbon disulfide	µg/L	100									0.17	J		
Toluene	µg/L	75												
Total xylenes	µg/L	1200												
Semivolatile Organic Compounds														
2,4-Dinitrophenol	µg/L	7.3												
2,4-Dinitrotoluene	µg/L	7.3	43		43									
2,6-Dinitrotoluene	µg/L	3.7	7.1	J	6.7	J								
2-Nitroaniline	µg/L	0.22	1.5	J	1.3	J								
3-Nitroaniline	µg/L	11			3.3	J								
4,6-Dinitro-2-methylphenol	µg/L	0.37	12	J										
4-Nitrophenol	µg/L	29												
Di-n-octyl phthalate	µg/L	73												
Nitrobenzene	µg/L	0.35												
bis(2-Ethylhexyl)phthalate	µg/L	4.8									5.1	J		
Explosives														
1,3,5-Trinitrobenzene	µg/L	110	14		15									
1,3-Dinitrobenzene	µg/L	0.37	17		19									
2,4,6-Trinitrotoluene	µg/L	1.8												
2,4-Dinitrotoluene	µg/L	7.3	47		47									
2,6-Dinitrotoluene	µg/L	3.7	7.8		8.9									
3-Nitrotoluene	µg/L	12			36									
Nitrobenzene	µg/L	0.35			2.6									
RDX	µg/L	0.61			6.2									
Metals - Unfiltered														
Aluminum	µg/L	3700									1040		11600	
Arsenic	µg/L	0.045											36.8	
Barium	µg/L	260											372	
Chromium	µg/L	18											39.8	
Cobalt	µg/L	220												
Copper	µg/L	150	62.6		30.7								30.8	
Iron	µg/L	1100			595	J	294				3040		41000	
Lead	µg/L	15									4.5		33.6	
Manganese	µg/L	73	896		764		191		361		1670		1460	
Mercury	µg/L	1.1							0.24					
Nickel	µg/L	73												
Selenium	µg/L	18												
Vanadium	µg/L	26											64.4	
Zinc	µg/L	1100							23.4					

Table 6-5

Blank Corrected Constituents in Overburden Monitoring Wells
West Area Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	IT-MW02				IT-MW08				IT-MW10			
		Sample No:	5540		5545		5580		5585		5605		5600	
		Sample Date:	21-Nov-97		15-May-98		19-Nov-97		13-May-98		14-Nov-97		14-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Filtered														
Chromium	µg/L	18												
Cobalt	µg/L	220												
Copper	µg/L	150	41.6											
Iron	µg/L	1100			509		327							
Manganese	µg/L	73	877		969		238		328		1630		621	
Nickel	µg/L	73												
Vanadium	µg/L	26												
Zinc	µg/L	1100	27.2	J					33.1					
Cyanide														
Cyanide, total	µg/L	73			16									
Water Quality Parameters														
Alkalinity	µg/L	ne	550000		650000		510000		470000		45000		480000	
Chloride	µg/L	ne	97000		23000		18000	J	14000		17000		13000	J
Hardness	µg/L	ne	2E+06		660000		1300000		1600000		760000		820000	
Nitrate	µg/L	5800									100		200	
Sulfate	µg/L	ne	270000		260000		920000	J	780000		300000		270000	J
Total dissolved solids	µg/L	ne	1E+06		1100000		1900000		1700000		930000		1100000	
Total organic carbon	µg/L	ne	41000		28000		6000	J	4400		2700		3000	J
Total suspended solids	µg/L	ne			370000						37000		400000	

Table 6-5

Blank Corrected Constituents in Overburden Monitoring Wells
West Area Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-WA-MW01				PB-WA-MW02			
		Sample No:	5670		5675		5680		5685	
		Sample Date:	21-Nov-97		18-May-98		23-Nov-97		15-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Carbon disulfide	µg/L	100								
Toluene	µg/L	75								
Total xylenes	µg/L	1200								
Semivolatile Organic Compounds										
2,4-Dinitrophenol	µg/L	7.3							7.6	J
2,4-Dinitrotoluene	µg/L	7.3							55	
2,6-Dinitrotoluene	µg/L	3.7							1.8	J
2-Nitroaniline	µg/L	0.22								
3-Nitroaniline	µg/L	11							330	J
4,6-Dinitro-2-methylphenol	µg/L	0.37								
4-Nitrophenol	µg/L	29							1.6	J
Di-n-octyl phthalate	µg/L	73	2.7	J						
Nitrobenzene	µg/L	0.35							3.7	J
bis(2-Ethylhexyl)phthalate	µg/L	4.8								
Explosives										
1,3,5-Trinitrobenzene	µg/L	110							23	
1,3-Dinitrobenzene	µg/L	0.37							23	
2,4,6-Trinitrotoluene	µg/L	1.8								
2,4-Dinitrotoluene	µg/L	7.3							21	
2,6-Dinitrotoluene	µg/L	3.7							4.1	
3-Nitrotoluene	µg/L	12								
Nitrobenzene	µg/L	0.35								
RDX	µg/L	0.61								
Metals - Unfiltered										
Aluminum	µg/L	3700	2710	J			3720	J	4220	
Arsenic	µg/L	0.045								
Barium	µg/L	260								
Chromium	µg/L	18					12.8		11.4	
Cobalt	µg/L	220					142		118	
Copper	µg/L	150					70.2		61.9	
Iron	µg/L	1100	5600		319	J	7930		9390	J
Lead	µg/L	15								
Manganese	µg/L	73	235		303		1660		1510	
Mercury	µg/L	1.1								
Nickel	µg/L	73					228		190	
Selenium	µg/L	18					18.7			
Vanadium	µg/L	26								
Zinc	µg/L	1100					36.7			

Table 6-5

Blank Corrected Constituents in Overburden Monitoring Wells
West Area Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-WA-MW01				PB-WA-MW02			
		Sample No:	5670		5675		5680		5685	
		Sample Date:	21-Nov-97		18-May-98		23-Nov-97		15-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Filtered										
Chromium	µg/L	18							12.4	
Cobalt	µg/L	220							126	
Copper	µg/L	150							66.9	
Iron	µg/L	1100							422	
Manganese	µg/L	73	163		253		1620		2260	
Nickel	µg/L	73							199	
Vanadium	µg/L	26								
Zinc	µg/L	1100								
Cyanide										
Cyanide, total	µg/L	73					79		89	
Water Quality Parameters										
Alkalinity	µg/L	ne	380000		470000		520000		640000	
Chloride	µg/L	ne	7000		7000		2000			
Hardness	µg/L	ne	4900000		940000		3300000		1500000	
Nitrate	µg/L	5800					80000	J	62000	
Sulfate	µg/L	ne	170000		200000		2300000		2000000	
Total dissolved solids	µg/L	ne	650000		630000		7700000		6400000	
Total organic carbon	µg/L	ne	2100		3000		970000		780000	
Total suspended solids	µg/L	ne			8000		40000		160000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-6

Blank Corrected Constituents in Overburden Monitoring Wells
Pentolite Road Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 1 of 2)

		Sample Location:	IT-MW05				PB-PR-MW7			
		Sample No:	5550		5555		5690		5695	
		Sample Date:	19-Nov-97		28-May-98		17-Nov-97		20-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
2-Butanone	µg/L	190								
2-Hexanone	µg/L	150								
Acetone	µg/L	370	22	J	45	J				
Benzene	µg/L	0.36			0.21	J				
Bromodichloromethane	µg/L	0.17								
Carbon disulfide	µg/L	100	0.21	J						
Ethyl benzene	µg/L	130							0.17	J
Toluene	µg/L	75								
Total xylenes	µg/L	1200							0.82	J
Semivolatile Organic Compounds										
2,4-Dinitrophenol	µg/L	7.3								
2,4-Dinitrotoluene	µg/L	7.3					1800		1800	NJ
2,6-Dinitrotoluene	µg/L	3.7					140	J		
2-Nitrophenol	µg/L	230							6.6	NJ
3-Nitroaniline	µg/L	11								
4,6-Dinitro-2-methylphenol	µg/L	0.37					660	J	12000	NJ
4-Nitrophenol	µg/L	29								
Dibenzofuran	µg/L	15								
Fluorene	µg/L	150								
Nitrobenzene	µg/L	0.35							13	NJ
bis(2-Ethylhexyl)phthalate	µg/L	4.8								
Explosives										
1,3,5-Trinitrobenzene	µg/L	110					2000		2800	
1,3-Dinitrobenzene	µg/L	0.37					1500		2000	
2,4-Dinitrotoluene	µg/L	7.3					1200		1600	
Metals - Unfiltered										
Aluminum	µg/L	3700	3970	J	15800	J	8960	J	10500	J
Arsenic	µg/L	0.045	11.5		14.3					
Barium	µg/L	260			312					
Chromium	µg/L	18	10.6		22.7					
Cobalt	µg/L	220					2320		2350	
Copper	µg/L	150			43.7		887		1060	
Iron	µg/L	1100	14700		26500		21700		32600	
Lead	µg/L	15	6.6		9.4					
Manganese	µg/L	73	302		592		17000		13700	
Mercury	µg/L	1.1	0.3							
Nickel	µg/L	73					1710		1790	
Zinc	µg/L	1100	476							
Metals - Filtered										
Arsenic	µg/L	0.045	12.5							
Cobalt	µg/L	220					2330		2610	
Copper	µg/L	150					911		1050	
Iron	µg/L	1100	3050		185		1360		2110	
Manganese	µg/L	73	114		223		17000		17600	
Nickel	µg/L	73					1710		1900	
Cyanide										
Cyanide, total	µg/L	73					120		200	
Water Quality Parameters										
Alkalinity	µg/L	ne	350000		680000		820000		840000	
Chloride	µg/L	ne	3000		11000				9500000	
Hardness	µg/L	ne	760000		570000		5000000		2300000	
Nitrate	µg/L	5800					400	J	190000	
Sulfate	µg/L	ne	48000		61000		8000000		5400000	
Total dissolved solids	µg/L	ne	420000		650000		17000000		18000000	
Total organic carbon	µg/L	ne	4700		6000		2700000		2900000	
Total suspended solids	µg/L	ne	6000		15000		25000		17000	

Table 6-6

Blank Corrected Constituents in Overburden Monitoring Wells
Pentolite Road Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-PR-MW8				PB-PR-MW9			
		Sample No:	5700		5705		5710		5715	
		Sample Date:	17-Nov-97		20-May-98		17-Nov-97		20-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
2-Butanone	µg/L	190			14	J				
2-Hexanone	µg/L	150			2	J				
Acetone	µg/L	370								
Benzene	µg/L	0.36							0.47	J
Bromodichloromethane	µg/L	0.17			0.23	J				
Carbon disulfide	µg/L	100								
Ethyl benzene	µg/L	130							1.5	
Toluene	µg/L	75							1.5	
Total xylenes	µg/L	1200			0.44	J			8	
Semivolatile Organic Compounds										
2,4-Dinitrophenol	µg/L	7.3	6000		3800	NJ	48	J		
2,4-Dinitrotoluene	µg/L	7.3	1500		1700	NJ	110		120	
2,6-Dinitrotoluene	µg/L	3.7	190	J						
2-Nitrophenol	µg/L	230			15					
3-Nitroaniline	µg/L	11	160	J			450	J		
4,6-Dinitro-2-methylphenol	µg/L	0.37	2300	J	20000	NJ			280	NJ
4-Nitrophenol	µg/L	29			42	NJ				
Dibenzofuran	µg/L	15			620	NJ				
Fluorene	µg/L	150			44	NJ				
Nitrobenzene	µg/L	0.35			14					
bis(2-Ethylhexyl)phthalate	µg/L	4.8								
Explosives										
1,3,5-Trinitrobenzene	µg/L	110	1600		2400				71	
1,3-Dinitrobenzene	µg/L	0.37	1500		2100		35		170	
2,4-Dinitrotoluene	µg/L	7.3	1300		2400		28		110	
Metals - Unfiltered										
Aluminum	µg/L	3700								
Arsenic	µg/L	0.045								
Barium	µg/L	260								
Chromium	µg/L	18								
Cobalt	µg/L	220	7270		7150				480	
Copper	µg/L	150	3790		3740				430	
Iron	µg/L	1100	22000		12100				2070	
Lead	µg/L	15								
Manganese	µg/L	73	34100		43900		1900		2300	
Mercury	µg/L	1.1								
Nickel	µg/L	73	7500		6950				466	
Zinc	µg/L	1100								
Metals - Filtered										
Arsenic	µg/L	0.045								
Cobalt	µg/L	220	6770		7450				522	
Copper	µg/L	150	3390		3900				294	
Iron	µg/L	1100	12200		9560					
Manganese	µg/L	73	29700		45500		1890		2500	
Nickel	µg/L	73	6820		7310				460	
Cyanide										
Cyanide, total	µg/L	73	240		1700		36		72	
Water Quality Parameters										
Alkalinity	µg/L	ne	990000		1500000		860000		810000	
Chloride	µg/L	ne	6500000		4700000		7200000		3600000	
Hardness	µg/L	ne	13000000		3100000		2200000		1200000	
Nitrate	µg/L	5800	1600000	J	1500000		200	J	110000	
Sulfate	µg/L	ne	12000000		12000000		3000000		1600000	
Total dissolved solids	µg/L	ne	50000000		49000000		8700000		6400000	
Total organic carbon	µg/L	ne	14000000		11000000		1300000		930000	
Total suspended solids	µg/L	ne	73000		79000		8000		7000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium are not presented on this table.
Analytical results for these elements may be referenced in Appendix H.
Shaded area indicates that concentration above the respective RBC.
ne - Not established.

Table 6-7

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	MK-MW22				MK-MW23				MK-MW24			
		Sample No:	5820		5825		5830		5835		5840		5845	
		Sample Date:	14-Nov-97		18-May-98		16-Nov-97		29-May-98		13-Nov-97		20-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
Acetone	µg/L	370					68	J						
Benzene	µg/L	0.36							0.17	J				
Carbon disulfide	µg/L	100					0.37	J						
Toluene	µg/L	75			7.8								10	
Semivolatile Organic Compounds														
Di-n-octyl phthalate	µg/L	73					9.3	J						
bis(2-Ethylhexyl)phthalate	µg/L	4.8							890	D				
Explosives														
1,3,5-Trinitrobenzene	µg/L	110	0.24		0.43									
2,4,6-Trinitrotoluene	µg/L	1.8	0.74		1.7									
2,4-Dinitrotoluene	µg/L	7.3	0.2		0.35									
2,6-Dinitrotoluene	µg/L	3.7	0.53		1.2									
4-Amino-2,6-dinitrotoluene	µg/L	0.22	0.62		0.86									
Nitrobenzene	µg/L	0.35			0.26									
Metals - Unfiltered														
Aluminum	µg/L	3700	7790		6200		27300		143000	J	6620		242	J
Antimony	µg/L	1.5							82					
Arsenic	µg/L	0.045					59.8		113					
Barium	µg/L	260							232					
Beryllium	µg/L	7.3							6.9					
Chromium	µg/L	18	16.6		13.7		67.1		258		25.2			
Cobalt	µg/L	220					50.8		222					
Copper	µg/L	150					47.3		225					
Iron	µg/L	1100	10900		10900	J	68200		304000		13500		1960	
Lead	µg/L	15	6.7		4.3		29.8		108		13.1			
Manganese	µg/L	73	185		142		1370		7550		788		458	
Mercury	µg/L	1.1							0.25					
Nickel	µg/L	73					125		628					
Vanadium	µg/L	26					76.2		244		60.9			
Zinc	µg/L	1100	35.6				167		735		127			

Table 6-7

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	MK-MW22				MK-MW23				MK-MW24			
		Sample No:	5820		5825		5830		5835		5840		5845	
		Sample Date:	14-Nov-97		18-May-98		16-Nov-97		29-May-98		13-Nov-97		20-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Filtered														
Arsenic	µg/L	0.045					13.8							
Barium	µg/L	260												
Chromium	µg/L	18									14.2			
Iron	µg/L	1100									2920		1440	
Manganese	µg/L	73	149		114		265		134		562		454	
Mercury	µg/L	1.1									0.76			
Vanadium	µg/L	26									53			
Zinc	µg/L	1100												
Water Quality Parameters														
Alkalinity	µg/L	ne	280000		370000		na		na		370000		370000	
Chloride	µg/L	ne	7000		3000		na		na				7000	
Hardness	µg/L	ne	420000		520000		na		na		1900000		1600000	
Sulfate	µg/L	ne	36000		30000		na		na		1200000		1100000	
Total dissolved solids	µg/L	ne	360000		370000		na		na		2400000		2000000	
Total organic carbon	µg/L	ne	11000		2000		na		na		21000		9000	
Total suspended solids	µg/L	ne	150000		130000		na		na		400000		7000	

Table 6-7

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:			PB-TNTA-MW10				PB-TNTA-MW11			
Sample No:			5610		5615		5620		5625	
Sample Date:			18-Nov-97		29-May-98		18-Nov-97		29-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Acetone	µg/L	370	35	J	7.6	J				
Benzene	µg/L	0.36								
Carbon disulfide	µg/L	100								
Toluene	µg/L	75								
Semivolatile Organic Compounds										
Di-n-octyl phthalate	µg/L	73								
bis(2-Ethylhexyl)phthalate	µg/L	4.8								
Explosives										
1,3,5-Trinitrobenzene	µg/L	110								
2,4,6-Trinitrotoluene	µg/L	1.8								
2,4-Dinitrotoluene	µg/L	7.3								
2,6-Dinitrotoluene	µg/L	3.7								
4-Amino-2,6-dinitrotoluene	µg/L	0.22								
Nitrobenzene	µg/L	0.35								
Metals - Unfiltered										
Aluminum	µg/L	3700	877	J	2280	J	3170	J	2990	J
Antimony	µg/L	1.5								
Arsenic	µg/L	0.045	**12.2**		**14.5**		**10.5**			
Barium	µg/L	260	**373**							
Beryllium	µg/L	7.3								
Chromium	µg/L	18					15.6		12.2	
Cobalt	µg/L	220								
Copper	µg/L	150								
Iron	µg/L	1100	**18200**		**18700**		**13300**		**6610**	
Lead	µg/L	15			5.6		10.4		3.2	
Manganese	µg/L	73	**1530**		**1250**		**1030**		**444**	
Mercury	µg/L	1.1								
Nickel	µg/L	73								
Vanadium	µg/L	26								
Zinc	µg/L	1100	27				47.1			

Table 6-7

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-TNTA-MW10				PB-TNTA-MW11			
		Sample No:	5610		5615		5620		5625	
		Sample Date:	18-Nov-97		29-May-98		18-Nov-97		29-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Filtered										
Arsenic	µg/L	0.045								
Barium	µg/L	260	338							
Chromium	µg/L	18								
Iron	µg/L	1100	7610		9330					
Manganese	µg/L	73	1440		1370		865		355	
Mercury	µg/L	1.1								
Vanadium	µg/L	26								
Zinc	µg/L	1100	25				45.4			
Water Quality Parameters										
Alkalinity	µg/L	ne	490000		410000		450000		460000	
Chloride	µg/L	ne	47000		100000		140000		180000	
Hardness	µg/L	ne	1100000		730000		940000		680000	
Sulfate	µg/L	ne	160000		100000		150000		93000	
Total dissolved solids	µg/L	ne	780000		760000		1000000		1000000	
Total organic carbon	µg/L	ne	4200		2000		4500		3000	
Total suspended solids	µg/L	ne	7000				140000		7000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.

ne - Not established.

na - Not analyzed.

Table 6-8

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area B
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	MK-MW16				MK-MW17			
		Sample No:	5780		5785		5790		5795	
		Sample Date:	21-Nov-97		18-May-98		21-Nov-97		27-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Acetone	µg/L	370			5.2	J				
Carbon disulfide	µg/L	100								
Semivolatile Organic Compounds										
2,4-Dinitrotoluene	µg/L	7.3							1.8	J
bis(2-Ethylhexyl)phthalate	µg/L	4.8	2.4	J						
Explosives										
2,4,6-Trinitrotoluene	µg/L	1.8							0.68	
2,4-Dinitrotoluene	µg/L	7.3							1.7	
4-Amino-2,6-dinitrotoluene	µg/L	0.22					3.6		5.7	
Metals - Unfiltered										
Aluminum	µg/L	3700	4990	J	1180		1830	J	6920	J
Arsenic	µg/L	0.045					12.6		18.7	
Cobalt	µg/L	220			69.8		78.8		54.9	
Copper	µg/L	150							32.9	
Iron	µg/L	1100	19800		20700	J	44300		41900	
Lead	µg/L	15							16.4	
Manganese	µg/L	73	6970		13600		1410		1120	
Nickel	µg/L	73	61.8		108		156		130	
Selenium	µg/L	18	5				5.1			
Zinc	µg/L	1100	75.5		209		137		152	
Metals - Filtered										
Aluminum	µg/L	3700	1080		663				7430	
Arsenic	µg/L	0.045							22	
Cobalt	µg/L	220			51.9		72.9		56.7	
Copper	µg/L	150			39.2				32.2	
Iron	µg/L	1100	2410		5970		34100		41600	
Lead	µg/L	15			7.4				17	
Manganese	µg/L	73	6900		8850		1260		1170	
Mercury	µg/L	1.1					0.3			
Nickel	µg/L	73	47.2		81.7		140		131	
Selenium	µg/L	18	5							
Zinc	µg/L	1100	54.7	J			87.7	J	157	
Cyanide										
Cyanide, total	µg/L	73								
Water Quality Parameters										
Alkalinity	µg/L	ne	36000		320000		38000			
Chloride	µg/L	ne			3000				6000	
Hardness	µg/L	ne	490000		750000		440000		490000	
Sulfate	µg/L	ne	470000		550000		300000		330000	
Total dissolved solids	µg/L	ne	290000		800000		660000		590000	
Total organic carbon	µg/L	ne	2500		2000		3400		3000	
Total suspended solids	µg/L	ne			9000		5000		120000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-9

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 1 of 2)

		Sample Location:	IT-MW09				MK-MW12				PB-TNTC-MW03			
		Sample No:	5590		5595		5750		5755		5630		5635	
		Sample Date:	23-Nov-97		19-May-98		17-Nov-97		14-May-98		21-Nov-97		18-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
Benzene	µg/L	0.36			0.16	J								
Chlorobenzene	µg/L	3.5	0.17	J										
Toluene	µg/L	75			17									
Semivolatile Organic Compounds														
bis(2-Ethylhexyl)phthalate	µg/L	4.8					28							
Metals - Unfiltered														
Aluminum	µg/L	3700	1200	J			310						6030	
Arsenic	µg/L	0.045											18.6	
Chromium	µg/L	18	10.4										30	
Cobalt	µg/L	220									67.5			
Copper	µg/L	150											31.5	
Iron	µg/L	1100	3370		131		830		396		805		23500	J
Lead	µg/L	15											13.8	
Manganese	µg/L	73	249		30.7		1130		1000		2950		973	
Nickel	µg/L	73									120			
Selenium	µg/L	18												
Zinc	µg/L	1100	27.2				25.8				34.5			
Metals - Filtered														
Aluminum	µg/L	3700												
Iron	µg/L	1100												
Lead	µg/L	15			4.1									
Manganese	µg/L	73	372		36.4		1060		1060		2900		617	
Nickel	µg/L	73									77.1			
Selenium	µg/L	18												
Zinc	µg/L	1100	73.3	J							28.5	J		
Water Quality Parameters														
Alkalinity	µg/L	ne	340000		410000		340000		270000		270000		350000	
Chloride	µg/L	ne	28000				6000		1000	J	17000		14000	
Hardness	µg/L	ne	2E+06				540000		450000		13000000		1800000	
Nitrate	µg/L	5800	17000	J	100									
Sulfate	µg/L	ne	2E+06		790000		54000		51000	J	2000000		1300000	
Total dissolved solids	µg/L	ne	3E+06		1600000		410000		400000		3000000		2900000	
Total organic carbon	µg/L	ne	2900		2000		2000		2000	J	2400		3000	
Total suspended solids	µg/L	ne	15000				5000						150000	

Table 6-9

Blank Corrected Constituents in Overburden Monitoring Wells
TNT Manufacturing Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-TNTC-MW04				PB-TNTC-MW05				PB-TNTC-MW06			
		Sample No:	5640		5645		5650		5655		5660		5665 / 5665R	
		Sample Date:	24-Nov-97		18-May-98		21-Nov-97		18-May-98		20-Nov-97		16-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
Benzene	µg/L	0.38												
Chlorobenzene	µg/L	3.5												
Toluene	µg/L	75											22	
Semivolatile Organic Compounds														
bis(2-Ethylhexyl)phthalate	µg/L	4.8									7.3	J		
Metals - Unfiltered														
Aluminum	µg/L	3700	3820	J	4570	J	3490	J	5230		496	J		
Arsenic	µg/L	0.045	21.6				10.1		21.3					
Chromium	µg/L	18	25.2		11		18.4		28					
Cobalt	µg/L	220												
Copper	µg/L	150							31					
Iron	µg/L	1100	17400		8230		13900		22700	J	2460		2080	J
Lead	µg/L	15	14.5		3.2		13.8		20.1					
Manganese	µg/L	73	800		715		713		616		3700		3830	
Nickel	µg/L	73	52.4											
Selenium	µg/L	18	7.2											
Zinc	µg/L	1100	58.7				53							
Metals - Filtered														
Aluminum	µg/L	3700	432											
Iron	µg/L	1100									1570		684	
Lead	µg/L	15	11				4.2							
Manganese	µg/L	73	1120		582		522		452		4020		3970	
Nickel	µg/L	73	56.6											
Selenium	µg/L	18	11.4											
Zinc	µg/L	1100	52	J										
Water Quality Parameters														
Alkalinity	µg/L	ne	330000		250000		320000		380000		610000		610000	
Chloride	µg/L	ne	23000		27000		50000		26000		3000		180000	
Hardness	µg/L	ne	9200000		720000		500000		850000		920000		790000	
Nitrate	µg/L	5800	91000	J	400				200					
Sulfate	µg/L	ne	1100000		990000		430000		240000					
Total dissolved solids	µg/L	ne	2100000		1600000		1000000		1200000		640000		620000	
Total organic carbon	µg/L	ne	2600		3000		3000		3000		10000		9000	
Total suspended solids	µg/L	ne	5000		280000		7000		240000		130000		4000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table Analytical results for these elements may be ref in Appendix H.

Shaded area indicates concentration above the respective RBC.

ne - Not established.

Table 6-10

Blank Corrected Constituents in Overburden Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 1				Acid Area No. 2							
		Sample Location:	IT-AA1-GW002				MK-MW09				MK-MW10			
		Sample No:	5490		5495		5720		5725		5730		5735	
		Sample Date:	20-Nov-97		13-May-98		16-Nov-97		13-May-98		13-Nov-97		12-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
1,1,1-Trichloroethane	µg/L	160												
1,1-Dichloroethane	µg/L	80												
1,1-Dichloroethene	µg/L	0.044												
Carbon disulfide	µg/L	100			1.2									
Chloroethane	µg/L	3.6												
Chloroform	µg/L	0.083											0.45	J
Toluene	µg/L	75												
Total xylenes	µg/L	1200												
Semivolatile Organic Compounds														
bis(2-Ethylhexyl)phthalate	µg/L	4.8									11			
Metals - Unfiltered														
Aluminum	µg/L	3700	2020	J							1140			
Arsenic	µg/L	0.045												
Chromium	µg/L	18												
Copper	µg/L	150												
Iron	µg/L	1100	32900		26200						2080			
Lead	µg/L	15					8.5				3.5			
Manganese	µg/L	73	6410		6900						90.9			
Vanadium	µg/L	26												
Zinc	µg/L	1100	67.4								25.5			
Metals - Filtered														
Copper	µg/L	150							50.7					
Iron	µg/L	1100	14400		39100								121	
Lead	µg/L	15												
Manganese	µg/L	73	4740		5550						65.4			
Zinc	µg/L	1100												
Cyanide														
Cyanide, total	µg/L	73												
Water Quality Parameters														
Alkalinity	µg/L	ne	350000		410000		300000		270000		450000		240000	
Chloride	µg/L	ne	9000		9000	J	5000		2000	J	14000		4000	J
Hardness	µg/L	ne	2E+06		2800000		370000		320000		370000		290000	
Nitrate	µg/L	5800					200		200				3200	
Sulfate	µg/L	ne	2E+06		1800000	J	32000		31000	J	270000		21000	J
Total dissolved solids	µg/L	ne	3E+06		3800000		350000		370000		350000		2700000	
Total organic carbon	µg/L	ne	6900		6000	J	1500		1000	J	1400		1000	J
Total suspended solids	µg/L	ne	5000		260000		5000				35000		74000	

Table 6-10

Blank Corrected Constituents in Overburden Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 2 (continued)				Acid Area No. 3				Maintenance Shop Area			
		Sample Location:	MK-MW11				IT-AA3-GW002				MK-MW19			
		Sample No:	5740		5745		5510		5515		5800		5805	
		Sample Date:	18-Nov-97		13-May-98		19-Nov-97		14-May-98		16-Nov-97		1-Jun-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
1,1,1-Trichloroethane	µg/L	160									170		140	
1,1-Dichloroethane	µg/L	80									17		17	
1,1-Dichloroethene	µg/L	0.044									3.4		2.2	J
Carbon disulfide	µg/L	100	0.31	J										
Chloroethane	µg/L	3.6									2.5		1.8	J
Chloroform	µg/L	0.063												
Toluene	µg/L	75									6.1			
Total xylenes	µg/L	1200												
Semivolatile Organic Compounds														
bis(2-Ethylhexyl)phthalate	µg/L	4.8												
Metals - Unfiltered														
Aluminum	µg/L	3700	6080		6810		11600	J					12500	
Arsenic	µg/L	0.045					10.3						12	
Chromium	µg/L	18	12.6		15.4		22.8						24.7	
Copper	µg/L	150					33.6						32.1	
Iron	µg/L	1100	12300		17000		27300						24300	
Lead	µg/L	15	9.4		9.1		16.6						30.6	
Manganese	µg/L	73	344		477		816		123		23.4		418	
Vanadium	µg/L	26											54	
Zinc	µg/L	1100	43.5		163		99.9							
Metals - Filtered														
Copper	µg/L	150												
Iron	µg/L	1100												
Lead	µg/L	15											3	
Manganese	µg/L	73					78.6		139		29.2		22.4	
Zinc	µg/L	1100					49.9							
Cyanide														
Cyanide, total	µg/L	73			38									
Water Quality Parameters														
Alkalinity	µg/L	ne	590000		320000		370000		320000		400000		370000	
Chloride	µg/L	ne	21000		18000	J	4000		4000	J	6000		5000	
Hardness	µg/L	ne	860000		580000		400000		530000		540000		640000	
Nitrate	µg/L	5800	600		4700									
Sulfate	µg/L	ne	54000		53000	J	18000		37000	J	110000		120000	
Total dissolved solids	µg/L	ne	500000		430000		460000		480000		600000		650000	
Total organic carbon	µg/L	ne	3100		2000	J	4500		2000	J	2900		3000	
Total suspended solids	µg/L	ne			58000		290000		150000		12000		10000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be re in Appendix H.
Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-11

Blank Corrected Constituents in Overburden Monitoring Wells
Burning Ground Areas
Former Plum Brook Ordnance Works, Sandusky, Ohio

(Page 1 of 2)

		Sample Area:	Additional Burning Ground				Snake Road Burning Ground							
		Sample Location:	IT-ABG-GW002				GCL-MW01				GCL-MW02A			
		Sample No:	5520		5526		5850		5855		5860		5865	
		Sample Date:	19-Nov-97		13-May-98		20-Nov-97		17-May-98		20-Nov-97		17-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
Acetone	µg/L	370			6.6	J								
Benzene	µg/L	0.38	0.53	J	0.5	J							0.27	J
Carbon disulfide	µg/L	100	0.24	J	0.35	J					0.64	J	0.2	J
Ethyl benzene	µg/L	130											0.14	J
Methylene chloride	µg/L	4.1												
Toluene	µg/L	75												
Total xylenes	µg/L	1200			0.15	J			0.62	J			0.84	J
Semivolatile Organic Compounds														
Diethyl phthalate	µg/L	2900												
Phenol	µg/L	2200												
bis(2-Ethylhexyl)phthalate	µg/L	4.8					100							
Metals - Unfiltered														
Aluminum	µg/L	3700	34500	J	18600		9410	J	4080		878	J	3350	
Arsenic	µg/L	0.045	66.2		56.8		36.3		13					
Barium	µg/L	260	314		233									
Chromium	µg/L	18	69.8		44.6		44.9		14.8		22.7		33.9	
Cobalt	µg/L	220	72.3		68.4									
Copper	µg/L	150	243		161		48		27.6				27.9	
Iron	µg/L	1100	103000		91100		76600		20300	J	3130		9630	J
Lead	µg/L	15	100		72.2		17.7		6.8				6.1	
Manganese	µg/L	73	3010		2300		432		300		434		548	
Mercury	µg/L	1.1			0.22									
Nickel	µg/L	73	212		142		71.8						48.1	
Selenium	µg/L	18	8.2		6.5		20.4							
Vanadium	µg/L	26	158		109									
Zinc	µg/L	1100	836		685		116							
Metals - Filtered														
Aluminum	µg/L	3700												
Iron	µg/L	1100	4890		9240		4350		3080		806		591	
Lead	µg/L	15												
Manganese	µg/L	73	2600		2010		350		301		421		470	
Zinc	µg/L	1100					22	J						
Water Quality Parameters														
Alkalinity	µg/L	ne	300000		330000		150000		180000		270000		210000	
Chloride	µg/L	ne	4000		5000	J			1000		13000		4000	
Hardness	µg/L	ne	1E+06		1500000		540000		430000		580000		550000	
Nitrate	µg/L	5800			200									
Sulfate	µg/L	ne	710000		860000	J	130000		93000		31000		150000	
Total dissolved solids	µg/L	ne	1E+06		2800000		500000		440000		330000		550000	
Total organic carbon	µg/L	ne	13000		15000	J	5400		3000		4500		3000	
Total suspended solids	µg/L	ne	17000		2200000				50000		27000		100000	

Table 6-11

Blank Corrected Constituents in Overburden Monitoring Wells
Burning Ground Areas
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Snake Road Burning Ground (continued)							
		Sample Location:	GCL-MW02B				GCL-MW03			
		Sample No:	5870		5875		5880		5885	
		Sample Date:	20-Nov-97		17-May-98		20-Nov-97		17-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Acetone	µg/L	370								
Benzene	µg/L	0.36							0.28	J
Carbon disulfide	µg/L	100			0.26	J				
Ethyl benzene	µg/L	130							0.19	J
Methylene chloride	µg/L	4.1								
Toluene	µg/L	75								
Total xylenes	µg/L	1200			0.53	J			1.6	
Semivolatile Organic Compounds										
Diethyl phthalate	µg/L	2900	2.7	J						
Phenol	µg/L	2200							10	
bis(2-Ethylhexyl)phthalate	µg/L	4.8								
Metals - Unfiltered										
Aluminum	µg/L	3700	451	J	410		2390	J	1380	
Arsenic	µg/L	0.045					40.2			
Barium	µg/L	260								
Chromium	µg/L	18	11.9							
Cobalt	µg/L	220								
Copper	µg/L	150								
Iron	µg/L	1100	3750		3570	J	26300		6140	J
Lead	µg/L	15								
Manganese	µg/L	73	475		615		493		368	
Mercury	µg/L	1.1								
Nickel	µg/L	73								
Selenium	µg/L	18								
Vanadium	µg/L	26								
Zinc	µg/L	1100								
Metals - Filtered										
Aluminum	µg/L	3700								
Iron	µg/L	1100	1130		1190		892		1270	
Lead	µg/L	15	3.2							
Manganese	µg/L	73	507		632		369		386	
Zinc	µg/L	1100	23.7	J						
Water Quality Parameters										
Alkalinity	µg/L	ne	190000		150000		190000		200000	
Chloride	µg/L	ne	240000		2000				2000	
Hardness	µg/L	ne	380000		480000		200000		360000	
Nitrate	µg/L	5800								
Sulfate	µg/L	ne	130000		200000		29000		23000	
Total dissolved solids	µg/L	ne	440000		570000		250000		280000	
Total organic carbon	µg/L	ne	2700		2000		4200		2000	
Total suspended solids	µg/L	ne			37000		8000		18000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.
Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-12

Blank Corrected Constituents in Overburden Monitoring Wells
Lower Toluene Tanks Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	MK-MW14				MK-MW15			
		Sample No:	5760		5765		5770		5775	
		Sample Date:	16-Nov-97		14-May-98		16-Nov-97		14-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Acetone	µg/L	370								
Carbon disulfide	µg/L	100	0.32	J			0.38	J		
Semivolatile Organic Compounds										
2,4-Dinitrotoluene	µg/L	7.3								
bis(2-Ethylhexyl)phthalate	µg/L	4.8	1.7	J			6	J		
Explosives										
2,4,6-Trinitrotoluene	µg/L	1.8								
2,4-Dinitrotoluene	µg/L	7.3								
4-Amino-2,6-dinitrotoluene	µg/L	0.22								
Metals - Unfiltered										
Aluminum	µg/L	3700	520		4550		292		4380	
Arsenic	µg/L	0.045								
Cobalt	µg/L	220								
Copper	µg/L	150							27.2	
Iron	µg/L	1100	19300		19100		12700		10300	
Lead	µg/L	15					7.1		7.2	
Manganese	µg/L	73	370		283		608		101	
Nickel	µg/L	73								
Selenium	µg/L	18								
Zinc	µg/L	1100	25.8				23			
Metals - Filtered										
Aluminum	µg/L	3700								
Arsenic	µg/L	0.045								
Cobalt	µg/L	220								
Copper	µg/L	150								
Iron	µg/L	1100	22900		22400		12700		226	
Lead	µg/L	15					5			
Manganese	µg/L	73	449		373		617		30.7	
Mercury	µg/L	1.1	0.68							
Nickel	µg/L	73								
Selenium	µg/L	18								
Zinc	µg/L	1100								
Cyanide										
Cyanide, total	µg/L	73			11					
Water Quality Parameters										
Alkalinity	µg/L	ne	120000		100000		110000		50000	
Chloride	µg/L	ne	8000		5000	J	3000		1000	J
Hardness	µg/L	ne	560000		370000		300000		380000	
Sulfate	µg/L	ne	280000		320000	J	160000		10000	J
Total dissolved solids	µg/L	ne	670000		560000		350000		92000	
Total organic carbon	µg/L	ne	6100		7000	J	2600		1000	J
Total suspended solids	µg/L	ne	190000		43000		5000		140000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-13

Blank Corrected Constituents in Overburden Monitoring Wells
Upper Toluene Tanks Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	MK-MW20			
		Sample No:	5810		5815 / 5815R	
		Sample Date:	16-Nov-97		19-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Chloroform	µg/L	0.063				
Toluene	µg/L	75	13000		63000	
Total xylenes	µg/L	1200				
Semivolatile Organic Compounds						
2-Methylphenol	µg/L	180	1300		240	D
4-Methylphenol	µg/L	18	1200		120	
Phenol	µg/L	2200	6.8	J	12	
bis(2-Ethylhexyl)phthalate	µg/L	4.8	5	J		
Metals - Total						
Aluminum	µg/L	3700	18400		245	J
Arsenic	µg/L	0.045	15.8			
Chromium	µg/L	18	42.7			
Copper	µg/L	150	29.7			
Iron	µg/L	1100	46700		2330	
Lead	µg/L	15	13.1			
Manganese	µg/L	73	994		75.3	
Nickel	µg/L	73	114			
Vanadium	µg/L	26	59.7			
Zinc	µg/L	1100	105			
Metals - Dissolved						
Iron	µg/L	1100	716		1190	
Manganese	µg/L	73	65.3		75.6	
Zinc	µg/L	1100				
Water Quality Parameters						
Alkalinity	µg/L	ne	430000		410000	
Chloride	µg/L	ne	410000		400000	
Hardness	µg/L	ne	900000		2200000	
Sulfate	µg/L	ne	240000		340000	
Total dissolved solids	µg/L	ne	1700000		1700000	
Total organic carbon	µg/L	ne	12000		6000	
Total suspended solids	µg/L	ne	250000			

Note: Nutritionally essential elements, including calcium, magnesium, potassium, results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established

Table 6-14

Blank Corrected Constituents in Overburden Monitoring Wells
Reactor Facility Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	IT-MW06			
		Sample No:	5560		5565	
		Sample Date:	19-Nov-97		28-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Toluene	µg/L	75	0.2	J		
Metals - Unfiltered						
Aluminum	µg/L	3700			860	J
Iron	µg/L	1100	1620		1810	
Manganese	µg/L	73	340		215	
Mercury	µg/L	1.1	0.3			
Zinc	µg/L	1100	47.4			
Metals - Filtered						
Manganese	µg/L	73			20.7	
Mercury	µg/L	1.1			0.44	
Zinc	µg/L	1100	27.6			
Water Quality Parameters						
Alkalinity	µg/L	ne	320000		290000	
Chloride	µg/L	ne	1000		3000	
Hardness	µg/L	ne	740000		380000	
Sulfate	µg/L	ne	47000			
Total dissolved solids	µg/L	ne	420000		410000	
Total organic carbon	µg/L	ne	3800		3000	
Total suspended solids	µg/L	ne			13000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-15

Blank Corrected Constituents in Bedrock Monitoring Wells
West Area Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-BED-MW14			
		Sample No:	5900		5905 / 5905R	
		Sample Date:	18-Nov-97		18-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Benzene	µg/L	0.36	1.1			
Carbon disulfide	µg/L	100	1.3		0.25	J
Ethyl benzene	µg/L	130	0.59	J		
Toluene	µg/L	75				
Total xylenes	µg/L	1200	3.9			
Semivolatile Organic Compounds						
2,4-Dinitrophenol	µg/L	7.3			14	J
2,4-Dinitrotoluene	µg/L	7.3			16	
4,6-Dinitro-2-methylphenol	µg/L	0.37			28	NJ
Nitrobenzene	µg/L	0.35			5.8	J
Metals - Unfiltered						
Aluminum	µg/L	3700	374	J		
Chromium	µg/L	18	10.2			
Iron	µg/L	1100	923		427	J
Manganese	µg/L	73	54		32	
Nickel	µg/L	73	42.3		45.5	
Zinc	µg/L	1100	39.8			
Metals - Filtered						
Cobalt	µg/L	220			65.4	
Iron	µg/L	1100			269	
Manganese	µg/L	73	29.1		32.6	
Nickel	µg/L	73	40.7		71.3	
Zinc	µg/L	1100	32.4			
Cyanide						
Cyanide, total	µg/L	73	16		44	
Water Quality Parameters						
Alkalinity	µg/L	ne	210000		500000	
Chloride	µg/L	ne	79000		3000	
Hardness	µg/L	ne	640000		730000	
Nitrate	µg/L	5800	300		24000	
Sulfate	µg/L	ne	610000		630000	
Total dissolved solids	µg/L	ne	2500000		2300000	
Total organic carbon	µg/L	ne	190000		160000	
Total suspended solids	µg/L	ne	37000		23000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates that concentration above the respective RBC.
ne - Not established.

Table 6-16

Blank Corrected Constituents in Bedrock Monitoring Wells
Pentolite Road Red Water Ponds
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-BED-MW15			
		Sample No:	5910		5915	
		Sample Date:	18-Nov-97		28-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
1,1,2-Trichloroethane	µg/L	0.19			4.9	J
Benzene	µg/L	0.36	570		780	
Chlorobenzene	µg/L	3.5			5.5	J
Chloroform	µg/L	0.063				
Ethyl benzene	µg/L	130	130		140	
Methylene chloride	µg/L	4.1				
Toluene	µg/L	75	490		550	
Total xylenes	µg/L	1200	920		880	
Semivolatile Organic Compounds						
2,4-Dimethylphenol	µg/L	73	6.7	J	10	
2-Methylnaphthalene	µg/L	150	31		37	
2-Methylphenol	µg/L	180	3	J	6.7	J
4-Methylphenol	µg/L	18	3.9	J	7.7	J
bis(2-Ethylhexyl)phthalate	µg/L	4.8	37			
Fluorene	µg/L	150	1.7	J		
Isophorone	µg/L	70	4.2	J	3.8	J
Naphthalene	µg/L	150	22		31	
Phenanthrene	µg/L	110	2.2	J	2	J
Phenol	µg/L	2200	18		32	
Explosives						
2,4-Dinitrotoluene	µg/L	7.3			0.89	
2,6-Dinitrotoluene	µg/L	3.7			0.89	
Metals - Unfiltered						
Aluminum	µg/L	3700			513	J
Barium	µg/L	260	605		1710	
Chromium	µg/L	18			20.6	
Copper	µg/L	150			39.5	
Iron	µg/L	1100	930		4810	
Manganese	µg/L	73	26.3		139	
Thallium	µg/L	0.23			50.8	
Zinc	µg/L	1100	30.6			
Metals - Filtered						
Barium	µg/L	260	555		1390	
Thallium	µg/L	0.23			62.2	
Zinc	µg/L	1100	30.9			
Water Quality Parameters						
Alkalinity	µg/L	ne	85000		500000	
Chloride	µg/L	ne	1400000		2200000	
Hardness	µg/L	ne	1500000		1800000	
Sulfate	µg/L	ne			82000	
Total dissolved solids	µg/L	ne	3200000		3800000	
Total organic carbon	µg/L	ne	11000		13000	
Total suspended solids	µg/L	ne	7000		13000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.

ne - Not established.

Table 6-17

Blank Corrected Constituents in Bedrock Monitoring Wells
TNT Manufacturing Area A
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-BED-MW17				PB-BED-MW18			
		Sample No:	5930		5935		5940		5945	
		Sample Date:	20-Nov-97		29-May-98		19-Nov-97		19-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Acetone	µg/L	370							34	J
Benzene	µg/L	0.36	10	J			11		5.7	
Carbon disulfide	µg/L	100	40	J			32		7.9	
Ethyl benzene	µg/L	130	79		9.9	J	32		88	
Methylene chloride	µg/L	4.1								
Toluene	µg/L	75	140				21		53	
Total xylenes	µg/L	1200	360		46		170		420	
Semivolatile Organic Compounds										
2,4-Dimethylphenol	µg/L	73			2.8	J	5.1	J	11	
2-Methylnaphthalene	µg/L	150			20		2.2	J	5	J
2-Methylphenol	µg/L	180					2.6	J	3.3	J
4-Methylphenol	µg/L	18					2.8	J	4	J
bis(2-Ethylhexyl)phthalate	µg/L	4.8					3.5	J		
Naphthalene	µg/L	150			18		3.8	J	10	
Phenol	µg/L	2200					21	J		
Explosives										
1,3,5-Trinitrobenzene	µg/L	110					1.5			
1,3-Dinitrobenzene	µg/L	0.37					1			
2,4-Dinitrotoluene	µg/L	7.3							0.49	
2,6-Dinitrotoluene	µg/L	3.7							3.6	
Nitrobenzene	µg/L	0.35	0.34				2			
Metals - Unfiltered										
Aluminum	µg/L	3700					283	J		
Barium	µg/L	260	948		800		893		942	
Iron	µg/L	1100	1580		456				166	
Manganese	µg/L	73	124		20.4		36.8		80.8	
Mercury	µg/L	1.1					1			
Zinc	µg/L	1100	49.9				31			
Metals - Filtered										
Arsenic	µg/L	0.045			13.1					
Barium	µg/L	260	1100		871		1010		994	
Lead	µg/L	15			6.8					
Manganese	µg/L	73					35.9		80.9	
Zinc	µg/L	1100	33.3	J						
Cyanide										
Cyanide, total	µg/L	73	320							
Water Quality Parameters										
Alkalinity	µg/L	ne	830000		930000		120000		550000	
Chloride	µg/L	ne	1800000		1600000		6900000		1200000	
Hardness	µg/L	ne	1800000		1300000		4000000		10000000	
Sulfate	µg/L	ne	59000		80000		16000		18000	
Total dissolved solids	µg/L	ne	3000000		2900000		12000000		33000000	
Total organic carbon	µg/L	ne	1200		3000		6500		3000	
Total suspended solids	µg/L	ne			4000		61000		100000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-18

Blank Corrected Constituents in Bedrock Monitoring Wells
TNT Manufacturing Area B
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	IT-TNTB-BED-GW001				IT-TNTB-BED-GW002			
		Sample No:	5420		5425		5430		5435	
		Sample Date:	17-Nov-97		18-May-98		16-Nov-97		18-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
1,1-Dichloroethane	µg/L	80			0.19	J				
Benzene	µg/L	0.36	0.14	J			0.91	J		
Carbon disulfide	µg/L	100	0.82	J	7.2		6.4			
Ethyl benzene	µg/L	130					0.85	J		
Total xylenes	µg/L	1200					12			
Semivolatile Organic Compounds										
bis(2-Ethylhexyl)phthalate	µg/L	4.8	3.6	J			3	J		
Phenol	µg/L	2200					2.3	J		
Metals - Unfiltered										
Aluminum	µg/L	3700	654		1130	J	317			
Arsenic	µg/L	0.045			12.9					
Barium	µg/L	260			1100		326		406	
Copper	µg/L	150	33.9		80.9					
Iron	µg/L	1100	41700		13000		1030		168	J
Lead	µg/L	15	3.9		6.2		4.8		7.1	
Manganese	µg/L	73	677		196		85.4		36.6	
Nickel	µg/L	73	42.1							
Zinc	µg/L	1100	48.8		150	J	73.9			
Metals - Filtered										
Barium	µg/L	260			1040		384		414	
Iron	µg/L	1100	16300		302		586			
Lead	µg/L	15					3			
Manganese	µg/L	73	694		278		71		36.5	
Zinc	µg/L	1100								
Water Quality Parameters										
Alkalinity	µg/L	ne	130000		360000		220000		380000	
Chloride	µg/L	ne	90000		600000		91000		74000	
Hardness	µg/L	ne	360000		650000		450000		530000	
Sulfate	µg/L	ne	140000		120000		90000		140000	
Total dissolved solids	µg/L	ne	730000		1200000		760000		7600000	
Total organic carbon	µg/L	ne	12000		5000		5000		4000	
Total suspended solids	µg/L	ne	480000		9000		5000		6000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-19

Blank Corrected Constituents in Bedrock Monitoring Wells
TNT Manufacturing Area C
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-BED-MW13			
		Sample No:	5890		5895	
		Sample Date:	13-Nov-97		29-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Benzene	µg/L	0.36	130		47	
Carbon disulfide	µg/L	100	5.8			
Ethyl benzene	µg/L	130	73		57	
Toluene	µg/L	75	170		120	
Total xylenes	µg/L	1200	520		540	
Semivolatile Organic Compounds						
2,4-Dimethylphenol	µg/L	73	16		13	J
2-Methylnaphthalene	µg/L	150	20		14	J
2-Methylphenol	µg/L	180	4.1	J	3.3	J
4-Methylphenol	µg/L	18	4.7	J	3.3	J
bis(2-Ethylhexyl)phthalate	µg/L	4.8	39		55	J
Isophorone	µg/L	70			2.7	J
Naphthalene	µg/L	150	15		10	J
Phenol	µg/L	2200	62		69	J
Metals - Unfiltered						
Barium	µg/L	260	1550			
Iron	µg/L	1100			207	
Manganese	µg/L	73	17.4		41.9	
Zinc	µg/L	1100	47.2			
Metals - Filtered						
Barium	µg/L	260	1680		208	
Iron	µg/L	1100				
Manganese	µg/L	73			43.8	
Zinc	µg/L	1100	30.1			
Water Quality Parameters						
Alkalinity	µg/L	ne	430000		300000	
Chloride	µg/L	ne	2500000			
Hardness	µg/L	ne	1600000		450000	
Sulfate	µg/L	ne	13000		5000	
Total dissolved solids	µg/L	ne	4800000		510000	
Total organic carbon	µg/L	ne	9600		2000	
Total suspended solids	µg/L	ne	16000			

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-20

Blank Corrected Constituents in Bedrock Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 1				Acid Area No. 2							
		Sample Location:	IT-AA1-BED-GW001				IT-AA2-BED-GW001				PB-BED-MW19			
		Sample No:	5450		5455		5460		5465		5950		5955	
		Sample Date:	16-Nov-97		12-May-98		20-Nov-97		12-May-98		14-Nov-97		16-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds														
2-Butanone	µg/L	190							18	J				
Acetone	µg/L	370							41	J	68	J		
Benzene	µg/L	0.36	11	J	31		33		130		11		1.9	J
Carbon disulfide	µg/L	100	29	J	63		5.5	J	1.7	J	2		6.9	
Chlorobenzene	µg/L	3.5					21	J						
Chloromethane	µg/L	1.5							10					
Ethylbenzene	µg/L	130	7.7	J	39		23	J	43		5.1		1.2	J
Methylene chloride	µg/L	4.1												
Toluene	µg/L	75			50				20		8.9			
Total xylenes	µg/L	1200	150		500		200		220		38		10	
Semivolatile Organic Compounds														
2,4-Dimethylphenol	µg/L	73			3.6	J	1.3	J	8.6	J				
2,4-Dinitrotoluene	µg/L	7.3												
2-Methylnaphthalene	µg/L	150	28		31		1.3	J	5.6	J	3.3	J	1.5	J
2-Methylphenol	µg/L	180							1.6	J				
4-Methylphenol	µg/L	18							1.6	J				
bis(2-Ethylhexyl)phthalate	µg/L	4.8	28								5.8	J		
Isophorone	µg/L	70	2.9	J										
Naphthalene	µg/L	150	16		18				8.1	J	2.1	J		
Phenanthrene	µg/L	110			2.3	J								
Phenol	µg/L	2200	43		15				74		55			
Explosives														
1,3-Dinitrobenzene	µg/L	0.37							0.81		0.22			
2,4-Dinitrotoluene	µg/L	7.3			0.23				2.5					
2,6-Dinitrotoluene	µg/L	3.7							1.2					
2-Nitrotoluene	µg/L	6.1			1.1									
3-Nitrotoluene	µg/L	12			0.31								0.62	
Nitrobenzene	µg/L	0.35									0.32			
RDX	µg/L	0.61			2.8									
Tetryl	µg/L	37			2.4									

Table 6-20

Blank Corrected Constituents in Bedrock Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 1				Acid Area No. 2							
		Sample Location:	IT-AA1-BED-GW001				IT-AA2-BED-GW001				PB-BED-MW19			
		Sample No:	5450		5455		5460		5465		5950		5955	
		Sample Date:	16-Nov-97		12-May-98		20-Nov-97		12-May-98		14-Nov-97		18-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Unfiltered														
Aluminum	µg/L	3700	637		468		1060	J	10200					
Arsenic	µg/L	0.045	16.5		21.2				34.2					
Barium	µg/L	260	1060		1330		220		645		1520		1800	
Chromium	µg/L	18	12.7						307		10			
Cobalt	µg/L	220							63.3					
Copper	µg/L	150	26.2						62.7		61.7			
Iron	µg/L	1100	1920		2540		5240		51600				141	J
Lead	µg/L	15							38.6		6.8			
Manganese	µg/L	73	575		732		522		5130		30.4			
Nickel	µg/L	73							238					
Vanadium	µg/L	26							108					
Zinc	µg/L	1100	32.8				55				62.3			
Metals - Filtered														
Arsenic	µg/L	0.045			19.6									
Barium	µg/L	260	1260		1490		212		279		1520		1740	
Iron	µg/L	1100												
Manganese	µg/L	73	516		696		351		995				16.3	
Zinc	µg/L	1100	105				66.2	J			57.4			
Cyanide														
Cyanide, total	µg/L	73											16	
Water Quality Parameters														
Alkalinity	µg/L	ne	830000		900000		510000		600000		310000		750000	
Chloride	µg/L	ne	1900000		3000000	J	47000		53000	J	330000		280000	
Hardness	µg/L	ne	1800000		2000000		700000		860000		1700000		750000	
Sulfate	µg/L	ne	7000		40000	J	48000		70000	J	14000		49000	
Total dissolved solids	µg/L	ne	3600000		730000		750000		310000		1200000		590000	
Total organic carbon	µg/L	ne	16000		11000	J	7400		6000	J	16000		9000	
Total suspended solids	µg/L	ne	6000		330000		4000				41000		5000	

Table 6-20

Blank Corrected Constituents In Bedrock Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 3				Maintenance Shop Area			
		Sample Location:	IT-AA3-BED-GW001				IT-MNTA-BED-GW001			
		Sample No:	5470		5475		5440		5445	
		Sample Date:	19-Nov-97		14-May-98		20-Nov-97		28-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
2-Butanone	µg/L	190								
Acetone	µg/L	370	36	J						
Benzene	µg/L	0.36							19	
Carbon disulfide	µg/L	100	4.2	J			3.7	J	21	
Chlorobenzene	µg/L	3.5								
Chloromethane	µg/L	1.5								
Ethylbenzene	µg/L	130							7.7	
Methylene chloride	µg/L	4.1								
Toluene	µg/L	75							18	
Total xylenes	µg/L	1200							150	
Semivolatile Organic Compounds										
2,4-Dimethylphenol	µg/L	73					1.7	J	1.8	J
2,4-Dinitrotoluene	µg/L	7.3							1.3	J
2-Methylnaphthalene	µg/L	150					1.9	J	1.2	J
2-Methylphenol	µg/L	180								
4-Methylphenol	µg/L	18								
bis(2-Ethylhexyl)phthalate	µg/L	4.8	5.8	J			3.9	J		
Isophorone	µg/L	70								
Naphthalene	µg/L	150					2.3	J		
Phenanthrene	µg/L	110								
Phenol	µg/L	2200	3.1	J			17		11	
Explosives										
1,3-Dinitrobenzene	µg/L	0.37							0.86	
2,4-Dinitrotoluene	µg/L	7.3							2	
2,6-Dinitrotoluene	µg/L	3.7							0.34	
2-Nitrotoluene	µg/L	6.1								
3-Nitrotoluene	µg/L	12								
Nitrobenzene	µg/L	0.35								
RDX	µg/L	0.61								
Tetryl	µg/L	37								

Table 6-20

Blank Corrected Constituents in Bedrock Monitoring Wells
Acid Areas and Maintenance Shop Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Acid Area No. 3				Maintenance Shop Area			
		Sample Location:	IT-AA3-BED-GW001				IT-MNTA-BED-GW001			
		Sample No:	5470		5475		5440		5445	
		Sample Date:	19-Nov-97		14-May-98		20-Nov-97		28-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Metals - Unfiltered										
Aluminum	µg/L	3700			397					
Arsenic	µg/L	0.045								
Barium	µg/L	260					424		457	
Chromium	µg/L	18								
Cobalt	µg/L	220								
Copper	µg/L	150								
Iron	µg/L	1100			450		6400		481	
Lead	µg/L	15								
Manganese	µg/L	73	74.6		83.8		849		181	
Nickel	µg/L	73								
Vanadium	µg/L	26								
Zinc	µg/L	1100	29.2							
Metals - Filtered										
Arsenic	µg/L	0.045								
Barium	µg/L	260					449		596	
Iron	µg/L	1100								
Manganese	µg/L	73	57.6		51.3		899		183	
Zinc	µg/L	1100	23				24.8	J		
Cyanide										
Cyanide, total	µg/L	73								
Water Quality Parameters										
Alkalinity	µg/L	ne	670000		790000		670000			
Chloride	µg/L	ne	790000		860000	J	55000		3800000	
Hardness	µg/L	ne	13000000		860000		2000000		2100000	
Sulfate	µg/L	ne			8000	J	62000		64000	
Total dissolved solids	µg/L	ne	1900000		1800000		5300000		7200000	
Total organic carbon	µg/L	ne	5300	J	2000	J	11000		7000	
Total suspended solids	µg/L	ne	38000		54000		4000		29000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.
Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-21

Blank Corrected Constituents in Bedrock Monitoring Wells
Burning Ground Areas
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Area:	Additional Burning Ground				G-8 Burning Ground			
		Sample Location:	IT-ABG-BED-GW001				IT-BG8-BED-GW001			
		Sample No:	5480		5485		5410		5415	
		Sample Date:	13-Nov-97		13-May-98		17-Nov-97		15-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds										
Carbon disulfide	µg/L	100			0.97	J	0.65	J		
Trichloroethene	µg/L	1.6	0.25	J						
Semivolatile Organic Compounds										
bis(2-Ethylhexyl)phthalate	µg/L	4.8					1.7	J		
Metals - Unfiltered										
Aluminum	µg/L	3700	522				9020		307	
Arsenic	µg/L	0.045	11.7				17.6			
Barium	µg/L	260					520			
Chromium	µg/L	18					18.2			
Copper	µg/L	150					59.5			
Iron	µg/L	1100	8890		5770		22600		1230	J
Lead	µg/L	15	6.9		20.2		26.3		6.8	
Manganese	µg/L	73	912		745		2240		130	
Mercury	µg/L	1.1	3.6							
Zinc	µg/L	1100	27.7				126			
Metals - Filtered										
Aluminum	µg/L	3700			408					
Barium	µg/L	260					366			
Iron	µg/L	1100	7260		5580		563			
Manganese	µg/L	73	990		813		1300		658	
Zinc	µg/L	1100								
Water Quality Parameters										
Alkalinity	µg/L	ne	280000		270000		350000		180000	
Chloride	µg/L	ne			3000	J	780000		34000	
Hardness	µg/L	ne	500000		530000		1000000		340000	
Nitrate	µg/L	5800					200		7300	
Sulfate	µg/L	ne	140000		190000	J	70000		45000	
Total dissolved solids	µg/L	ne	640000		600000		1800000		300000	
Total organic carbon	µg/L	ne	3800		3000	J			1000	
Total suspended solids	µg/L	ne	11000		7000		10000		280000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-22

Blank Corrected Constituents in Bedrock Monitoring Wells
Upper Toluene Tanks Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	PB-BED-MW16			
		Sample No:	5920		5925	
		Sample Date:	24-Nov-97		1-Jun-98	
Parameter	Units	RBC	Result		Result	Val Qlfr
Volatile Organic Compounds						
Benzene	µg/L	0.36	490		450	J
Ethyl benzene	µg/L	130	130		140	J
Methylene chloride	µg/L	4.1				
Toluene	µg/L	75	390		350	J
Total xylenes	µg/L	1200	1100		1000	J
Semivolatile Organic Compounds						
1,2,4-Trichlorobenzene	µg/L	19			1.6	J
1,3-Dichlorobenzene	µg/L	1.4			4.4	J
2,4,5-Trichlorophenol	µg/L	370			35	
bis(2-Ethylhexyl)phthalate	µg/L	4.8	920	J		
Metals - Unfiltered						
Aluminum	µg/L	3700	502	J	11000	
Barium	µg/L	260	463		612	
Chromium	µg/L	18	24.4		105	
Copper	µg/L	150			84.9	
Iron	µg/L	1100	1140		45900	
Lead	µg/L	15			40.4	
Manganese	µg/L	73	133		2200	
Nickel	µg/L	73			54.7	
Thallium	µg/L	0.23			101	
Vanadium	µg/L	26	64.7		126	
Zinc	µg/L	1100	30		235	
Metals - Filtered						
Barium	µg/L	260	389		523	
Chromium	µg/L	18	13.6		14.8	
Thallium	µg/L	0.23			53.1	
Vanadium	µg/L	26	58.3		50.6	
Water Quality Parameters						
Alkalinity	µg/L	ne	1600000		1700000	
Chloride	µg/L	ne	88000		140000	
Hardness	µg/L	ne	5300000		2000000	
Sulfate	µg/L	ne	150000		37000	
Total dissolved solids	µg/L	ne	6400000		4000000	
Total organic carbon	µg/L	ne	8400		14000	
Total suspended solids	µg/L	ne	7000		330000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 6-23

Blank Corrected Constituents in Bedrock Monitoring Wells
Reactor Facility Area
Former Plum Brook Ordnance Works, Sandusky, Ohio

		Sample Location:	REACTOR 1			
		Sample No:	5970		5975	
		Sample Date:	21-Nov-97		1-Jun-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Acetone	µg/L	370			45	J
Benzene	µg/L	0.36	8.8	J	4.3	J
Carbon disulfide	µg/L	100			2.1	J
Ethyl benzene	µg/L	130			1.6	J
Methylene chloride	µg/L	4.1				
Toluene	µg/L	75			1.3	J
Total xylenes	µg/L	1200	4	J	5.5	
Semivolatile Organic Compounds						
bis(2-Ethylhexyl)phthalate	µg/L	4.8	23	J		
Metals - Unfiltered						
Aluminum	µg/L	3700			298	
Barium	µg/L	260	405			
Chromium	µg/L	18	11.1			
Copper	µg/L	150			29.3	
Iron	µg/L	1100	8000		11100	
Lead	µg/L	15	19.1		12.2	
Manganese	µg/L	73	198		388	
Zinc	µg/L	1100	69.7			
Metals - Filtered						
Barium	µg/L	260	397			
Iron	µg/L	1100			1210	
Lead	µg/L	15	3.5			
Manganese	µg/L	73	144		386	
Zinc	µg/L	1100	22.3	J		
Water Quality Parameters						
Alkalinity	µg/L	ne	487000		67000	
Chloride	µg/L	ne	56900		15000	
Hardness	µg/L	ne	484000		180000	
Nitrate	µg/L	5800	na		300	
Sulfate	µg/L	ne	13900		22000	
Total dissolved solids	µg/L	ne	570000	J	110000	
Total organic carbon	µg/L	ne	2500		5000	
Total suspended solids	µg/L	ne	35000	J	230000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.
na - Not analyzed.

Table 6-24

Blank Corrected Constituents in Monitoring Wells
Background Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Sample Location:			IT-MW01			
Sample No:			5530		5535 / 5535R	
Sample Date:			19-Nov-97		16-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Toluene	µg/L	75			22	
Metals - Unfiltered						
Iron	µg/L	1100	1320		2200	J
Manganese	µg/L	73	323		348	
Mercury	µg/L	1.1	0.45			
Zinc	µg/L	1100	51.6		149	
Metals - Filtered						
Aluminum	µg/L	3700			276	
Iron	µg/L	1100	1090		1970	
Manganese	µg/L	73	331		395	
Zinc	µg/L	1100	46.9			
Water Quality Parameters						
Alkalinity	µg/L	ne	360000		110000	
Chloride	µg/L	ne	4000		3000	
Hardness	µg/L	ne	420000		200000	
Sulfate	µg/L	ne	79000		140000	
Total dissolved solids	µg/L	ne	310000		400000	
Total organic carbon	µg/L	ne	8600		7000	
Total suspended solids	µg/L	ne	84000		5000	

Sample Location:			PB-BED-MW20			
Sample No:			5960		5965	
Sample Date:			17-Nov-97		28-May-98	
Parameter	Units	RBC	Result	Val Qlfr	Result	Val Qlfr
Volatile Organic Compounds						
Benzene	µg/L	0.36	0.83	J	1.6	
Carbon disulfide	µg/L	100			0.17	J
Ethylbenzene	µg/L	130	0.15	J		
Total xylenes	µg/L	1200	2.6		0.91	J
Semivolatile Organic Compounds						
2-Methylnaphthalene	µg/L	150	1.1	J		
Metals - Unfiltered						
Aluminum	µg/L	3700	3290		678	J
Barium	µg/L	260	19000		16400	
Copper	µg/L	150	32.8			
Iron	µg/L	1100	13200		6770	
Manganese	µg/L	73	180		153	
Zinc	µg/L	1100	41.6			
Metals - Filtered						
Barium	µg/L	260	21000		4950	
Iron	µg/L	1100	2310		1320	
Manganese	µg/L	73	162		47	
Mercury	µg/L	1.1			0.24	
Water Quality Parameters						
Alkalinity	µg/L	ne	240000		260000	
Chloride	µg/L	ne	19000000		21000000	
Hardness	µg/L	ne	20000000		10000000	
Total dissolved solids	µg/L	ne	32000000		24000000	
Total suspended solids	µg/L	ne	74000		90000	

Note: Nutritionally essential elements, including calcium, magnesium, potassium, and sodium, are not presented on this table. Analytical results for these elements may be referenced in Appendix H.

Shaded area indicates concentration above the respective RBC.
ne - Not established.

Table 8-1

Summary of Detected Organic and Explosive Compounds Exceeding RBCs
Site-Wide Overburden Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	WARWP	PRRWP	TNTA	TNTB	TNTC	AA1	AA2	AA3	MNTA	ABG	Snake Rd BG	Lower Toluene	Upper Toluene	Reactor
Volatile Organic Compounds																
1,1,1-Trichloroethane	µg/L	160									◆					
1,1-Dichloroethene	µg/L	0.044									◆					
Benzene	µg/L	0.36										◆				
Chloroform	µg/L	0.063							◆							
Toluene	µg/L	75													◆	
Semivolatile Organic Compounds																
2,4-Dinitrophenol	µg/L	7.3	◆	◆												
2,4-Dinitrotoluene	µg/L	7.3	◆	◆												
2,6-Dinitrotoluene	µg/L	3.7	◆	◆												
2-Methylphenol	µg/L	180													◆	
2-Nitroaniline	µg/L	0.22	◆													
3-Nitroaniline	µg/L	11	◆	◆												
4,6-Dinitro-2-methylphenol	µg/L	0.37	◆	◆												
4-Methylphenol	µg/L	18													◆	
4-Nitrophenol	µg/L	29		◆												
Dibenzofuran	µg/L	15		◆												
Nitrobenzene	µg/L	0.35	◆	◆												
bis(2-Ethylhexyl)phthalate	µg/L	4.8	◆		◆		◆		◆				◆	◆	◆	
Explosives																
1,3,5-Trinitrobenzene	µg/L	110		◆												
1,3-Dinitrobenzene	µg/L	0.37	◆	◆												
2,4-Dinitrotoluene	µg/L	7.3	◆	◆												
2,6-Dinitrotoluene	µg/L	3.7	◆													
3-Nitrotoluene	µg/L	12	◆													
4-Amino-2,6-dinitrotoluene	µg/L	0.22			◆	◆										
Nitrobenzene	µg/L	0.35	◆													
RDX	µg/L	0.61	◆													

Table 8-2

Summary of Detected Organic and Explosive Compounds in Groundwater
Site-Wide Overburden Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	Mean Concentration	Quantity Detected	Percentage	Minimum Concentration	Maximum Concentration
Volatile Organic Compounds							
1,1,1-Trichloroethane	µg/L	160	155	2 / 76	2.63%	140	170
1,1-Dichloroethane	µg/L	80	17	2 / 76	2.63%	17	17
1,1-Dichloroethene	µg/L	0.044	2.8	2 / 76	2.63%	2.2	3.4
2-Butanone	µg/L	190	14	1 / 76	1.32%	14	14
2-Hexanone	µg/L	150	2	1 / 76	1.32%	2	2
Acetone	µg/L	370	27.06	7 / 76	9.21%	5.2	68
Benzene	µg/L	0.36	0.32	8 / 76	10.53%	0.16	0.53
Bromodichloromethane	µg/L	0.17	0.23	1 / 76	1.32%	0.23	0.23
Carbon disulfide	µg/L	100	0.39	12 / 76	15.79%	0.17	1.2
Chlorobenzene	µg/L	3.5	0.17	1 / 76	1.32%	0.17	0.17
Chloroethane	µg/L	3.6	2.15	2 / 76	2.63%	1.8	2.5
Chloroform	µg/L	0.063	0.45	1 / 76	1.32%	0.45	0.45
Ethylbenzene	µg/L	130	0.5	4 / 76	5.26%	0.14	1.5
Toluene	µg/L	75	7608.66	10 / 76	13.16%	0.2	63000
Total xylenes	µg/L	1200	1.63	8 / 76	10.53%	0.15	8
Semivolatile Organic Compounds							
2,4-Dinitrophenol	µg/L	7.3	2463.9	4 / 76	5.26%	7.6	6000
2,4-Dinitrotoluene	µg/L	7.3	717.28	10 / 76	13.16%	1.8	1800
2,6-Dinitrotoluene	µg/L	3.7	69.12	5 / 76	6.58%	1.8	190
2-Methylphenol	µg/L	180	770	2 / 76	2.63%	240	1300
2-Nitroaniline	µg/L	0.22	1.4	2 / 76	2.63%	1.3	1.5
2-Nitrophenol	µg/L	230	10.8	2 / 76	2.63%	6.6	15
3-Nitroaniline	µg/L	11	235.83	4 / 76	5.26%	3.3	450
4,6-Dinitro-2-methylphenol	µg/L	0.37	5875.33	6 / 76	7.89%	12	20000
4-Methylphenol	µg/L	18	660	2 / 76	2.63%	120	1200
4-Nitrophenol	µg/L	29	21.8	2 / 76	2.63%	1.6	42
Dibenzofuran	µg/L	15	620	1 / 76	1.32%	620	620
Di-n-octyl phthalate	µg/L	73	6	2 / 76	2.63%	2.7	9.3
Diethyl phthalate	µg/L	2900	2.7	1 / 76	1.32%	2.7	2.7
Fluorene	µg/L	150	44	1 / 76	1.32%	44	44
Nitrobenzene	µg/L	0.35	10.23	3 / 76	3.95%	3.7	14
Phenol	µg/L	2200	9.6	3 / 76	3.95%	6.8	12
bis(2-Ethylhexyl)phthalate	µg/L	4.8	105.65	10 / 76	13.16%	1.7	890
Explosives							
1,3,5-Trinitrobenzene	µg/L	110	882.37	10 / 76	13.16%	0.24	2800
1,3-Dinitrobenzene	µg/L	0.37	818.22	9 / 76	11.84%	17	2100
2,4,6-Trinitrotoluene	µg/L	1.8	1.04	3 / 76	3.95%	0.68	1.7
2,4-Dinitrotoluene	µg/L	7.3	562.94	12 / 76	15.79%	0.2	2400
2,6-Dinitrotoluene	µg/L	3.7	4.51	5 / 76	6.58%	0.53	8.9
3-Nitrotoluene	µg/L	12	36	1 / 76	1.32%	36	36
4-Amino-2,6-dinitrotoluene	µg/L	0.22	2.7	4 / 76	5.26%	0.62	5.7
Nitrobenzene	µg/L	0.35	1.38	2 / 76	2.63%	0.26	2.5
RDX	µg/L	0.61	6.2	1 / 76	1.32%	6.2	6.2

Table 8-3

Summary of Detected Inorganic Constituents Exceeding RBCs by Site
Site-Wide Overburden Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	WARWP	PRRWP	TNTA	TNTB	TNTC	AA1	AA2	AA3	MNTA	ABG	Snake Rd BG	Lower Toluene	Upper Toluene	Reactor
Metals - Total																
Aluminum	µg/L	3700	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆	◆	
Antimony	µg/L	1.5			◆											
Arsenic	µg/L	0.045	◆	◆	◆	◆	◆			◆	◆	◆	◆		◆	
Barium	µg/L	260	◆	◆	◆							◆				
Chromium	µg/L	18	◆	◆	◆		◆			◆	◆	◆	◆		◆	
Cobalt	µg/L	220		◆	◆											
Copper	µg/L	150		◆	◆							◆				
Iron	µg/L	1100	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
Lead	µg/L	15	◆		◆	◆	◆			◆	◆	◆	◆			
Manganese	µg/L	73	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
Nickel	µg/L	73	◆	◆	◆	◆	◆					◆			◆	
Selenium	µg/L	18											◆			
Vanadium	µg/L	26	◆		◆						◆	◆			◆	
Metals - Dissolved																
Aluminum	µg/L	3700				◆										
Arsenic	µg/L	0.045		◆	◆	◆										
Barium	µg/L	260			◆											
Cobalt	µg/L	220		◆												
Copper	µg/L	150		◆												
Iron	µg/L	1100		◆	◆	◆	◆	◆				◆	◆	◆	◆	
Lead	µg/L	15				◆										
Manganese	µg/L	73	◆	◆	◆	◆	◆	◆		◆		◆	◆	◆	◆	
Nickel	µg/L	73		◆		◆	◆									
Vanadium	µg/L	26			◆											
Cyanide																
Cyanide, total	µg/L	73	◆	◆												
Water Quality Parameters																
Nitrate	µg/L	5800	◆	◆												

Table 8-4

Summary of Detected Inorganic Constituents in Groundwater
Site-Wide Overburden Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	Mean Concentration	Frequency of Detection			Percentage	Minimum Concentration	Maximum Concentration	Quantity > RBC
Metals - Total										
Aluminum	µg/L	3700	8274.09	54	/	76	71.05%	242	143000	29
Antimony	µg/L	1.5	82	1	/	76	1.32%	82	82	1
Arsenic	µg/L	0.045	28.41	22	/	76	28.95%	10.1	113	22
Barium	µg/L	260	306	6	/	76	7.89%	232	373	4
Beryllium	µg/L	7.3	6.9	1	/	76	1.32%	6.9	6.9	0
Chromium	µg/L	18	32.64	30	/	76	39.47%	10.4	258	17
Cobalt	µg/L	220	1367.63	15	/	76	19.74%	50.8	7270	6
Copper	µg/L	150	448.99	25	/	76	32.89%	27.2	3790	8
Iron	µg/L	1100	21920.44	68	/	76	89.47%	131	304000	61
Lead	µg/L	15	19.52	32	/	76	42.11%	3.2	108	10
Manganese	µg/L	73	2787.98	73	/	76	96.05%	23.4	43900	71
Mercury	µg/L	1.1	0.29	6	/	76	7.89%	0.22	0.45	0
Nickel	µg/L	73	1045.16	20	/	76	26.32%	48.1	7600	16
Selenium	µg/L	18	9.87	7	/	76	9.21%	5	20.4	1
Vanadium	µg/L	26	101.9	8	/	76	10.53%	54	244	8
Zinc	µg/L	1100	152.68	32	/	76	42.11%	23	836	0
Metals - Dissolved										
Aluminum	µg/L	3700	1976.2	5	/	76	6.58%	276	7430	1
Arsenic	µg/L	0.045	16.1	3	/	76	3.95%	12.5	22	3
Barium	µg/L	260	338	1	/	76	1.32%	338	338	1
Chromium	µg/L	18	13.3	2	/	76	2.63%	12.4	14.2	0
Cobalt	µg/L	220	2221.06	9	/	76	11.84%	51.9	7450	5
Copper	µg/L	150	977.56	10	/	76	13.16%	32.2	3900	5
Iron	µg/L	1100	7040.23	40	/	76	52.63%	121	41600	28
Lead	µg/L	15	6.86	8	/	76	10.53%	3	17	1
Manganese	µg/L	73	2641.48	70	/	76	92.11%	20.7	45500	63
Mercury	µg/L	1.1	0.55	4	/	76	5.26%	0.3	0.76	0
Nickel	µg/L	73	1577.73	12	/	76	15.79%	47.2	7310	10
Selenium	µg/L	18	8.2	2	/	76	2.63%	5	11.4	0
Vanadium	µg/L	26	53	1	/	76	1.32%	53	53	1
Zinc	µg/L	1100	50.27	15	/	76	19.74%	22	157	0
Cyanide										
Cyanide, total	µg/L	73	236.45	11	/	76	14.47%	11	1700	6
Water Quality Parameters										
Alkalinity	µg/L		390397.26	73	/	76	96.05%	36000	1500000	NA
Chloride	µg/L		511969.7	66	/	76	86.84%	1000	9500000	NA
Hardness	µg/L		1491917.81	73	/	76	96.05%	200000	13000000	NA
Nitrate	µg/L	5800	174319.05	21	/	76	27.63%	100	1600000	8
Sulfate	µg/L		993957.75	71	/	76	93.42%	10000	12000000	NA
Total dissolved solids	µg/L		3123270.27	74	/	76	97.37%	92000	50000000	NA
Total organic carbon	µg/L		472170.27	74	/	76	97.37%	1000	14000000	NA
Total suspended solids	µg/L		121050.85	59	/	76	77.63%	4000	2200000	NA

Table 8-5

Summary of Detected Organic and Explosive Compounds Exceeding RBCs
Site-Wide Bedrock Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	WARWP	PRRWP	TNTA	TNTB	TNTC	AA1	AA2	AA3	MNTA	ABG	BG8	Upper Toluene	Reactor
Volatile Organic Compounds															
1,1,2-Trichloroethane	µg/L	0.19		◆											
Benzene	µg/L	0.36	◆	◆	◆	◆	◆	◆	◆		◆			◆	◆
Chlorobenzene	µg/L	3.5		◆					◆						
Ethylbenzene	µg/L	130		◆										◆	
Toluene	µg/L	75		◆	◆		◆							◆	
Semivolatile Organic Compounds															
1,3-Dichlorobenzene	µg/L	1.4												◆	
2,4-Dinitrophenol	µg/L	7.3	◆												
2,4-Dinitrotoluene	µg/L	7.3	◆												
4,6-Dinitro-2-methylphenol	µg/L	0.37	◆												
bis(2-Ethylhexyl)phthalate	µg/L	4.8		◆			◆	◆	◆	◆				◆	◆
Nitrobenzene	µg/L	1.8	◆												
Explosives															
1,3-Dinitrobenzene	µg/L	0.37			◆				◆		◆				
Nitrobenzene	µg/L	0.35			◆										
RDX	µg/L	0.61						◆							

Table 8-6

Summary of Detected Organic and Explosive Compounds in Groundwater
Site-Wide Bedrock Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	Mean Concentration	Quantity Detected	Percentage	Minimum Concentration	Maximum Concentration
Volatile Organic Compounds							
1,1,2-Trichloroethane	µg/L	0.19	4.9	1 / 34	2.94%	4.9	4.9
1,1-Dichloroethane	µg/L	80	0.19	1 / 34	2.94%	0.19	0.19
2-Butanone	µg/L	190	18	1 / 34	2.94%	18	18
Acetone	µg/L	370	44.8	5 / 34	14.71%	34	68
Benzene	µg/L	0.36	119.49	23 / 34	67.65%	0.14	780
Carbon disulfide	µg/L	100	11.03	22 / 34	64.71%	0.17	63
Chlorobenzene	µg/L	3.5	13.25	2 / 34	5.88%	5.5	21
Chloromethane	µg/L	1.5	10	1 / 34	2.94%	10	10
Ethylbenzene	µg/L	130	48.04	21 / 34	61.76%	0.15	140
Toluene	µg/L	75	170.16	14 / 34	41.18%	1.3	550
Total xylenes	µg/L	1200	315.34	23 / 34	67.65%	0.91	1100
Trichloroethene	µg/L	1.6	0.25	1 / 34	2.94%	0.25	0.25
Semivolatile Organic Compounds				/			
1,2,4-Trichlorobenzene	µg/L	19	1.6	1 / 34	2.94%	1.6	1.6
1,3-Dichlorobenzene	µg/L	1.4	4.4	1 / 34	2.94%	4.4	4.4
2,4,5-Trichlorophenol	µg/L	370	35	1 / 34	2.94%	35	35
2,4-Dimethylphenol	µg/L	73	6.6	12 / 34	35.29%	1.3	16
2,4-Dinitrophenol	µg/L	7.3	14	1 / 34	2.94%	14	14
2,4-Dinitrotoluene	µg/L	7.3	8.65	2 / 34	5.88%	1.3	16
2-Methylnaphthalene	µg/L	150	12.76	16 / 34	47.06%	1.1	37
2-Methylphenol	µg/L	180	3.51	7 / 34	20.59%	1.6	6.7
4,6-Dinitro-2-methylphenol	µg/L	0.37	28	1 / 34	2.94%	28	28
4-Methylphenol	µg/L	18	4	7 / 34	20.59%	1.6	7.7
bis(2-Ethylhexyl)phthalate	µg/L	4.8	80.89	14 / 34	41.18%	1.7	920
Fluorene	µg/L	150	1.7	1 / 34	2.94%	1.7	1.7
Isophorone	µg/L	70	3.4	4 / 34	11.76%	2.7	4.2
Naphthalene	µg/L	150	13.03	12 / 34	35.29%	2.1	31
Nitrobenzene	µg/L	1.8	5.8	1 / 34	2.94%	5.8	5.8
Phenanthrene	µg/L	110	2.17	3 / 34	8.82%	2	2.3
Phenol	µg/L	2200	32.49	13 / 34	38.24%	2.3	74
Explosives				/			
1,3,5-Trinitrobenzene	µg/L	110	1.5	1 / 34	2.94%	1.5	1.5
1,3-Dinitrobenzene	µg/L	0.37	0.72	4 / 34	11.76%	0.22	1
2,4-Dinitrotoluene	µg/L	7.3	1.22	5 / 34	14.71%	0.23	2.5
2,6-Dinitrotoluene	µg/L	3.7	1.51	4 / 34	11.76%	0.34	3.6
2-Nitrotoluene	µg/L	6.1	1.1	1 / 34	2.94%	1.1	1.1
3-Nitrotoluene	µg/L	12	0.47	2 / 34	5.88%	0.31	0.62
Nitrobenzene	µg/L	0.35	0.89	3 / 34	8.82%	0.32	2
RDX	µg/L	0.61	2.8	1 / 34	2.94%	2.8	2.8
Tetryl	µg/L	37	2.4	1 / 34	2.94%	2.4	2.4

Table 8-7

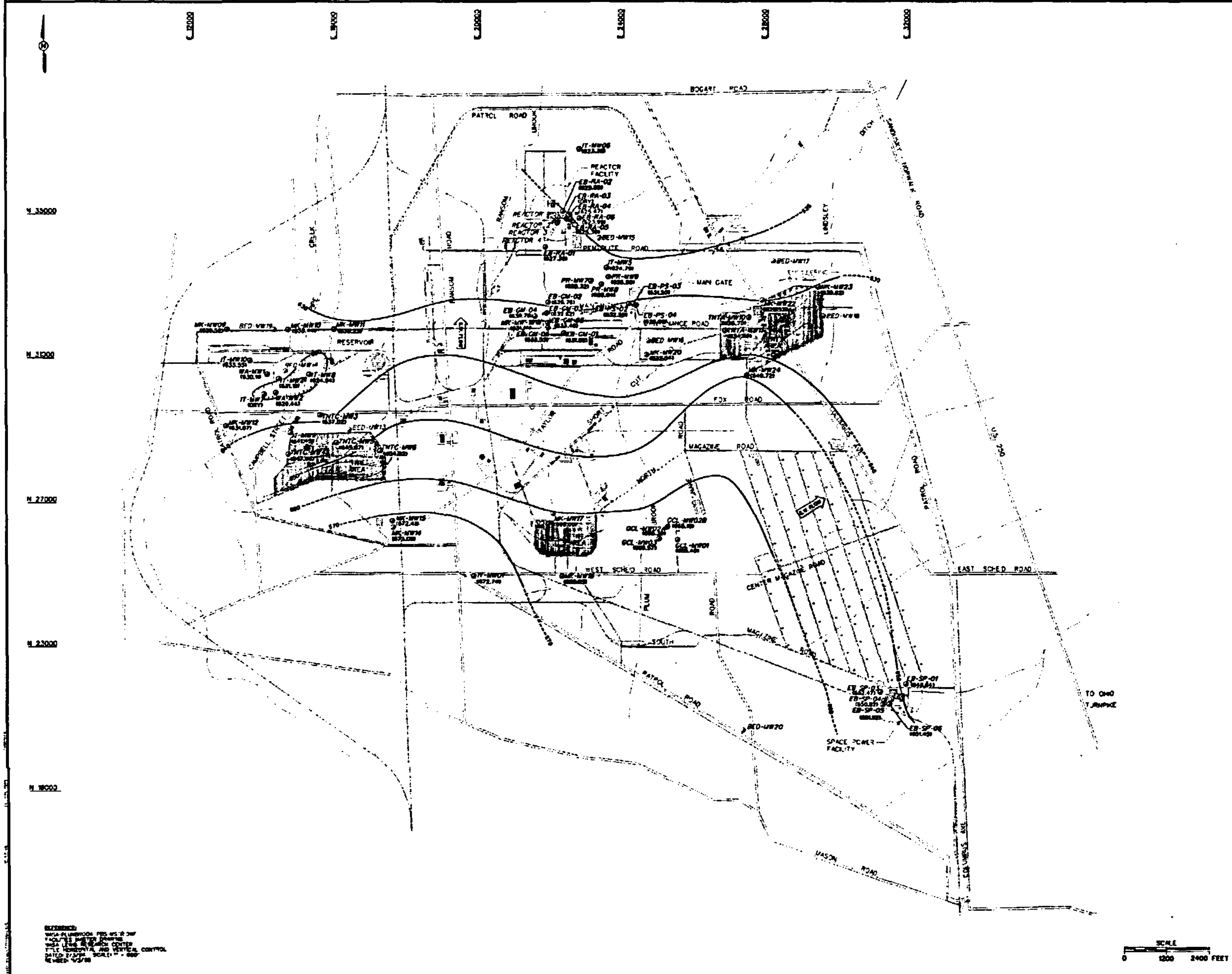
Summary of Detected Inorganic Constituents Exceeding RBCs by Site
Site-Wide Bedrock Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	WARWP	PRRWP	TNTA	TNTB	TNTC	AA1	AA2	AA3	MNTA	ABG	BG8	Upper Toluene	Reactor
Metals - Total															
Aluminum	µg/L	3700							◆				◆	◆	
Arsenic	µg/L	0.045				◆		◆	◆			◆	◆		
Barium	µg/L	260		◆	◆	◆	◆	◆	◆		◆		◆	◆	◆
Chromium	µg/L	18		◆					◆				◆	◆	
Iron	µg/L	1100		◆	◆	◆		◆	◆		◆	◆	◆	◆	◆
Lead	µg/L	15							◆			◆	◆	◆	◆
Manganese	µg/L	73		◆	◆	◆		◆	◆	◆	◆	◆	◆	◆	◆
Mercury	µg/L	1.1										◆			
Nickel	µg/L	73							◆						
Thallium	µg/L	0.23		◆										◆	
Vanadium	µg/L	26							◆					◆	
Metals - Filtered															
Arsenic	µg/L	0.045			◆			◆							
Barium	µg/L	260		◆	◆	◆	◆	◆	◆		◆		◆	◆	◆
Iron	µg/L	1100				◆						◆			◆
Manganese	µg/L	73			◆	◆		◆	◆		◆	◆	◆		◆
Thallium	µg/L	0.23		◆										◆	
Vanadium	µg/L	26												◆	
Cyanide															
Cyanide, total	µg/L	73	◆												

Table 8-8

Summary of Detected Inorganic Constituents in Groundwater
Site-Wide Bedrock Monitoring Wells
Former Plum Brook Ordnance Works, Sandusky, Ohio

Parameter	Units	RBC	Mean Concentration	Frequency of Detection			Percentage	Minimum Concentration	Maximum Concentration	Quantity > RBC
Metals - Total										
Aluminum	µg/L	3700	2192.11	19	/	33	57.58%	283	11000	3
Arsenic	µg/L	0.045	19.02	6	/	33	18.18%	11.7	34.2	6
Barium	µg/L	260	2255.67	24	/	33	72.73%	220	19000	23
Chromium	µg/L	18	57.69	9	/	33	27.27%	10	307	5
Cobalt	µg/L	220	63.3	1	/	33	3.03%	63.3	63.3	0
Copper	µg/L	150	51.14	10	/	33	30.30%	26.2	84.9	0
Iron	µg/L	1100	8625.63	30	/	33	90.91%	141	51600	19
Lead	µg/L	15	15.33	13	/	33	39.39%	3.9	40.4	5
Manganese	µg/L	73	515.89	33	/	33	100.00%	17.4	5130	24
Mercury	µg/L	1.1	2.3	2	/	33	6.06%	1	3.6	1
Nickel	µg/L	73	84.52	5	/	33	15.15%	42.1	238	1
Thallium	µg/L	0.23	75.9	2	/	33	6.06%	50.8	101	2
Vanadium	µg/L	26	99.57	3	/	33	9.09%	64.7	126	3
Zinc	µg/L	1100	65.58	18	/	33	54.55%	27.7	235	0
Metals - Filtered										
Aluminum	µg/L	3700	408	1	/	33	3.03%	408	408	0
Arsenic	µg/L	0.045	16.35	2	/	33	6.06%	13.1	19.6	2
Barium	µg/L	260	1792.68	25	/	33	75.76%	208	21000	23
Chromium	µg/L	18	14.2	2	/	33	6.06%	13.6	14.8	0
Cobalt	µg/L	220	65.4	1	/	33	3.03%	65.4	65.4	0
Iron	µg/L	1100	3570	10	/	33	30.30%	269	16300	6
Lead	µg/L	15	4.43	3	/	33	9.09%	3	6.8	0
Manganese	µg/L	73	367.96	26	/	33	78.79%	16.3	1300	16
Mercury	µg/L	1.1	0.24	1	/	33	3.03%	0.24	0.24	0
Nickel	µg/L	73	56	2	/	33	6.06%	40.7	71.3	0
Thallium	µg/L	0.23	57.65	2	/	33	6.06%	53.1	62.2	2
Vanadium	µg/L	26	54.45	2	/	33	6.06%	50.6	58.3	2
Zinc	µg/L	1100	42.54	10	/	33	30.30%	22.3	105	0
Cyanide										
Cyanide, total	µg/L	73	99	4	/	33	12.12%	16	320	1
Water Quality Parameters										
Alkalinity	µg/L		516939.39	33	/	33	100.00%	67000	1700000	NA
Chloride	µg/L		2211528.13	32	/	33	96.97%	3000	21000000	NA
Hardness	µg/L		2703352.94	34	/	33	103.03%	180000	20000000	NA
Nitrate	µg/L	5800	6420	5	/	33	15.15%	200	24000	2
Sulfate	µg/L		101096.67	30	/	33	90.91%	5000	630000	NA
Total dissolved solids	µg/L		5061764.71	34	/	33	103.03%	110000	33000000	NA
Total organic carbon	µg/L		17861.29	31	/	33	93.94%	1000	190000	NA
Total suspended solids	µg/L		75677.42	31	/	33	93.94%	4000	480000	NA



LEGEND:

- BUILDING
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- MK-MW22 OVERBURDEN MONITORING WELL
- BED-MW16 BEDROCK MONITORING WELL
- GROUNDWATER FLOW DIRECTION
- GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERED)

NOTES:

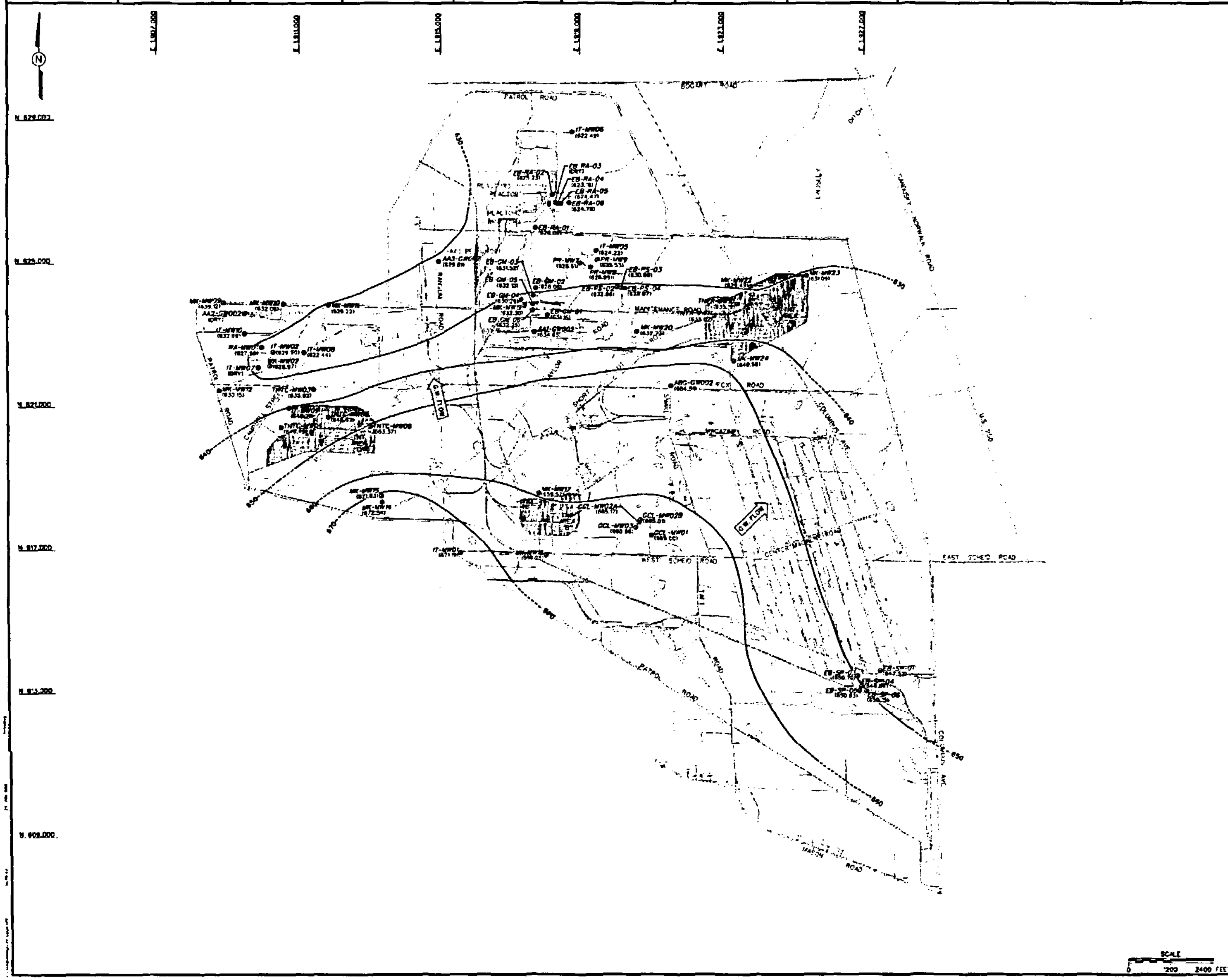
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE).

IT CORPORATION

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-1
OVERBURDEN GROUNDWATER ELEVATION CONTOUR MAP (AUGUST 1997)

AREA	JOB NO.	DRAWING NO.	REV
	771481	771481ES.176	



LEGEND:

- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- GROUNDWATER ELEVATION (FT-MSL)
- G.W. FLOW — GROUNDWATER FLOW DIRECTION
- GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)
- BUILDING
- RAILROAD
- SURFACE WATER
- DITCH
- FENCE (PBOW BOUNDARY)

NOTES:

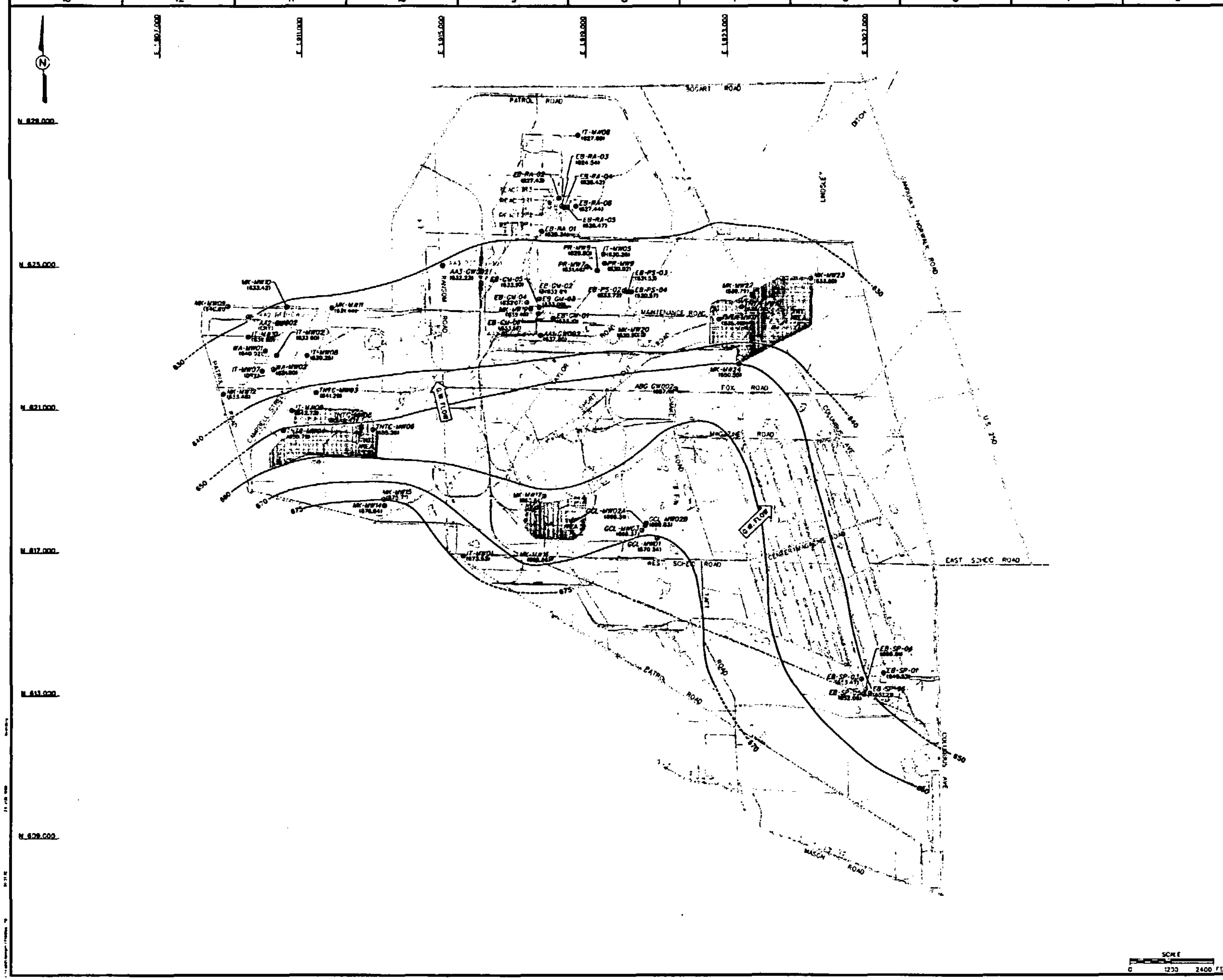
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE)

IT CORPORATION

SUMMARY REPORT, SITE-WIDE
GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-2
OVERBURDEN GROUNDWATER ELEVATION
CONTOUR MAP (NOVEMBER 1997)

AREA	JOB NO	DRAWING NO.	REV
SITEWIDE	77'48'	771481ES.177	



LEGEND:

MK-MW09	OVERBURDEN MONITORING WELL
	BEDROCK MONITORING WELL
633.000	GROUNDWATER ELEVATION (FT-MSL)
G.W. FLOW	GROUNDWATER FLOW DIRECTION
630	GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)
	BUILDING
	RAILROAD
	SURFACE WATER
	DITCH
	FENCE (PBOW BOUNDARY)

NOTES:

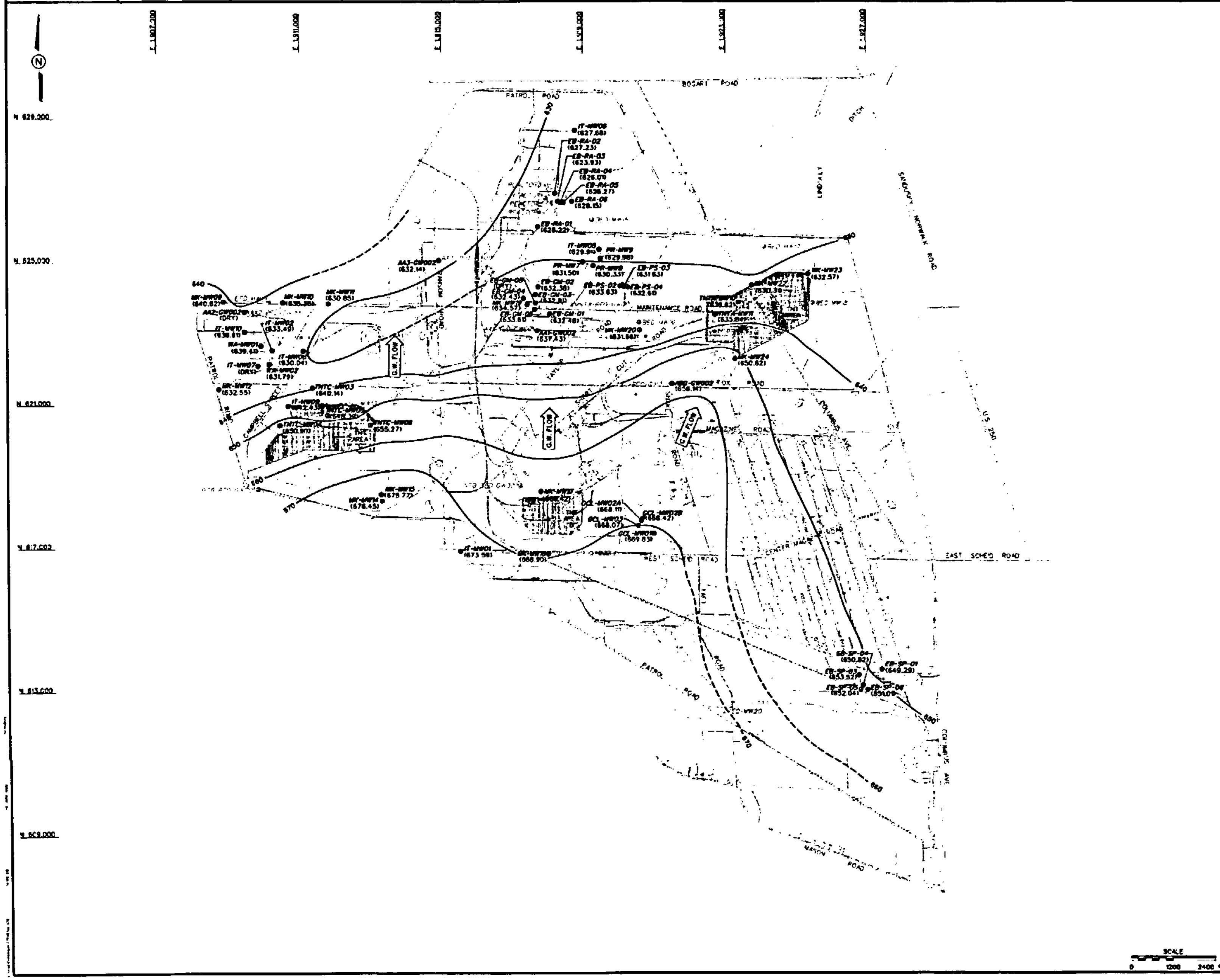
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE)

IT CORPORATION

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-3
OVERBURDEN GROUNDWATER ELEVATION CONTOUR MAP (FEBRUARY 1998)

AREA	JOB NO	DRAWING NO.	REV
SITEWIDE	771481	771481ES.178	



LEGEND:

● ABC-GW002	OVERBURDEN MONITORING WELL
	BEDROCK MONITORING WELL
	BUILDING
	RAILROAD
	SURFACE WATER
	DITCH
	FENCE (PBOW BOUNDARY)
(630.63)	GROUNDWATER ELEVATION (FT-MSL)
—610—	GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)
G.W. FLOW	GROUNDWATER FLOW DIRECTION

NOTES:

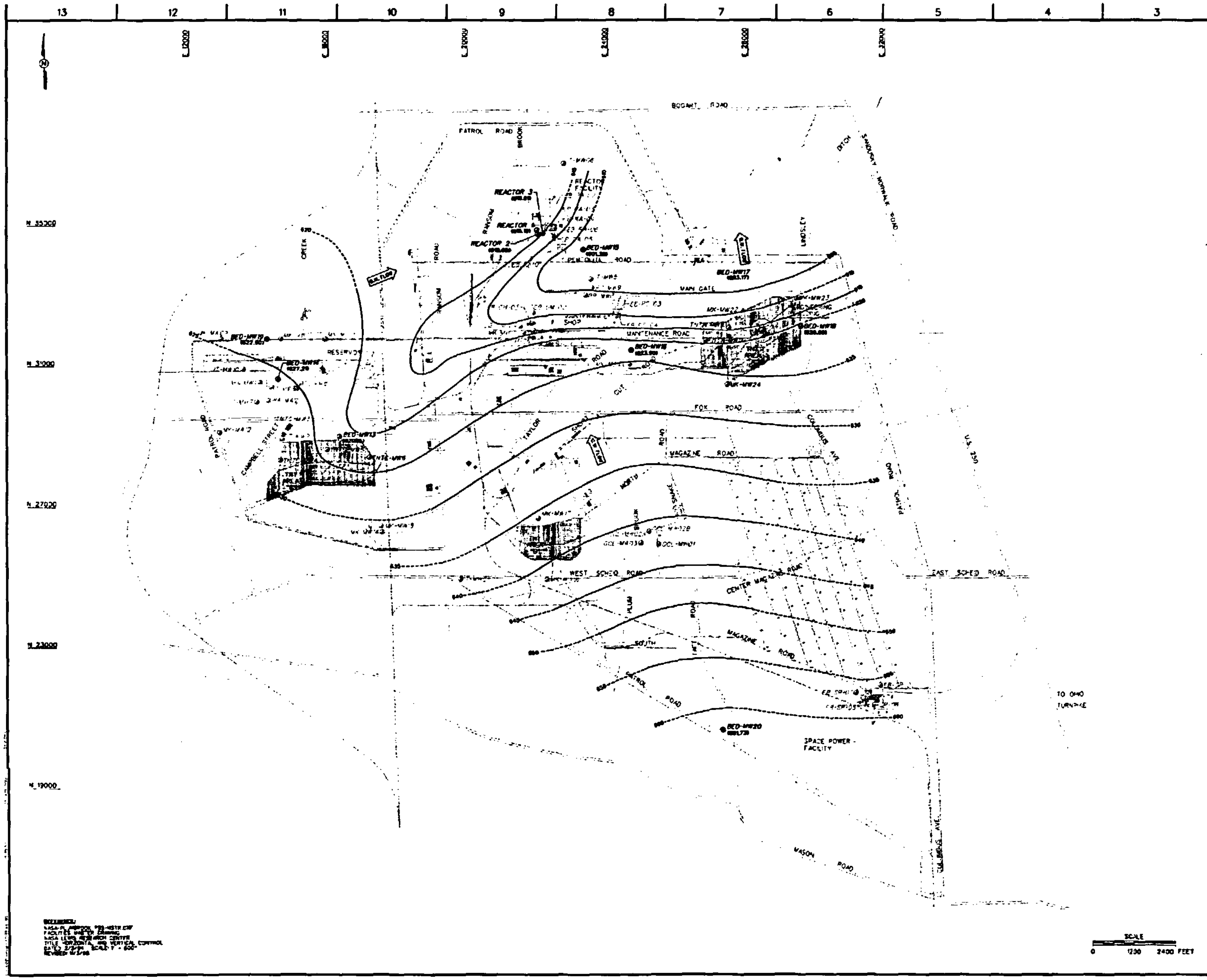
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE).

IT CORPORATION

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-4
OVERBURDEN GROUNDWATER ELEVATION CONTOUR MAP (MAY, 1998)

AREA	JOB NO	DRAWING NO	REV
SITEWIDE	771481	771481ES.179	



LEGEND:

- BUILDING
- FENCE (PBOW BOUNDARY)
- RAILROAD
- DITCH
- SURFACE POND
- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- GROUNDWATER FLOW DIRECTION
- 1620.92) GROUNDWATER ELEVATION (FT-MSL)
- GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)

NOTES:

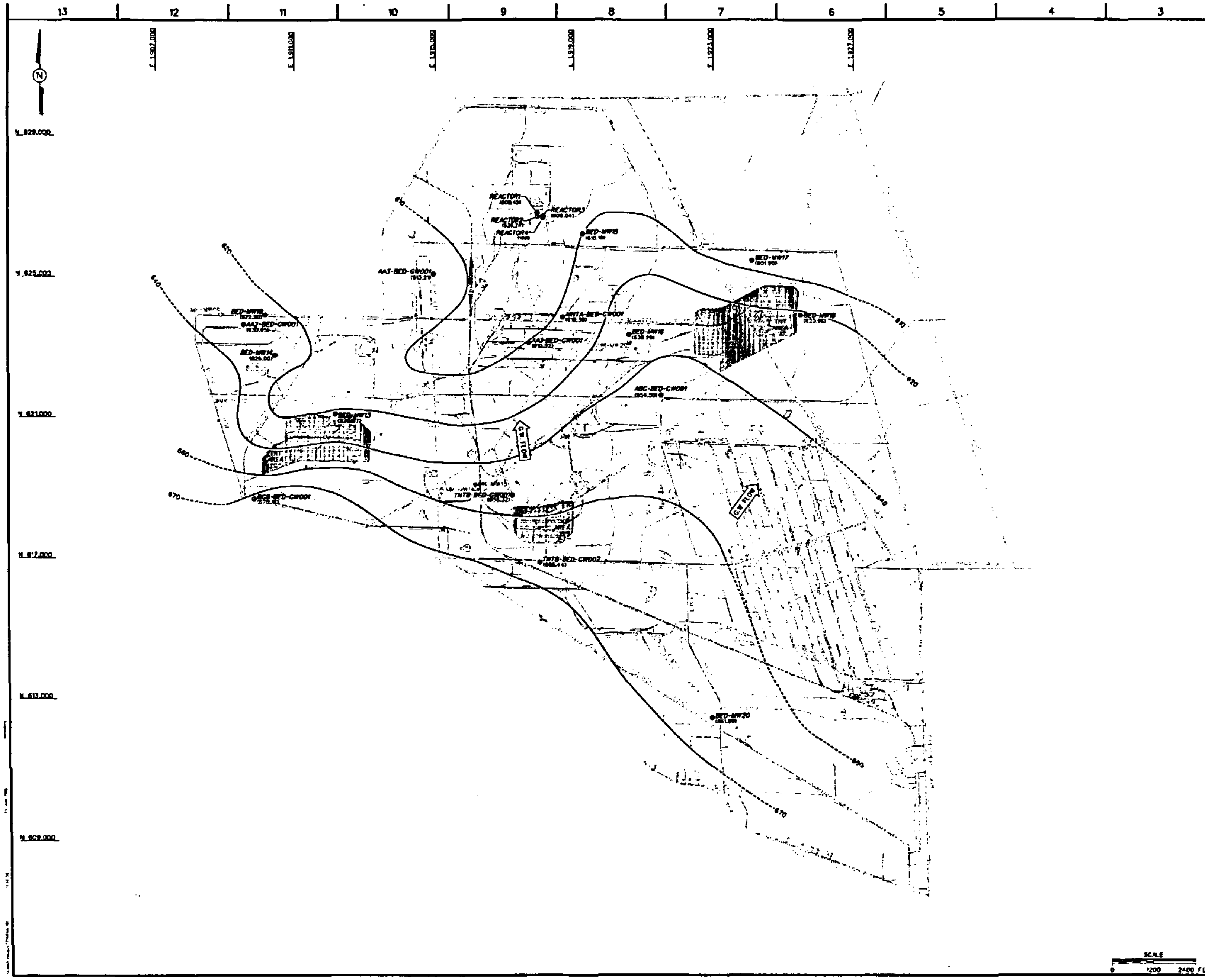
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE)

IT CORPORATION

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-5
BEDROCK GROUNDWATER ELEVATION CONTOUR MAP (AUGUST 1997)

AREA	JOB NO.	DRAWING NO.	REV
	771481	771481ES.180	



LEGEND:

PB-MW01	OVERBURDEN MONITORING WELL
BED-MW18	BEDROCK MONITORING WELL
(633.00)	GROUNDWATER ELEVATION (FT-MSL)
	NOT MEASURED
G.W. FLOW	GROUNDWATER FLOW DIRECTION
630	GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)
	BUILDING
	RAILROAD
	SURFACE WATER
	DITCH
	FENCE (PBOW BOUNDARY)

NOTES:

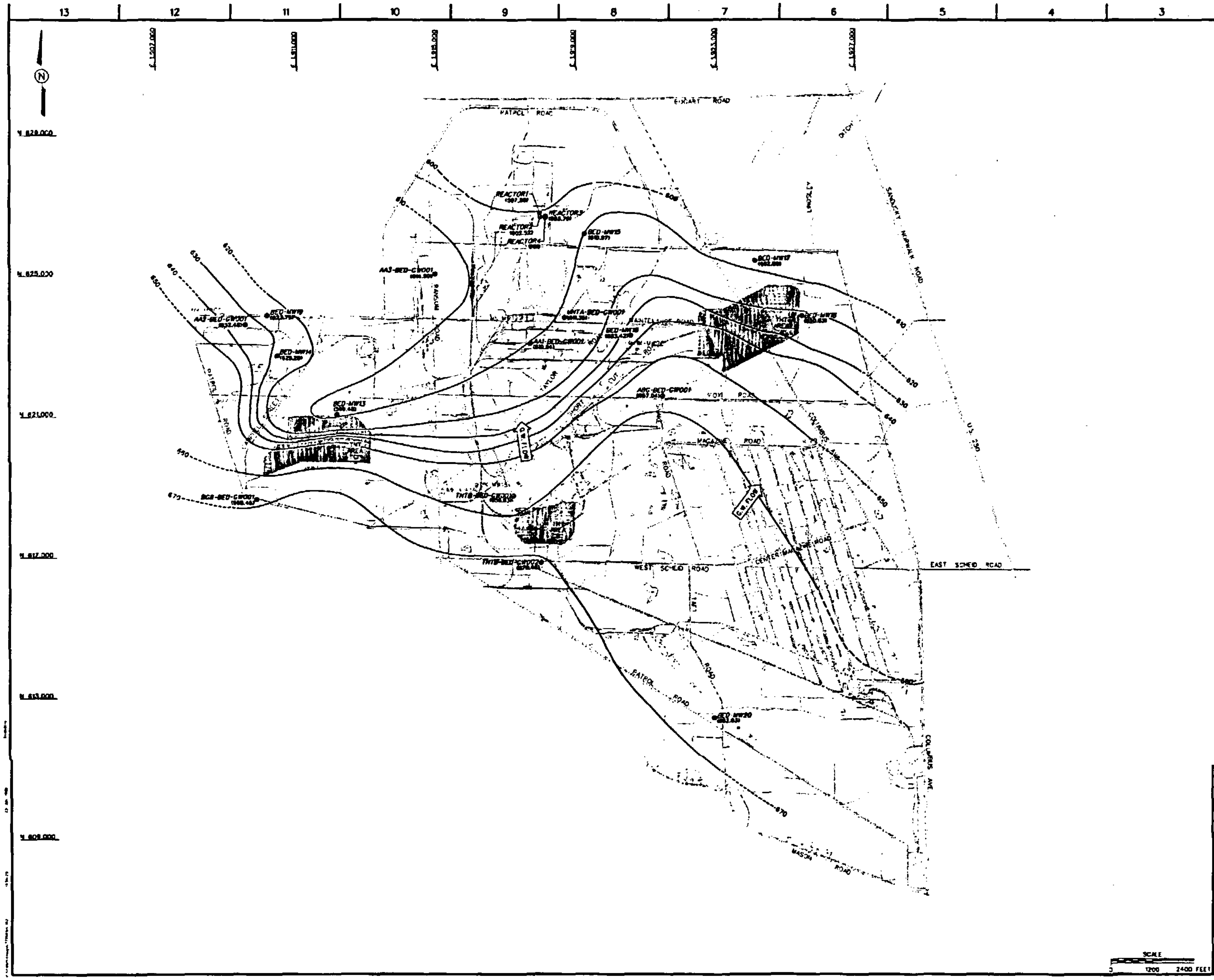
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE).
2. GROUNDWATER ELEVATION 626.24 FT OF REACTOR WELL NO. 2 NOT USED DURING CONTOURING.

IT CORPORATION
A Member of The IT Group

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-6
BEDROCK GROUNDWATER ELEVATION CONTOUR MAP (NOVEMBER 1997)

AREA	JOB NO	DRAWING NO	REV
SITEWIDE	771481	771481ES.181	



LEGEND:

- OVERBURDEN MONITORING WELL
- BEDROCK MONITORING WELL
- GROUNDWATER ELEVATION (FT-MSL)
- NOT MEASURED
- G.W. FLOW — GROUNDWATER FLOW DIRECTION
- 630 — GROUNDWATER ELEVATION CONTOUR (FT-MSL) (DASHED WHERE INFERRED)
- BUILDING
- RAILROAD
- SURFACE WATER
- DITCH
- FENCE (PBOW BOUNDARY)

NOTES:

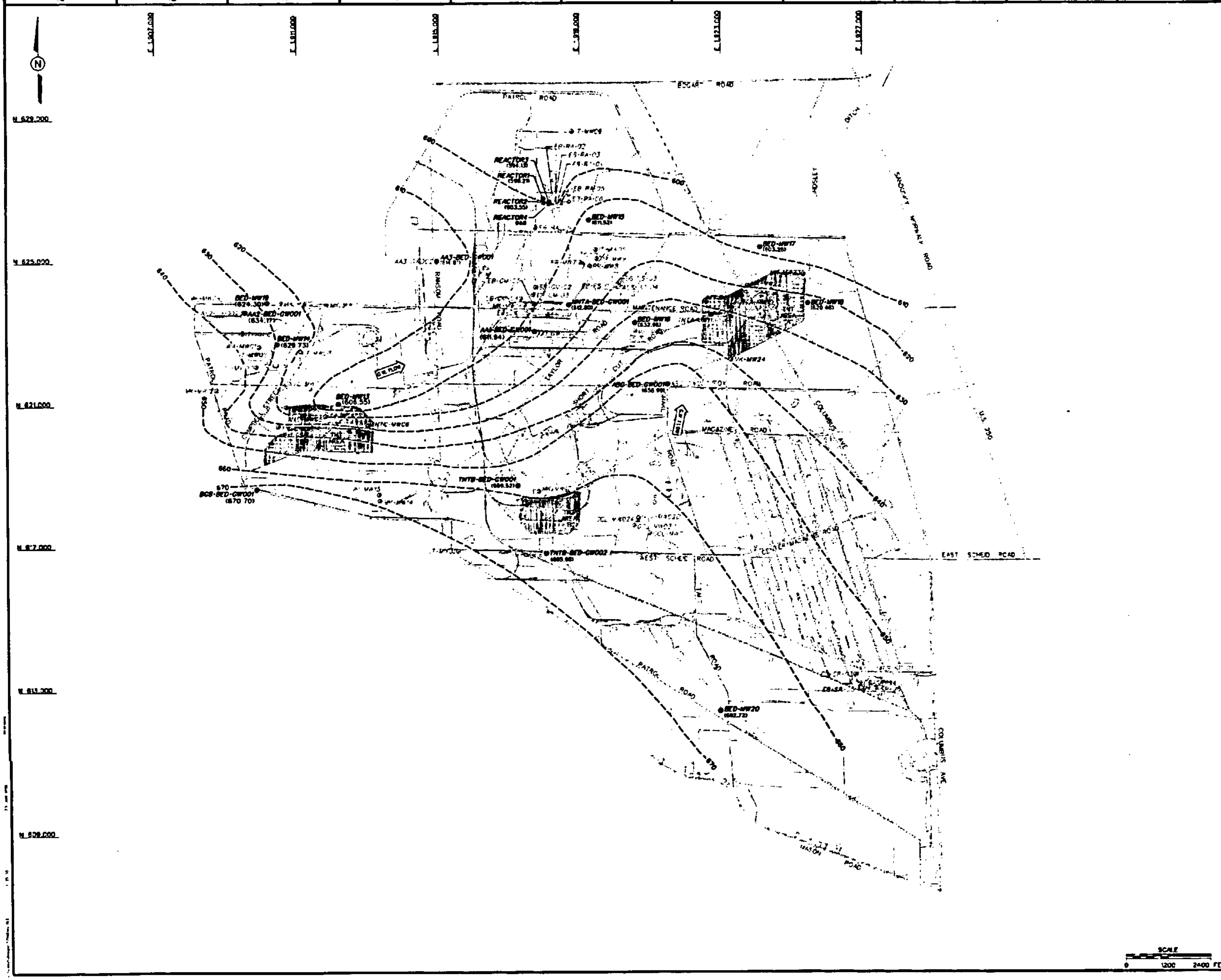
1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE).

IT CORPORATION

SUMMARY REPORT, SITE-WIDE
GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-7
BEDROCK GROUNDWATER ELEVATION
CONTOUR MAP (FEBRUARY 1998)

AREA	JOB NO.	DRAWING NO.	REV
SITEWIDE	771481	771481ES.182	



LEGEND:

- ●ABC-BED-GW001 MONITORING WELL LOCATION
- ●MK-MW09 OVERBURDEN WELL LOCATION
- BUILDING
- RAILROAD
- SURFACE WATER
- DITCH
- FENCE (PBOW BOUNDARY)
- (634.77) GROUNDWATER ELEVATION (FT-MSL)
- (NM) NOT MEASURED
- —610— GROUNDWATER ELEVATION CONTOUR
- G.W. FLOW INTERPRETED GROUNDWATER FLOW DIRECTION

NOTES:

1. MONITORING WELLS PB-MW01, PB-MW02, PB-MW03, PB-MW04, AND REACTOR 5 ARE NOT SHOWN (SURVEY COORDINATES NOT AVAILABLE).

SCALE 0 1200 2400 FEET

IT CORPORATION

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

FIGURE 6-8
BEDROCK GROUNDWATER ELEVATION CONTOUR MAP
(MAY 1998)

AREA	JOB NO	DRAWING NO.	REV
SITEWIDE	771481	771481ES.183	

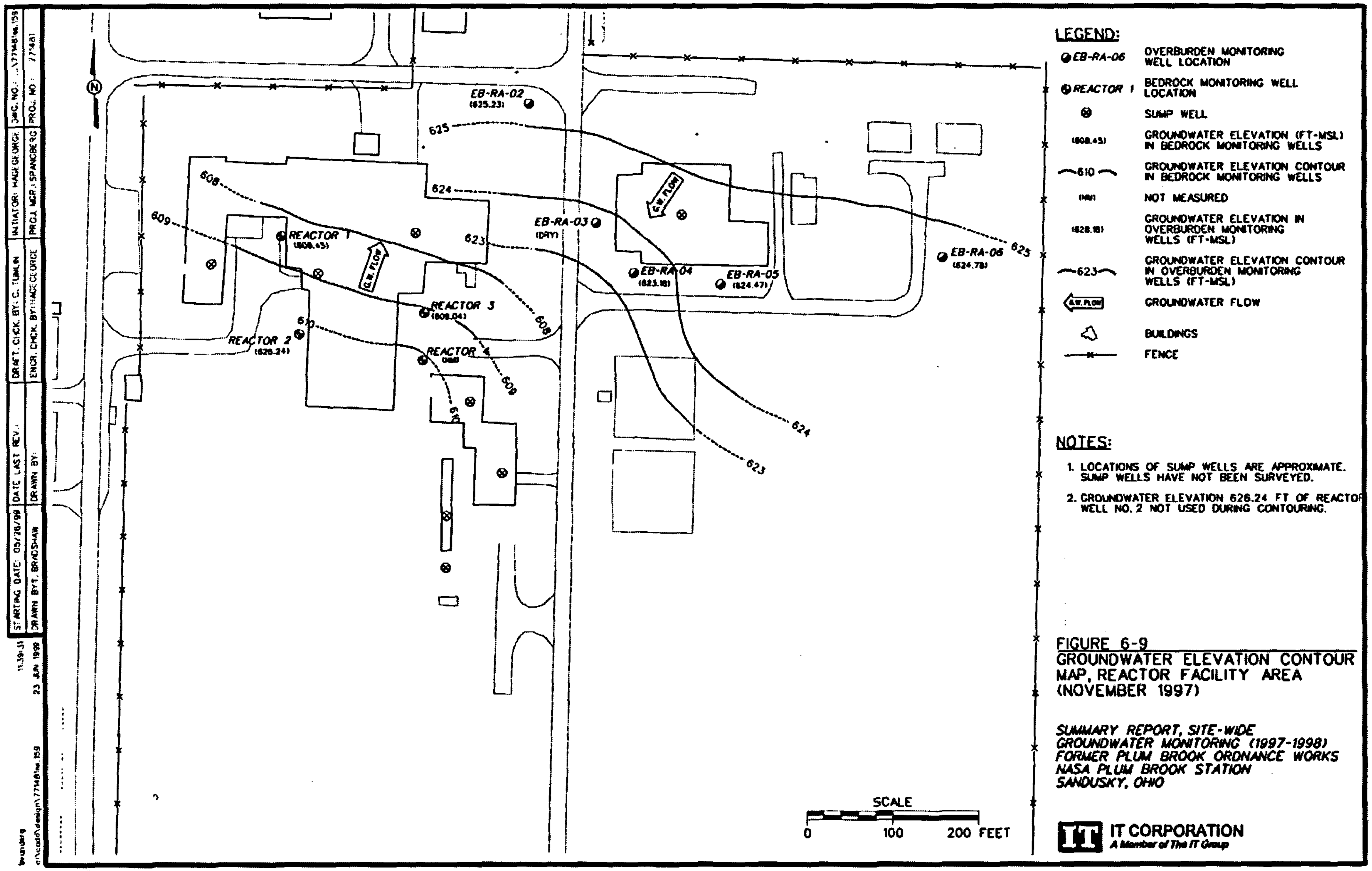
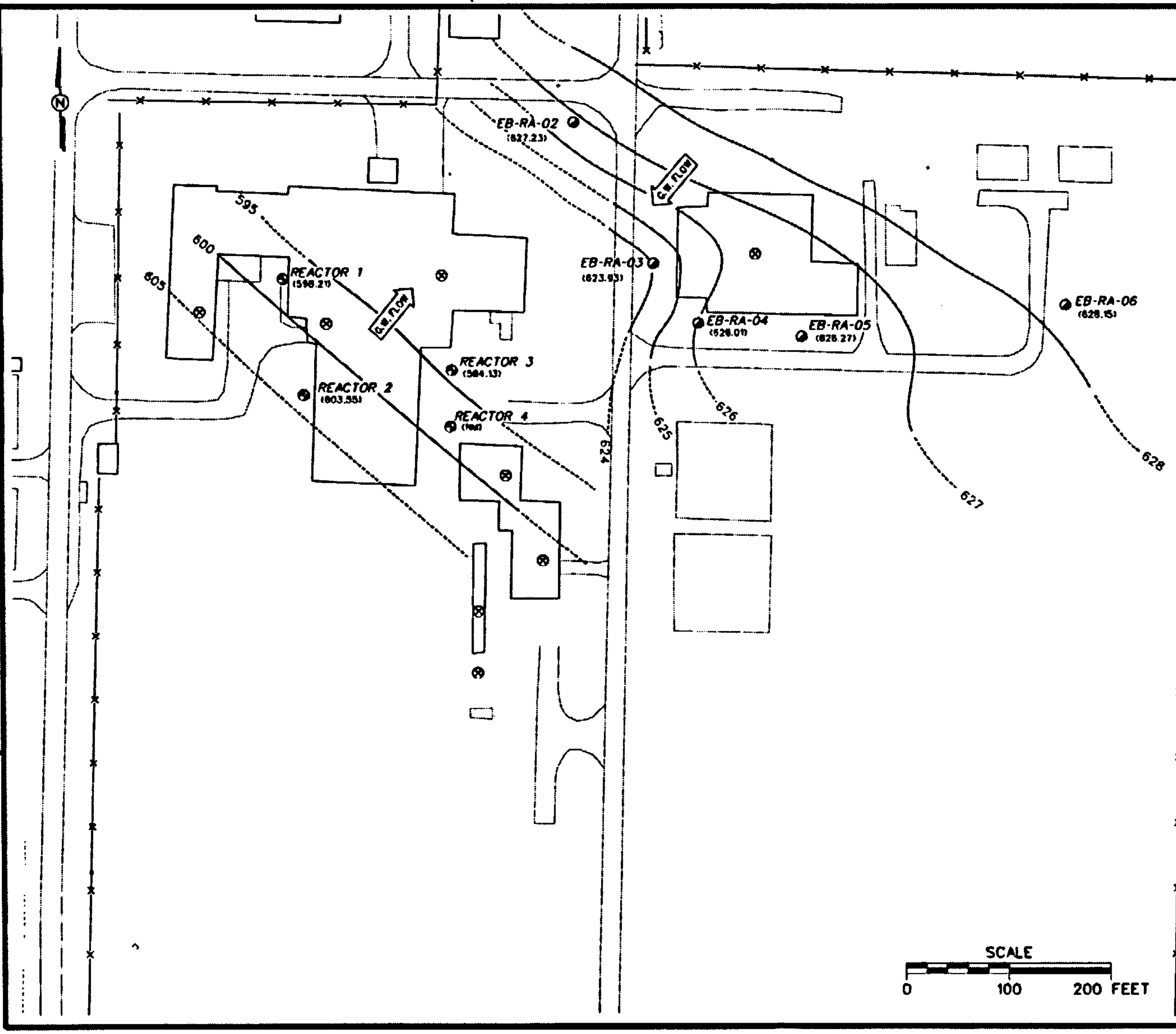


FIGURE 6-9
GROUNDWATER ELEVATION CONTOUR MAP, REACTOR FACILITY AREA (NOVEMBER 1997)



LEGEND:

EB-RA-06	OVERBURDEN MONITORING WELL LOCATION
REACTOR 1	BEDROCK MONITORING WELL LOCATION
⊗	SUMP WELL
(598.21)	GROUNDWATER ELEVATION (FT-MSL) IN BEDROCK MONITORING WELLS
600	GROUNDWATER ELEVATION CONTOUR IN BEDROCK MONITORING WELLS
(NM)	NOT MEASURED
(628.15)	GROUNDWATER ELEVATION IN OVERBURDEN MONITORING WELLS (FT-MSL)
628	GROUNDWATER ELEVATION CONTOUR IN OVERBURDEN MONITORING WELLS (FT-MSL)
G.W. FLOW	GROUNDWATER FLOW
	BUILDINGS
—x—	FENCE

NOTES:

LOCATIONS OF SUMP WELLS ARE APPROXIMATE. SUMP WELLS HAVE NOT BEEN SURVEYED.

FIGURE 6-10
GROUNDWATER ELEVATION CONTOUR MAP, REACTOR FACILITY AREA (MAY 1998)

SUMMARY REPORT, SITE-WIDE GROUNDWATER MONITORING (1997-1998)
FORMER PLUM BROOK ORDNANCE WORKS
NASA PLUM BROOK STATION
SANDUSKY, OHIO

IT CORPORATION
A Member of The IT Group

STARTING DATE: 05/26/99 | DATE LAST REV.: | DRAFT. CHCK. BY: C. TUMLIN | INITIATOR: HAGEORGE | DWG. NO.: ...\771481es.160
DRAWN BY: T. BRADSHAW | DRAWN BY: | ENGR. CHCK. BY: HAGEORGE | PROJ. MGR.: SPANGBERG | PROJ. NO.: 771481

23 JUN 1999

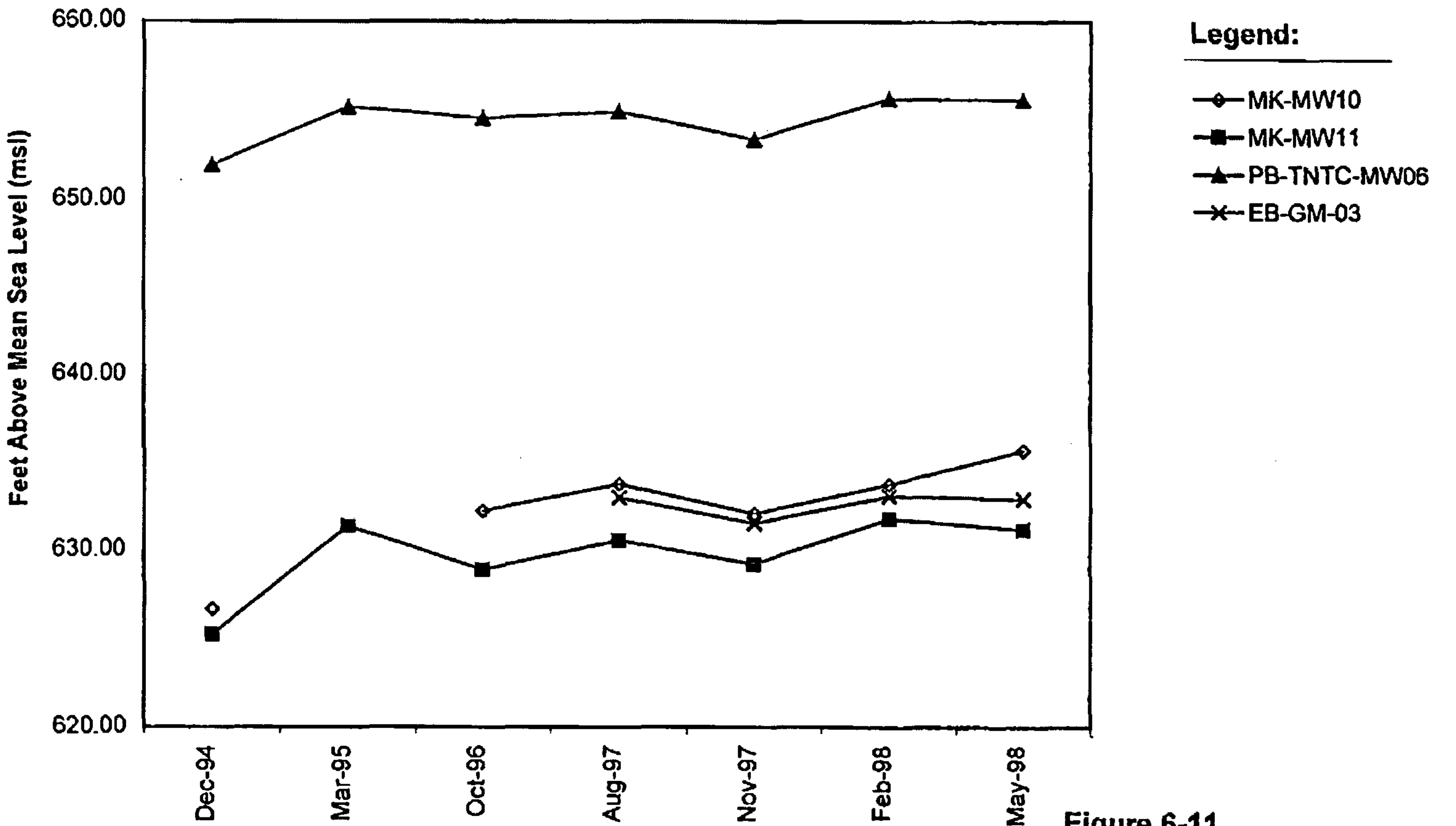


Figure 6-11
Typical Groundwater Elevation Fluctuation, Overburden Wells

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

KN/4379/Figs(typob)/6/28/99(1:12 PM)

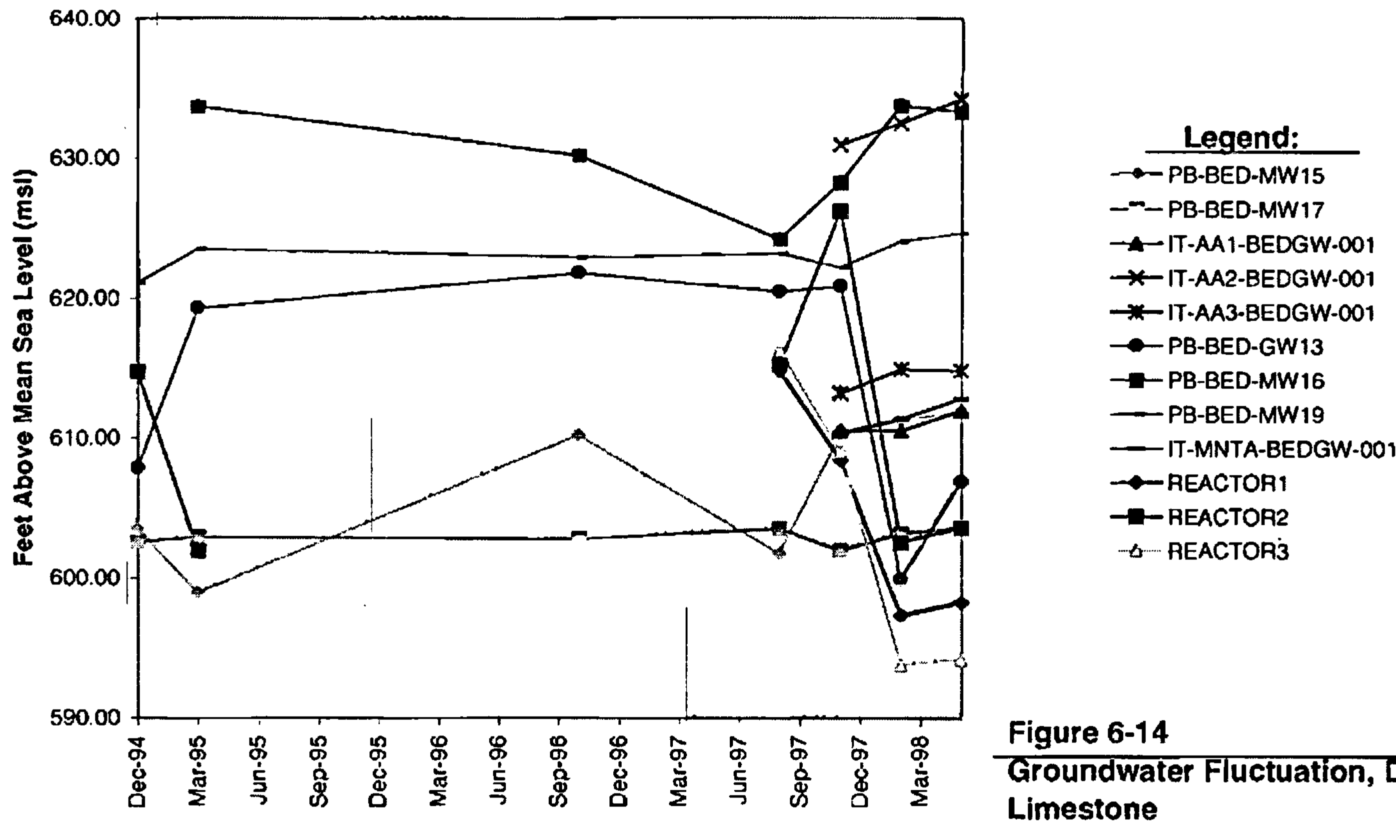


Figure 6-14
Groundwater Fluctuation, Delaware Limestone

IT CORPORATION

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

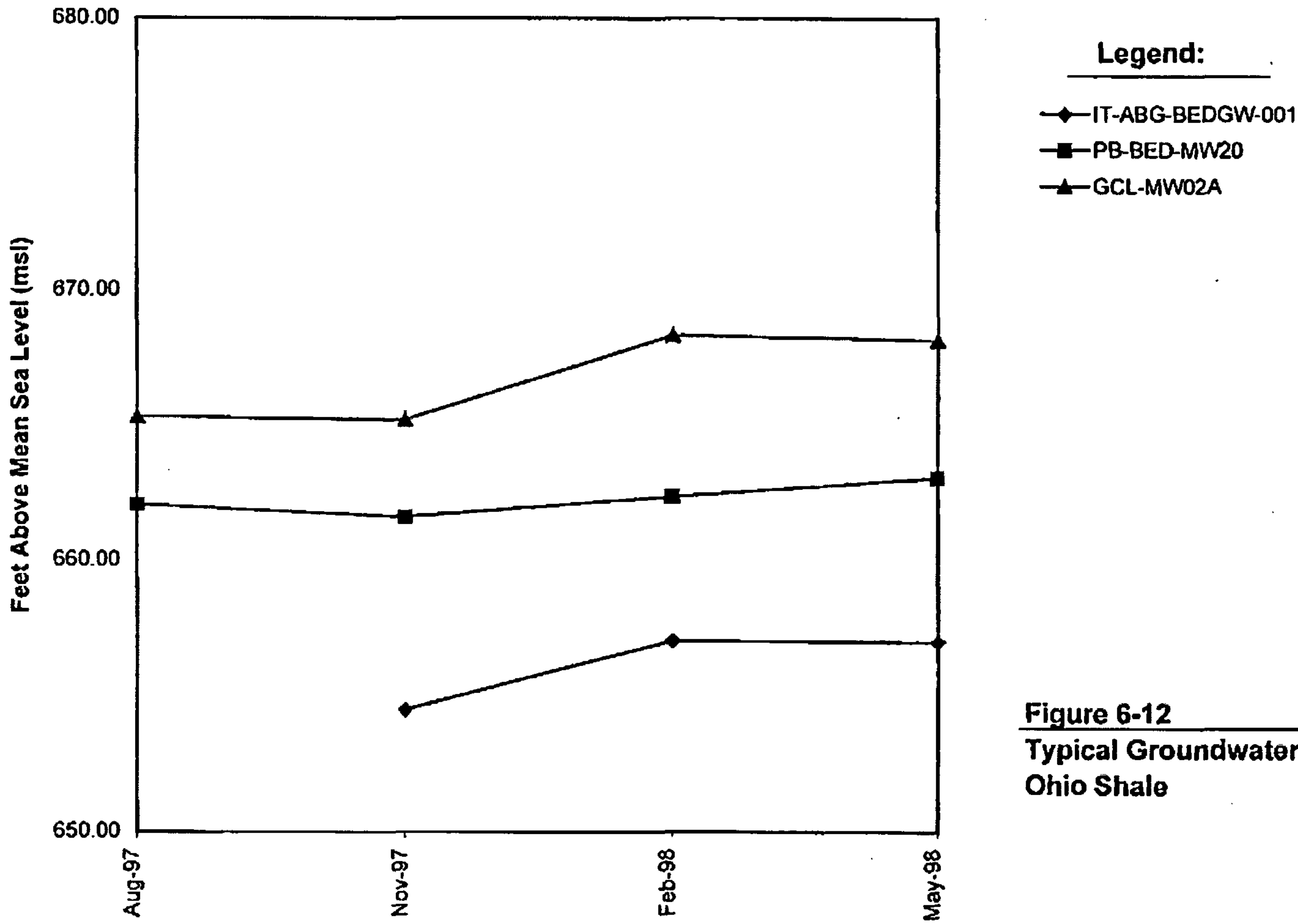


Figure 6-12
Typical Groundwater Fluctuation, Ohio Shale

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

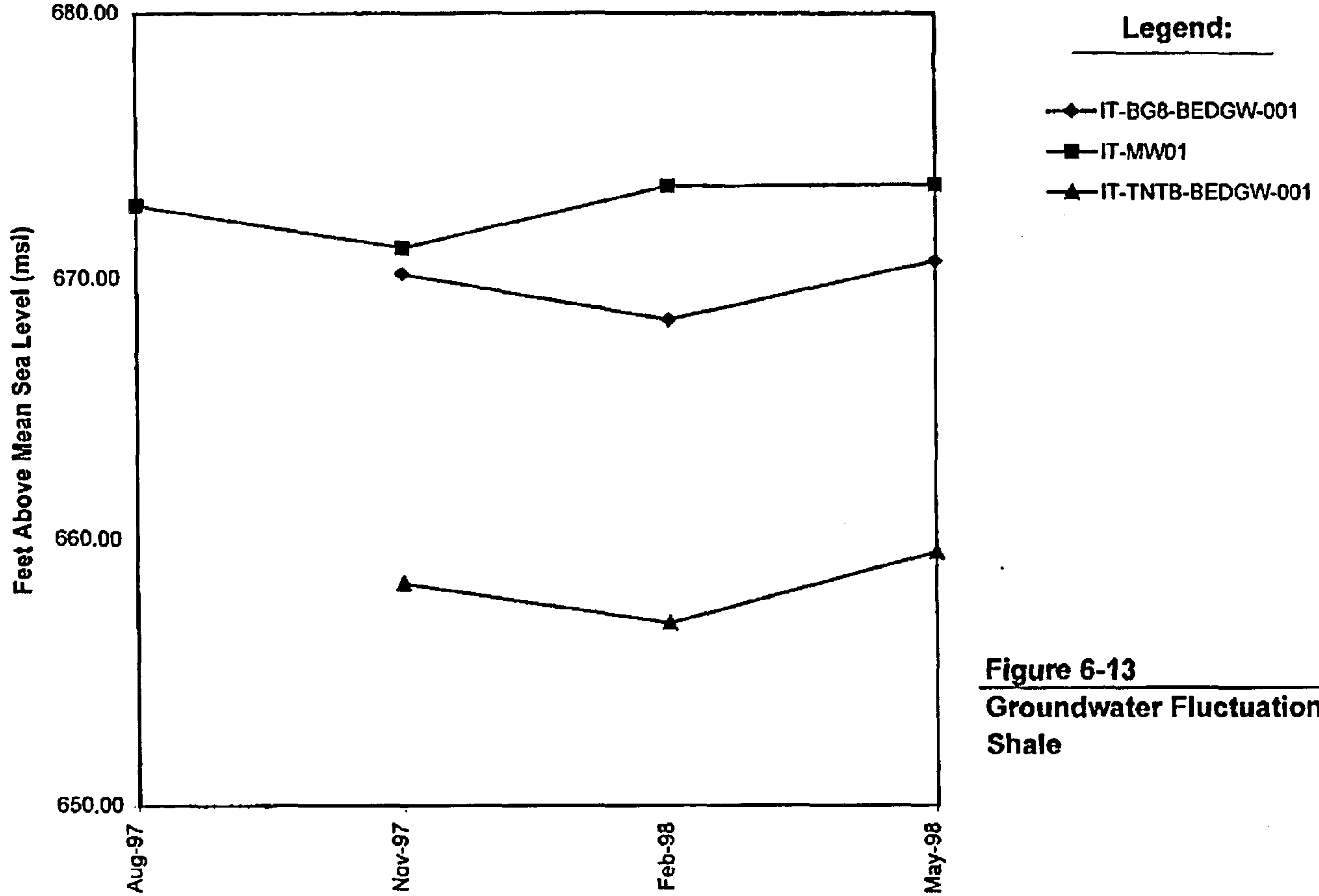


Figure 6-13
Groundwater Fluctuation, Olentangy Shale

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

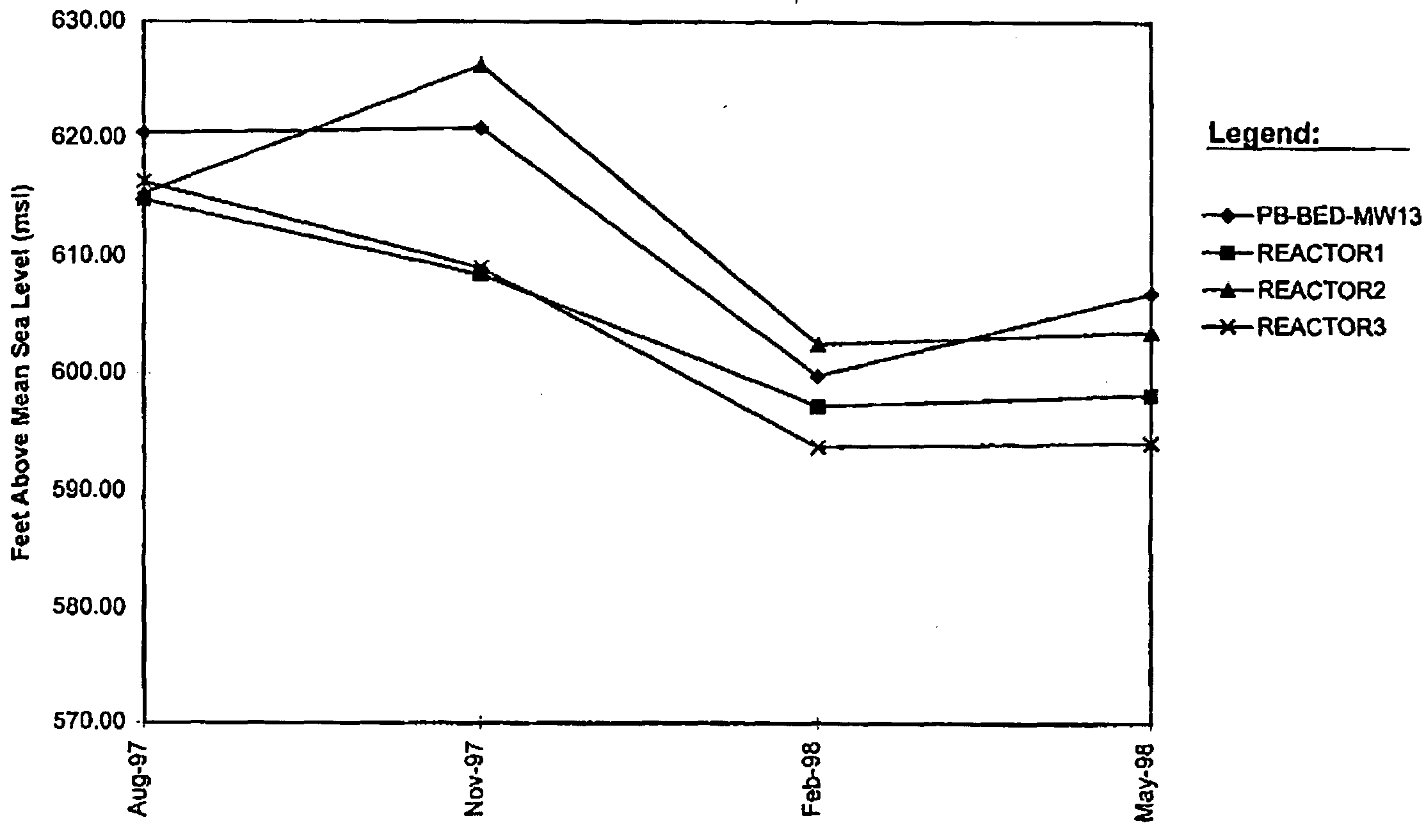


Figure 6-15

Typical Groundwater Fluctuation, Reactor Wells 1, 2, 3 and PB-BED-MW13

IT CORPORATION

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

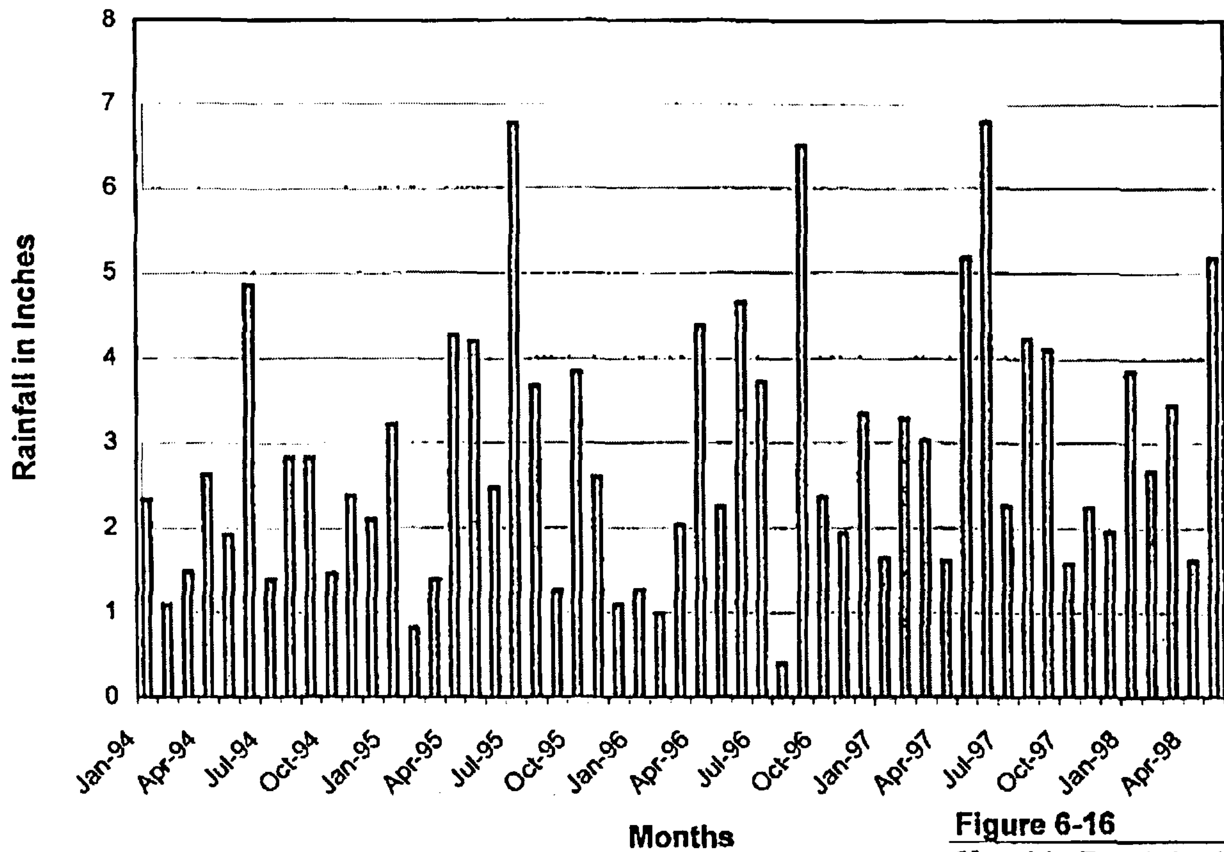


Figure 6-16

Monthly Precipitation Data, January 1994 Through May 1998

IT CORPORATION

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

Kn/4379/Mo_rechg(Rainfall)/6/28 99(1:13 PM)

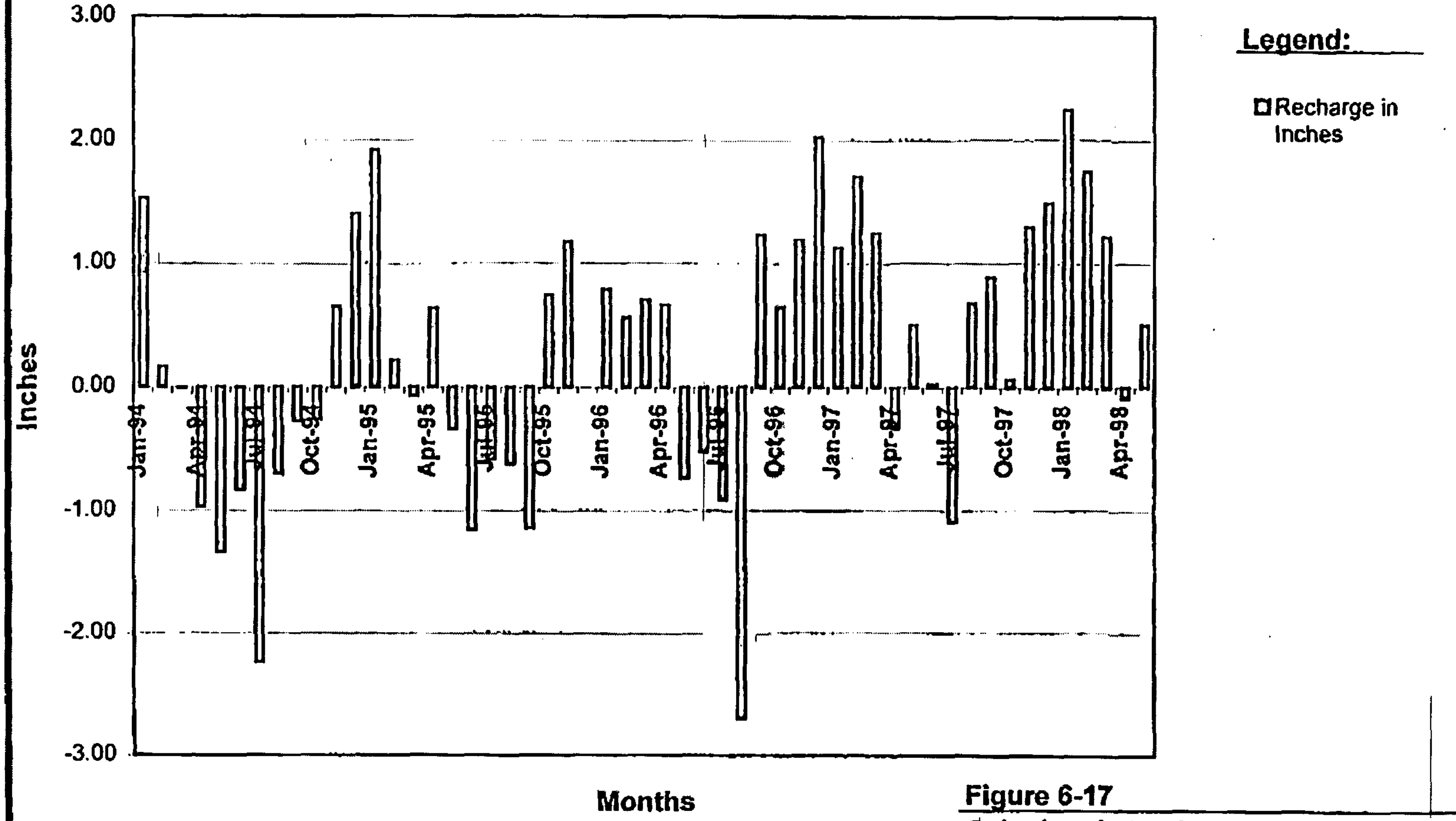


Figure 6-17

Calculated Monthly Recharge Rates at Site

Former Plum Brook Ordnance Works
NASA Plum Brook Station
Sandusky, Ohio

KN/4379/Mo_rechg(Recharge)/6/28/99(1:13 PM)

APPENDIX C

MONITORING WELL HTRW DRILL LOGS
WELL CONSTRUCTION DIAGRAMS

HTRW DRILLING LOG

DISTRICT	Nashville, TN
HOLE NUMBER	PB-BED-MW22
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
SHEET 1 OF 6 SHEETS	
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson / Paul Schradt
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81 / Contera C2-250
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4 1/4" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8 1/4" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well. See ...
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	627.22 Ft
10. DATE STARTED	8/24/01
11. DATE COMPLETED	9/10/01
12. OVERBURDEN THICKNESS	19.5 Ft
13. DEPTH DRILLED INTO ROCK	23.5 Ft
14. TOTAL DEPTH OF HOLE	43 Ft
15. DEPTH GROUNDWATER ENCOUNTERED	4.7 Ft (overburden) ~40 Ft Bedrock
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	NA
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA

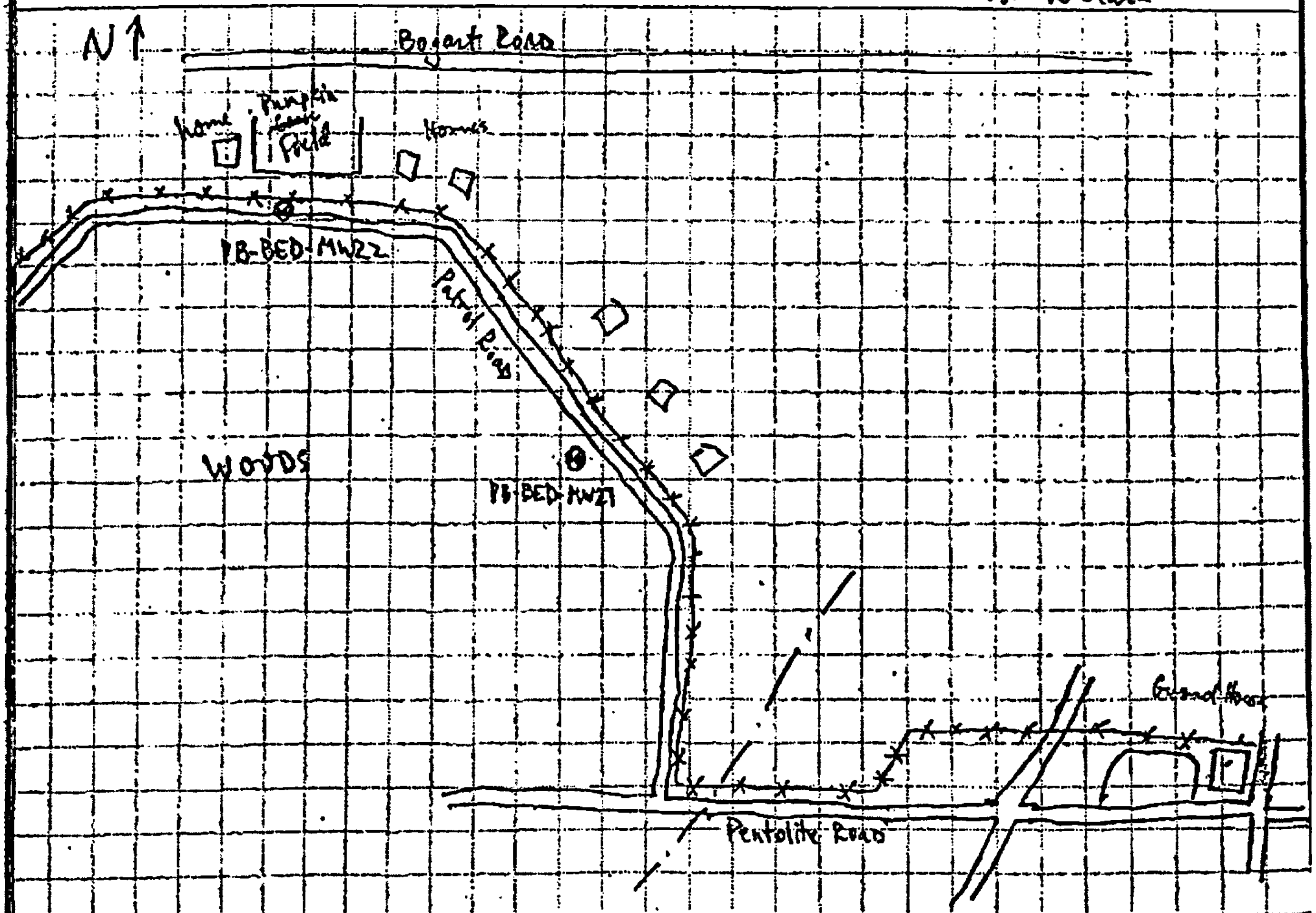
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	6

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY %
	NA	NA	NA	NA	NA	100

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kessler / Reed Adoris

LOCATION SKETCH/COMMENTS

SCALE: Not to Scale



PROJECT PBOW

HOLE NO. PB-BED-MW22

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW22

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample ~~No.~~ Blows	Recovery (ft)	Remarks
		Grass ORGANICS (grass, roots) 0.2						
	0–2	Fill Loose, Dark brown (10YR 3/3), very fine grain, SAND, trace silt (10%), very well sorted, dry)	SP	0	NA	2/3/ 5/8	1.5/ 2.0	Began drilling 8/24/01 Blow Counts w/ 140 lb Hammer Background/Breathing 0.0 ppm = PID
	2–4	Fill Loose, dark yellowish brown (10YR 4/6), fine grain, SAND, trace silt (5%), very well sorted, dry, mottled (brownish yellow, light/dark brown) (moist at 4.7 ft))		0	NA	1530 2/2/ 5/9	1.7/ 2.0	VRAE: CO = 0 ppm LEL = 0% H_2S = 0 ppm O_2 = 21.0 %
	4–6	Medium dense, olive brown (2.5Y 4/3), homogeneous, vfg, SAND, very well sorted, wet	SP	0	NA	1535 5/7/ 12/25	1.8/ 2.0	∇ Encountered (overburden) groundwater at 4.7 ft
	6–7.4	Dense, dark olive gray (5Y 3/2), homogeneous, vfg, SAND very well sorted, trace of pebbles (2%), rounded, (black/gray), wet 7.4		0	NA	1538 8/13/ 20/27	2.0/ 2.0	
	7.4–10	Stiff, dark gray (2.5Y 4/1), homogeneous, SILT, little sand (15%), high plasticity, trace pebbles (8mm), ~~soft~~; trace light pink "specks" (2) saturated	ML	0	NA	1544 8/9/ 6/5	2.0/ 2.0	

Project: PBOW | Hole Number: PB-BED-MW22

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW22

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Unc	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample ~~No.~~ Blows	Recovery (ft)	Remarks
	10–12	Very stiff, dark gray (2.5Y 4/1), homogeneous, SILT, trace to little sand (10%), ~~the~~ high plasticity, black spot (manganese?), trace light pink spots (3mm), wet, trace clay (5%)	ML	0	NA	5/6/ 17/22 1555	2.0/ 2.0	
	12–14	As above, 3% black spots, ~~trace~~ few sand pockets (2)		0	NA	7/8/ 9/12 1558	2.0/ 2.0	
	14–16	As above, 5% black spots,		0	NA	3/4/ 6/6 1603	2.0/ 2.0	
	16–18	As above. Trace rock pebbles (black, dark gray) 2-4 mm, rounded, NO sand, wet		0	NA	2/4/ 6/5 1613	2.0/ 2.0	
	18–19.5	Hard, ~~[illegible]~~, as above, rounded pebbles increase in number 15%, moist		0	NA	5/6 50 for 6" 1621	1.5/ 1.5	
	19.5–20	Spoon refusal @ 19.5 Ft						

Project: PBOW | Hole Number: PB-BED-MW22

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW22

Project: PBOW

Geologist: D. Kessler/S. McLeod

Sheet 4 of 6

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	Very Hard, dark gray, LIMESTONE	NA	NA	NA	NA	NA	Began cutting with 8" rotary bit at 19.5 Ft Recirculated w/ water
	21							*Distinct H_2S odor VRAE: CO - 0 ppm LEL - 0 % H_2S - 0 ppm O_2 - 20.9%
	22	Soft zone 22 to 22.3 Ft (22 – 22.3)						
	23							Drilled to 24.5' w/ 8" OD roller bit. 6" ID/6 5/8" OD casing installed to 24.5'
	24					Began Coring 9/18/01		
						HRCS	Run 1	Depth - 24.5-31
	25	gray, hard, massive limestone, no bedding, no weathering						Run - 6.5' Rec - 4' Start time: 10:20 End " - 10:45
	26				BOX 1 24.5-28.5	26.5		PID - NA MSA - 20.7 - O_2 0 - H_2S 0 - CO 0 - LEL
	27					27.5		
	28					28.5		
	29							
	30							

Project: PBOW

Hole Number: PB-BED-MW22

HTRW DRILLING LOG (continuation sheet)

Hole No.: ~~PB-BED-MW~~ [illegible]

Project: PBOW | Geologist: S.M. [illegible] | Sheet 5 of 6 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30							
	31	gray, hard, massive ls. no bedding, no weathering			BOX 3 31-34	31.4	Run 2	Run 5' Rec - 5' End time: 11:27 depth - 31-36'
	32					32.2 32.3		MSA - 0 - H_2S 0 - LEL 0 - CO 20.7 - O_2
	33					33.3		
	34				BOX 3 34-~~3~~	34.5		
	35					35.5		
	36	very hard gray, mass. dol. no weathering, no bedding			Box # 4	35.8	Run 3	Run - 4' Rec - 3' Run 36-40
	37					37.0		
	38					~~[illegible]~~ 38		
	39				Box # 5	39		
	40					40		pull pump 11:46

Project: PBOW | Hole Number: PB-BED-MW22

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW22

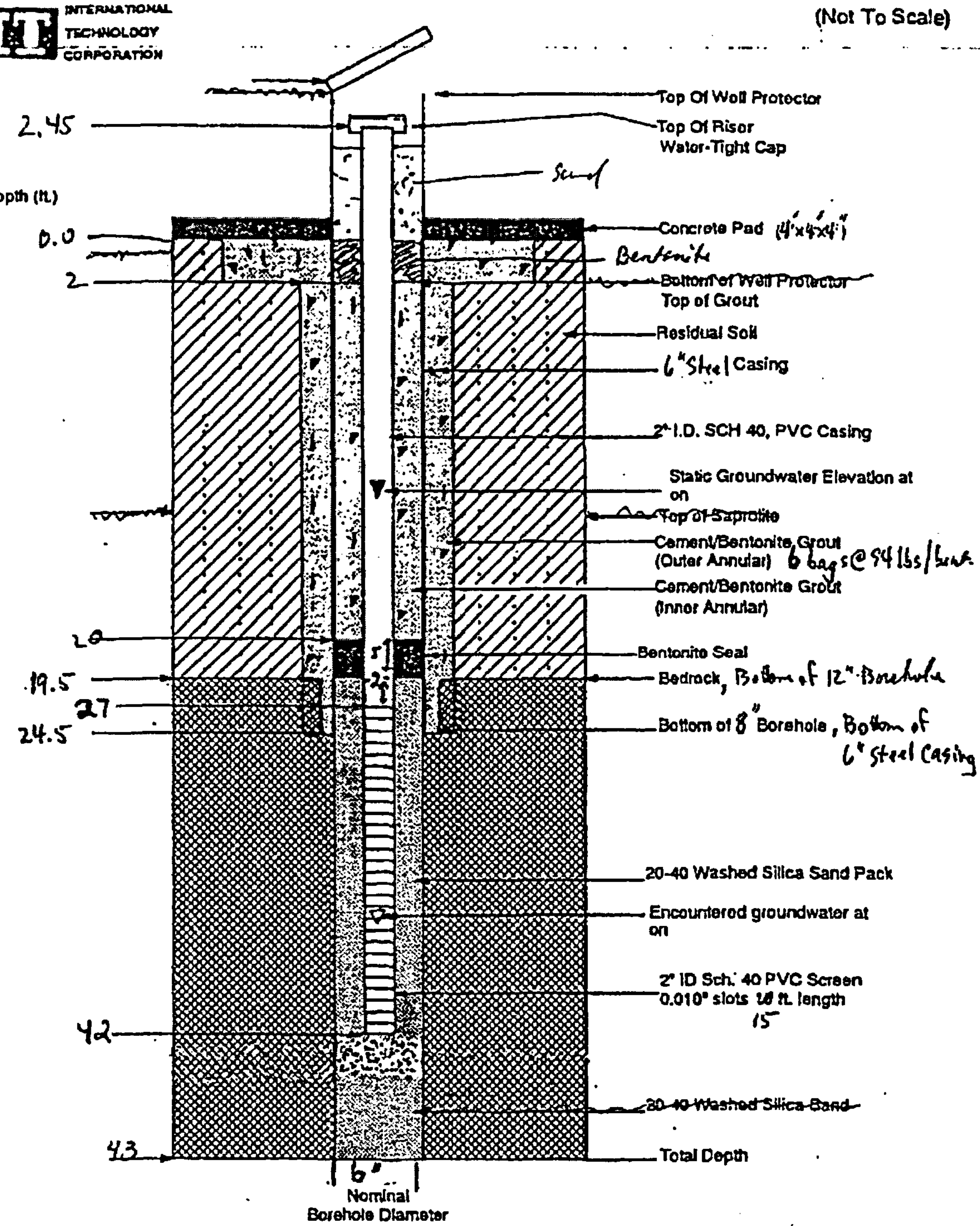
Project: PBDW | Geologist: [illegible] | Sheet 6 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/ASA	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	40	gray, massive, hard, limestone, w/no bedding, no weathering, no. odor, visible			Box 5		Run 4	Depth - 40.43' Run - 3' Rec - 3'
	41				Box 6	40.7		End time 13:25 MSA 20.7% O_2 0-CO 0-H_2S 0-LEL
	42					41.8		SET WELL MW 22
	43	Total Depth 43 Ft				42.3 / 43.0		
	44							
	45							
	46							
	47							
	48							
	49							
	50							

Project: PBDW | Hole Number: PB-BED-MW22

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Notes:

Well No.: PB-BED-MW22

Date Installed: 9-10-01

Elevation Top of Casing: 629.67 Ft.

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

DWMWA23DWC.DRW/3-28-80

HTRW DRILLING LOG

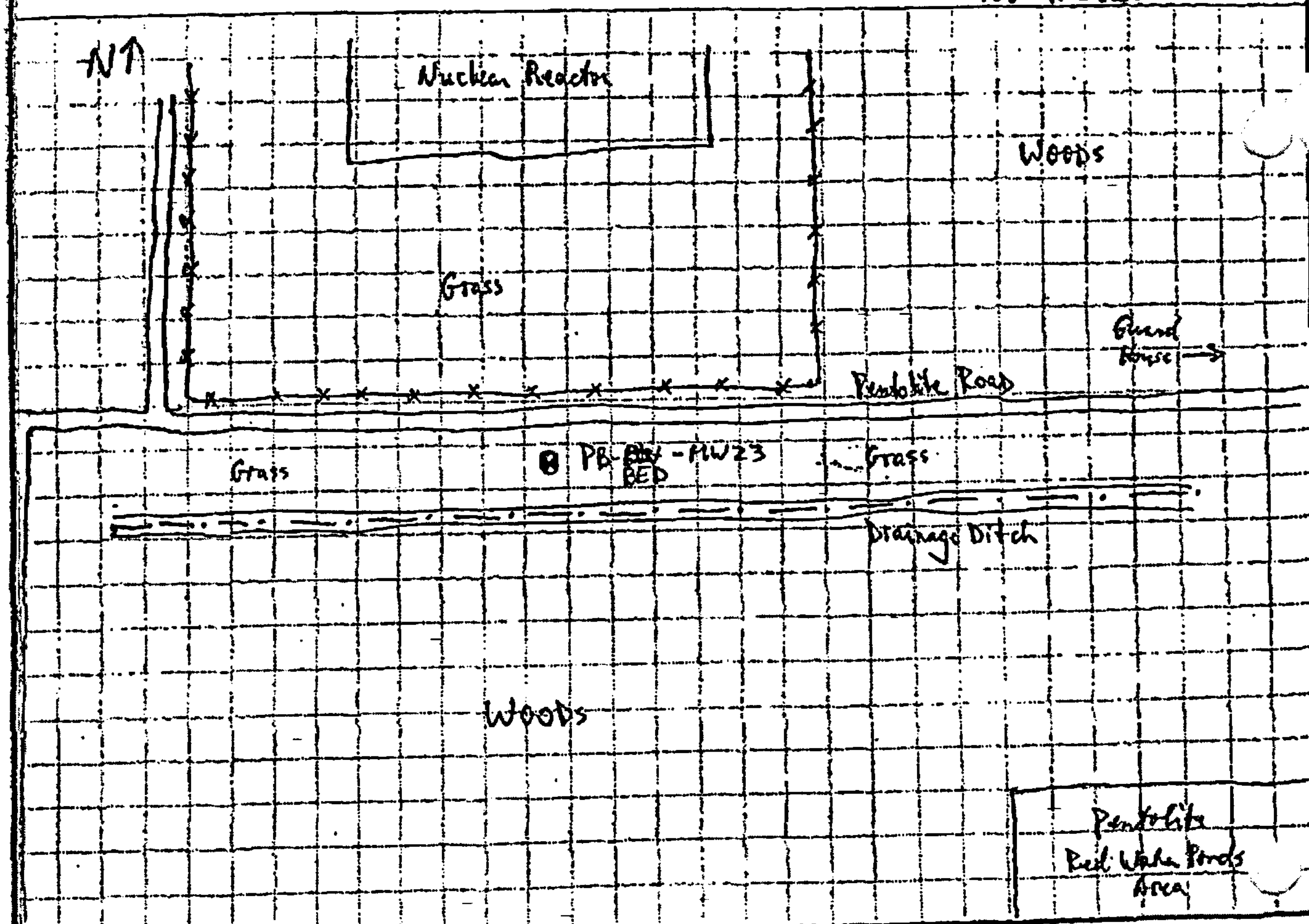
DISTRICT: Nashville, TN		HOLE NUMBER: PB-BED-MW23
1. COMPANY NAME: IT Corporation	2. DRILL SUBCONTRACTOR: Boart Longyear	SHEET 1 OF 9 SHEETS
3. PROJECT: PBOW	4. LOCATION: NASA Plum Brook Station, Sandusky, OH	
5. NAME OF DRILLER: Paul Dickinson \ ~~[illegible]~~ Schnalfeldt	6. MANUFACTURER'S DESIGNATION OF DRILL: BK81 \ Cantera C2-250	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID/8" OD HSA with 1.4" ID Stain-less Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6⅝" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD. borehole 6" OD. Installed 2" PVC monitoring well.	8. HOLE LOCATION: See Sketch	
	9. SURFACE ELEVATION: 631.11 Ft	
	10. DATE STARTED: 8/25/01	11. DATE COMPLETED: 9/~~[illegible]~~06/01
12. OVERBURDEN THICKNESS: ~~[illegible]~~ 26.3 Ft	15. DEPTH GROUNDWATER ENCOUNTERED: 7.1 Ft (overburden)	
13. DEPTH DRILLED INTO ROCK: 47.7 Ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: ~~[illegible]~~ 58.8 Ft 9/08/01 1430	
14. TOTAL DEPTH OF HOLE: 74 Ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): NA	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES		
	NA	NA			

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	%

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kesel / [signature]

LOCATION SKETCH/COMMENTS — SCALE: Not to Scale



PROJECT: PBOW — HOLE NO. PB-BED-MW23

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW23

Project: PBOW | Geologist: D. Kyssler | Sheet 2 of 9

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
		Grass						
		Fill: Soft, very dark grayish brown (2.5Y 3/2), sandy SILT with organics, moist 0.3			NA	2/4	1.5/	Began drilling 8/25/01 1230
		Fill: Loose, (10YR 4/6) dark yellowish brown, homogeneous, vfg, silty SAND, silt (40%), dry 1.2				6/7	2.0	
	1	color change 1.0-1.2 ft; (2.5Y 3/3) dark olive brown	SM	0				Backg
	2	Fill: (Loose, (10YR 5/6) yellowish brown, homogeneous 2.0, vfg. SAND, trace silt (5%), very well sorted, dry)	SP					
		Fill: Stiff, (10YR 4/6) dark yellowish brown, mottled (tan, black), sandy SILT, low plasticity, dry 2.8	SP ML		NA	5/5	1.4/	
	3	Fill: Loose, (2.5Y 4/4) olive brown, mottled, whitish brown) 30%, vfg, SAND, trace silt, moist 3.4	SP	0		7/8	2.0	
						1235		
	4	Stiff, (10YR 5/2) grayish brown, mottled (brown), silty CLAY, little sand (10%), high plasticity, moist	CL		NA	4/5	2.0/	
	5	Sand content begins increasing at 5 ft		0		8/9	2.0	
		Sand layer 5.8-6.0; very fine grain (10YR 3/6) dark yellowish brown 5.8						
		6.0	SP			1238		
	6	Medium stiff (10YR 5/2) grayish brown, mottled brown, high plasticity, silty CLAY with sand, moist.	CH		NA	4/4	1.9/	
	7	Loose, (2.5Y 3/3) dark olive brown, homogeneous vfg, SAND, trace silt (10%), very well sorted, wet	SP	0		6/6	2.0	Encountered ∇ overburden groundwater at 7.1 ft
						1242		
	8	8.3			NA	2/3		
	9	Medium stiff, (2.5Y 4/1) dark gray, homogeneous, high plasticity, clayey SILT little sand (20%), vfg sand, black manganese spots (2), wet	MH	0		2/2	2.0/ 2.0	
	10					1245		

Project: PBOW | Hole Number: PB-BED-MW23

HTRW DRILLING LOG (continuation sheet) Hole Number: PB-BED-MW23

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 9 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Code	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	10	Soft, (2.5Y 4/1) dark gray, homogeneous, high plasticity, clayey SILT, trace sand<5%, black manganese spots(2), pink spots (<5%), wet (5-8mm) to (3mm)	mh	0	NA	2/2/2/5 1249	2.0/2.0	
	12	As above		NM	NA	1/3/4/5 1251	2.0/2.0	
	14	As above	mh	NM	NA	1/3/4/3 1253	2.0/2.0	
	16	As above		NM	NA	1/2/4/5 1303	2.0/2.0	
	18	As above		NM	NA	1/2/3/4 1307	2.0/2.0	
	20							

Project: PBOW | Hole Number: PB-BED-MW23

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW23

Project: PBOW | Geologist: D. Kessler | Sheet 4 of 9 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	20–22	Soft, (2.5 y 4/1) dark gray, homogeneous, high plasticity, clayey SILT, trace sand (10%). black manganese spots, light pink spots (3mm) (5-8mm), trace pebbles (5mm), rounded	mh	NM	NA	1/1/ 2/4 1314	2.0/ 2.0	
	22–24	As above, stiff, pebbles and granules increase w/depth	mh	NM	NA	3/5/ 7/9 1318	2.0/ 2.0	
	24–26	As above, hard, pebbles and granules 30-40%,		NM	NA	5/7/ 27/32 1336	2.0/ 2.0	Bent spoon. Limestone pebbles in shoe 28x60mmx12 mm and 22x22x22 mm
	26–26.3	As above, pebbles/granules 45%		NM	NA	50 for 3" 1354	0.3/ 0.3	Bottom of 12" OD Borehole
	26.3–30	Spoon Refusal @ 26.3 Ft. LIMESTONE, dark gray, soft, fossiliferous (brachs), very slight weathering	NA	NA	NA	NA	NA	Began cutting rock w/ 8" OD tricone roller bit. Flushed with recirculated water. Competent drilling. VRAE: CO= 0ppm LEL= 0% H_2S = 0ppm O_2 = 21.2% Occasional faint H_2S odor. 8" OD Borehole to 30 Ft 6" Casing Set at 30 Ft

Project: PBOW | Hole Number: PB-BED-MW23

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW23

Project: PBOW | Geologist: R. Poderis | Sheet 5 of 9 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30	limestone, grey, hard, massive, not weathered natural hydrocarbon odor			Box #1 1			Coring starts at 30' 9/6/01. Depth 30-33 start time 730 end 915 LEL ø 9/6/01 CO ø H_2S ø O_2 20.7 PID 0.0 Run 3' Recovery 1' Run #1
	31					Photo RSP 1 #1		
	32							
	33	Same			Run 2 33 Box #2	33.5		33 Depth 33-38 start time 930 end 945 Run 5' recovery 5' Run #2
	34	Ø nat. hydrocarbon odor. nat frac. visible throughout						
	35					35.5 36		
	36				Photo 2			945 LEL 0 CO 0 H_2S 0 O_2 20.7 PID 1.6
	37							
	38				Run 3 38 Box 3 + Box 4 (Box 3 = 38-41.5')	38.5		38 Depth 38-43 start 945 end 1000 Run 5' recovery 5' Run #3
	39							
	40							

Project: PBOW | Hole Number: PB-BED-MW23

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW-23

Project:

Geologist: R. Podenis

Sheet 6 of 9 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Use	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	40							
	41				Box 4 38.5 – 44.5			
	42							
	43				43 Run #4			depth 43-48 run 5' recovery 4' start 1000 end 1110
	44	Massive gray limestone oil seeps from core				44.2 44.5		
	45							
	46					46		
	47				Box 5 44.5 – 48	47.2 47.8		
	48	same			48 Run 5			48-53 run 5' recov 5' end 11[30]
	49				Box 6 48 – 51	48.8 48.9 50.4 50.6 51.8		
	50							

Project: PBOW

Hole Number: PB-BED-MW23

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW23

Project: PBOW

Geologist: R Podens

Sheet 7 of 9 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. fracture	Recovery (ft)	Remarks
	50	grey massive hard limestone nat. no odor + oil seeps						LEL 0 CO 0 H_2S 0 O_2 20.6 PID 0.0
	51				51	52		
	52	↓			Box 7 (51-54')			Box 7 51-54
	53					53 Run 6 ↓		depth 53-58 run 5' recovery 5' end time 1200 start time 1130
	54				54	54		
	55				Box 8 (54-57.5')	55		Box 8 54-57.5
	56					56		
	57				57.5	57.5		
	58					58 Run 7		depth 58-63 run 5' recov 5' start 1200 end 1210
	59				Box 9 (57.5-60')			
	60							

Project: PBOW

Hole Number: BED MW-23

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED MW23

Project: PBOW | Geologist: R Widen's | Sheet 8 of 9 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Log	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	60	Massive grey limestone, hard			Box 10 (60-63')	61.5		Box 9 57.5-60.0; Box 10 60-63
	61							
	62							
	63	Same			63 Run 8 63			depth 63-68 run 5' recov 5' end 1230
	64				Box 11 (63-66.5')	64.7		Box 6026
	65							Box 11 63-66.5
	66				66.5			
	67				Box 12 (66.5-69.5')	67		
	68							depth 68-73 run 5' Box 12 66.5-69.5 recov. 5' end 1
	69				69.5			
	70							

Project: PBOW | Hole Number: MW-23

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB BEDMW-23

Project: PBOW

Geologist: RPacker

Sheet 9 of 9 Sheets

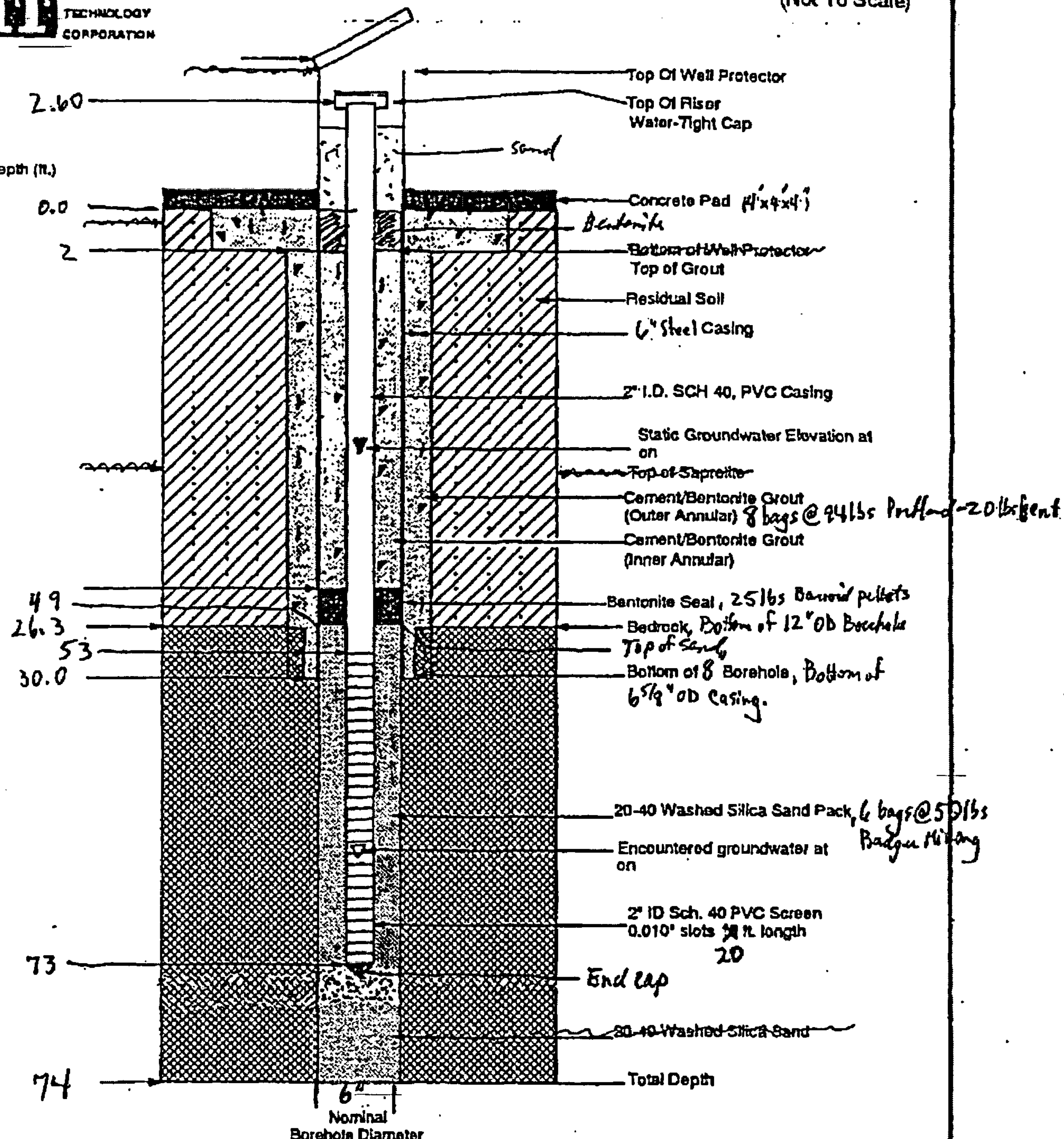
Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	70	grey limestone, hard, massive hc odor			Box 13 (69.5-74')	70.5		
	72							Box 13 BEDICK 69.5-74
	73				74			Stop and pump test 11AM
	74	Total Depth = 74 Ft						slowly recharging 230 PM
	75							
	76							
	77							
	78							
	79							
	80							

Project:

Hole Number:

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Notes:

Well No.: PB-BED-MW23
Date Installed: 9/8/01
Elevation Top of Casing: 633.71 ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

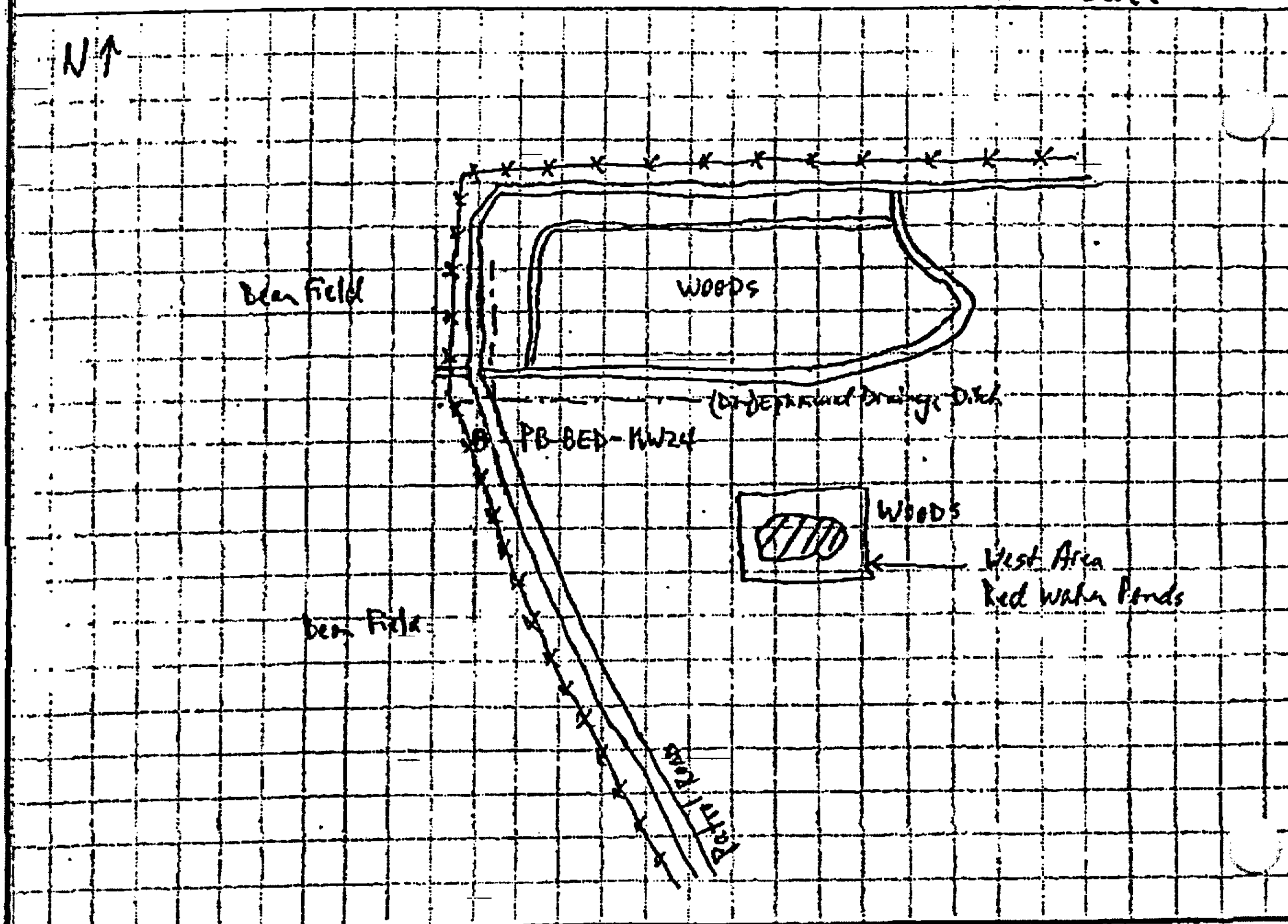
BWMWA2.DWG.DRW/3-28-93

HTRW DRILLING LOG

DISTRICT: Nashville, TN		HOLE NUMBER: PB-BED-MW2
1. COMPANY NAME: IT Corporation	2. DRILL SUBCONTRACTOR: Boart Longyear	SHEET 1 OF 6 SHEETS
3. PROJECT: PBOW	4. LOCATION: NASA Plum Brook Station, Sandusky	
5. NAME OF DRILLER: Paul Dickinson	6. MANUFACTURER'S DESIGNATION OF DRILL: BK81	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.	8. HOLE LOCATION: See Sketch	
	9. SURFACE ELEVATION: 644.20 Ft	
	10. DATE STARTED: 8/26/01	11. DATE COMPLETED: 9/13/01
12. OVERBURDEN THICKNESS: 17.3 Ft	15. DEPTH GROUNDWATER ENCOUNTERED: 7.0 Ft (overburden), Bedrock unknown	
13. DEPTH DRILLED INTO ROCK: 24.2 Ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 26.5 Ft @ 1 Hr	
14. TOTAL DEPTH OF HOLE: 41.5 Ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): NA	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES			
	NA	NA	6			
20. SAMPLES FOR CHEMICAL ANALYSIS	**VOC**	**METALS**	**OTHER (SPECIFY)**	**OTHER (SPECIFY)**	**OTHER (SPECIFY)**	**21. TOTAL CORE RECOVERY**
	NA	NA	NA	NA	NA	100 %
22. DISPOSITION OF HOLE	**BACKFILLED**	**MONITORING WELL**	**OTHER (SPECIFY)**	**23. SIGNATURE OF INSPECTOR**		
	NA	X	NA	David Kesich		

LOCATION SKETCH/COMMENTS SCALE: Not To Scale



PROJECT: PBOW HOLE NO. PB-BED-MW24

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW24

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Lith	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
		Grass						
	0–0.8	Stiff, (10YR 3/2) very dark grayish br. homogeneous, sandy SILT (30% sand), organics (roots), dry. 0.8	ml	0.0	NA	3/4/ 6/10	1.5/ 2.0	Began drilling 8/26/01 0910
	1	Stiff, (10YR 5/6) yellowish brown, mottled (30%-gray), vfg, sandy SILT, very well sorted, organics (roots), dry	ml			0910		Breathing Air/ Background: PID = 0.0 ppm
	2–3	As above (no organics)		0-0	NA	6/8/ 10/7	1.4/ 2.0	VRAE: CO = 0 ppm, LEL - 0%, H_2O - 0 ppm, O_2 - 20.7%
	4	4.2				0915		
	4.2–6	Stiff, (2.5Y 5/2) gray brown, mottled (50%-dark yellow), ~~vfg~~, high plasticity, SILT, little clay (10%), trace vfg sand, even-parallel bedding planes, moist		0.0	NA	8/7/ 8/9	2.0/ 2.0	
	6					0920		
	6–8	As above		0.0	NA	4/3/ 7/10	2.0/ 2.0	∇ Encountered (overburden) groundwater at 7.0 ft
	8					0925		
	8–10	Very stiff, (2.5Y 5/3) light olive br, mottled (20%), SILT, trace clay, even-parallel bedding, wet		0.0	NA	5/7/ 12/14	2.0/ 2.0	Mottling along vertical fractures
	10					0927		

Project: PBOW | Hole Number: PB-BED-MW24

HTRW DRILLING LOG (Continuation Sheet)

Hole Number: PB-BED-MW24

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 6 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
	10	Stiff, (2.5Y 4/1) dark gray, homogeneous, high plasticity, SILT, trace clay, rounded pebbles (light gray), 1-5mm, wet		NM	NA	3/5/ 6/8 0930	2.0/ 2.0	Brown staining along horizontal fractures
	12	As above, granules/pebbles increase 10%, 1-10 mm		NM	NA	3/4/ 5/5 0935	2.0/ 2.0	
	14	As above		NM	NA	3/5/ 6/8 0938	2.0/ 2.0	
	16	As above, granules/pebbles 30%		NM	NA	7/8 50 for 3" 0945	1.3/ 1.3	Limestone pebble in shoe, 20x15mm. Bottom of 12" OD Borehole 17.3
	17.3	Spoon refusal @ 17.3 ft. LIMESTONE, gray, calcareous, fossils, fine grained, very fine grain pyrite <5%, trace calcite, clear quartz "spot" 5x5 mm.	NA	NM	NA	NA	NA	Began cutting with 8" rotary bit. Faint H_2S odor. Breathing Air: PID=0.0 ppm, CO=0 ppm, LEL=0%, H_2S=0 ppm, O_2=20.8%
	20							

Project: PBOW | Hole Number: PB-BED-MW24

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW24

Project: PBOW

Geologist: D. Kessler

Sheet 4 of 6 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Code	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	LIMESTONE, gray, average to hard (to 21.5)	NA	NM	NA	NA	NA	Hardness based on cutting speed. Bottom of 8" OD Borehole at 21.5 ft
	21.5	LIMESTONE, gray, hard, massive bedding, slightly weathered, calcareous, slightly fractured, fossils (brachs). Limey shale layer 21.9-22.0 ft, soft.			Limey shale { 21.9 - 22.0	Fracs		Bottom of 6 5/8" OD Steel casing at 21.5'. Began coring 9/13/01 0925. C-1 (21.5-26.5') End: 0933 Start: 0925. 5 Ft Run / 5 Ft Recovery, 0
	23.4	Large coral 23.4-23.9' (0.3' x 0.3') white			Box # 1			
	24.6			0.4		24.6		Breathing Air/Bckgrd: PID = 0.0 ppm. VRAE: CO = 0 ppm, LEL = 0%, H_2S = 0 ppm, O_2 = 20.9%
	25.2				25.2 / Box # 2	25.6		
	26.5					26.5		C-2 (26.5-31.5') End: 0955 Start: 0944
	27.5	As above, massive, slightly fractured.						HC odor drilling. 5 Ft Run / 5 Ft Recovery, 0 Loss. HC odor
	28.5				28.5 / Box # 3	29.3		
	30							

Project: PBOW Hole Number: PB-BED-MW24

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW24

Project: PBOW | Geologist: D. Kessler | Sheet 5 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Log	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30				Box #3	Trace -30.8 -31.5		C-2 (con't)
	31–32	LIMESTONE, gray, hard to very hard, massive bedding, slight to fresh weathering, calcareous, slightly fractured, fossils (brachs/ stromatolites) corals			32.4			31.5 C-3 (31.5-36.7') End: - start: -
	33–34			32.7	Box #4			5 Ft Run 5.2 Ft Recovery 0.2 Ft GAIN
	35–36				36.3	-35.0 white shale filled		HC staining on core Strong odor Can hear water gurgling after pumping gas
	37	As above			Box #5	-37.7 -38.2 -39.[illegible] -39.6		36.7 C-4 (36.7-41.5') End: 1052 start: 1039 5 Ft Run 4.8 Ft Recovery 0.2 Ft Loss
	38–40							

Project: PBOW | Hole Number: PB-BED-MW24

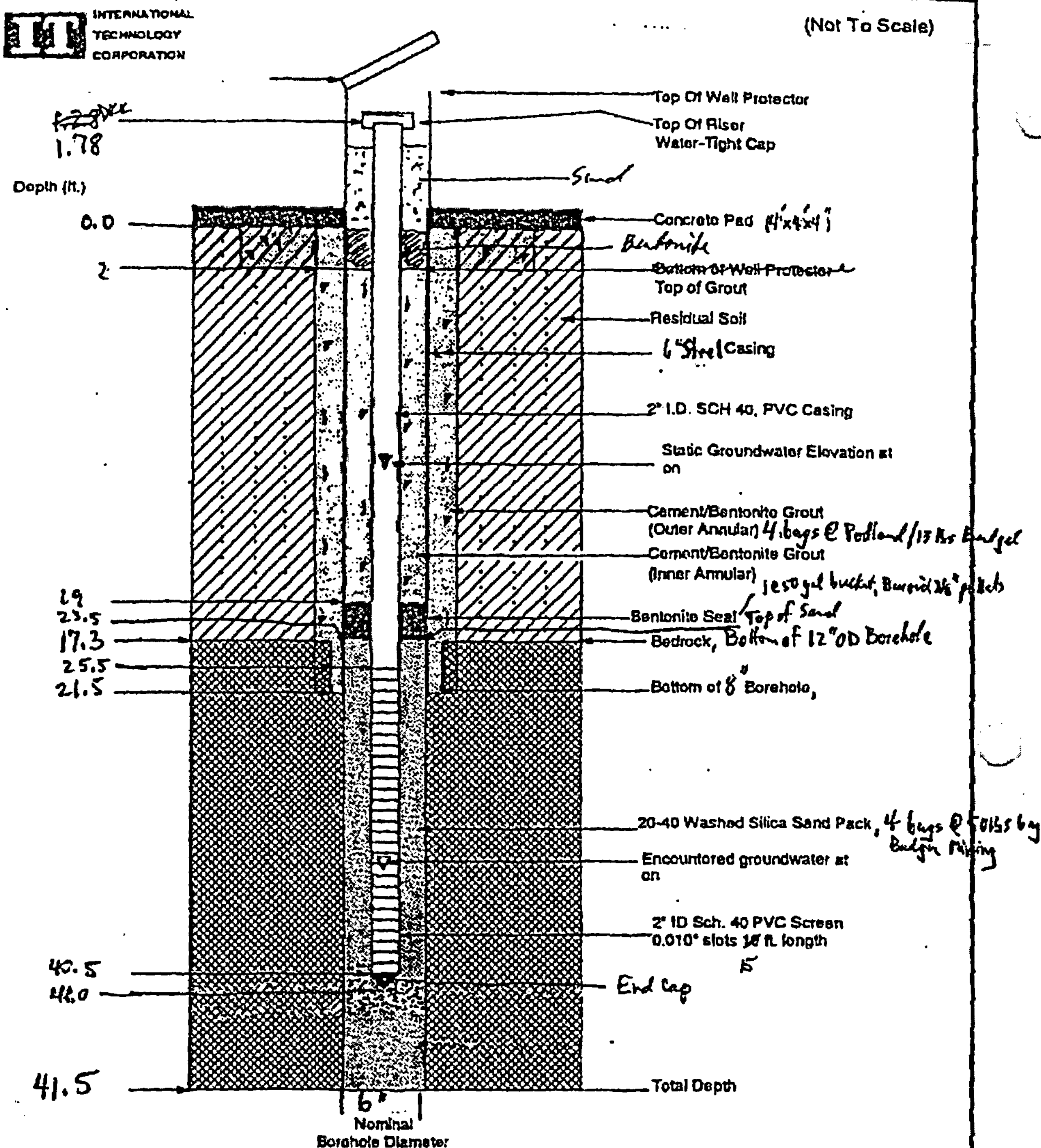
HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW24

Project: PBOW | Geologist: D. Kessler | Sheet 6 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Log	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	40	LIMESTONE, gray, very hard, massive, fresh weathering, calcareous. fossils (brachs/stromalites corals)		20.1	40.6 Box 6			C-4 (con't) HC staining on core.
	41.5	Total Depth- 41.5 Ft				41.5		pumped borehole 1807 >3.5' 1110 1111 >4.5' Can hear water gurgling during recharge.
	42							
	43							
	44							
	45							
	46							
	47							
	48							
	49							
	50							

Project: PBOW | Hole Number: PB-BED-MW24



Notes:

Well No.: PB-BED-MW24
Date Installed: 9/13/01
Elevation Top of Casing: 645.98 Ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

SWMWA23DWC.DRW

HTRW DRILLING LOG

DISTRICT: Nashville, TN		HOLE NUMBER: PB-BED-MW25
1. COMPANY NAME: IT Corporation	2. DRILL SUBCONTRACTOR: Boart Longyear	SHEET 1 OF 5 SHEETS
3. PROJECT: PBOW	4. LOCATION: NASA Plum Brook Station, Sandusky, OH	
5. NAME OF DRILLER: Paul Dickinson	6. MANUFACTURER'S DESIGNATION OF DRILL: BK81	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4¼" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6⅝" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.	8. HOLE LOCATION: See Sketch	
	9. SURFACE ELEVATION: 681.99 Ft	
	10. DATE STARTED: 8/26/01	11. DATE COMPLETED: 9/11/01
12. OVERBURDEN THICKNESS: 8.8 Ft	15. DEPTH GROUNDWATER ENCOUNTERED: 4.8 Ft (overburden)	
13. DEPTH DRILLED INTO ROCK: 29.7 Ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: NA	
14. TOTAL DEPTH OF HOLE: 38.5 Ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): NA	

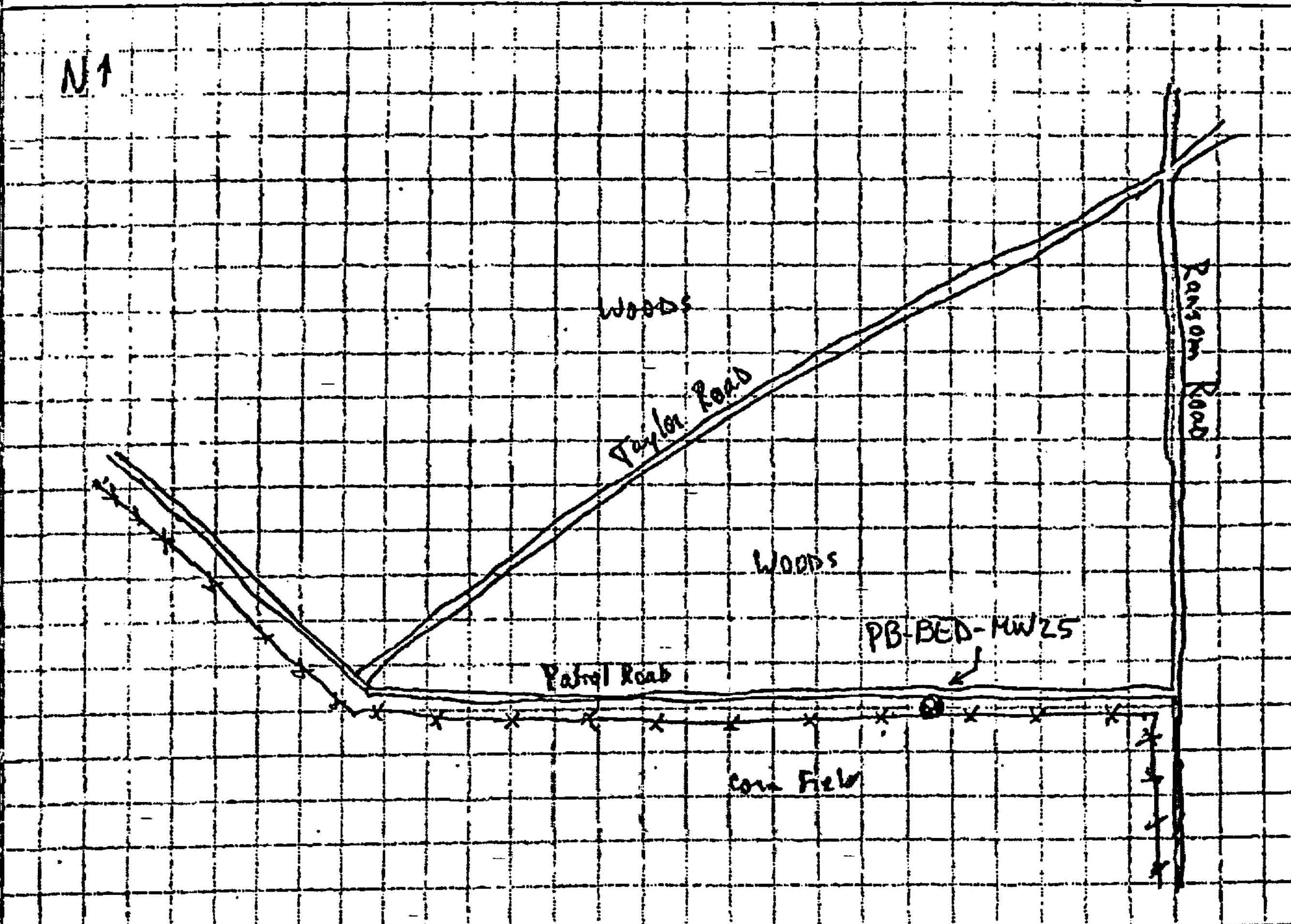
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	100 %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kessler

LOCATION SKETCH/COMMENTS

SCALE: Not To Scale



PROJECT: PBOW

HOLE NO.: PB-BED-MW25

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW25

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 5 Sheets

Elev (ft)	Depth (ft)	Description of Materials	USCS Letter	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
		Grass/Weeds						
	Fill	Very loose (10YR 3/3) dark brown, mottled (light brown), silty SAND, organics (roots), dry) 0.6	SM		NA	1/1	1.4/	Began Drilling 8/26/01 1455
	1	Fill: (Loose, (10YR 6/6) brownish yellow, homogeneous, vfg. SAND, very well sorted, dry)	SP	0		4/7	2.0	With 4¼ ID/8" OD augers. Borehole reamed w/ 12" OD augers to 10 ft. Background (Breathing) PID = 0.0 ppm
	2	As above	SP	0	NA	1455 2/6/ 4/4	1.8/ 2.0	VRAE: CO = 0 ppm, LEL = 0%, H_2O = 0.0 ppm, O_2 = 20.9% (strong breeze)
	3							
	4	As above, color changing to (10YR 4/4) dark yellowish brown. Silt content in SAND 5% at 4.8 Ft	SP	0	NA	1458 3/5/ 6/4	2.0/ 2.0	∇ Encountered overburden groundwater at 4.8 Ft
	5							
	6	As above 4-6 Ft interval 7.3		0	NA	1459 2/11 1/12	2.0/ 2.0	
	7	Medium dense, (10YR 3/2) very dark grayish brown, homogeneous, vfg. SAND, some silt (25%), very well sorted, wet, black shale fragments 7.7-8.0 Ft (10%), trace gravel, very coarse to ~~[illegible]~~ 8.8	SM					
	8			0	NA	1504 5/7/ 8/50 for 6"	1.6/ 2.0	
	9	~~[illegible]~~ Weathered SHALE, dark brown, very soft, thinly laminated		0				Black coal (ash?) laminations (?) 9.1 and 9.4 ft
	10	Spoon refusal @ 10.0 Ft				1512		

Project: PBOW | Hole Number: PB-BED-MW25

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW25

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 5 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	10	SHALE, highly weathered, dark brown, thinnly laminated, soft	NA	0	NA	NA	NA	Bottom of 12 ¼ OD augers at 10 Ft. Description from cuttings
	11							
	12							
	13							
	14	Dry						Shale from bottom of augers - dry. 4¼" ID/8" OD auger bit
	15	8" OD Auger Refusal @ 15 Ft. SHALE, soft, dark brown,						
	16							
	17							
	18							More competent w/ depth.
	19							Detected solid competent shale cuttings at ~20 Ft
	20							

Project: PBOW | Hole Number: PB-BED-MW25

HTRW DRILLING LOG	(continuation sheet)	Hole Number: PB-BED-MW25
Project: PBOW.	Geologist: D. Kessler	Sheet 4 of 5 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	SHALE, dark brown, average hardness	NA	NM	NA	NA	NA	
	21							Began drilling 8/27/01 to 23.3 ft w/ 6" rotary bit
		21.5 LIMESTONE						
	22							
	23							Drilled to 23.3 ft w/ 6" rotary bit. 6" steel casing at 23.3 ft
	23.3	LIMESTONE, light gray, hard, massive bedding, slightly weathered; calcareous, moderately fractured,				Fracs		Began drilling 9/4/01
	24				Box # 1	24.2, 24.3, 24.7 (iron stained edges)		C-1 (23.3-28.3')
	25	25.1 - 25.7 ft; many corals white nodules		0.0				End: — Start: —
	26				rounded	26, 26.3, 26.35 highly weathered		5 ft Run / 5 ft Recovery, 0 Loss
	27	27.3 - 28.3; pitted 30%, highly weathered zone 27.3 - 27.6'			27.3	27.3 Rounded edges		
	28				Box # 2	28, 28.5		
	28.3	LIMESTONE, as above						C-2 (28.3 - 33.5')
	29					29.3 (rounded edges)		End: 1020 Start: 1000
	30							

Project: PBOW Hole Number: PB-BED-MW25

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW25

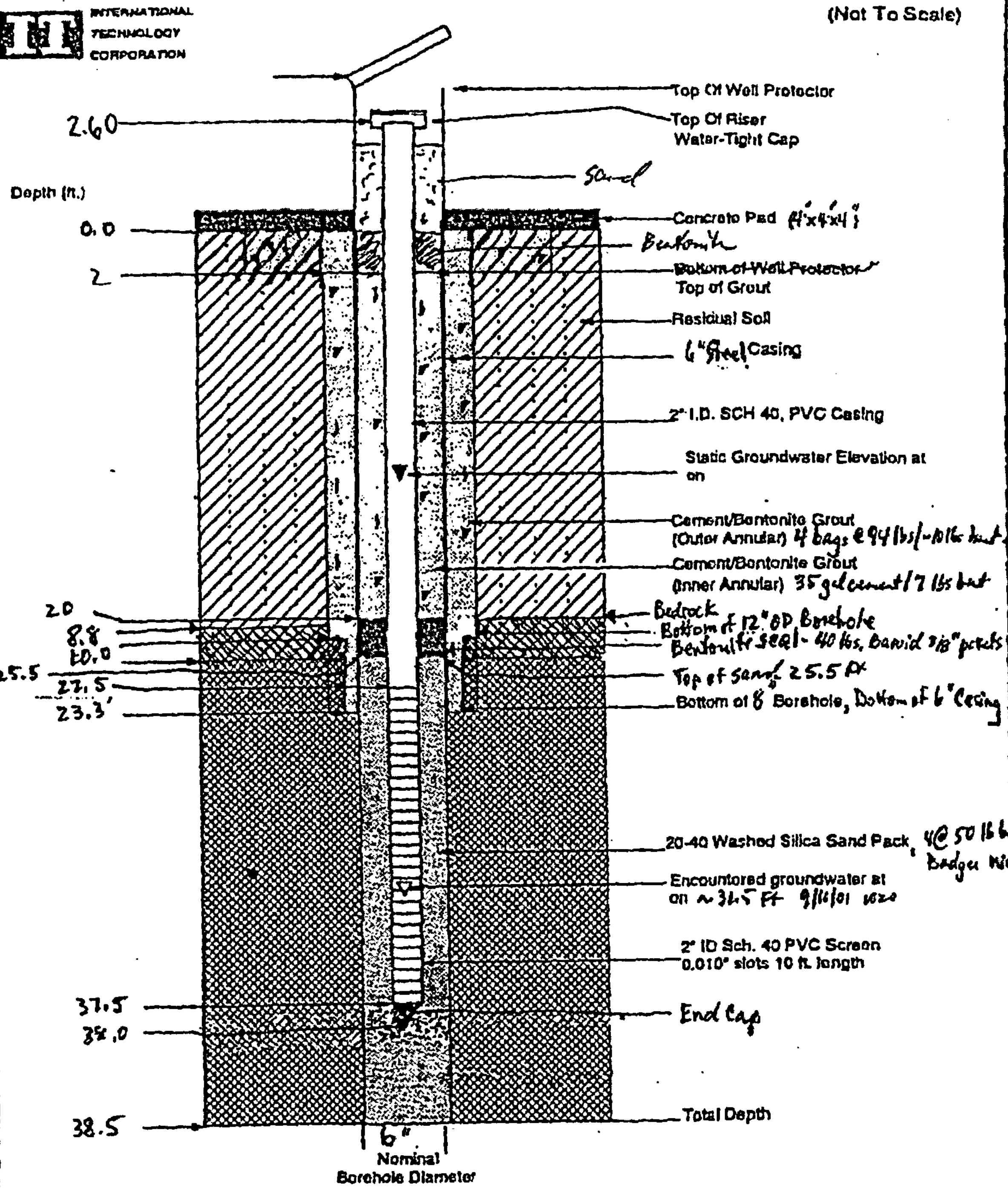
Project: PBOW | Geologist: D. Kessler | Sheet 5 of 5 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	30	LIMESTONE, light gray, hard, massive bedding, slightly weathered, calcareous, moderately fractured, fossils 31.5			31	30.2 (rough)		5 Ft Run; 5.2 Ft Recovery; 0.2 Ft Gain
	31.5	SHALE, very dark gray, soft, thinly bedded, highly weathered 31.5-31.9; decomposed pyrite vugs(?) 32.4-32.5; clay/silt filled 33		NM	Box #3	31.5; 32.4		Breathing Air/Bck ground: PID = 0.0 ppm; CO = 0 ppm; LEL = 0%; H_2S = 0 ppm; O_2 = 21.0%
	33	Limey SHALE, very dark gray, moderately hard, thinly bedded, moderately weathered, fossils (brachs/corals), calcareous, moderately to highly fractured; pryite vug 35.6 Ft 37			34.8; Box # 4	32.8; 34.9; 35.3; 35.7; 36.X; 36.3; 36.4 (clay filled, rounded edges); 36.75		33.5: C-3 (33.5-38.5'); End: 1048; Start: 1035; HC odor; 5 Ft Run; 5 Ft Recovery; 0 Loss
	37	LIMESTONE, light gray, hard, massive, slightly weathered, fossils (brachs/corals), calcareous, moderate to slightly fractured.				37.5		
	38.5	Total Depth = 38.5 Ft						

Project: PBOW | Hole Number: PB-BED-MW25

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Notes:

Well No.: PB-BED-MW25

Date Installed: ~~9/11/01~~ 9/12/01

Elevation Top of Casing: 684.59 Ft.

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

BWUMWA23DWC.DRW

HTRW DRILLING LOG

DISTRICT	Nashville, TN
HOLE NUMBER	PB-BED-MW26
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
SHEET	1 OF 7 SHEETS
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID / 8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID / 12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID / 6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	674.61 Ft
10. DATE STARTED	8/27/01
11. DATE COMPLETED	9/10/01
12. OVERBURDEN THICKNESS	6.5 Ft
15. DEPTH GROUNDWATER ENCOUNTERED	Not encountered (overburden), Bedrock ~ ~~47.0~~ 47.0 Ft
13. DEPTH DRILLED INTO ROCK	52.0 Ft
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	NA
14. TOTAL DEPTH OF HOLE	58.5 Ft
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA

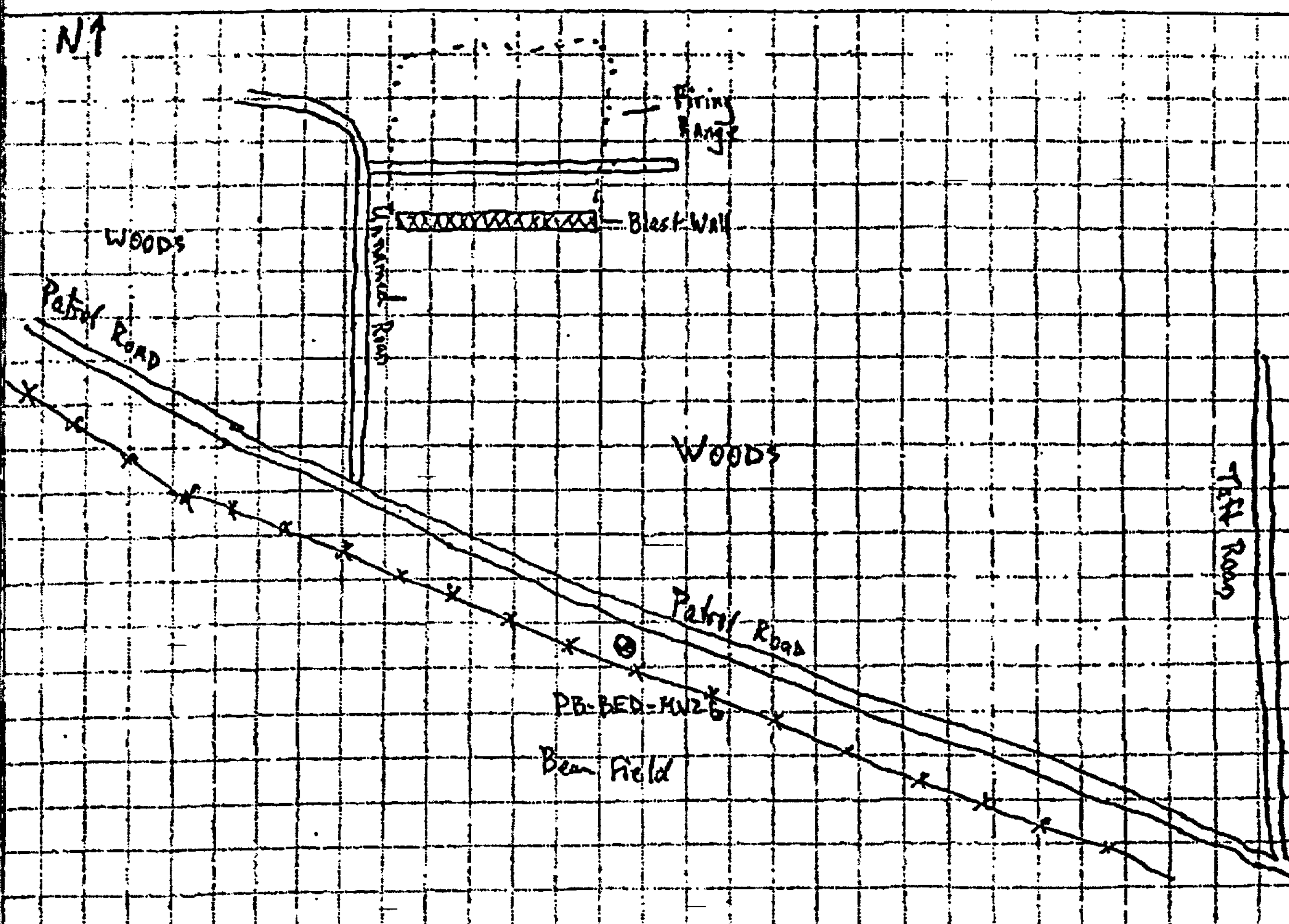
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	9

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	100 %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kosh

LOCATION SKETCH/COMMENTS

SCALE: Not to Scale



PROJECT PBOW

HOLE NO. PB-BED-MW26

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW26

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 7 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Class	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
		Grass/Weeds						
		Medium stiff, (10YR 2/1) black, homogeneous, medium plasticity, SILT, organics (roots), vfg sand (15%), moist 0.7		0.0	NA	3/4/ 5/7	1.3/ 2.0	Began drilling 8/27/01 1140
	1	Stiff, (10YR 4/6) dark yellowish brown, mottled (50%) (light brown/gray), clayey SILT, vfg sand (20%), dry shale fragments 5%	ML			1142		Breathing Air/Background PID: 0.0 ppm CO: 0 ppm LEL: 0% H_2S: 0 ppm O_2: 20.9%
	2	As above 2.8		0.0	NA	2/4/ 6/7	1.7/ 2.0	
	3	Medium dense, (10YR 5/3) brown, mottled (gray, dark brown)(10%), vfg, SAND, silt (20%), dry 3.8	SM			1146		
	4	Medium stiff, (10YR 5/6) yellowish br, mottled (5% gray), platy bedding, Silty CLAY, shale fragments, black oxidized specks (15%), moist medium plasticity.	CL	0.0	NA	2/2/ 5/7	1.4/ 2.0	
	5					1148		
	6	As above, moist 6.5		0.0	NA	5/7/ 12/48	2.0/ 2.0	Bedrock
	7	SHALE, very severe (decomposed) weathering, (2 GLEY 5PB 6/1) bluish gray, relic bedding, thinly bedded, soft, dry	NA			1154		Rock crumbles in hand
	8			NM	NA	NA	NA	Discontinued split-spoon sampling
	9							
	10							Bottom of 12" Borehole

Project: PBOW | Hole Number: PB-BED-MW26

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW26

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 7 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	10	SHALE, dark brown, thinnly bedded. severely (highly) weathered dry	NA	~~NM~~ NM	NA	NA	NA	Described from cuttings w/ 8" OD augers. Color change ~10 Ft
	11							
	12							
	13							
	14							
	15							
	16							
	17							▽ Water encountered ~17 Ft
	18							
	19							
	20							

Project: PBOW | Hole Number: PB-BED-MW26

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW26

Project: PBOW | Geologist: D. Kessler | Sheet 4 of 7 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	SHALE, dark brown	NA	NM	NA	NA	NA	
	21							Cuttings ~~became~~ became dry ~~[illegible]~~ at ~21 Ft
	22							
	23							Strange, sweet organic odor from cuttings. PID=0.0 ppm, Borehole 0.0 ppm
	24	SHALE, bluish gray, hard, micro-laminated, slightly broken, fresh weathering						Description from rock core knocked out of augers (24.3-24.5')
		8" OD Auger Refusal @ 24.5 Ft						
	25	SHALE, hard, competent						PID= 0.0 ppm, H_2S = 0.0 ppm (Still strange odor) Natural HC
	26							
	27							Drilled to 27.5 Ft w/8" rotary bit. Set 6 5/8" steel casing at 27.5 Ft.
	28	SHALE, very dark brown, moderately hard, thinly laminated, slight weathering, pyrite vug at 30.1 Ft, wavy limestone layers 28.2-28.3', 29.4-29.5', 29.7-29.75', ~~29~~ 30.3-30.4', 30.65-30.75',		0.0	Box # 1	Fracs 28.8, 29.1		Began coring 9/8/01 1700. C-1 (27.5-32.5)
	29				photo	29.8		Breathing Air: PID ~0.0 ppm, CO ~0 ppm, O_2 = 21.1%, LEL ~0%, H_2S ~ 0 ppm
	30							

Right margin: 20, 21, 27.5, 28, 29

Project: PBOW | Hole Number: PB-BED-MW26

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW26

Project: PBOW

Geologist: D. Kessler

Sheet 5 of 7 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Unit	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample "No" Fracs	Recovery (ft)	Remarks
	30	SHALE, very dark brown, moderately hard, thinnly laminated, slight weathering, Lm layers wavy, continuous 30.95-31', 32.35-32.45'			Box #1 30.8	30.1 (clay filled)		End: 1715 Start: 1702
	31				Box #2 photo 32.6	30.8 (clay filled) 31.4 (clay filled) 32.2		5 Ft Run 5.1 Ft Recovery 0.1 Ft Gain
	32.5 / 32.6							
	33	As above, unbroken, pyrite in vugs. wavy Lm layer at 32.5-32.6'			Box # 3 photo 36.4	36.4 Vertical Frac (Not water bearing)		C-2 (32.6-37.5') End: 1745 Start: 1735 HC odor while drilling 5 Ft Run 5 Ft Recovery 0 Loss
	37				Box #4	37.5		
	37.5 / 38	As above, unbroken (except few pieces of vertical frac			Box #4 photo 39.5	Vertical Fracture		C-3 (37.5-43.0') End: 1816 Start: 1804
	40							

Project: PBOW

Hole Number: PB-BED-MW26

HTRW DRILLING LOG	(continuation sheet)	Hole Number: PB-BED-MW26
Project: PBOW	Geologist: D. Kessler	Sheet 6 of 7 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS or Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No: Fracs	Recovery (ft)	Remarks
	40	SHALE, very dark brown.		NM	Box #5	40.2 ft vertical clay filled; 40.6; 40.7 (clay filled)		(C-3 cont') 5.5 Ft Run; 5.5 Ft Recovery; 0 Loss
	41.5	LIMESTONE, gray, hard, massive, slightly weathered, 1 vug, calcareous			photo	42.1 horizontal; 42.3 vertical		HC odor
	43.0	As above. 43.55-43.6 frac rounded edges; 44.0 – 45.6; pitted LM (30%) 5% vugs; 45.1-45.3 - Honeycombed; 46.3-47'; pitted, vugs		NM	43.0 Box #6 photo 46.4	Frac 43.1; 43.55-43.6; 45.3		Began drilling 9/10/01 0835; C-4 (43-48.4'); 5 Ft Run; 5.4 Ft Recovery; 0.4 Ft Gain
	47	SHALE, dark gray, soft, thinly laminated, highly weathered, intensely fractured (fell apart) (decomposed).			Box #7 photo	47; Fracs		▽ Possible Bedrock water at 47'
	48.4	As above						C-5 (48.4-53.4'); End 1103; start 1048
	49.5	Limy SHALE, highly weathered				pyrite		

Project: PBOW — Hole Number: PB-BED-MW26

HTRW DRILLING LOG

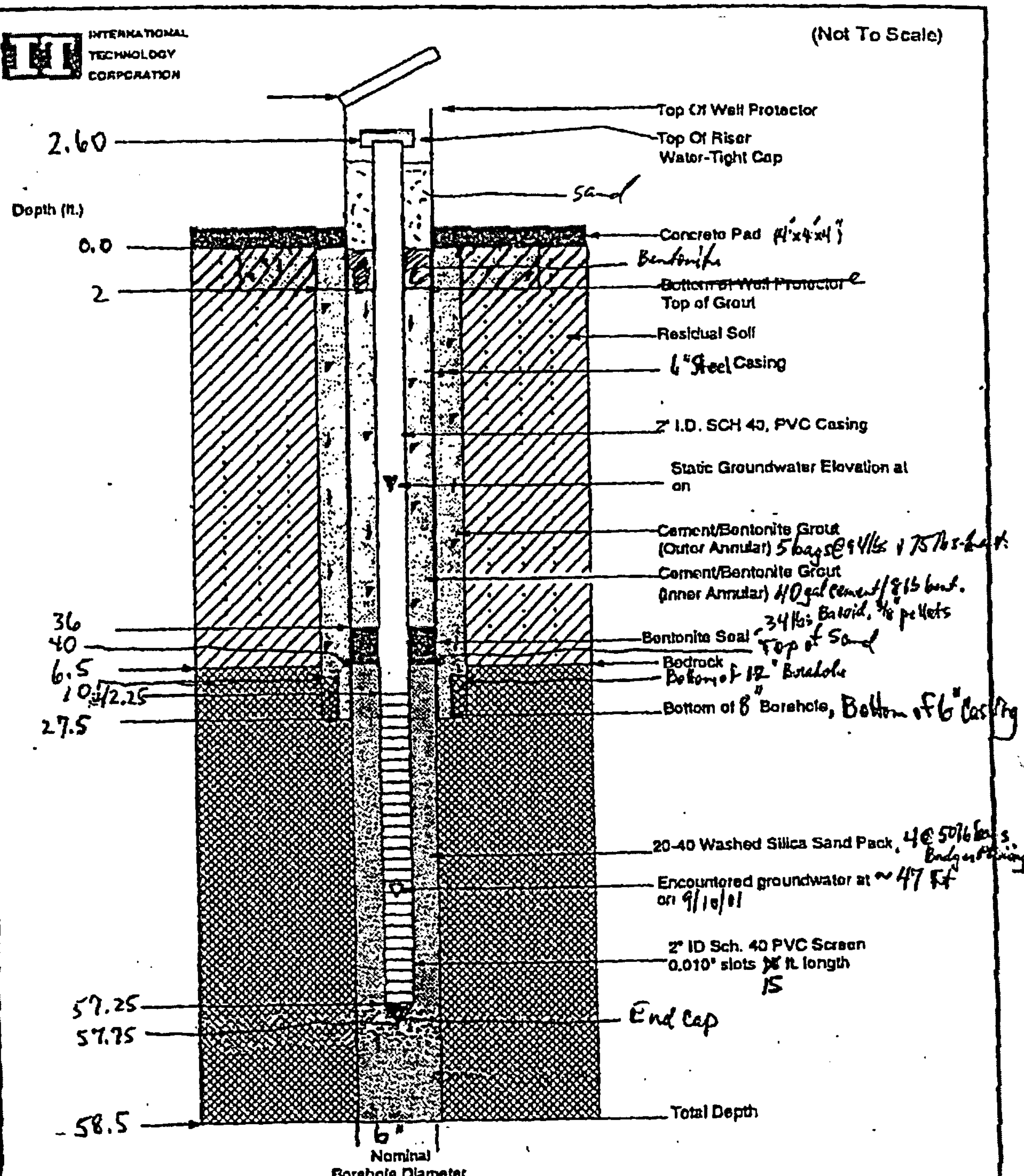
(continuation sheet)

Hole Number: PB-BED-MW26

Project: PBOW | Geologist: D. Kessler | Sheet 7 of 7 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	50	Limey SHALE, dark gray, moderately hard, thinnly bedded, moderately weathered. Fossils (brachs, corals), calcareous moderate to highly fractured (not yet broken)		NM	50.5 Box # 8 photo	Fracs 51 Pyrite		HC odor 5 Ft Run 5.2 Ft Recovery 0.2 Ft Gain Pumped well Recharge: 1225 @ 3 min = 0.1' 1228 @ 3 min = 0.1' 1231 @ 3 min = 0.1' 1245 @ 11 min = 0.1' 1256 @ 11 min = 0.8' 1312 @ 16 min = 0.1'
	53	~~According to box~~ ~~Limey SHALE~~ ~~Shaley~~ LIMESTONE, dark gray, soft to moderately hard, thinly bedded ~~MASSIVE~~, moderately weathered fossils, (brachs, corals, crinoids), 2 pyrite filled vugs, unbroken		NM	53.6 Box # 9 photo	54.3 (rounded edges)		C-6 (53.6 – 58.5) End: 1408 Start: 1355 4.9 Ft Run 4.85 Ft Recovery 0.05 Ft Loss
	58.5	Total Depth – 58.5 Ft						

Project: PBOW | Hole Number: PB-BED-MW26



Notes:

Well No.: PB-BED-MW26
Date Installed: 9/10/01
Elevation Top of Casing: 677.21 ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

DWM/WA23DWC.DRW/8/5-25

HTRW DRILLING LOG

DISTRICT	Nashville, TN
HOLE NUMBER	PB-BED-MW27
SHEET 1 OF 12 SHEETS	
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson / Todd Schmalfeldt
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81 / Cantera CZ-250
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID / 8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID / 12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID / 6⅝" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. ~~Installed 2" PVC monitoring well box~~
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	~~627.14 ft~~ 625.24 Ft
10. DATE STARTED	8/23/01
11. DATE COMPLETED	9/8/01
12. OVERBURDEN THICKNESS	18.8 Ft
15. DEPTH GROUNDWATER ENCOUNTERED	4.2 Ft (Overburden)
13. DEPTH DRILLED INTO ROCK	~~105 feet~~ 86.2 Ft
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	104.9 ~~102.15~~ / 1hr
14. TOTAL DEPTH OF HOLE	105 feet
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA

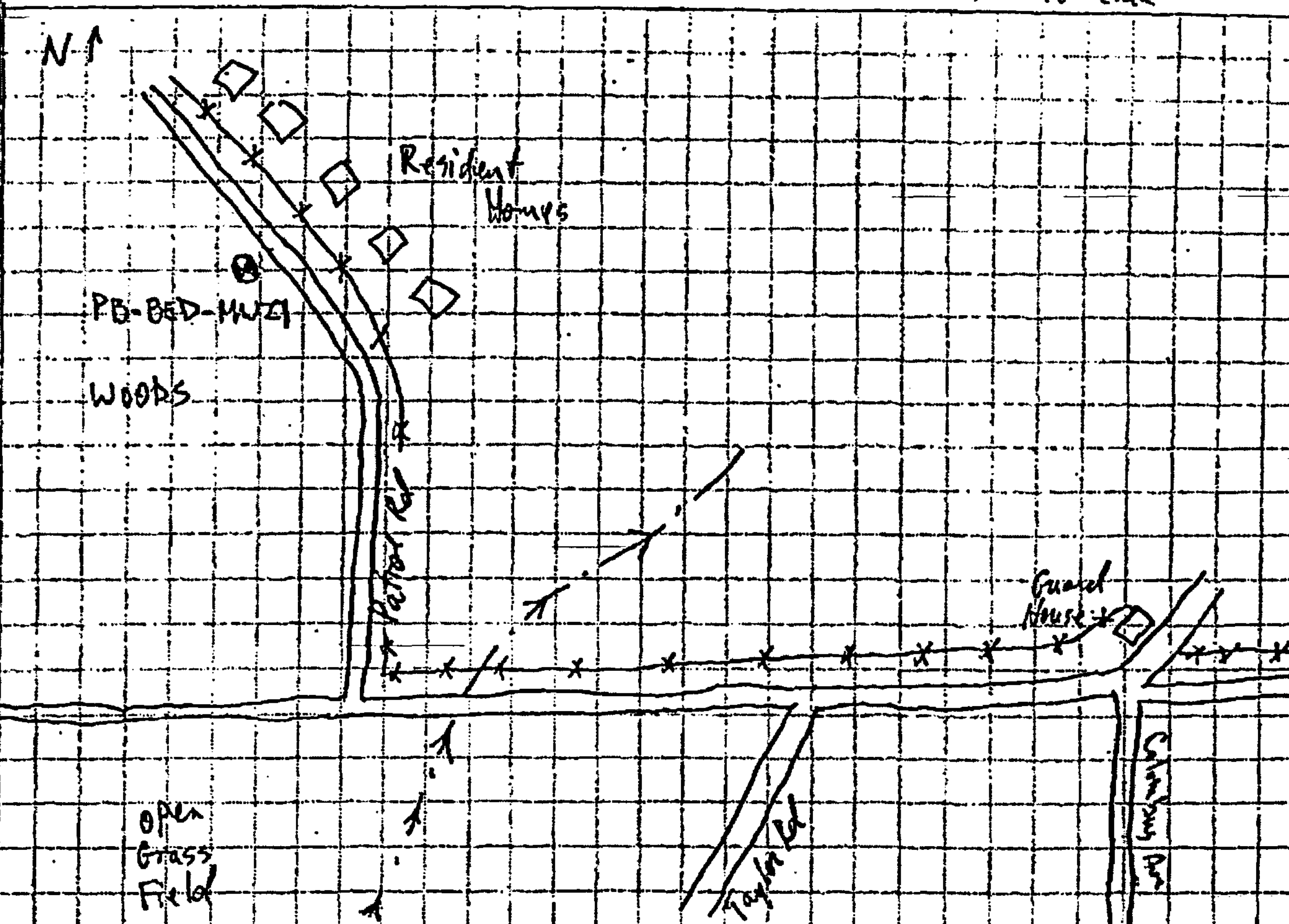
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	24

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	76 feet

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kessler / [signature]

LOCATION SKETCH/COMMENTS

SCALE: Not to Scale



PROJECT	PBOW
HOLE NO.	PB-BED-MW27

HTRW DRILLING LOG

(continuation sheet)

Hole No.: PB-~~BW~~ BED-MW21

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 12 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS/Uses	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	~~Analytical Sample No.~~ Blows	Recovery (ft)	Remarks
	0	Grass SAND, very dark grayish brown, organics 0.3			NA			Began drilling 8/23/01 1630
	1	Fill: (SAND, trace silt (5%), medium dense, yellowish brown (10YR 5/8), homogeneous till 0.9 ft. At 0.9 ft, becomes mottled with (10YR 7/6) yellow, vfg, very well sorted, dry)	SP	0		3/5/ 8/10	1.5/ 2.0	Breathing Air: CO = 0ppm LEL = 0% H_2S = 0ppm O_2 = 20.9%
	2	Fill: (SAND, some clay (35%), clay content increases w/ depth, dry)		0		3/4/ 7/10	2.0/ 2.0	Water pocket at 2.5 ft
	4	4 SILT, some sand (30%), grayish brown (10YR 5/2), mottled (5%) with strong brown (7.5YR 5/6), high plasticity, sand vfg, wet sand content decreases w/ depth	ML	0		2/2/ 4/7	1.8/ 2.0	Encountered groundwater ∇ 4.2 ft
	6	Medium stiff, SILT, same color as above, sand content 5%, wet		0		1650 2/3/ 4/6	2.0/ 2.0	
	8	Stiff, SILT, dark gray (10YR 4/1), homogeneous, high plasticity, wet		0		2/3/ 6/6	2.0/ 2.0	
	10							

Project: PBOW | Hole Number: PB-BED-MW21

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW27

Project: PBOW | Geologist: D. Keisler | Sheet 3 of 12 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	10	Stiff, dark gray (10YR 4/1), homogeneous, SILT, high plasticity, wet		0	NA	3/5/8/8	2.0/2.0	
	12					1705		
	13	As above	mh	0		2/3/6/8	2.0/2.0	
	14					1708		
	15	As above		0		2/4/6/9	2.0/2.0	
	16					1711		
	17	As above		0			2.0/2.0	
	18	As above, with rounded pebbles (3 mm), broken shale fragments				1730 2/50 for 3"	0.8/0.8	Drilled to 18.5 ft w/ 12" OD HSA
	19	Spoon Refusal @ 18.8 Ft Auger Refusal @ 18.8 Ft SHALE bedrock, very dark gray / black						Began drilling 8/24/01 0540 w/ 8" OD Tricone Roller Bit for casing.
	20	20 Ft						

Project: PBOW | Hole Number: PB-BED-MW27

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW27

Project: PBOW

Geologist: D. Kessler

Sheet 4 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	LIMESTONE, weathered, fractured, soft, gray	NA	NM	NA	NA	NA	Drilling w/ 8" OD Tricone Roller bit to set 6" steel casing.
	21	21' LIMESTONE, hard, gray						Observing only chips of bedrock
		21.5' Shaley LIMESTONE, greenish gray, soft, thinly bedded						Background / Breathing Air: PID: 0.0 ppm
	22	22.5' LIMESTONE, gray, hard, competent						VRAE: CO = 0 ppm LEL = 0% H_2S = 0ppm O_2 = 20.9 ppm
	23–26							Drilled to 26.5' with 8" Tricone Roller Bit. 6" OD casing set at 26.5 ft.
	26.5	26.5	NA		NA	NA	NA	
	27–28							Began casing 9/7/01
	29	massive limestone, gray, hard, no weathering, no bedding			BOX 1 29-33			Start time - 10:30 End " - 11:00
	30							

30

Project: PBOW

Hole Number: PB-BED-MW27

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED MW27

Project: PBOW | Geologist: McLeod | Sheet 5 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30							Run - 5' Rec - 5' Depth 29-34' PID - 0.0 MSA - 0 - comb 20.3 - O_2 0 - H_2S 0 - CO
	31							
	32							
	33					33		
	34	Massive limestone gray, no weathering, no bedding, hard nat. hydrocarbs. odor			BOX 2 33-37	34, 35, 35.5	Run 2	Run 5' Rec - 5' Depth 34-39 End time: 11:15 PID - 0.0 MSA - 0 - comb 20.4 - O_2 0 - H_2S 0 - CO
	35							
	36							
	37					37.0		
	38					38		
	39	gray massive limestone w/fracture ~ 42'-43'			BOX 3 37-41	40	Run 3	Run 5' Rec. 5' Depth - 39-44
	40							

Project: PBOW | Hole Number: PB-BED MW27

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-mw27

Project: PBOW

Geologist: S McLeod

Sheet 6 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
						40.5		End time - 11:30
	41					41.5		
	42				BOX 4 41-44'			fracture
	43					43.0		
	44	light-gray, massive limestone, hydrocarbon odor no bedding, no weathering				44	run 4	Run - 5' Rec - 5' Depth - 44-49 End time - 11:45
	45					45		stop - pump to check for water - none detected
	46				BOX 5 44-48'	46		
	47					47		PID - 0.0 MSA - 0 - comb 0 H_2S 0 - CO 20.7 O_2
	48					48		
	49					49	run 5	PID - 0.0 MSA - 0 - comb 20.6 O_2 0 - CO 0 - H_2S
	50					50		

Project: PBOW

Hole Number: PB-BED-mw27

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW27

Project: PBOW | Geologist: S. Maguire | Sheet 7 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/ Uscs	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
		same as above			BOX 6 48-51			Run 5' Rec. 5 End time 13:18 Depth - 49-54
	51					51.5		Start 13:00 PID 0.0
	52				BOX 7 51-54			
	53					53.5		
	54	gray, massive limestone no weath., no bedding hard				54	Run 6	mech Run - 5 Rec - 5 End: 13:30 Depth - 54-59
	55				Box 8 54-57.5	56.5		mech PID - 0.0 MSA - 0 comb 20.8 O_2 0 - H_2S 0 CO
	56							
	57					57.5		
	58				BOX 9 57.5-59	58.6		mech
	59	gray massive limestone no weath, no bedding hard					Run 7	Run 5' Rec 5' Depth 59-64 End time 13:48
	60							

Project: PBOW | Hole Number: PB-BED-MW27

HTRW DRILLING LOG (continuation sheet)

Hole Number: PB-BED-MW29

Project: PBOW

Geologist: S McGel

Sheet 8 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
					BOX 10 59-63	/60.5		PID - 0.0 MSA - 0 - comb 20.8 - O_2 0 - H_2S 0 - CO
	61					/61		
	62					/62		
	63							
	64	gray massive limestone w/ hydrocarbon odor hard			BOX 11 63-65		Run 8	Run 5' Rec - 5' Depth - 64.69 End time 14:00
	65							PID - 0.0 MSA 0 comb 20.8 O_2 0 - H_2S 0 - CO
	66				BOX 12 65-69	/66		
	67					/67		Stop and pump for water - the water came up very little ~0.4 go to 75
	68							
	69						Run 9	Start - 15:30 End - 16:00 Run 6' Rec - 5.5
	70							

Project: PBOW

Hole Number: PB-BED-MW29

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW23

Project: PBOW

Geologist: S.M. Gird

Sheet 9 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/ Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	71	gray, massive, hard nats hc. odor no bedding, no weathering			70.5 BOX 13 69-72.5			PID-0.0 MSA-0 Comb 0-H_2S 0-CO 20.8-O_2 Depth 69-75'
	72				72.5			
	73				BOX 14 72.5-74.5			
	74				74.5			
	75	massive, gray, hard limestone, no weathering, no bedding			BOX 15 74.5-78.5		run 10	depth-75-80 end time-9:46 run-5' rec. 5'
	77				77			
	79				78.5 BOX 16 78.5-81.5			
	80				80			

Project: PBOW Hole Number: PB-BED-MW23

HTRW DRILLING LOG

(continuation sheet)

Hole Number: PB-BED-MW2

Project: PBOW

Geologist: S. McLeod

Sheet 10 of 12 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Info	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	80	gray, massive, hard limestone, no bed, no weath.					Run 11	Depth - 80-85, run - 5', rec - 5', End time: 10:00
	81					81.5		PID - 0.0
	82				BOX 17 81.5-85.5	82, 82.3		MSA 0 comb, 0 - H_2S, 20.7 - O_2, 0 - CO
	83					83.5		
	84							
	85	Same as above w/ minor fracture breaks				85, 85.5	Run 12	depth - 85-90, Run 5', Rec - 5', End time: 10:20
	86				BOX 18 85.5-88			
	87					87		Photo of all three runs left to right (Run 10-12)
	88				BOX 19 88-90	88.5		
	89					89.5		Drillers to put together pump (10:25)
	90							

Project: PBOW

Hole Number: PB-BED-MW2

HTRW DRILLING LOG	(continuation sheet)	Hole Number: PB-BED-MW 27
Project: PBOW	Geologist: E.M. [illegible]	Sheet 11 of 12 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	VISCAV Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	90–95	gray, massive, limestone hard, no weath. no bedding			BOX20 90-92 ; BOX21 92-95	91.5 ; 92.5 ; 94.5	Run 5	Depth 90-95 Run - 5' Rec - 5' End time 13:10 Start: 12:50 PID - 0.0 MSA 0% LEL 0-CO 20.4 - O_2 0 - H_2S
	95–100	Same as above w/ hydrocarbon visibility and odor.			BOX22 95-98 ; BOX23 98-101.5	98 ; 100	Run 14	Depth - 95-100 Run - 5' Rec. 5' End time: 13:25 1-3' section 1-2' section PID - 0.0 MSA - 0% LEL 0-CO 20.3 O_2 0 - H_2S

Project: PBOW

Hole Number: PB-BED-MW 27

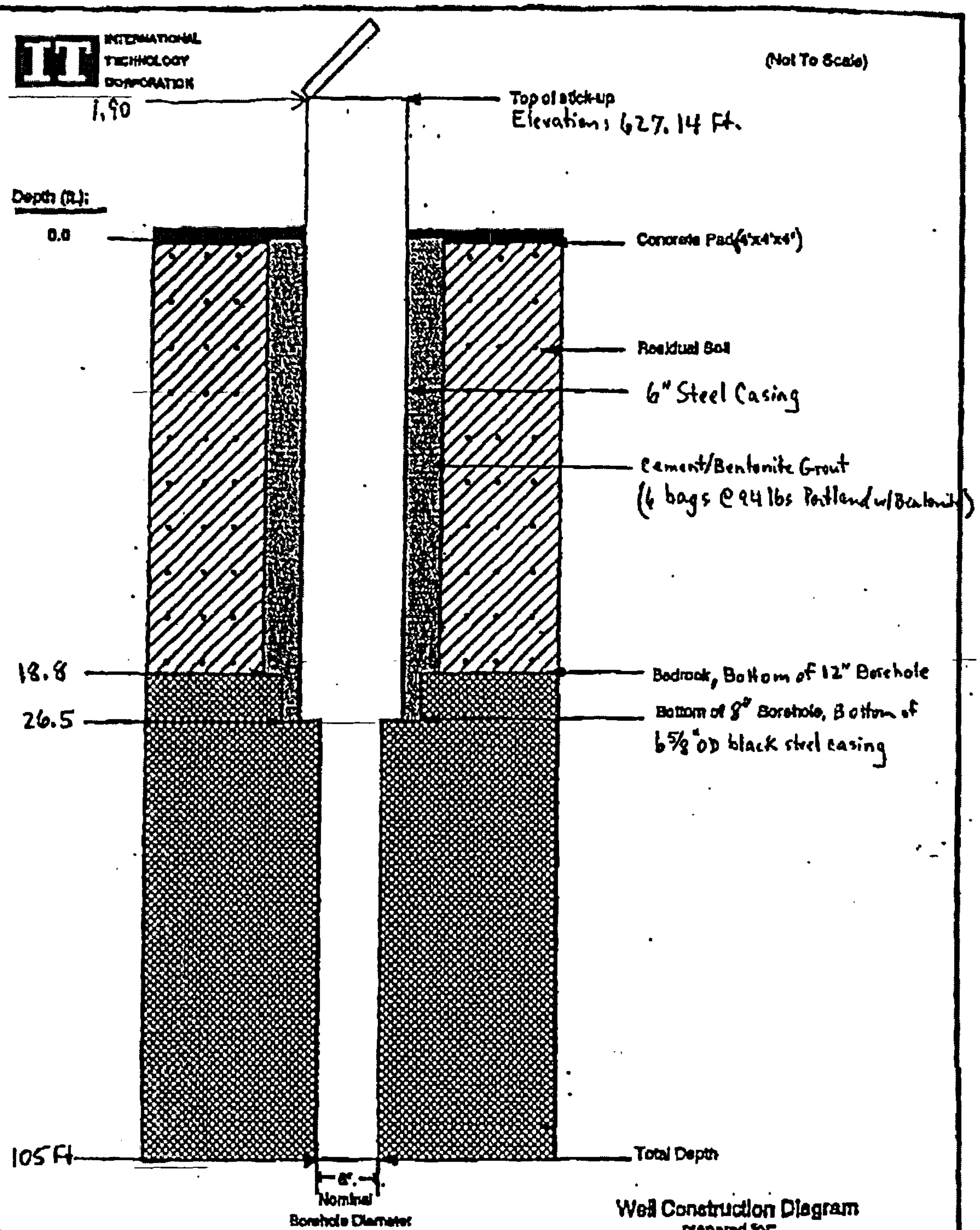
HTRW DRILLING LOG	(continuation sheet)	Hole Number: PB-BED-MW27
Project: PBOW	Geologist: S. McLeod	Sheet 12 of 12 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	100	gray, mas. limestone w/no bedding, no weathering					Run 15	Depth - 100-105 Run - 5' Rec. 5'
	101							End: 13:45
						101.5		PID - 0.0 MSA - 0 - LEL
	102					102		0 - CO 20.3 - O_2 0 - H_2S
	103				Box 24 101.5-105			2' piece section 3' piece section
	104							
	105	Total Depth - 105 Ft						
	106							
	107							
	108							
	109							
	110							

Project: PBOW Hole Number: PB-BED-MW27

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Well Construction Diagram

prepared for:

Plum Brook Ordnance Works
Sandusky, Ohio

Notes:

Well No.: PB-BED-MW27

Date Installed: 9/8/01

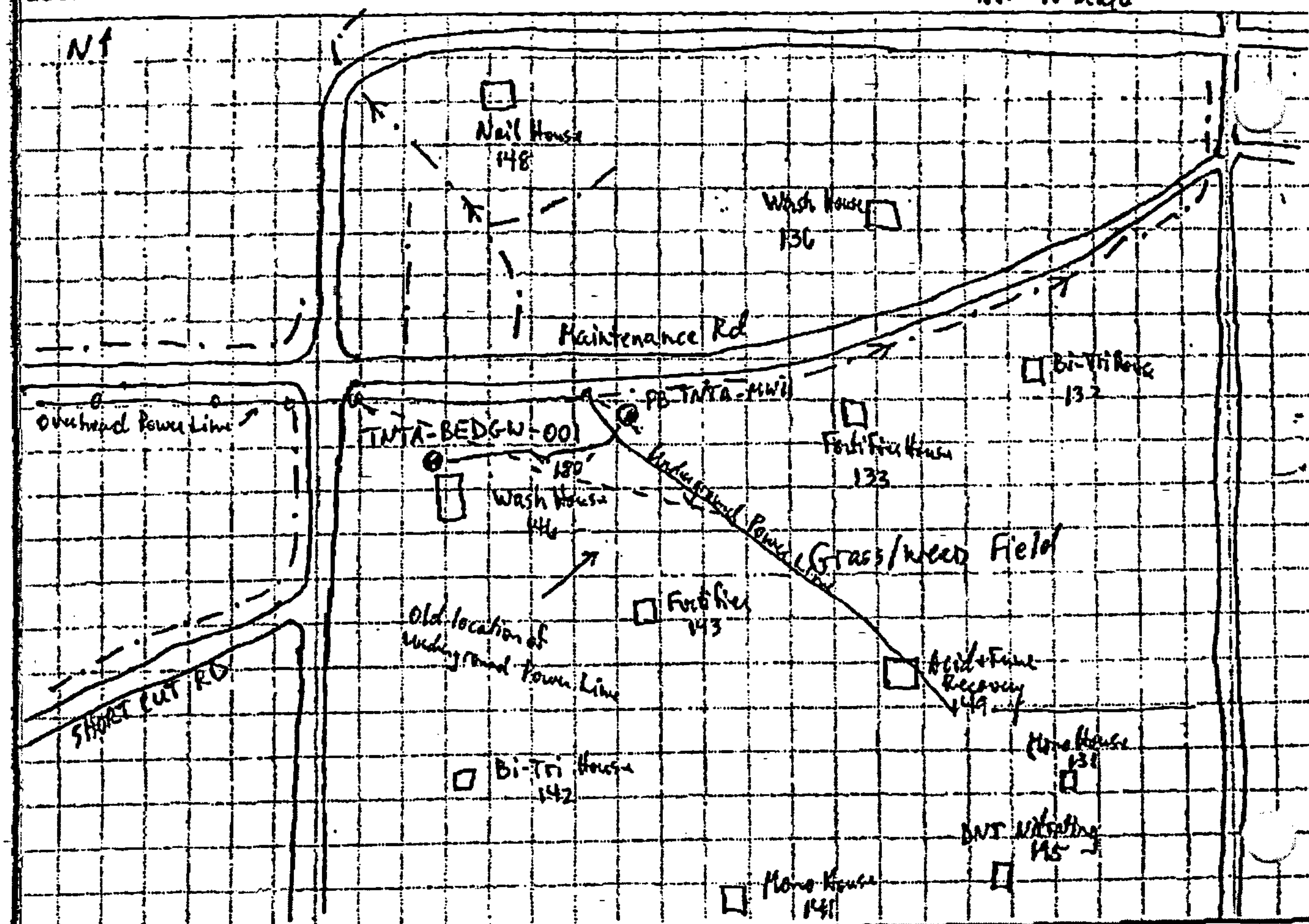
Elevation Top of Casing: 627.14 Ft (outer edge of protective casing with lid open)

HTRW DRILLING LOG

Field	Entry
DISTRICT	Nashville, TN
HOLE NUMBER	TNTA-BEDGW-001
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
SHEET	1 of 10
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson / Tod Schmalfeldt
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81 / Cantera C2-250
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	636.99 Ft
10. DATE STARTED	8/24/01
11. DATE COMPLETED	9/13/01
12. OVERBURDEN THICKNESS	8.5 Ft
15. DEPTH GROUNDWATER ENCOUNTERED	Groundwater not encountered (overburden)
13. DEPTH DRILLED INTO ROCK	77.5 Ft
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	NA
14. TOTAL DEPTH OF HOLE	86 ft.
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA
18. GEOTECHNICAL SAMPLES	DISTURBED: NA; UNDISTURBED: NA
19. TOTAL NUMBER OF CORE BOXES	9
20. SAMPLES FOR CHEMICAL ANALYSIS	VOC: NA; METALS: NA; OTHER (SPECIFY): NA; OTHER (SPECIFY): NA; OTHER (SPECIFY): NA
21. TOTAL CORE RECOVERY	%
22. DISPOSITION OF HOLE	BACKFILLED: NA; MONITORING WELL: X; OTHER (SPECIFY): NA
23. SIGNATURE OF INSPECTOR	David Kessel / [signature]

LOCATION SKETCH/COMMENTS

SCALE: Not To Scale



PROJECT: PBOW

HOLE NO. TNTA-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTA-BEDGW-001

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 10 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Log	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
		Weeds				Blows		
		Loose, (10YR 3/2) very dark grayish brown SAND, trace silt, organics weeds(roots), dry 0.4	SP		NA	5/5/	1.4/	Began drilling 6/4/01 1429
		Fill: (Loose (10YR 5/4) yellowish brown, homogeneous, very fine grain, SAND, very well sorted, organics (roots), dry) 1.0		0.0		5/5	2.0	
	1	Fill: (Loose, whitish gray, sandy GRAVEL, very fine grain, 30% sand, very fine grain to 20 mm gravel pebbles, dry)	Gm					Old Road bed, parking Area
	2					1630		
		Fill: (Loose, (10YR 3/3) dark brown mottled (brownish yellow, black), very fine grain, SAND, very well sorted 1", 2", 4" black ash layers, moist) 1/4" dark gray clay layers (wavy) in black sand ~~3.3-4.0~~ ft 3.3-3.7	SP	0.0	NA	4/4/	1.7/	Background / Breathing Air: PID = 0.0 ppm
	3					5/5	2.0	Black sand(ash) this is carbon from burning
	4	4.4				1632		VRAE:
		Stiff, (10YR 4/1) dark gray, homogeneous, silty CLAY, low plasticity, blocky bedding, dry		0.0	NA	1/3/		CO = 0 ppm
	5					7/12	1.8/	LEL 0%
							2.0	H_2S = 0 ppm
								O_2 = 21.3%
	6					1634		
		Consistency increasing w/ depth	CL		NA	4/8/		
		As above. shale bedding (laminations) visible at 8.5 ft.		0.0		12/20	2.0/	
	7						2.0	
						1642		wet pockets w/in bedding
	8	As above, 8.5		0.0	NA	3/20/	1.7/	Bedrock 8.5'
		SHALE, dark gray, soft, very thinly laminated, severely weathered, dry				23/50 for 4"	1.7	
	9		NA					Almost clay
	10					1647		

Project: PBOW | Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TATA-BEDGW-001

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 10 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Type	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	10	SHALE, severely weathered, very soft, very thin laminations, dry	NA	0.0	NA	25/ 50 for 5"	0.9/ 0.9	
	11	spoon refusal @ 10.9 SHALE, gray, dry	NA	NA	NA	NA	NA	10.9 Began with 4¼" ID augers
	12							
	13							
	14							
	15							Bottom of 12" OD Borehole at 15 Ft
	16							
	17							
	18							
	19							
	20							

Project: PBOW | Hole Number: TATA-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTA-BEDGW-001

Project: PBOW | Geologist: | Sheet 4 of 10 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	SHALE, gray, dry	NA	0.0	NA	NA	NA	
	21							
	22							
	23							
	24							
	25	4¼" ID Auger Refusal @ 25 ft SHALE, gray, soft	NA	1.5	NA	NA	NA	Began drilling 9/5/01 0930 w/ 8" OD rotary bit Breathing Air / Background: PID: 0.0 ppm VRAE: CO: 0 ppm LEL: 0% H_2S: 0 ppm O_2 = 20.7%
	26							
	27							
	28							
	29							
	30							

Project: PBOW | Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTA-BEDGW-001

Project: PBOW

Geologist: D. Kessler

Sheet 5 of 10 Sheets

Elev (ft)	Depth (ft) bgs.	Description of Materials	USCS Lithology	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30	SHALE, gray, soft	NA		NA	NA	NA	Background/ Breathing Air: PID: 0.0ppm
	31			0.6				VRAE: CO= 0 ppm LEL= 1% H_2S = 0 ppm O_2 = 20.8%
	32							
	33							
	34							
	35							Using water to circulate cuttings from borehole. No water loss.
	36							Strange, sweet organic odor 1.6 ppm
	37							
	38							Clay slug attempt to wash out. (2-3 ft length)
	39							
	40							

Project: PBOW

Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTA-BEDGW-001

Project: PBOW

Geologist: D. Kessler

Sheet 6 of 10 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Lito	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	40	SHALE, gray, soft	NA		NA	NA	NA	Large 2 ft Slug of silty CLAY with pebbles surges to top of ~~well~~ borehole. pebbles subrounded, gray, brown
	41							
	42							
	43							Drill Rod begins chatter at 43.5'
	44							Chattering stops at 44 ft
	45							
	46							SHALE ?
	47	SHALE, gray, soft						Still no coreable bedrock.
	48							No rock cuttings, only silty clay nodules gathered from water,
	49							
	50							

Project: PBOW

Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTA-BEDGW-001

Project: PBOW

Geologist: D. Kessler

Sheet 7 of 10 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Uses	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	50	SHALE, gray, soft		NM	NA	NA	NA	
	51	shaley LIMESTONE, average hardness, dark gray, moderately weathered, pyrite, fossils						Described from cuttings
	52							
	53							
	54							Bottom of 8" Borehole, Bottom of 6" steel casing @ 55 ft
	55					Frac[illegible]s 55.8		9/13/01 coring Run ~~55~~-60 [illegible] Run 5' 60' Rec 4' Start 10 Am End 1040
	56					56.6		
	57	v. hard, massive, gray, limestone		NM	Box 1 55-58	Run 1 ~~57.8~~ 58 ~~58.6~~		~~55-60~~
	58							
	59							
	60					60		

Project: PBOW

Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTA-BEDGW001

Project: PBOW

Geologist: RPeters

Sheet 8 of 10 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. / Fracs	Recovery (ft)	Remarks
	60	LIMESTONE, gray, very hard, massive bedding			60.3, 60.7, 61, 61.3, 61.4, 62	Run 1		Run 60-65
	62	as above		NM	62.9, 63.5, 64	Run 2; Box 2; ~~[illegible]~~ ~~58-62~~ 58-62		Run 60-65; Run 5'; Recov 5'; PID 0.0; 1900
	65	as above		NM	66.2, 67.5, 68.3	Run 3; Box 3; ~~62-65~~ 65; Box 4; ~~65-69~~		Run 65-70; Run 5'; Recov 5'; Box 3 62-65; Box 4 65-69
	70							

Project: PBOW

Hole Number: TNTA-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTA BED GW001

Project: PBOW | Geologist: R Podong | Sheet 9 of 10 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Log	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	70	as above			Run 4			Run 70-75 Start 11:45 Run 5' Rcov 5'
	71	LIMESTONE, gray, very hard, massive bedding			Box 5 69-72			PID 0.0
					71.4			
	72				71.9			
					~~72.8~~ ~~72.9~~			
	73			NM				
					73.8 73.7 74			
	74							
	75				Run 5			Run 75-80 Start 12:00 Run 5' Rcov 4.5'
					Box 6 ~~72-76~~			
	76			NM		76.2		
					Box 7 76-79.5	76.8		Box 6 72-76
	77					77.5		
	78					78.2		
	79					79		
	80							

Project: PBOW | Hole Number: TNTA BED GW001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTA8ED CW001

Project: PBOW | Geologist: R Pulonis | Sheet 10 of 10 sheets

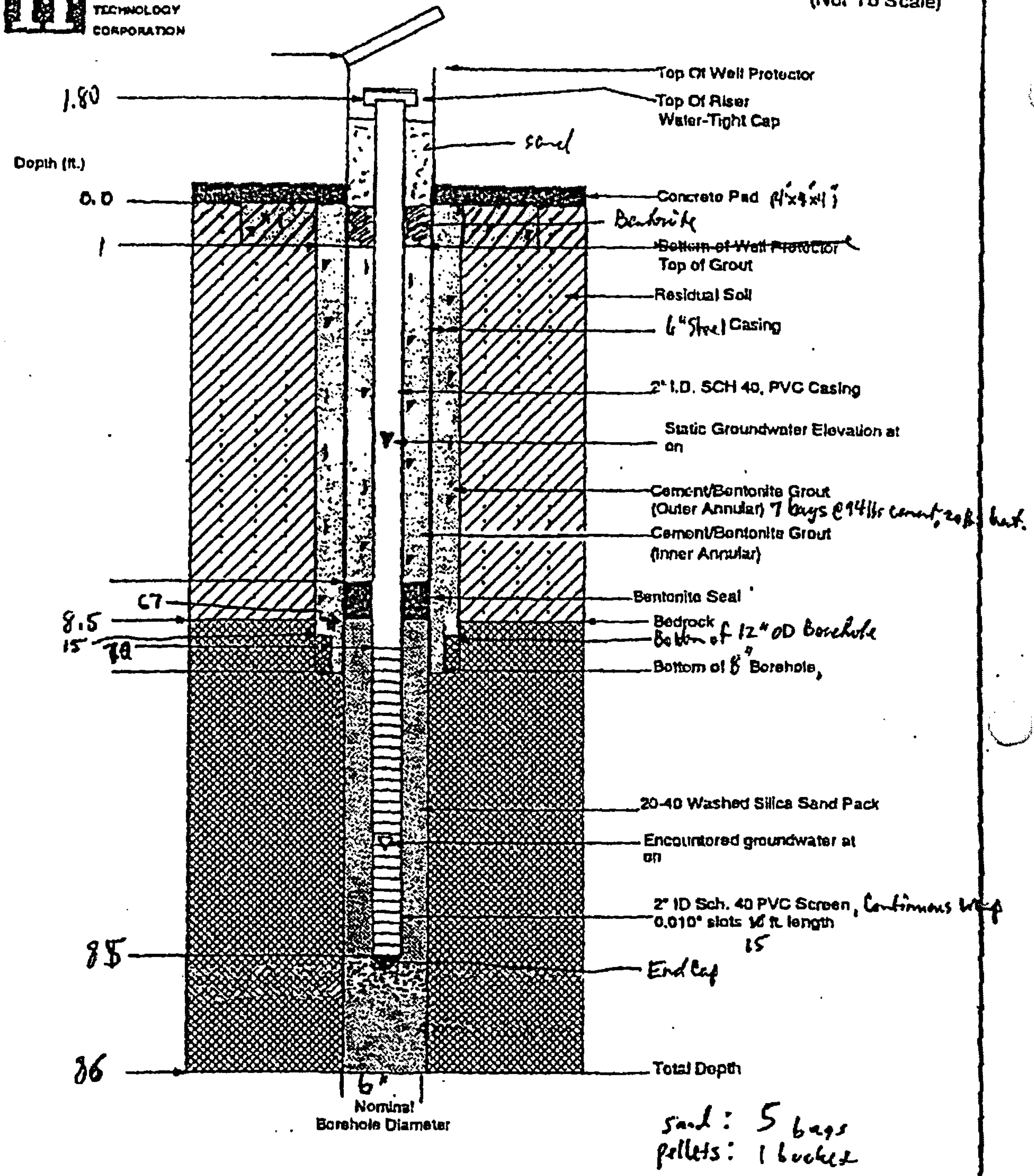
Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Code	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	80				Run 6	Fracs		Run 80-85
								Run 5'
								Rec 5'
	81	as above		80.8	Box 8			
		LIMESTONE, gray, very hard, massive bedding		81.5	79.5-			Box 8 79.5-83
	82			NM	82.7			
	83				83.1			
					83.6			Box 9
	84				84.1			83-85
	85							set at 85; 15' screen; 85-70'
	86	Total Depth = 86 ft						
	87							
	88							
	89							
	90							

Project: PBOW

Hole Number: TNTA-BEDW001

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Notes:

Well No.: TNTA-BEDGW-001

Date Installed: 9/13/01

Elevation Top of Casing: 638.79 Ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

BWMWAZOWC.DRW

HTRW DRILLING LOG

DISTRICT	Nashville, TN
HOLE NUMBER	TNTB-BEDGW-00[illegible]
SHEET	1 OF 6 SHEETS
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6⅝" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole [illegible] OD. Installed 2" PVC monitoring well.
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	681.34 Ft
10. DATE STARTED	8/30/01
11. DATE COMPLETED	9/8/01
12. OVERBURDEN THICKNESS	~~14.8 Ft~~ 4.3 Ft
13. DEPTH DRILLED INTO ROCK	28.5 Ft
14. TOTAL DEPTH OF HOLE	43.3 Ft
15. DEPTH GROUNDWATER ENCOUNTERED	11.3 Ft (overburden), Bedrock gw suspected at 40.9 Ft
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	NA
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA

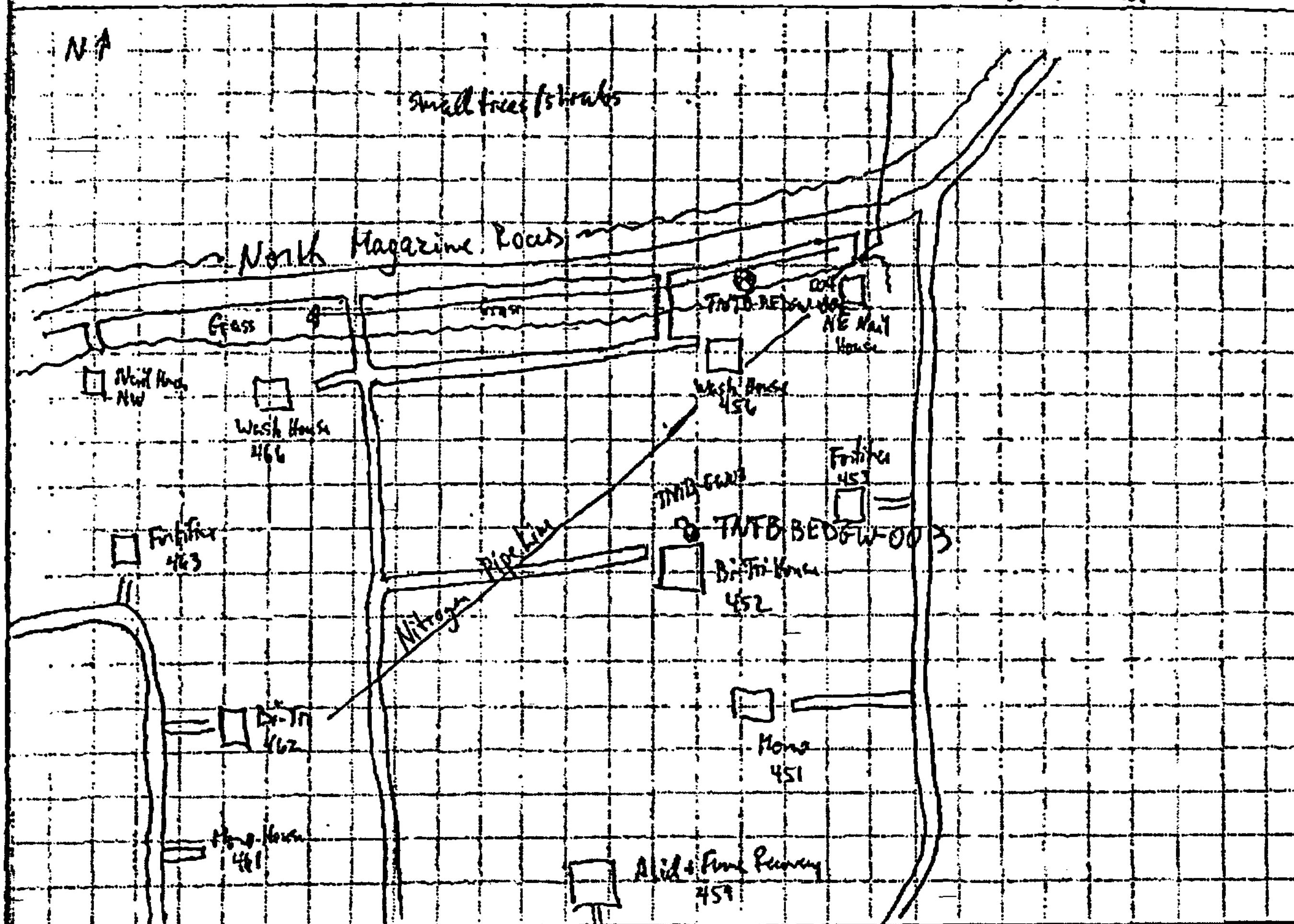
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	5

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	100 %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kesel

LOCATION SKETCH/COMMENTS

SCALE: Not to Scale



PROJECT PBOW	HOLE NO. TNTB-BEDGW-003

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-003

Geologist: D. Kessler

Sheet 2 of 6 sheets

Project: PBOW

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Use	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
		Weeds						
		Fill: Black, silty SAND, dry 0.1						Began drilling 8/30/01 1135 with 4¼" ID HSA
	1	Fill: (Loose, 10YR 4/6) dark yellowish brown, homogeneous, SAND, very fine grain, very well sorted, dry)	SP	0.0	NA	2/2/ 3/3 1140	1.5/ 2.0	Background/breathing PID=0.0ppm CO=0ppm LEL=1% H_2S=0 ppm O_2=21.0%
	2–3	As above	SP	0.0	NA	2/2/ 1/2 1142	1.0/ 2.0	
	4	4.3						
	5	Loose, (10YR 2/2) very dark brown, mottled (50% - black, yellow, rust), very fine grain, shaley SAND, with silt (20%), 30% shale, broken, thinly laminated, severely weathered, dry	SM	0.0	NA	~~2/3/~~ ~~3/4~~ ~~6/6/~~ ~~4/5~~ 1144	0.5/ 2.0	Began very weathered-decomposed shale
	6–7	As above	SM	0.0	NA	~~5/4/~~ ~~14/17~~ 6/6/ 7/5 1152	1.4/ 2.0	
	8–9	As above Moist at 9 ft	SM	0.0	NA	~~5/4/~~ ~~14/17~~ ~~9/9/~~ ~~7/7~~ 1155	2.0/ 2.0	
	10							

Project: PBOW

Hole Number: TNTB-BEDGW-003

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-003

Project: PBOW

Geologist: D. Kessler

Sheet 3 of 6 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
	10	Medium dense, (10YR 2/2) very dark brown, mottled (black, yellow, rust), 50% mottled, very fine grain, shaley SAND, 40% shale, trace sand 10%, moist 11	Sm	0.0	NA	9/4/ 7/7	1.5/ 2.0	
	11	Medium dense, (10YR 3/1) very dark gray, very fine grain, SAND, trace silt (<5%) shale 40%, black shale, broken, wet				1158		▽ Encountered overburden groundwater at 11.3 Ft
	12–13	As above, silt content increases with depth. 14	SP	NM	NA	5/12/ 13/17 1200	1.8/ 2.0	
	14	~~As above,~~ As above, silt 20%, shale 30%, SAND 50%, wet 14.8	Sm	NM	NA	9/12/ 26/40	1.6/ 2.0	
	15	SHALE, black, broken, thinly laminated (5Y 5/6) olive, 1% pocket of silt, friable, wet	NA			1204		Bedrock Bottom of 12" borehole at 15 Ft
	16			NM	NA	50 for 5" 1234	0.4/ 0.4	
	16.4–17	Spoon Refusal @ 16.4 Ft SHALE	NA	NA	NA	NA	NA	
	18–20	4¼" ID Auger Refusal @ 18 Ft SHALE	NA	NA	NA	NA	NA	Fractured (Dry) at 18.5'

Project: PBOW

Hole Number: TNTB-BEDGW-003

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-003

Project: PBOW

Geologist: D. Kessler

Sheet 4 of 6 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	20	SHALE, black/dark brown, moderately weathered, moderately hard chips, 10% stained, thinly laminated	NA	NM	NA	NA	NA	
	21							
	22							Bottom of 8" OD Borehole; Bottom of 6" Steel Casing @ 23 Ft
	23				~~Box #1~~ KK	Fracs		C-1 (23-28'); End: 1619; Start: 1548
	24							
	25			NM				5 Ft Run; 0 Ft Recovery
	26							Borehole open to 28 ft. Core washed away. Core barrel lined w/ very dark brown, SILT
	27							No water lost
	28	SHALE, black/very dark brown, moderately hard, thinly bedded, slightly broken, moderately weathered, pyrite in lamination 28.2; pyrite vugs 7mm to 25mm		0.0	Box #1	28.5, 28.6, 28.65, 28.9, 29.4, 29.45		C-2 (28-33'); End: 1700; Start: 1645; 5 Ft Run; 4 Ft Recovery
	29							
	30							

Project: PBOW

Hole Number: TNTB-BEDGW-003

HTRW DRILLING LOG (continuation sheet) — Hole Number: TNTB-BEDGW-003

Project: PBOW — Geologist: D. Kessler — Sheet 5 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample Fracs	Recovery (ft)	Remarks
	30–33	SHALE, black/very dark brown, moderately hard, thinly bedded, slightly broken, moderately weathered, pyrite in vugs		NM	Box # 1, photo 27	30; 30.7; 30.8		(C-2 cont) 5 Ft Run, 4 Ft Recovery, 1 Ft Loss. Obtained portion of lost breaker bar
	33–35.1	SHALE, as above; 33-33.9 Ft, Intensely fractured			Box # 2, photo 26	33; Intense; 33.9; 34.1; vertical also; 34.8		C-3 (33-38') End: 1815 Start: 1759. 5 Ft Run, 5 Ft Recovery, 0 Loss
	35.1–38	LIMESTONE, gray, hard, massive, slightly weathered, fossils (brachs, corals), 5% vugs (quartz filled), unbroken. 37-38 Ft; pitted, highly weathered			35.9; Box # 3, photo 25; 38	36; 36; 37.5		
	38–40	As above, 90% intensely pitted 38-38.5'. 39-39.4; wavy, continuous, shale laminations			Box # 4, photo 24	38.2; 38.6; 39; 39.4		Began Coring 9/8/01 0857. C-4 (38-43) End: 0911 start: 0857

Project: PBOW — Hole Number: TNTB-BEDGW-003

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-003

Project: PBOW

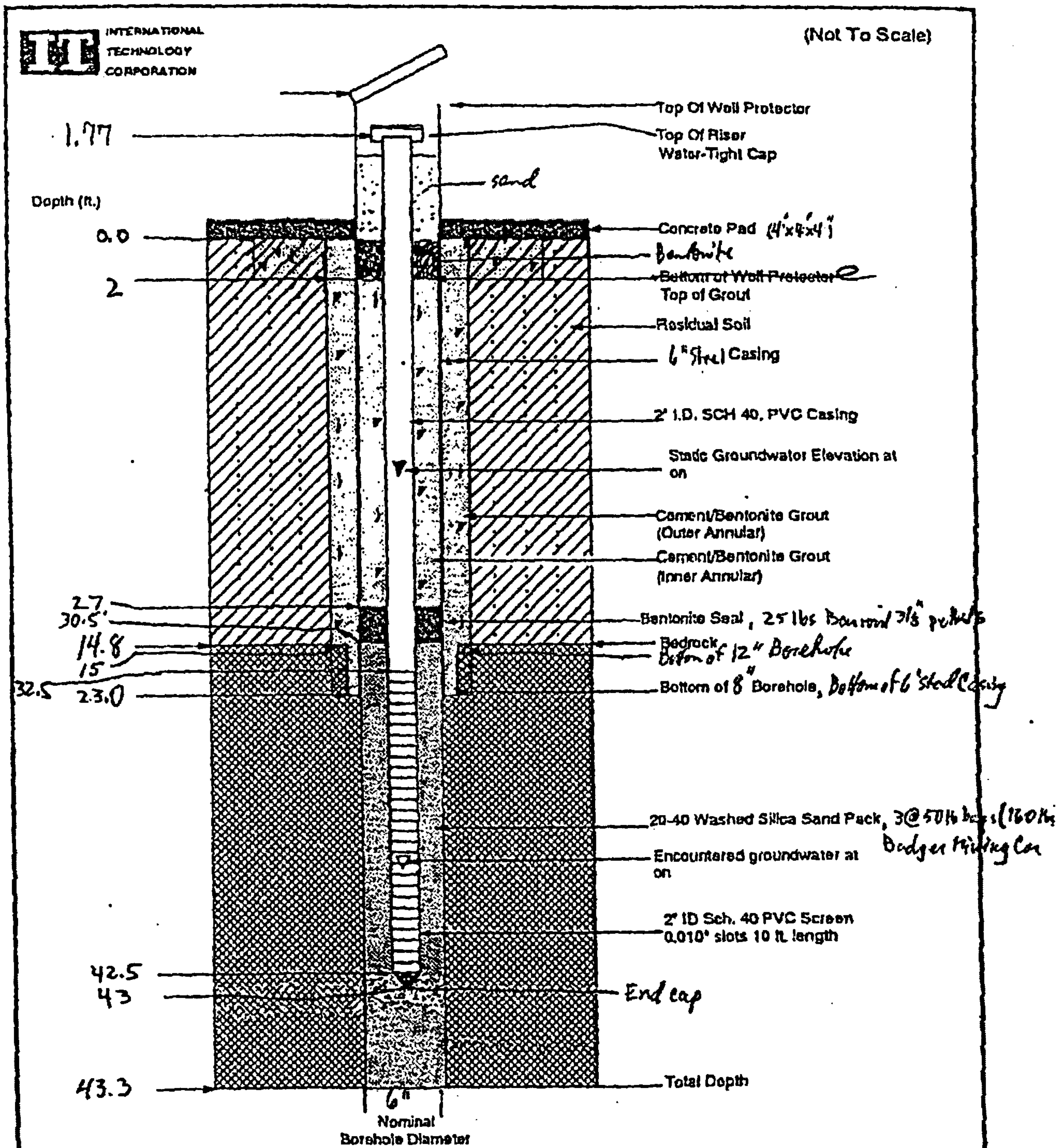
Geologist: D. Kessler

Sheet 6 of 6 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	~~Analytical Sample No.~~ FRACS	Recovery (ft)	Remarks
	40	LIMESTONE 40.9		-40.1 NM	Box # 4	-40.1		C-4 (cont) (38-43.3)
	41	SHALE, gray, highly weathered/decomposed thinly laminated, very soft,			41.8	-41.0 } Intense -41.3 -41.6		53 ft Run; 53 ft Recovery / 0 Loss
	42	42.5 pyrite vugs (8) 40.9–42.7 highly weathered/decomposed			Box # 5	-41.9 } Intense -42 -42.4		pumped borehole
	43	Moderately hard ~~clay~~ SHALE 42.6–42.9			photo 23 43.3	-42.9 } Intense -43.3		
		Total Depth = 43.3 Ft						
	44							
	45							
	46							
	47							
	48							
	49							
	50							

Project: PBOW

Hole Number: TNTB-BEDGW-003



Notes:

Well No.: TNTB-BEDGW-003

Date Installed: 9/8/01

Elevation Top of Casing: 683.11 ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

DWMWA23DWC.DRW/75-26-93

HTRW DRILLING LOG

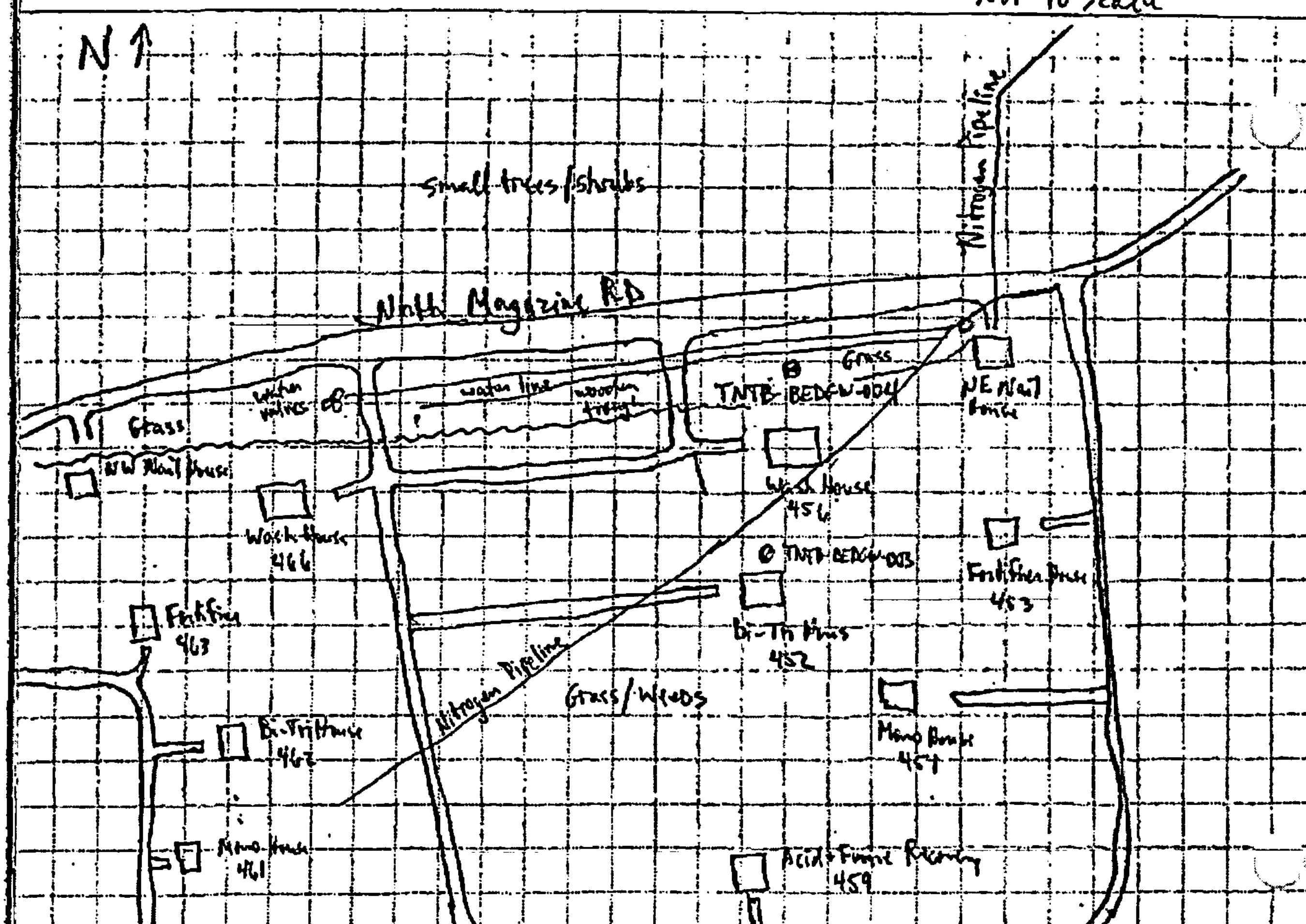
DISTRICT: Nashville TN	HOLE NUMBER: TNTB-BEDGW-004	SHEET 1 OF 4
1. COMPANY NAME: IT Corporation	2. DRILL SUBCONTRACTOR: Boart Longyear	
3. PROJECT: PBOW	4. LOCATION: NASA Plum Brook Station, Sandusky, O	
5. NAME OF DRILLER: Paul Dickinson	6. MANUFACTURER'S DESIGNATION OF DRILL: BK81	
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT: 4 1/4" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8 1/4" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.	8. HOLE LOCATION: See Sketch	
	9. SURFACE ELEVATION: 666.78 ft	
	10. DATE STARTED: 8/28/01	11. DATE COMPLETED: 9/7/01
12. OVERBURDEN THICKNESS: 4.9 ft	15. DEPTH GROUNDWATER ENCOUNTERED: Overburden groundwater not encountered/Bedrock unknown	
13. DEPTH DRILLED INTO ROCK: 21.2 ft	16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED: 4.8 ft BGS 9/7/01 0855	
14. TOTAL DEPTH OF HOLE: 26.1 ft	17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY): 9.69 dtw	

18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	4

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	100 %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kersh

LOCATION SKETCH/COMMENTS SCALE: Not To Scale



PROJECT PBOW | HOLE NO. TNTB-BEDGW-004

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-004

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 4 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS/Unit	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. / Blows	Recovery (ft)	Remarks
		Grass						
	0–1	Fill: Stiff, (10YR 2/1) black, mottled (3% - brown), clayey SILT, some sand (20%), organics (roots) trace pebbles, dry) 0.4	ml	0.0	NA	3/4/5/7	1.4/2.0	Began drilling 8/29/01 1745 w/4¼" ID augers
	1–2	Fill: (Stiff, (10YR 5/2) grayish brown, mottled (yellowish brown) - 50%), clay SILT, some sand (20%), vfg, very well sorted, low plasticity, dry)				1746		
	2–3		ml	0.0	NA	4/4/5/7	1.8/2.0	thinly laminated, very weathered decomposed, former Shale
	3–4	As above				1752		
	4–5	4.9		0.0	NA	8/27/50 for 2"	1.2/1.2	Began drilling 8/30/01 0745 Advanced 12" Borehole to 4.9 ft
	5	SHALE, dark gray, broken, thinly laminated, dry 5.2				1757		
		Spoon Refusal @ 5.2 ft						Continued drilling with augers.
	5.5–6	SHALE						
	6–6.3			0.0	NA	100 for 7"	0.7/0.7	Attempted spoon
	6.3	4¼" ID Auger Refusal @ 6.3 ft				1800		
		SHALE, dark gray, broken, thin lam, dry						
	6.7	Spoon Refusal @ 6.7 ft						Breathing Air / Background PID = 0.0 ppm VRAE: CO = 0 ppm LEL = 0% H_2S = 0 ppm O_2 = 20.9%
	8–10	SHALE, very dark brown/black, slightly weathered, average hardness						Organic odor in borehole PID = 30.8 ppm

Project: PBOW | Hole Number: TNTB-BEDGW-004

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTB-BEDGW-004

Project: PBOW | Geologist: D. Kessler | Sheet 3 of 4 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Unit	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	10	SHALE, very dark brown/black, slight weathering, average hardness	NA	NM	NA	NA	NA	Bottom of 8" OD Borehole. Bottom of 6" steel Casing
	11					Fracs		Cut w/ 6" roller bit during clean-out.
	11.5–16.8	SHALE, very dark brown, moderately hard, thin lamination, moderate weathering, pyrite in pits/laminations (2%), highly fractured Large vug filled w/ pyrite 14.4–14.5 Ft		0.0	Pyrite → 12.1; Box #1 (to 15.3); Box #2 (15.3–16.5)	Fracs: 11.8, 12.1, 12.1, 12.4, 12.9, 13.1 (1"), 13.2, 13.7, 13.9 (1/4"), 14.3, 15.3, 15.9 vertical, 16.3		Began coring w/ PQ bit 9/6/97 1705 C-1 11.5–16.5' End Time: 1712 Start Time: 1705 5 Ft Run 4.5 Ft Recovery 0.5 Ft Loss Breathing Air PID: 0.0 ppm CO: 0 ppm LEL: 0% H2S: 0 ppm O2: 21.7%
	16.8–20	LIMESTONE, greenish gray, hard, massive, slightly weathered, fossils (brachs/corals) in pits/vugs (10%), moderately fractured			Box #2 (16.5–19.2); Box #3	16.7 (mech), 16.7, 17.1' (mech), 17.5 (mech), 17.7 (mech), Frac 18, 19.2 (mech), 19.6 Frac		C-2 16.5–21.5 Ft End: 1749 Start: 1740 5 Ft Run 5.3 Ft Recovery 0.3 Ft Gain

Project: PBOW | Hole Number: TNTB-BEDGW-004

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTB-BEDGW-004

Project: PBOW

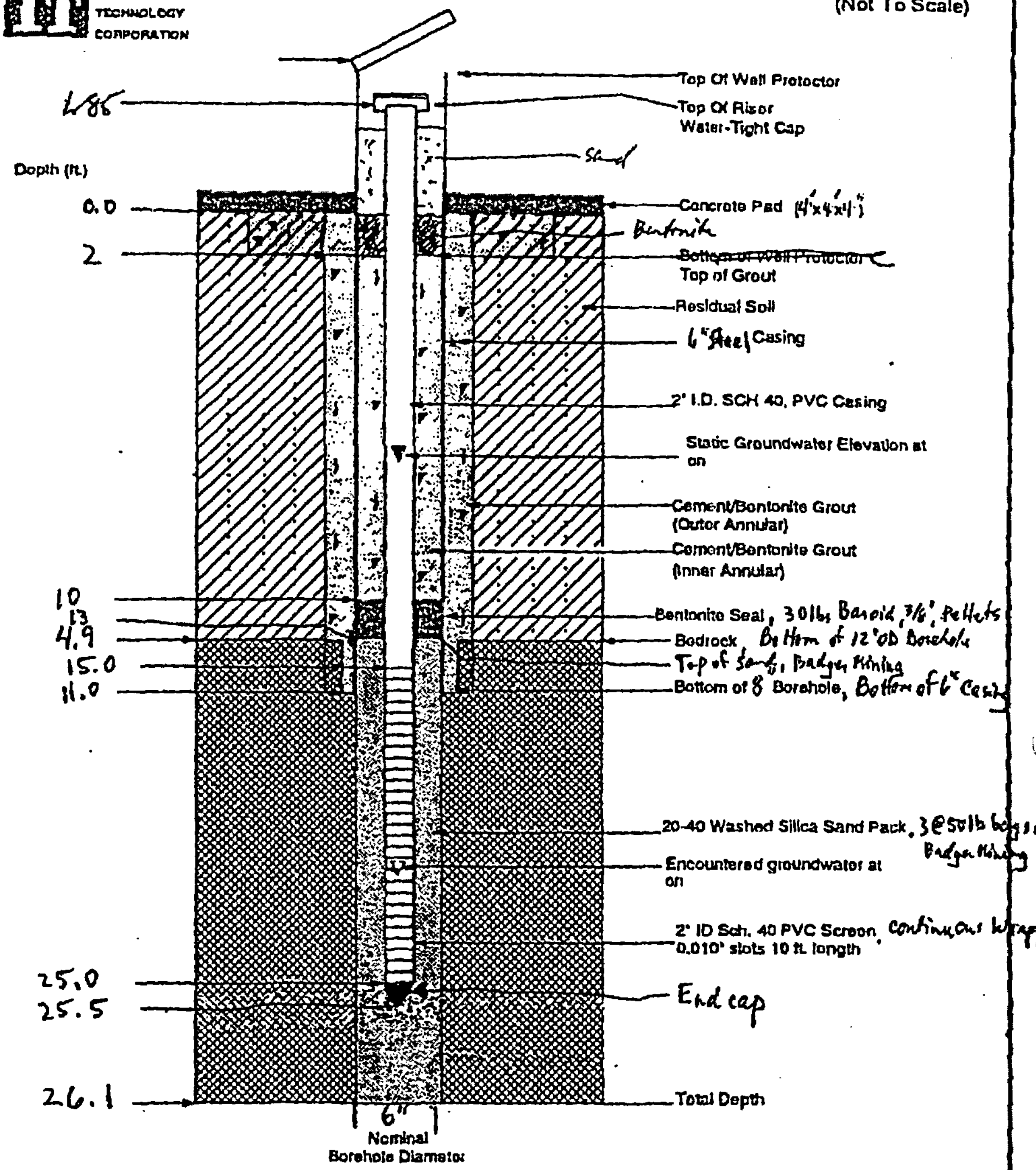
Geologist: D. Kessler

Sheet 4 of 4 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Lithe	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	20	LIMESTONE, greenish gray, hard, massive, slightly weathered, fossils (brachs, corals) in pits/vugs (10%)				20.2		(C-2 cont)
						20.8 filled w/ shale		
	21			0.5	Box #3	21.3 (Mech)		
	21.5							C-3 21.5-26.1 Ft
						21.7		
	22					22.7		End 1817 Start 1808
	23	23.2				23.2		
		SHALE, gray, soft, very thinnly laminated, highly weathered				23.6 / 23.6 Frac		
	24					24 (mech)		4.6' Run 4.6' Recovery 0 Loss
					Box # 4			
	25					25.1		
						25.4		
		25.7				25.7		
		LIMESTONE, gray, hard 26						
	26	SHALE				26.1		
		Total Depth: 26.1 Ft						
	27							
	28							
	29							
	30							

Project: PBOW

Hole Number: TNTB-BEDGW-004



Notes:

Well No.: TNTB-BEDGW-004

Date Installed: 9/7/01

Elevation Top of Casing: 668.63 ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

BWMWA23DWC.DRW

26.1
13
13.1

HTRW DRILLING LOG

Field	Entry
DISTRICT	Nashville, TN
HOLE NUMBER	TNTC-BEDGW-00
SHEET	1 of 10
1. COMPANY NAME	IT Corporation
2. DRILL SUBCONTRACTOR	Boart Longyear
3. PROJECT	PBOW
4. LOCATION	NASA Plum Brook Station, Sandusky, OH
5. NAME OF DRILLER	Paul Dickinson / Todd Schmaltfeldt
6. MANUFACTURER'S DESIGNATION OF DRILL	BK81 for overburden Cantera CZ-250 for coring
7. SIZES AND TYPES OF DRILLING AND SAMPLING EQUIPMENT	4¼" ID/8" OD HSA with 1.4" ID Stainless Steel split-spoons. Borehole reamed with 8¼" ID/12" OD HSA. Bedrock cut with 8" OD tricone rotary bit. Installed 6" ID/6 5/8" OD black steel casing. Bedrock cored with PQ bit. Cores 3" OD, borehole 6" OD. Installed 2" PVC monitoring well.
8. HOLE LOCATION	See Sketch
9. SURFACE ELEVATION	664.04 Ft
10. DATE STARTED	8/28/01
11. DATE COMPLETED	9/12/01
12. OVERBURDEN THICKNESS	14.5 Ft
13. DEPTH DRILLED INTO ROCK	~~86 Ft~~ 71.5 Ft
14. TOTAL DEPTH OF HOLE	86 Ft.
15. DEPTH GROUNDWATER ENCOUNTERED	8.8 Ft (overburden)
16. DEPTH TO WATER AND ELAPSED TIME AFTER DRILLING COMPLETED	NA
17. OTHER WATER LEVEL MEASUREMENTS (SPECIFY)	NA

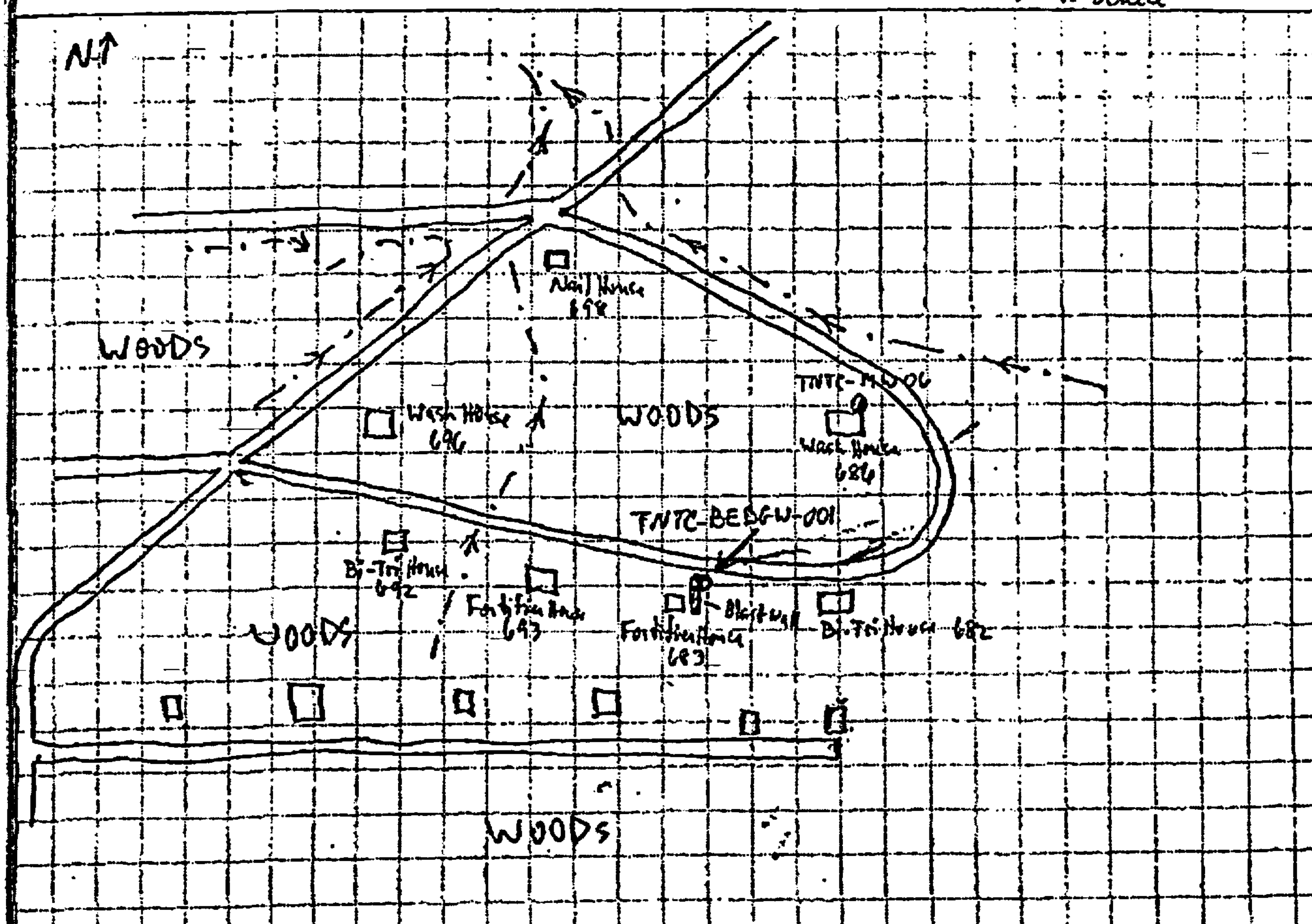
18. GEOTECHNICAL SAMPLES	DISTURBED	UNDISTURBED	19. TOTAL NUMBER OF CORE BOXES
	NA	NA	9

20. SAMPLES FOR CHEMICAL ANALYSIS	VOC	METALS	OTHER (SPECIFY)	OTHER (SPECIFY)	OTHER (SPECIFY)	21. TOTAL CORE RECOVERY
	NA	NA	NA	NA	NA	100 %

22. DISPOSITION OF HOLE	BACKFILLED	MONITORING WELL	OTHER (SPECIFY)	23. SIGNATURE OF INSPECTOR
	NA	X	NA	David Kusch / Reed [illegible]

LOCATION SKETCH/COMMENTS

SCALE: Not To Scale



PROJECT PBOW

HOLE NO. TNTC-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTC-BEDGW-001

Project: PBOW | Geologist: D. Kessler | Sheet 2 of 10 Sheets

Elev (ft)	Depth (ft)	Description of Materials	USCS Litho	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
		Weeds						
	0–2	Fill: Loose, (10YR 4/3) brown, homogeneous, SAND, trace silt, organics (roots), vfg, very well sorted, dry 0.5 Fill: (color grading to yellowish brown (10YR 5/6)) No SILT	SP	0.0	NA	2/2/5/4 1640	1.4/2.0	Began drilling 8/28/01 1640 with 4¼" ID augers Background/Breathing Air: PID = 0.0 ppm
	2–4	As above	SP	0.0	NA	2/4/5/5 1644	1.6/2.0	VRAE: CO = 0 ppm LEL = 0% H_2S = 0 ppm O_2 = 21.1%
	4–6	As above Fill: (color grading to (10YR 5/8) yellowish brown)	SP	0.0	NA	3/5/5/5	2.0/2.0	
	6–8	At 7.6 Ft; color changing to (10YR 4/3) brown, moist	SP	0.0	NA	4/3/5/5	2.0/2.0	
	8–10	At 9.5–10 Ft; color changing to (5Y 4/2) olive gray, trace silt begins, dark red/blackish red nodules at 9.6 Ft	SP	0.0	NA	5/4/5/5	2.0/2.0	∇ Encountered overburden groundwater at 8.8 Ft PID = 0.0 ppm of nodules

Project: PBOW | Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG	(continuation sheet)	Hole Number: TNTC-BEDGW-001
Project: PBOW	Geologist: D. Kessler	Sheet 3 of 10 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Class	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample / Blows	Recovery (ft)	Remarks
	10–11.3	Medium dense, (5Y 4/2) olive gray, homogeneous, SAND, trace silt, very fine grain, very well sorted, wet. 11.3	sp	NM	NA	5/8/ 17/29 1658	2.0/ 2.0	
	11.3–13	Medium dense, (2.5Y 4/1) dark gray homogeneous, very fine grain SAND and GRAVEL, coarse grain to 30 mm size, limestone, wet 13	gm	NM	NA	8/17/ 9/32 1700	2.0/ 2.0	
	13–14.5	Very stiff, (10YR 5/1) gray, homogeneous, low plasticity, silty CLAY, coarse grain shale fragments (35%), wet 14.5	cl					
	14.5–16	Very stiff, (1 GLEY 5/N) gray, homogeneous, high plasticity, silty CLAY, irregular bedding, dry	ch	NM	NA	10/11/ 12/30 1707	1.5/ 2.0	Bedrock @ Decomposed severely weathered SHALE
	16–18	As above		NM	NA	8/12/ 29/32 1713	2.0/ 2.0	
	18–20	As above		NM	NA	17/29/ 33/42 1722	1.5/ 2.0	

Project: PBOW — Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG	(continuation sheet)	Hole Number: TNTC-BEDGW-001
Project: PBOW	Geologist: D. Kessler	Sheet 4 of 10 sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Code	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample ~~No.~~ Blows	Recovery (ft)	Remarks
	21	Very hard, (1GLEY 5/N) gray, homogeneous high plasticity, silty CLAY, occasional laminated bedding planes, dry, 20% shale fragments	ch	NM	NA	10/16/50 for 3" 1729	1.3/1.3	Decomposed shale. Very hard clay in shoe tip.
	22	Spoon Refusal @ 21.3 Ft		NM	NA	NA	NA	Began advancing only 4¼" ID augers.
	23							
	24		ch					
	25	Very hard, (1GLEY 5/N), gray, homogeneous high plasticity, silty CLAY, ~~wet~~ dry		NM	NA	16/50 for 3" 1745	0.8/0.9	Augers turning/advancing fairly easily attempted spoon. End of Day
	26	Spoon Refusal @ 25.8 Ft		NM	NA	NA	NA	Began drilling 8/29/01 0730 with 4¼" ID augers. 8¼" ID/~~8~~ 12" OD augers drilled to 25 Ft
	27	Very hard, (1GLEY 5/N) gray, homogeneous, high plasticity, silty CLAY, dry	ch					Decomposed shale
	28							
	29							
	30							

Project: PBOW | Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG (continuation sheet)

Hole Number: TNTC-BEDGW-001

Project: PBOW | Geologist: D. Kessler | Sheet 5 of 10 Sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Line	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No.	Recovery (ft)	Remarks
	30	Very hard, (GLEY 5/N) gray, homogeneous, high plasticity, silty CLAY, thinnly laminated bedding, dry	ch	NM	NA	100 for 4"	0.8/0.4	30.4
	31							Augers advancing easily.
	32							Decomposed, (severely weathered) shale
	33							
	34							
	35	As above	ch	NM	NA	50 for 3"	0.3/0.3	35 / 35.3
	36							
	37							
	38							
	39							Sweet, organic odor 0.8 ppm = PID
	40							

Project: PBOW | Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTC-BEDFW-001

Project: PBOW | Geologist: D. Kessler | Sheet 6 of 10 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Lith	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	40	Very hard, (1GLEY5/N) gray, homogeneous, high plasticity, silty CLAY, very thinly laminated bedding, dry, friable, 80% shale relict	ch	0.8	NA	100 for 6"	0.5/0.5	40.5
	41							Could not core material with wet or dry coring method.
	42							
	43							
	44							Augers cut easily
	45	As above	ch	2.2	NA	100 for 4" 0831	0.3/0.3	Strong organic odor 45.3
	46							
	47							
	48							
	49							
	50							

Project: PBOW | Hole Number: TNTC-BEDFW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTC-BEDGW-001

Project: PBOW | Geologist: D. Kessler | Sheet 7 of 10 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Code	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Blows	Recovery (ft)	Remarks
	50	Very hard, light gray, homogeneous, very thinly laminated bedding, SHALE, very friable, dry limestone pebble (20x20x30mm)	NA	1.8	NA	100 for 7" 0847	0.7/0.7	50.6
	51							Augers difficulty cutting 51-51.5 ft
	55	As above, limestone pebble (18x20x28mm)		NM	NA	100 for 7" 0910	0.7/0.7	Layers of limestone shale. Shale layers much thicker. Will stop 4¼" ID auger drilling. Shale competent. 55.7
	57							Bottom of 8"OD Borehole at 57.2'. Bottom of Isolation Casing at 57.2
	57–59	~~massive, very hard gray~~ ~~limestone~~ grey, washed limey shale from 57-58.0 then 58 massive very hard limestone	SH / ~~LS~~ / LS			Run # 1 Fracs 58.5, 58.8, 59.3, 59.6		Run 1 Began Coring 9/11/01 57-62 Run 5' Recov 5'
	60							

Project: PBOW | Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG		(continuation sheet)		Hole Number: TNTC-BEDGW-001
Project: PBOW		Geologist: R Poderis		Sheet 8 of 10 sheets

Elev (ft)	Depth (ft) bgs	Description of Materials	USCS Lithe	Field Screening Results (ppm)	Geotech. Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	60							Box 1 57-62
	61					61.0		start 500
						61		end 510
						61.5		
	62	Massive vy hard limestone				Run 2		Run 62-67 Run 5' Rec 5'
	63					63		
						63.7		Box 2 62-65
	64					64.5		Box 3 65-67
						64.8		
	65							start 510 end 530
	66					66.5		
	67							67
						Run 3 9-11-01		67-72 Run 5' Rec 5'
						67.4		
	68					67.8		
						68.1		Box 4 67-69.5
	69							Box 5 69.5-
						68.5		start 830
						68.6		
	70					69.5		end 8??

Project: PBOW	Hole Number: TNTC-BEDGW-001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTC-BEDGW001

Project: PBOW

Geologist: R. Podonis

Sheet 9 of 10 Sheets

Elev (ft)	Depth (ft bgs)	Description of Materials	USCS Uses	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. Fracs	Recovery (ft)	Remarks
	70							
	71					70.8		Box 5 69-74
	72	Massive very hard gray limestone			Run 4	72.1		72-77
					Box 6 74-76	72.8		5' recov 5' run
	73							pink 905
						73.8		
	74					73.9		
						74.5		Box 6 74-76
	75					[illegible]		
						75.5		
	76					76		
						~~78.5~~		
						76.4		
	77					76.6		
					Box 7 76-78.5			Began Coring 9/12/01
	78				Box 8 78.5-82	76		Box 7 76-78.5
						76.5		Box 8 78.5-82
	79					78		Run 77-82
	80					78.5		

Project: PBOW

Hole Number: TNTC-BEDGW001

HTRW DRILLING LOG

(continuation sheet)

Hole Number: TNTC-GW001

Project: PBOW | Geologist: R Dolan's | Sheet 10 of 10 sheets

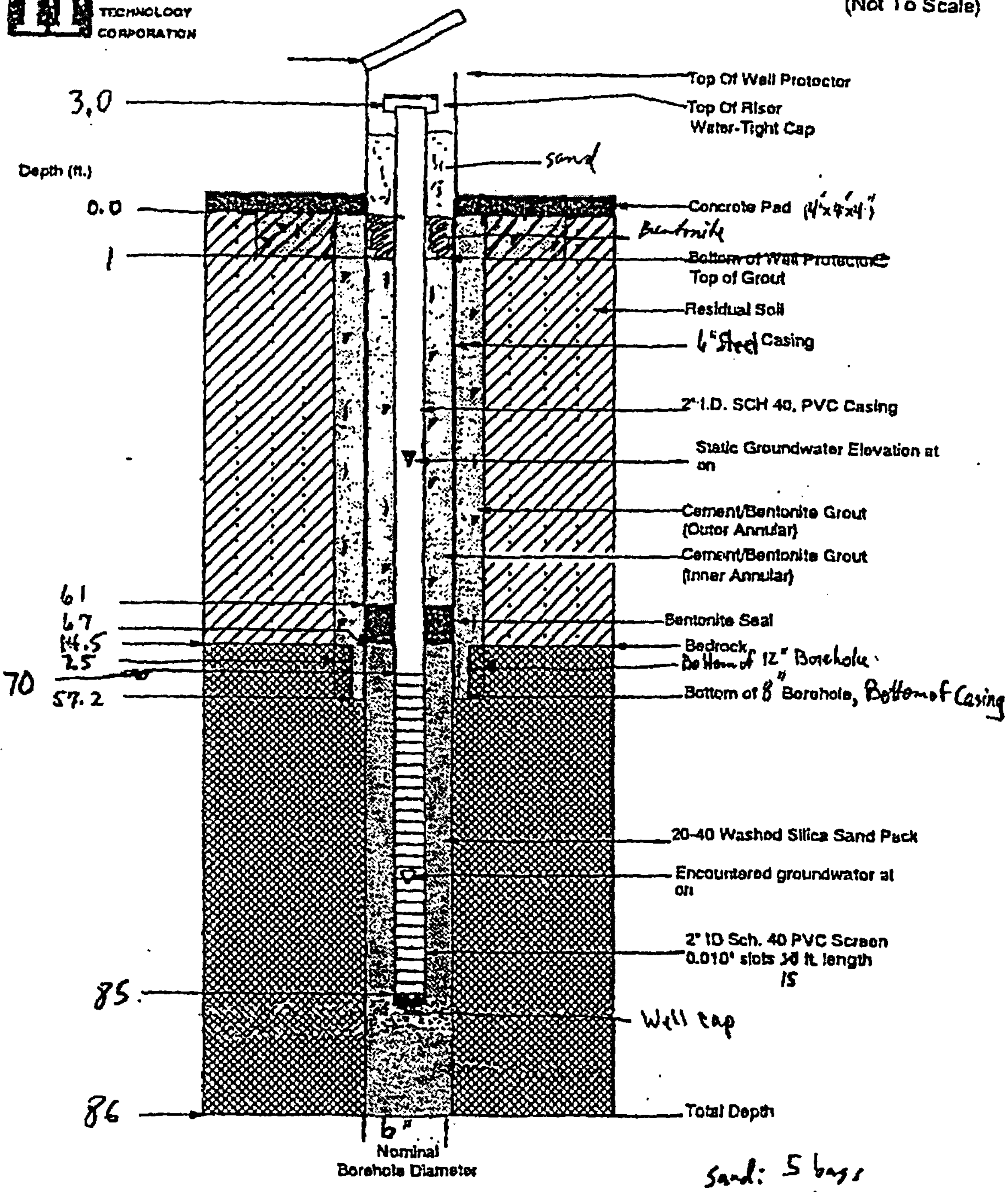
Elev (ft)	Depth (ft bgs)	Description of Materials	USCS/Unc	Field Screening Results (ppm)	Geotech Sample or Core Box No.	Analytical Sample No. FTCCS	Recovery (ft)	Remarks
	80							
	81					81.5		~~[illegible]~~
	82	Massive gry limestone, very hard with vertical calcite deposits in fractures.						82-86
	83					83		
	84				Box 9 82-86	84		vertical fracture
						84.7		Box 9 82-86
	85							Clean
	86	Total Depth - 86 Ft						See wellhead 85, 1' seal

Project: PBOW

Hole Number: TNTC-BEDGW001

INTERNATIONAL TECHNOLOGY CORPORATION

(Not To Scale)



Sand: 5 bags
bent: 1 bucket

Notes:

Well No.: TNTC-BEDGW-001
Date Installed: 9/12/01
Elevation Top of Casing: 667.04 ft

Well Construction Diagram
prepared for:
Plum Brook Ordnance Works
Sandusky, OHIO

SW/LMWAZ30WC.DRW

APPENDIX A

SECTION 12

2000 Amended Closure Plan

(URS Greiner Woodward Clyde, March 2000)

REACTOR AREA
BUILDING 1131

AMENDED CLOSURE PLAN

TASK ORDER 7521-004

PREPARED FOR:

NASA GLENN RESEARCH CENTER
21000 BROOKPARK ROAD
CLEVELAND, OHIO 44135

MARCH 2000

PREPARED BY:

URS GREINER WOODWARD CLYDE
800 WEST ST. CLAIR AVENUE
CLEVELAND, OHIO 44113-1232

4.0 HYDROGEOLOGIC CHARACTERIZATION

The characterization of local hydrogeology is necessary to understand the potential for the migration of contaminants at the RA. The following sections describe the physiographic and topographic features of the site, the geology of the bedrock and unconsolidated soils, and the groundwater.

4.1 PHYSIOGRAPHY AND TOPOGRAPHY

The PBS is located in a transition zone between the Erie Lake Section and the Bellevue-Castalia Karst Plain of the Central Lowland Province. The Erie Lake Section, which occurs throughout the central to southeast portion of PBS, is characterized by Pleistocene sand, silt, clay, and clay till over Devonian and Mississippian-aged shales and sandstones. The Bellevue-Castalia Section, which occurs throughout the north to northwest portion of PBS, is characterized by Columbus and Delaware Limestone overlain by thin silty and sandy lacustrine deposits and clay till (ODNR, 1998).

The local terrain is relatively flat and characterized by topography that slopes gently north toward Lake Erie. The ground surface has an average slope of less than six percent. The surficial deposits and landforms were produced by glacial processes. The approximate elevation at the RA is 630 feet above mean sea level (amsl).

4.2 GEOLOGY

4.2.1 Unconsolidated Soils

During the field activities at the RA closure unit, soils were continuously sampled at 12 locations to a maximum depth of 16 feet bgs. Additionally, five monitoring wells were installed upgradient of the Closure Unit to the depth of bedrock, which was encountered at 22 to 26 feet bgs. A site map showing the locations of the boreholes and the monitoring wells are presented on Figures 2.2 and 4.1, respectively.

The subsurface soils are generally 0-1 foot of brown silty sand topsoil material with roots extending to approximately 8 to 10 inches bgs. The top soil is underlain by 7 to 10 feet of brown grading to gray, dry grading to wet sand and sandy silt with a trace of clay. These soils are underlain by a medium to dark gray, moist, plastic clay with an occasional interbedded silt that extends to the depth of bedrock which is 22 to 26 feet bgs.

4.2.2 Bedrock Geology

One well (RA-MW-05) (Figure 4-1) was drilled into the bedrock material at the RA to a depth of 50 feet bgs. The bedrock material encountered in the bedrock well is generally consistent with the description of the Delaware Limestone (IT, 1999). The limestone encountered in the deep borehole consisted of light to medium gray to brown, hard, fossiliferous limestone with several zones of pyrite deposits.

4.3 GROUNDWATER

Water-level measurements were collected from all of the monitoring wells that were sampled at the RA on November 10, 1998, February 17, 1999, May 19, 1999, and August 23, 1999 (as listed in Table 2-1). Groundwater was present at the RA site between approximately 7 and 18 feet below the top of casing (TOC) in the monitoring wells installed in the unconsolidated material. The water level in RA-MW-05 (bedrock well) was encountered at approximately 20 to 32 feet below the top of the casing. The resulting contour maps are shown on Figures 4-2, 4-3, 4-4, and 4-5 for the November 10, 1998, February 17, 1999, May 19, 1999, and August 23, 1999 water levels, respectively.

IT reported that several of the monitoring wells (Reactor 1, 2, and 3, located west and north of the RCRA unit) and two piezometers were dry, presumably due to the effects of the sumps in the reactor building area in November, 1997 (IT, 1998). Water was present in the monitoring wells (not the piezometers) in the May 1998 sampling event conducted by IT. These observations were consistent with current water level measurements that show seasonal variability in water levels.

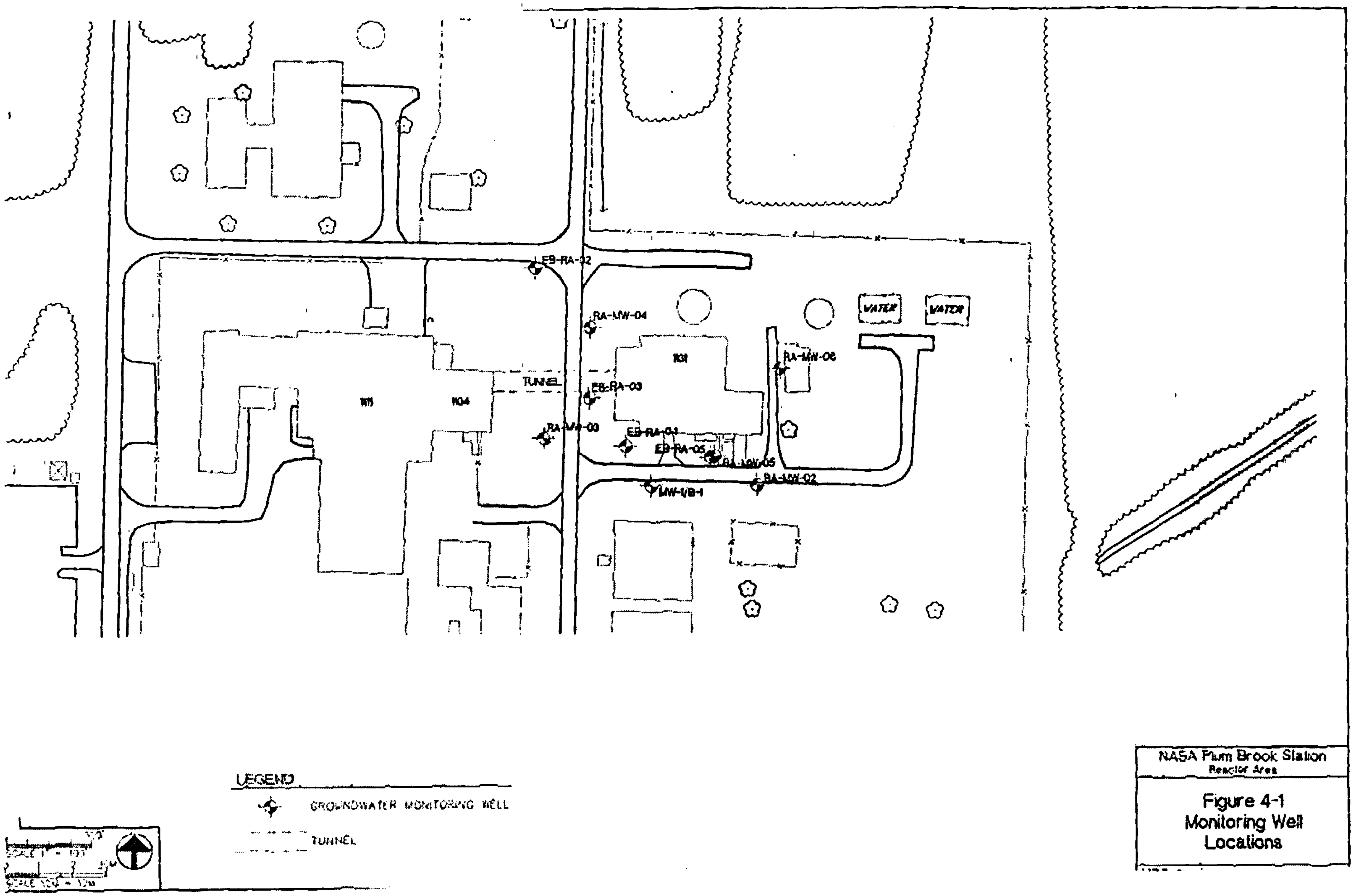
Groundwater flow direction and gradient in the unconsolidated material of the RA are variable and differ from the regional northerly flow direction. This was observed during the current investigation and previous investigations (IT, 1998). In addition to seasonal variability, the variability in groundwater levels may be attributable to three anthropogenic conditions: groundwater interception and discharge by the sump systems in the RA, the deep foundations of the structures in the RA, and the quarrying operation north of PBS. Since the RA sump system is closest to the site, it potentially has the greatest influence on groundwater levels. This can be observed by reviewing the groundwater contour maps (Figures 4-2 through 4-5). The groundwater contours show that groundwater flows toward Building 1131 and the tunnel connecting this building with the reactor to the west (Buildings 1134 and 1111). Construction drawings indicate that the building and tunnel foundations extend approximately 15 feet below grade and are drained by a sump system (NACA, 1958).

The single bedrock monitoring well monitored during this investigation, RA-MW-05, showed significant water level variability (602.26 to 595.45 feet amsl). The variability in the bedrock monitoring wells was also observed by IT (1998) in the northern portion of PBS and was attributed to fracture generation (during blasting) and routine dewatering by Wagner Quarries Corp. (Sandusky, Ohio), north of PBS (Figure 1-1). Although these operations will likely have their greatest impact on groundwater in the bedrock, a connection likely exists between groundwater in the bedrock and the overburden (IT, 1998; 1999). The connection between these two hydrologic units is likely to be minimal at the RA, however, based on the difference in groundwater chemical constituents between the adjacent bedrock and unconsolidated monitoring wells, RA-MW-05 and EB-MW-05. As discussed in Section 3.2 (Groundwater Sampling Results), the bedrock monitoring well (RA-MW-02) indicated the presence of BTEX which was not detected in the shallow monitoring well (EB-MW-05). The contaminants detected in the bedrock monitoring well are similar to those detected in an upgradient bedrock monitoring well, BED-MW-15 (IT, 1999). This well is located approximately 1,000 feet to the southeast of RA-MW-05. Contamination at BED-MW-15 was attributed to the PRRWP Area (IT, 1999).

Table 2-1
Groundwater Elevations
Reactor Area
NASA Plum Brook Station, Sandusky, Ohio

Monitoring Well	Measuring Point Elevation (msl)	November 10, 1998		February 17, 1999		May 19, 1999		August 23, 1999	
		Depth to Water (feet)	Elevation (msl)	Depth to Water (feet)	Elevation (msl)	Depth to Water (feet)	Elevation (msl)	Depth to Water (feet)	Elevation (msl)
MW1/B-1	627.48	7.28	620.20	5.51	621.97	5.79	621.69	7.44	611.84
EB-RA-02	631.81	10.16	621.65	7.23	624.58	8.27	623.54	10.80	612.80
EB-RA-03	631.43	Dry	Dry	14.20	617.23	15.09	616.34	15.85	607.37
EB-RA-04	631.34	11.63	619.71	9.56	621.78	13.20	618.14	11.75	611.38
EB-RA-05	631.10	10.15	620.95	7.84	623.26	8.64	622.46	10.71	612.18
RA-MW-02	628.07	14.17	613.90	11.71	616.36	9.75	618.32	11.98	607.88
RA-MW-03	627.82	10.75	617.07	9.01	618.81	8.95	618.87	10.72	608.89
RA-MW-04	628.36	18.42	609.94	16.80	611.56	16.13	612.23	17.24	602.91
RA-MW-05	627.67	25.41	602.26	32.22	595.45	33.00	594.67	20.47	598.99
RA-MW-06	627.64	13.70	613.94	11.28	616.36	9.25	618.39	11.73	617.71

NM = Not measured
Dry = No water in well
Measuring point elevations were surveyed by G&T Associates, Inc.
Water levels were measured with an oil/water interface probe. Nonaqueous phase liquid (light or dense) was not detected in any of the monitoring wells.



NASA Plum Brook Station
Reactor Area

Figure 4-1
Monitoring Well
Locations

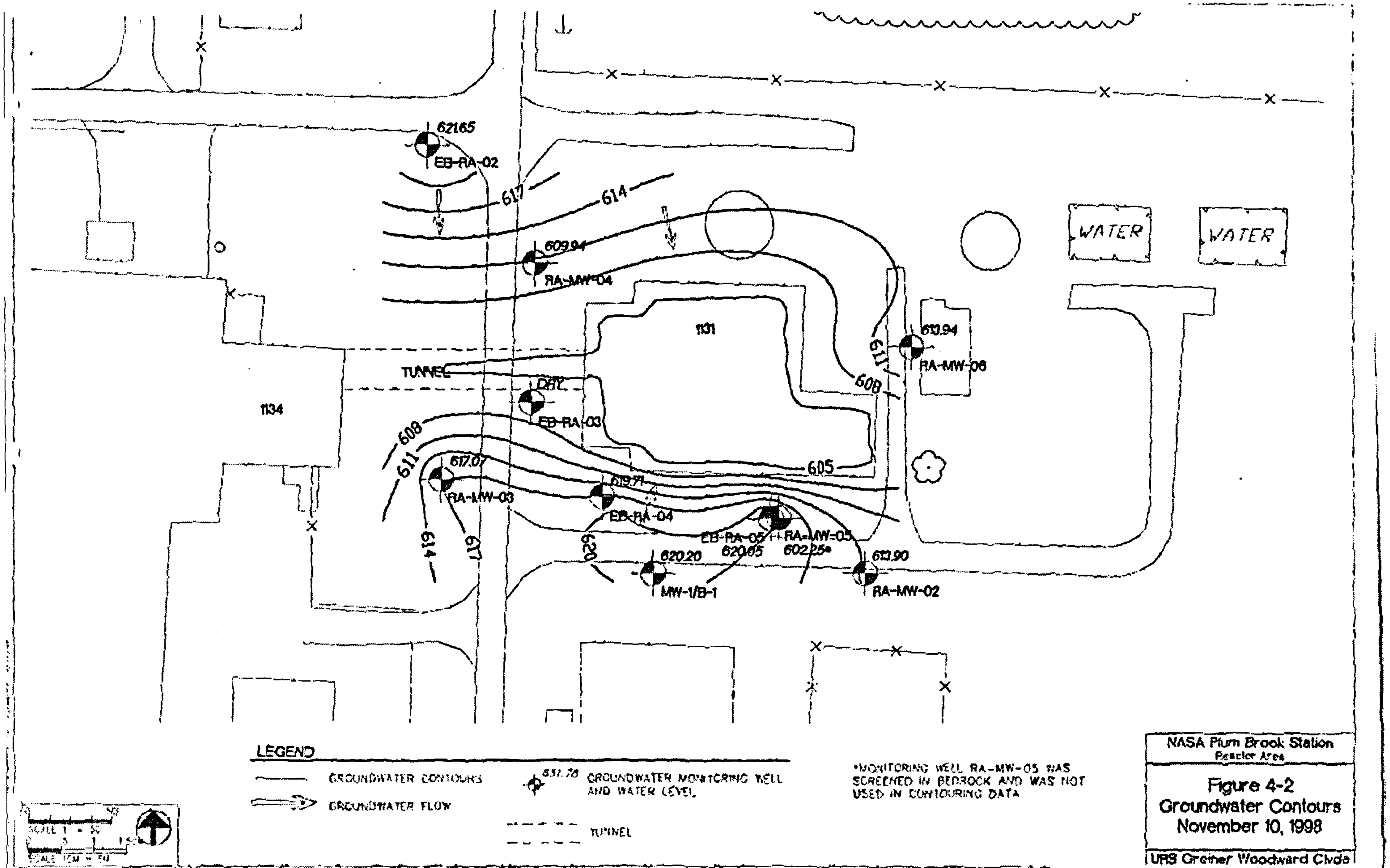


Figure 4-2
Groundwater Contours
November 10, 1998

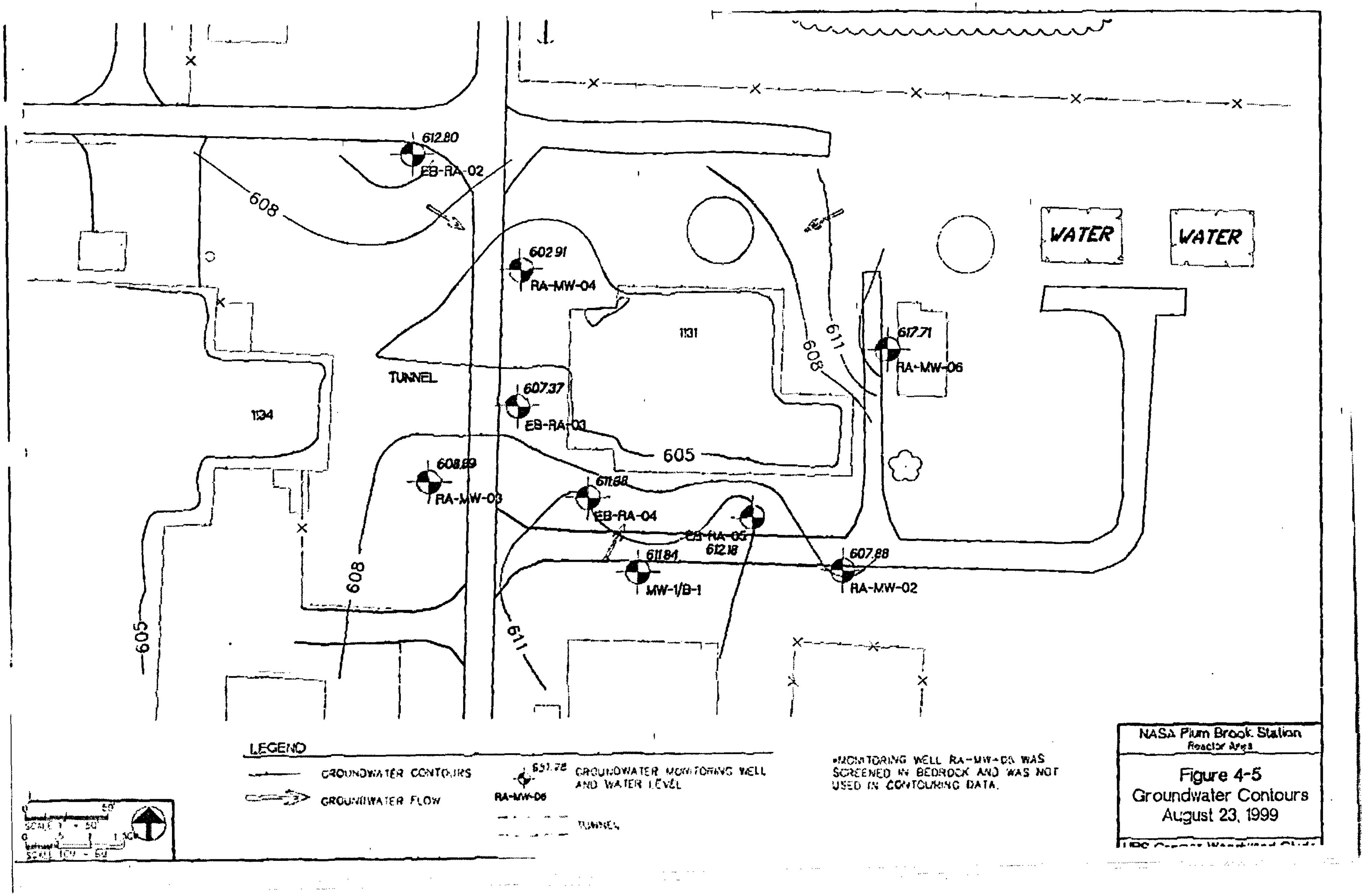
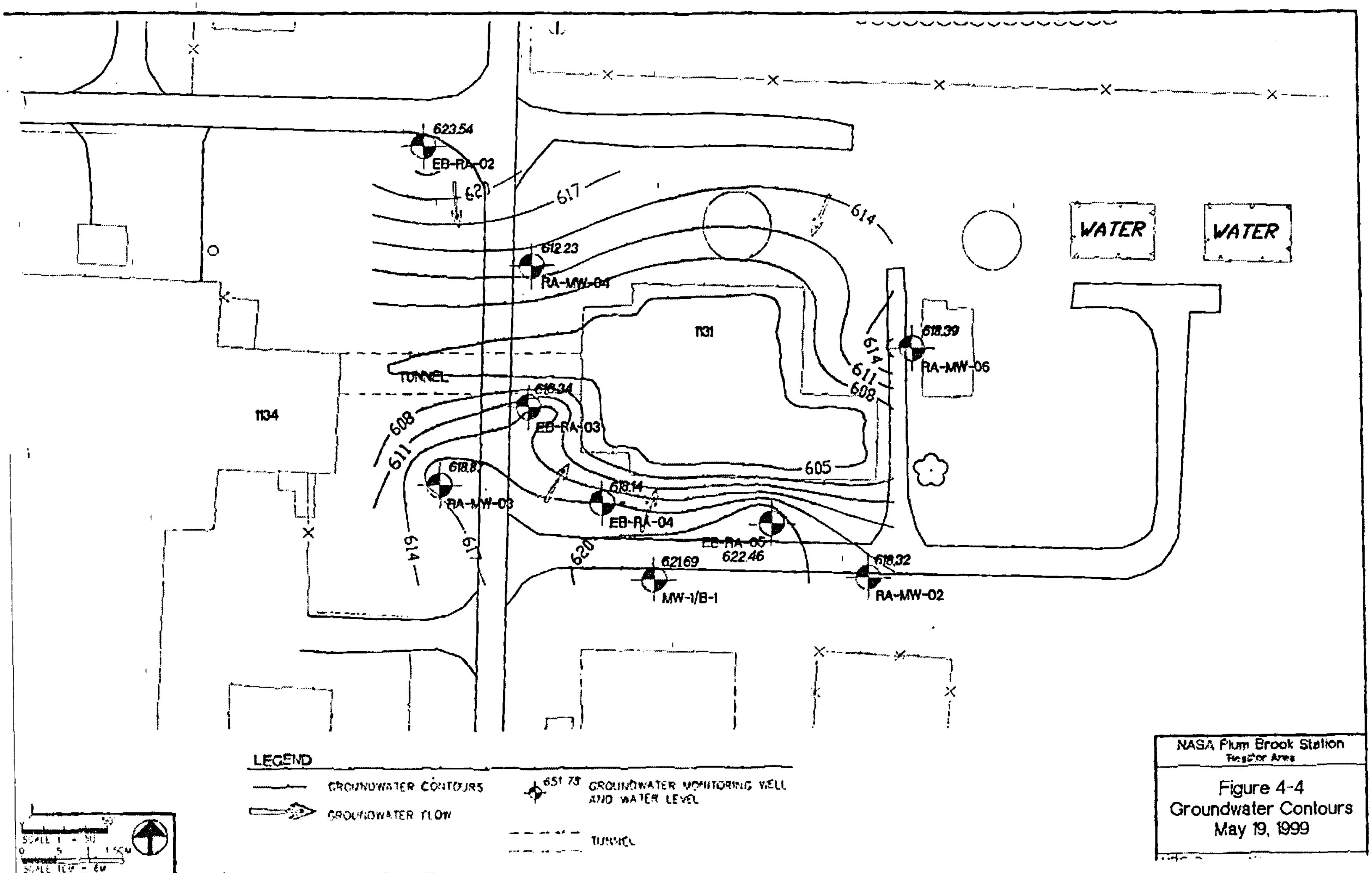
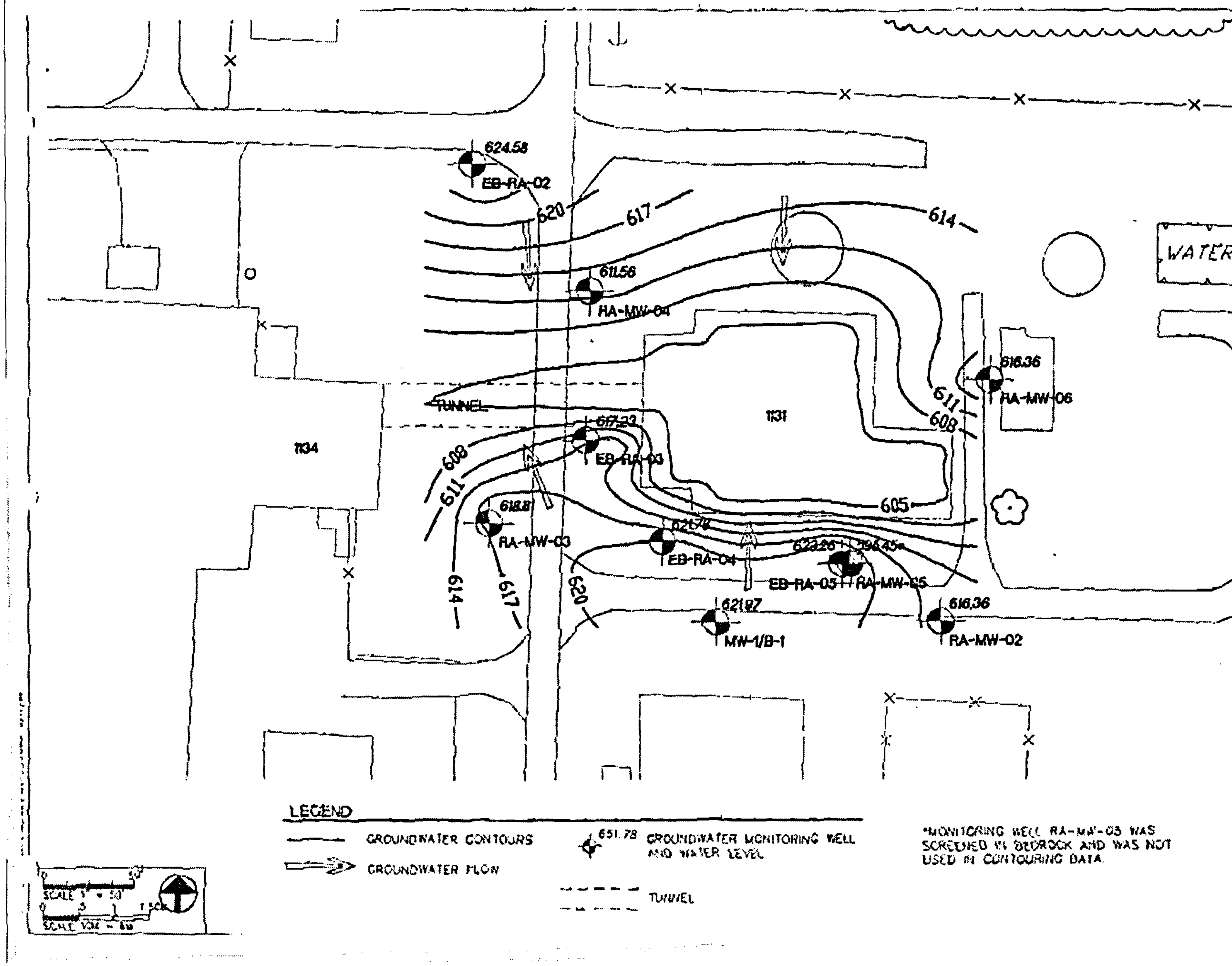


Figure 4-5
Groundwater Contours
August 23, 1999



NASA Plum Brook Station
Reactor Area

Figure 4-4
Groundwater Contours
May 19, 1999



NASA Plum Brook Station
Reactor Area

Figure 4-3
Groundwater Contours
February 17, 1999

Project: NASA Plum Brook, Reactor Area Project Location: Plum Brook, Ohio Project Number: 19-F0087521.00	# Log of Boring RA-MW-06 Sheet 1 of 1

Date(s) Drilled and Installed	September 8, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	23.9 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	627.64 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (18-23 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-14 feet, bentonite pellets 14-16 feet	Comments	Refer to site plan for well location.		

Elevation feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	0		1	NA	90	<1		GP	Sandy GRAVEL		8-in.-dia. borehole
								SM	Moist, brown, silty fine SAND		
			2	NA	90	<1					Concrete (0-2.5 ft)
625			3	NA	80	<1					
	5		4	NA	NA	<1					Bentonite-cement (2.5-14 ft)
620			5	NA	75	<1			grading to ...		2-in.-dia. stainless steel casing
								ML	Moist, gray, clayey SILT		
	10		6	NA	100	<1			Becomes wet		
			7	NA	100	<1		CL	Wet, gray, silty CLAY		
615			8	NA	100	<1					Bentonite pellets (14-16 ft)
	15		9	NA	100	<1			Becomes moist		#5 Global sand pack (16-23.9 ft)
610			10	NA	100	<1					
	20		11	NA	100	<1		CH	Moist, gray, very plastic CLAY		#10 slot stainless screen (18-23 ft)
			12	NA	50	<1			Becomes wet		
605									SHALE		
	25								Boring terminated at 23.9 feet due to auger refusal		
600											
	30										

Report: ENV_12 CLEVELAND; File: NASAPLUM.GPJ; 5/5/99

URS Greiner Woodward Clyde

Project: NASA Plum Brook, Reactor Area **Project Location:** Plum Brook, Ohio **Project Number:** 19-F0087521.00	**Log of Boring RA-MW-05** Sheet 2 of 2

Elevation feet	Depth, feet	SAMPLES: Type	SAMPLES: Number	SAMPLES: Sampling Resistance, blows / 6 in.	SAMPLES: Recovery, %	SAMPLES: Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	30								Gray LIMESTONE (continued)		2-in.-dia. stainless steel well casing
595											Bentonite pellets (30.5-34.5 ft)
	35										#5 Global sand pack (34.5-50 ft)
590											
	40										
585											
	45										#10 slot stainless steel screen (44-49 ft)
580											
	50								Bottom of boring at 50.0 feet Unconsolidated material was logged using soil cuttings.		
575											
	55										
570											
	60										
565											
	65										

Log of Boring RA-MW-05

Project: NASA Plum Brook, Reactor Area
Project Location: Plum Brook, Ohio
Project Number: 19-F0087521.00

Date(s) Drilled and Installed	September 21 and 29, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger, NX core, air rotary with roller bit	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	50.0 feet
Sampling Method	No sampling performed (boring logged from cuttings)	Hammer Data	Not applicable	Top of Casing Elevation	627.67 feet MSL
Size and Type of Well Casing	6-inch-ID galvanized steel 0-28 feet; 2-inch-dia. stainless steel 0-50 feet	Screen Perforation	#10 slot (44-49 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 26-30.5 feet, bentonite pellets 30.5-34.5 feet	Comments	Drilled to 26 ft using 8-1/4-in.-ID auger; to 28 ft with air rotary to set outer casing; cored through casing to 38.5 ft, reamed and drilled 50 ft with 5-7/8-in. roller bit		

Elevation feet	Depth, feet	SAMPLES: Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	0							ML	Moist, medium brown to light brown, sandy SILT		12-in.-dia. borehole (0-28 ft); Concrete (0-2.5 ft)
625											
	5							SM	Wet, brown, silty fine SAND		6-in.-ID galvanized steel outer casing, flush-threaded to 28 ft
620											Bentonite-ce: (2.5-25 ft)
	10								grading to ...		
615								CL	Wet, gray, sandy CLAY		2-in.-dia. stainless steel well casing
	15							CL	Wet, gray, plastic CLAY with trace silt and sand		
610											
	20								No silt or sand		
605									Weathered LIMESTONE, fractured		
	25								[Auger refusal at 26.0 feet]		Concrete plug (25-26 ft)
									Gray LIMESTONE		
600									...Bedrock releasing 18 ppm H_2S, LEL=16%		Bentonite-cement (26-30.5 ft); 6-in.-dia. boreh... (28-50 ft)
	30										

Project: NASA Plum Brook, Reactor Area **Project Location:** Plum Brook, Ohio **Project Number:** 19-F0087521.00	**Log of Boring RA-MW-04** Sheet 1 of 1

Date(s) Drilled and Installed	September 9, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	26.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	628.36 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (20-25 feet)	Approximate Surface Elevation	628.5 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-16 feet, bentonite pellets 16-18 feet	Comments	Refer to site plan for well location.		

Elevation feet	Depth, feet	SAMPLES: Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	FIELD NOTES AND WELL DETAILS
	0	1	NA	75	<1		Topsoil	8-in.-dia. borehole
						SM	Moist, brown, silty fine SAND	
		2	NA	90	<1			Concrete (0-4 ft)
625		3	NA	60	<1			
	5							Bentonite-cement (4-16 ft)
		4	NA	100	<1	SP	Wet, gray SAND with some dark gray organic streaking grading to ...	
						CL	Moist, gray, silty CLAY with thin sand seams	
620		5	NA	100	<1	SM	Wet, gray, silty fine SAND	2-in.-dia. stainless steel casing
	10	6	NA	90	<1	ML	Wet, gray SILT with some sand and clay, some organic streaking	
		7	NA	NA	<1	CL	Moist, gray, silty CLAY with trace fine sand and organic streaking	
615		8	NA	NA	<1	CL	Moist, gray, plastic CLAY	
	15						Silty	
		9	NA	100	<1		With trace organic streaking and sand seams to 1/8 inch thick	Bentonite pellets (16-18 ft)
610		10	NA	80	<1		With trace gravel fragments, no organic streaking or sand	
	20	11	NA	100	<1		With trace dark gray organic streaking, no gravel fragments	#5 Global sand pack (18-26 ft)
		12	NA	NA	<1		Becomes wet, more plastic	#10 slot stainless steel screen (20-25 ft)
605		13	NA	20	<1		With shale and limestone fragments 3/4 to 1 inch size	
	25							
							Boring terminated at 26.0 feet due to auger refusal	
600								
	30							

Report ENV_12 CLEVELAND; File NASAPLUM.GPJ; 5/5/99

Project: NASA Plum Brook, Reactor Area **Project Location:** Plum Brook, Ohio **Project Number:** 19-F0087521.00	**Log of Boring RA-MW-03** Sheet 1 of 1

Date(s) Drilled and Installed	September 8, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	22.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	627.82 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (15.5-20.5 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-11.5 feet, bentonite pellets 11.5-13.5 feet	Comments	Refer to site plan for well location.		

Elevation feet	Depth, feet	SAMPLES: Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	0		1	NA	75	<1			Topsoil		8-in.-dia. borehole
								ML	Moist, brown mottled SILT		Concrete (0-2 ft)
625			2	NA	75	<1		SM	Moist, gray-brown mottled, silty fine SAND with trace clay		
	5		3	NA	75	<1		SP-SM	Moist, brown mottled, fine SAND with trace silt		Bentonite-cement (2-11.5 ft)
			4	NA	90	<1		ML	Wet, gray, fine sandy SILT with some clay		
620			5	NA	NA	<1		ML	Wet, medium dark gray, fine sandy SILT with trace clay, some very fine sand seams at 2- to 3-inch intervals, some dark gray organic staining		2-in.-dia. stainless steel casing
	10		6	NA	100	<1			Becomes moist, gray, with no sand seams, trace dark gray organic streaking		
615			7	NA	100	<1		ML	Damp, gray SILT with little clay, trace dark gray organic streaking		Bentonite pellets (11.5-13.5 ft)
	15		8	NA	100	<1		CL	Damp, light to dark gray mottled CLAY with thin silt seams		#5 Global sand pack (13.5-22 ft)
			9	NA	100	<1					
610			10	NA	100	<1			Becomes dark gray, with trace dark black organic streaking		#10 slot stainless steel screen (15.5-20.5 ft)
	20		11	NA	100	<1			Becomes more plastic		
									With little shale fragments at end of split-spoon sampler		
605									Boring terminated at 22.0 feet due to auger refusal		
	25										
600											
	30										

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Project: NASA Plum Brook, Reactor Area
Project Location: Plum Brook, Ohio
Project Number: 19-F0087521.00

Log of Boring RA-MW-02

Sheet 1 of 1

Date(s) Drilled and Installed	September 9, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	25.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	628.07 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (19-25 feet)	Approximate Surface Elevation	628.5 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-15 feet, bentonite pellets 15-17 feet	Comments	Refer to site plan for well location.		

Elevation feet	Depth, feet	SAMPLES Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	FIELD NOTES AND WELL DETAILS
	0	1	2-4-5-9	75	<1		Topsoil	8-in.-dia. borehole
						SM	Loose, moist, brown, silty fine SAND	
		2	2-3-4-6	100	<1		With occasional silt interbeds	Concrete (0-3.5 ft)
625								
		3	6-7-12-12	100	<1		Becomes medium dense	
	5							
		4	2-3-4-5	100	<1		Becomes loose, wet, gray	Bentonite-cement (3.5-15 ft)
						CL	Medium stiff, wet, gray, sandy CLAY with some dark gray organic streaking	
620		5	3-2-4-6	75	<1	SM	Loose, wet, medium dark gray, silty fine SAND; grades lighter gray with depth	2-in.-dia. stainless steel casing
	10	6	2-2-3-4	100	<1	CL	Medium stiff, wet, gray, silty plastic CLAY	
		7	2-3-2-4	100	<1			
615								
		8	1-2-4-3	100	<1			
	15							
		9	1-2-3-3	100	<1			Bentonite pellets (15-17 ft)
610		10	1-2-1-1	100	<1		Becomes soft	#5 Global sand pack (17-25 ft)
	20	11	1-1-2-1	100	<1			
		12	1-1-2-10	100	<1	CL	Soft, wet, gray CLAY	#10 slot stainless steel screen (19-24 ft)
605								
		13	4-50/3"	20	<1		Weathered SHALE, wet, friable	
	25						Boring terminated at 25.0 feet due to auger refusal	
600								
	30							

Report: ENV_12 CLEVELAND File: NASAPLUM.GPJ 5/5/99

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URS GREINER

TEST BORING LOG

BORING NO.	RA-A1
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 9/2/98
	DATE FINISHED: 9/2/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL Date	Time	Level	TYPE		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	DESCRIPTION MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1		1	SS	3	6			75	0-1': Moist brown topsoil, sandy SILT	SM	<1	Boring back-filled with bentonite chips
2–3		2	SS	4	11	6	6	100	1-3': Dark brown grading to mottled medium to light brown fine sandy SILT. Trace clay	SM	<1	
4–5				4	3	3	3		3-5': Moist to wet, brown fine silty SAND	SM		
5		3	SS	4	1			100	5-6': Saturated fine SAND. Some silt	SM	<1	
6–7		4	SS	2	2	2	2	100	6-8': Wet, brown fine silty SAND, grading to moist, gray, soft plastic CLAY	SM CL	<1	
8–9		5	SS	2	2	4	4	100	8-10': Moist to wet, gray sandy SILT. Some clay. 1/8" fine sand seams spaced at 2-4"	SM	<1	
10–11		6	SS	1	1	3	6	100	10-12': Moist, gray, silty sandy CLAY	CL	<1	
12–13		7	SS	3	3	3	5	100	12-14'. Moist gray CLAY. Occasional 1/8" sand seams spaced 6-8" apart	CL	<1	
14–15		8	SS	2	2	5	5	100	14-16': Moist to wet gray clayey SILT. Some sandy seams END OF BORING	ML	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-A2
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 9/2/98
									DATE FINISHED: 9/2/98
				DIA.		2 in			DRILLER:
				WT.		140 lbs			GEOLOGIST: D Wazny
				FALL		30"			REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	DESCRIPTION MATERIAL DESCRIPTION	USCS CLASS	HNu Cont ppm	WELL CONSTRUCTION
0	.S.S.S								4-6" Topsoil			
1	.S.S.S	1	SS	2	7			75	0-1': Moist, brown silty SAND. Some roots and grass	SM	<1	Boring back-filled with bentonite chips
2	.S.S.S								1-3': Moist, dark brown, grading to medium brown, fine silty SAND			
3	.S.S.S	2	SS	4	10	9	7	100		SM	<1	
4	.S.S.S			6	5	4	4					
5	.S.S.S	3	SS	5	4			100	3-6': Moist, mottled brown/some gray, fine silty SAND	SM	<1	
6	.S.S.S											
7	.S.S.S	4	SS	3	3	3	3	100	6-8': Moist to wet, gray, fine silty SAND. Some clay	SM	<1	
8	.S.S.S											
9	.S.S.S	5	SS	2	3	4	5	100	8-10': Wet, gray, fine silty SAND. Some dark gray organic streaking	SM	<1	
10	.S.S.S											
11	.S.S.S	6	SS	2	2	3	5	100	10-12': Moist, gray, fine sandy SILT grading to silty CLAY	ML CL	<1	
12	\\\\\\											
13	\\\\\\	7	SS	2	4	4	3	100	12-14': Moist, gray, soft plastic CLAY	CL	<1	
14	\\\\\\											
15	\\\\\\	8	SS	2	2	2	3	100	14-16': Moist, gray, plastic CLAY	CL	<1	
16									END OF BORING			
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-A3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 9/2/98
	DATE FINISHED: 9/2/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2 in		
WT.		140 lbs		
FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0									Brown organic topsoil			Boring back-filled with bentonite chips
1		1	SS	4	9			75	0-1': Sandy SILT. Some large gravel in hole	SM	<1	
2–3		2	SS	7	9	4	4	100	1-3': Moist, brown, crumbly, fine silty SAND. Dark brown popssible discoloration from 1.5-2'.	SM	1	
4–5				5	4	3	2					
		3	SS	4	3			100	3-6': Moist to wet, brown, fine silty SAND. Trace clay	SM	<1	
6–7		4	SS	6	4	3	4	100	6-8': Wet, brown, fine silty SAND, grading to wet, gray, soft, plastic CLAY with sand	SM CL	<1	
8–9		5	SS	3	3	4	4	100	8-10': Moist to wet, medium gray, sandy SILT grading to clayey SILT. Dark gray-black streaking in 1/8" sand seams	SM SC	<1	
10–11		6	SS	1	3	3	4	100	10-12': Same as above. Becoming more stiff. Some dark gray-black organic streaking	SC	<1	
12–13		7	SS	2	4	4	5	100	12-14': Moist, gray, stiff CLAY with silt	CL	<1	
14–15		8	SS	1	2	3	4	100	14-16': Moist, gray, stiff plastic CLAY. Trace silt END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-B1
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

DATE STARTED:	8/27/98
DATE FINISHED:	8/27/98
DRILLER:	
GEOLOGIST:	D Wazny
REVIEWED BY:	

* POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV. %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1	S.S.S	1	SS	1	2			75	0-1'. Moist, brown silty SAND, grading to brown sand	SM	<1	Boring back-filled with bentonite chips
2–3		2	SS	1	2	1	2	30	1-3': Moist to dry, brown, loose SAND. (Fill)	SP	<1	
4–5		3	SS	2 / 2	3 / 3	3	2	75	3-6': Moist to dry, brown, loose SAND	SP	<1	
6–7		4	SS	1	1	3		30	6-8': Saturated brown SAND	SP	<1	
8–9		5	SS	WH				40	8-10': Saturated gray-green SAND	SP	<1	
10–11		6	SS	1	1/2			40	10-12': Saturated brown/gray, loose SAND	SP	<1	
12–13		7	SS	1	1	1	2	90	12-13.5': Same as above 13.5-14': Gray, plastic CLAY	CL	2	
14–15		8	SS	4	4	4	5	100	14-16'. Moist, gray, plastic CLAY END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-B2
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 8/31/98
	DATE FINISHED: 8/31/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0									0-4": Dry, brown sandy SILT			Boring back-filled with bentonite chips
1		1	SS	3	3			75	4"-1': Dry, brown, loose SAND	SP	<1	
2–3		2	SS	3	4	3	3	30	1-3': Dry, brown, loose SAND	SP	<1	
4–5		3	SS	3 / 2	2 / 3	2	4	75	3-6': Dry, brown, loose SAND	SP	<1	
6–7		4	SS	3	2	2	1	30	6-7': Wet brown SAND 7-7½': Wet, gray sandy CLAY 7½'-8': Wet gray SAND	SP CL SP	4	
8–9		5	SS	1	1	1	1	80	8-10': Wet to saturated gray-green SAND	SP	<1	
10–11		6	SS	1	2	1	2	100	10-12': Saturated gray-green SAND	SP	<1	
12–13		7	SS	WH				100	12-13.5': Saturated gray-green SAND 13.5-14': Gray, plastic CLAY	SP CL	<1	
14–15		8	SS	2	3	4	5	75	14-16': Wet, gray, plastic CLAY END OF BORING	CL	<1	
16–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-B3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 9/1/98
									DATE FINISHED: 9/1/98
				DIA.		2 in			DRILLER:
				WT.		140 lbs			GEOLOGIST: D Wazny
				FALL		30"			REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods • POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1		1	SS	2	7			75	2-3" gravel at surface 0-1': Moist, brown sandy SILT	SM	3	Boring back-filled with bentonite chips
2–3		2	SS	8	7	7	7	100	1-3' Dry, dark brown (discolored), crumbly, fine silty SAND	SM	<1	
4–5		3	SS	5 7	5 10	7	10	100	3-6': Dry, mottled brown fine silty SAND, grading to clayey SAND, to sandy CLAY at 5'	SM SC	<1	
6–7		4	SS	3	3	3	3	100	6-8': Moist to wet, brown, fine silty SAND grading to moist, gray silty sandy CLAY	SM CL	<1	
8–9		5	SS	2	3	5	4	90	8-10': Moist, gray, sandy CLAY. Some fine sand seams spaced 2-4" apart	SC	<1	
10–11		6	SS	2	2	3	3	100	10-12': Moist, gray, soft to medium stiff CLAY	CL	<1	
12–13		7	SS	2	2	2	3	100	12-14': Moist gray CLAY. Some sand	CL	<1	
14–15		8	SS	2	2	2	3	100	14-16': Wet, gray, plastic CLAY END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER

TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-C1
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:
	DATE STARTED: 8/27/98
	DATE FINISHED: 8/27/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

* POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV ROD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1	S.S.S	1	SS	2	3			75	0-6": Dry, brown sandy SILT. (Topsoil) 6"-1': Dry, brown, loose SAND	SP	<1	Boring back-filled with bentonite chips
2–3		2	SS	2	1	1	3	30	1-3'; Dry, brown, loose SAND	SP	<1	
4–5		3	SS	2 2	3 3	3	2	90	3-6': Dry, brown SAND	SP	<1	
6–7		4	SS	1	1	1	1	90	6-8': Moist, brown, loose SAND. Wet at 7.25'	SP	<1	
8–9		5	SS	1	2	WH		75	8-10': Saturated gray-green SAND	SP	<1	
10–11		6	SS	WH	3			80	10-11.5': Same as above 11.5-12': Moist, gray, plastic CLAY	SP CL	<1	
12–13		7	SS	2	3	3	4	40	12-14': Gray, plastic CLAY	CL	<1	
14–15		8	SS	2	2	4	4	100	14-16': Same as above END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-C2
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 8/31/98
	DATE FINISHED: 8/31/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV 100 %	MATERIAL DESCRIPTION	USCS CLASS	kg/cm² Cone	WELL CONSTRUCTION
0–1		1	SS	3	3			75	0-1': Dry, brown, loose SAND. Some grass at top	SP	<1	Boring back-filled with bentonite chips
2–3		2	SS	3	4	3	3	30	1-3': Same as above (Fill) 3-4': SAND (Fill)	SP SP	<l	
4–5	S.S.	3	SS	1 2	2 2	1	1	75	4-6': Dry, dark brown, fine silty SAND. Possible discoloration. No odor	SM	<1	
6–7		4	SS	1	1	1	1	30	6-8': Saturated, brown, grading to gray-green SAND	SP	<1	
8–9		5	SS	1	1	1	1	75	8-10': Saturated gray-green SAND. Some dark organic streaking	SP	<1	
10–11	S.S.	6	SS	3	1	1	3	100	10-12': Saturated, gray-green SAND. Fine silty SAND, grading to silty CLAY at tip	SP SM	<1	
12–13		7	SS	3	2	2	3	100	12-14': Moist, gray, plastic CLAY	CL	2	
14–15		8	SS	2	3	3	3	100	14-16': Moist, gray, very soft, plastic CLAY END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-C3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 9/1/98
	DATE FINISHED: 9/1/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2 in		
WT.		140 lbs		
FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1	S.S.S	1	SS	6	12			75	0-1': 2" brown sandy SILT topsoil, grading to brown, loose SAND. Re-sampled	SP	–	Boring back-filled with bentonite chips
2–3	S.S.S	2	SS	6	8	7	6	100	1-3': Moist to dry, dark brown, fine silty SAND. Discolored. Becoming mottled light brown in tip	SM	<1	
4–5	S.S.S			6	6	7	8					
		3	SS	12	12			75	3-6': Moist, brown, loose fine silty SAND	SM	<1	
6–7		4	SS	3	3	4	4	100	6-8': Moist to wet, gray, fine clayey SAND, grading to sandy CLAY	SC CL	<1	
8–9		5	SS	4	4	7	6	100	8-10': Moist to wet, gray sandy CLAY. Some 1/8" fine sandy seams	CL	<1	
10–11		6	SS	2	3	4	5	100	10-12': Moist, gray, plastic silty CLAY. Some sand	CL	<1	
12–13		7	SS	2	2	4	6	100	12-14': Moist, gray CLAY, becoming more stiff	CL	<1	
14–15		8	SS	2	2	3	4	100	14-16': Moist, gray plastic CLAY. Occasional thin sand seam	CL	<1	
16									END OF BORING			
17–29												

COMMENTS

URS GREINER
TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-D1
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 8/30/98
				DIA.		2 in			DATE FINISHED: 8/30/98
				WT.		140 lbs			DRILLER:
				FALL		30"			GEOLOGIST: D Wazny
									REVIEWED BY:

WL=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–2	S.S.S	1	SS	2	5			75	0-3": Topsoil 3"-1': Brown, loose SAND	SP	<1	Boring back-filled with bentonite chips
2–4	S.S.	2	SS	4	4	5	6	30	1-3': Dry, dark brown, organic silty SAND. Some roots near top	SP	<1	
4–6	S.S.	3	SS	3 4	2 3	3	3	75	3-5.5': Same as above 5.5-6': Moist, light brown, silty SAND, trace clay	SM	<1	
6–8		4	SS	2	2	2	6	30	6-8': Wet to saturated, brown SAND, grading to gray silty CLAY with interbedded sand seams	SP CL	<1	
8–10		5	SS	1	1	4	5	40	8-10': Wet, gray, soft plastic CLAY. Some interbedded sand seams	CL	<1	
10–12		6	SS	1	1	2	4	40	10-12': Moist to wet, gray CLAY with interbedded fine sands	CL	<1	
12–14		7	SS	1	2	3	3	90	12-14' Moist, gray with trace earthen red, soft CLAY	CL	<1	
14–16		8	SS	2	3	3	4	90	14-16': Moist, gray, plastic CLAY END OF BORING	CL	<1	

COMMENTS

URS GREINER
TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-D3
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:
	DATE STARTED: 9/1/98
	DATE FINISHED: 9/1/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2 in		
WT.		140 lbs		
FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	PID Conc ppm	WELL CONSTRUCTION
0–2	S S S	1	SS	3	8			75	0-1': 2-3" asphalt. Moist, mottled brown SILT 1-2': Dark brown sandy SILT. Discoloration	ML SM	<1	Boring back-filled with bentonite chips
2–4	S S S	2	SS	8	6	7	5	100	2-3': Brown silty SAND. Less discoloration	SM	1	
4–6	S S S	3	SS	4 / 5	4 / 6	4	4	75	4-6': Moist, brown, fine silty SAND. Wet at 5.5'	SM	1	
6–8	\ \ \	4	SS	4	3	3	4	100	6-8': Brown, fine silty, clayey SAND, grading to wet to moist, plastic soft, silty, sandy CLAY	SC CL	<1	
8–10	S S S	5	SS	3	3	5	7	100	8-10': Wet, gray, fine silty SAND grading to wet, gray clayey sandy SILT	SM	<1	
10–12	\ \ \	6	SS	1	1	3	4	100	10-12': Wet, gray plastic CLAY. Some sand	CL	<1	
12–14	\ \ \	7	SS	2	2	2	2	100	12-14': Moist, gray, plastic CLAY with silt	CL	<1	
14–16	\ \ \	8	SS	2	2	2	3	100	14-16': Moist to wet, gray plastic CLAY END OF BORING	CL	<1	
16–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-D2
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 8/31/98
	DATE FINISHED: 8/31/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1	.S.S.S	1	SS	4	16			75	0-1': Moist, brown, sandy SILT. Some gravel-size fragments	SM	<1	Boring back-filled with bentonite chips
2–3	.S.S.S	2	SS	9	4	12	12	30	1-3': Moist to dry, brown, crumbly fine sandy SILT turning dark brown. Possible stain at 2.5'	SM	<1	
4–5	.S.S.S /	3	SS	6 / 4	6 / 2	7	6	75	3-4.5': Same as above 4.5-6': Moist, light brown fine silty SAND. Saturated, medium-brown SAND at 5.5'	SM SP	<1	
6–7	.... / .S.S.S	4	SS	3	2	4	3	30	6-7.5': Same as above 7.5-8': Grades to sandy SILT. Gray plastic CLAY in tip	SP SM	<1	
8–9	\\\\\\	5	SS	2	4	5	5	95	8-10': Wet, gray CLAY with sand. Interbedded 1/8" sand seams spaced 2-3" apart	CL	<1	
10–11	\\\\\\	6	SS	2	4	5	6	100	10-12': Moist to wet, gray plastic CLAY. Some sand in thin seams	CL	<1	
12–13	\\\\\\	7	SS	2	3	4	5	100	12-14': Moist, gray, soft plastic CLAY	CL	<1	
14–15	\\\\\\	8	SS	2	3	3	3	100	14-16': Same as above END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER

TEST BORING LOG

BORING NO.	RA-E2.5
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 02/16/99
	DATE FINISHED: 02/16/99
	DRILLER:
	GEOLOGIST: J. Anderson
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–10												Boring back-filled with bentonite chips
10–12	\\\\\	1	SS	3	5	6	9	100	10-12'. Moist to wet, gray sandy SILT some clay	ML	<2.5	
12–14	\\\\\	2	SS	3	3	4	5	100	12-14'. Wet, gray, plastic silty CLAY	CL	<2.5	
14									END OF BORING			

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-E1.5
PROJECT NO.	
PROJECT: NASA PLUM BROOK	**SHEET NO.** 1 **OF** 1
CLIENT: NASA	**GROUND ELEVATION:**
BORING CONTRACTOR: Summit Drilling	**TOC ELEVATION:**
	DATE STARTED: 02/16/99
	DATE FINISHED: 02/16/99
	DRILLER:
	GEOLOGIST: J. Anderson
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–10												Boring back-filled with bentonite chips
10–12	\\\\\	1	SS	6	7	8	10	90	10-12': Moist, gray sandy, clayey SILT	ML	<2.5	
12–14	\\\\\	2	SS	8	6	6	7	90	12-14': Moist, gray, plastic sandy silty CLAY	CL		
14									END OF BORING			

COMMENTS

Reactor Area
NASA Plum Brook Station
Sandusky, Ohio

Amended Closure Plan

Volume 2 of 2

March, 2000

URS Greiner Woodward Clyde

Project: NASA Plum Brook, Reactor Area **Project Location:** Plum Brook, Ohio **Project Number:** 19-F0087521.00	# Log of Boring RA-MW-02 Sheet 1 of 1

Date(s) Drilled and Installed	September 9, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	25.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	828.07 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (19-25 feet)	Approximate Surface Elevation	828.5 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-15 feet, bentonite pellets 15-17 feet	Comments	Refer to site plan for well location.		

Elevation feet	Depth, feet	SAMPLES: Number	SAMPLES: Sampling Resistance, blows / 6 in.	SAMPLES: Recovery, %	SAMPLES: Headspace HNu, ppm	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION
	0	1	2-4-5-9	75	<1		Topsoil
						SM	Loose, moist, brown, silty fine SAND
		2	2-3-4-6	100	<1		With occasional silt interbeds
625		3	6-7-12-12	100	<1		Becomes medium dense
	5	4	2-3-4-5	100	<1		Becomes loose, wet, gray
						CL	Medium stiff, wet, gray, sandy CLAY with some dark gray organic streaking
620		5	3-2-4-6	75	<1	SM	Loose, wet, medium dark gray, silty fine SAND; grades lighter gray with depth
	10	6	2-2-3-4	100	<1	CL	Medium stiff, wet, gray, silty plastic CLAY
		7	2-3-2-4	100	<1		
615		8	1-2-4-3	100	<1		
	15	9	1-2-3-3	100	<1		
610		10	1-2-1-1	100	<1		Becomes soft
	20	11	1-1-2-1	100	<1		
		12	1-1-2-10	100	<1	CL	Soft, wet, gray CLAY
605		13	4-50/3"	20	<1		Weathered SHALE, wet, friable
	25						Boring terminated at 25.0 feet due to auger refusal
600							
	30						

FIELD NOTES AND WELL DETAILS (Well Completion Schematic)

- 8-in.-dia. borehole
- Concrete (0-3.5 ft)
- Bentonite-cement (3.5-15 ft)
- 2-in.-dia. stainless steel casing
- Bentonite pellets (15-17 ft)
- #5 Global sand pack (17-25 ft)
- #10 slot stainless steel screen (19-24 ft)

Project: NASA Plum Brook, Reactor Area	Log of Boring RA-MW-03
Project Location: Plum Brook, Ohio	Sheet 1 of 1
Project Number: 19-F0087521.00	

Date(s) Drilled and Installed	September 9, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	22.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	627.82 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (15.5-20.5 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-11.5 feet, bentonite pellets 11.5-13.5 feet	Comments	Refer to site plan for well location.		

Elevation, feet	Depth, feet	SAMPLES: Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	0		1	NA	75	<1			Topsoil		8-in.-dia. borehole
								ML	Moist, brown mottled SILT		Concrete (0-2 ft)
			2	NA	75	<1		SM	Moist, gray-brown mottled, silty fine SAND with trace clay		
625											
			3	NA	75	<1		SP-SM	Moist, brown mottled, fine SAND with trace silt		Bentonite-cement (2-11.5 ft)
	5										
			4	NA	90	<1		ML	Wet, gray, fine sandy SILT with some clay		
620			5	NA	NA	<1		ML	Wet, medium dark gray, fine sandy SILT with trace clay, some very fine sand seams at 2- to 3-inch intervals, some dark gray organic staining		2-in.-dia. stainless steel casing
	10		6	NA	100	<1			Becomes moist, gray, with no sand seams, trace dark gray organic streaking		
			7	NA	100	<1		ML	Damp, gray SILT with little clay, trace dark gray organic streaking		Bentonite pellets (11.5-13.5 ft)
615											
			8	NA	100	<1		CL	Damp, light to dark gray mottled CLAY with thin silt seams		#5 Global sand pack (13.5-22 ft)
	15										
			9	NA	100	<1					#10 slot stainless steel screen (15.5-20.5 ft)
610			10	NA	100	<1			Becomes dark gray, with trace dark black organic streaking		
	20		11	NA	100	<1			Becomes more plastic		
									With little shale fragments at end of split-spoon sampler		
									Boring terminated at 22.0 feet due to auger refusal		
605											
	25										
600											
	30										

Report: ENV_12_CLEVELAND; File NASAPLUM.GPJ;

Project: NASA Plum Brook, Reactor Area Project Location: Plum Brook, Ohio Project Number: 19-F0087521.00	**Log of Boring RA-MW-04** Sheet 1 of 1

Date(s) Drilled and Installed	September 9, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	26.0 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	628.36 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (20-25 feet)	Approximate Surface Elevation	628.5 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-16 feet, bentonite pellets 16-18 feet	Comments	Refer to site plan for well location.		

Elevation, feet: 625, 620, 615, 610, 605, 600
Depth, feet: 0, 5, 10, 15, 20, 25, 30

SAMPLES: Type / Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	FIELD NOTES AND WELL DETAILS
1	NA	75	<1	SM	Topsoil Moist, brown, silty fine SAND	8-in.-dia. borehole
2	NA	90	<1			Concrete (0-4 ft)
3	NA	80	<1			
4	NA	100	<1	SP CL	Wet, gray SAND with some dark gray organic streaking grading to... Moist, gray, silty CLAY with thin sand seams	Bentonite-cement (4-16 ft)
5	NA	100	<1	SM	Wet, gray, silty fine SAND	2-in.-dia. stainless steel casing
6	NA	90	<1	ML	Wet, gray SILT with some sand and clay, some organic streaking	
7	NA	NA	<1	CL	Moist, gray, silty CLAY with trace fine sand and organic streaking	
8	NA	NA	<1	CL	Moist, gray, plastic CLAY Silty	
9	NA	100	<1		With trace organic streaking and sand seams to 1/8 inch thick	Bentonite pellets (16-18 ft)
10	NA	80	<1		With trace gravel fragments, no organic streaking or sand	
11	NA	100	<1		With trace dark gray organic streaking, no gravel fragments	#5 Global sand pack (18-26 ft)
12	NA	NA	<1		Becomes wet, more plastic	#10 slot stainless steel screen (20-25 ft)
13	NA	20	<1		With shale and limestone fragments 3/4 to 1 inch size	
					Boring terminated at 26.0 feet due to auger refusal	

Report ENV_12_CLEVELAND File NASAPLUM.GPJ 5/5/99

Project: NASA Plum Brook, Reactor Area Project Location: Plum Brook, Ohio Project Number: 19-F0087521.00	# Log of Boring RA-MW-05 Sheet 1 of 2

Date(s) Drilled and Installed	September 21 and 29, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger, NX core, air rotary with roller bit	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	50.0 feet
Sampling Method	No sampling performed (boring logged from cuttings)	Hammer Data	Not applicable	Top of Casing Elevation	627.67 feet MSL
Size and Type of Well Casing	6-inch-ID galvanized steel 0-28 feet; 2-inch-dia. stainless steel 0-50 feet	Screen Perforation	#10 slot (44-49 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 26-30.5 feet, bentonite pellets 30.5-34.5 feet	Comments	Drilled to 26 ft using 8-1/4-in.-ID auger; to 28 ft with air rotary to set outer casing; cored through casing to 38.6 ft, reamed and drilled 50 ft with 5-7/8-in. roller bit		

Elevation feet	Depth, feet	SAMPLES: Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	0							ML	Moist, medium brown to light brown, sandy SILT		12-in.-dia. borehole (0-28 ft); Concrete (0-2.5 ft)
625											
	5							SM	Wet, brown, silty fine SAND		6-in.-ID galvanized steel outer casing, flush-threaded to 28 ft
620											Bentonite-cem (2.5-25 ft)
	10										
									grading to ...		
								CL	Wet, gray, sandy CLAY		
615											2-in.-dia. stainless steel well casing
	15							CL	Wet, gray, plastic CLAY with trace silt and sand		
610											
	20								No silt or sand		
605											
									Weathered LIMESTONE, fractured		
	25										Concrete plug (25-26 ft)
									[Auger refusal at 26.0 feet]		
									Gray LIMESTONE		
600									....Bedrock releasing 18 ppm H_2S, LEL=16%		Bentonite-cement (26-30.5 ft); 6-in.-dia. boreh. (26-50 ft)
	30										

Project: NASA Plum Brook, Reactor Area
Project Location: Plum Brook, Ohio
Project Number: 19-F0087521.00

Log of Boring RA-MW-05

Elevation feet	Depth, feet	Type	Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm	Graphic Log	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION	Well Completion Schematic	FIELD NOTES AND WELL DETAILS
	30								Gray LIMESTONE (continued)		2-in.-dia. stainless steel well casing
-595											Bentonite pellets (30.5-34.5 ft)
	35										#5 Global sand pack (34.5-50 ft)
-590											
	40										
-585											
	45										#10 slot stainless steel screen (44-49 ft)
-580											
	50								Bottom of boring at 50.0 feet Unconsolidated material was logged using soil cuttings.		
-575											
	55										
-570											
	60										
-565											
	65										

Report: ENV_12_CLEVELAND; File: NASAPLUM.GPJ; 5/5/99

Project:	NASA Plum Brook, Reactor Area
Project Location:	Plum Brook, Ohio
Project Number:	19-F0087521.00

Log of Boring RA-MW-06

Sheet 1 of 1

Date(s) Drilled and Installed	September 8, 1998	Geologist	J. Anderson	Reviewer	J. Berk
Drilling Method	Hollow-stem auger	Drilling Contractor	Summit Drilling, Inc.	Total Depth of Borehole	23.9 feet
Sampling Method	2-inch-dia. unlined split spoon	Hammer Data	140 lbs / 30-inch drop	Top of Casing Elevation	627.64 feet MSL
Size and Type of Well Casing	2-inch-dia. stainless steel	Screen Perforation	#10 slot (18-23 feet)	Approximate Surface Elevation	628 feet MSL
Seal or Backfill	Bentonite-cement grout 3.5-14 feet, bentonite pellets 14-16 feet	Comments	Refer to site plan for well location.		

Sample Number	Sampling Resistance, blows / 6 in.	Recovery, %	Headspace HNu, ppm
1	NA	90	<1
2	NA	90	<1
3	NA	80	<1
4	NA	NA	<1
5	NA	75	<1
6	NA	100	<1
7	NA	100	<1
8	NA	100	<1
9	NA	100	<1
10	NA	100	<1
11	NA	100	<1
12	NA	50	<1

Depth, feet (approx.)	Lithologic Log (USCS Code)	MATERIAL DESCRIPTION
0	GP	Sandy GRAVEL
0.5	SM	Moist, brown, silty fine SAND
9		grading to ...
9	ML	Moist, gray, clayey SILT
10		Becomes wet
12	CL	Wet, gray, silty CLAY
16		Becomes moist
20	CH	Moist, gray, very plastic CLAY
22		Becomes wet
23		SHALE
23.9		Boring terminated at 23.9 feet due to auger refusal

FIELD NOTES AND WELL DETAILS

- 8-in.-dia. borehole
- Concrete (0-2.5 ft)
- Bentonite-cement (2.5-14 ft)
- 2-in.-dia. stainl. steel casing
- Bentonite pellets (14-16 ft)
- #5 Global sand pack (16-23.9 ft)
- #10 slot stainless screen (18-23 ft)

Report: ENV_12_CLEVELAND; File: NASAPLUM.GPJ; 5/5/99

URS Greiner Woodward Clyde

URS GREINER

TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-A1
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 9/2/98
				DIA.		2 in			DATE FINISHED: 9/2/98
				WT.		140 lbs			DRILLER:
				FALL		30"			GEOLOGIST: D Wazny
									REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–2		1	SS	3	6			75	0-2'. Moist brown topsoil, sandy SILT	SM	<1	Boring back-filled with bentonite chips
2–4		2	SS	4	11	6	6	100	2-3': Dark brown grading to mottled medium to light brown fine sandy SILT. Trace clay	SM	<1	
4–6				4	3	3	3		3-5'. Moist to wet, brown fine silty SAND	SM		
		3	SS	4	1			100	5-6'. Saturated fine SAND. Some silt	SM	<1	
6–8		4	SS	2	2	2	2	100	6-8': Wet, brown fine silty SAND, grading to moist, gray, soft plastic CLAY	SM CL	<1	
8–10		5	SS	2	2	4	4	100	8-10'. Moist to wet, gray sandy SILT. Some clay. 1/8" fine sand seams spaced at 2-4"	SM	<1	
10–12		6	SS	1	1	3	6	100	10-12': Moist, gray, silty sandy CLAY	CL	<1	
12–14		7	SS	3	3	3	5	100	12-14': Moist gray CLAY. Occasional 1/8" sand seams spaced 6-8" apart	CL	<1	
14–16		8	SS	2	2	5	5	100	14-16'. Moist to wet gray clayey SILT. Some sandy seams END OF BORING	ML	<1	

COMMENTS

URS GREINER

TEST BORING LOG

PROJECT: NASA PLUM BROOK							BORING NO. RA-A2
CLIENT: NASA							PROJECT NO.
BORING CONTRACTOR: Summit Drilling							SHEET NO. 1 OF 1
GROUND WATER LEVEL				CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE	SS		
				DIA.	2 in		
				WT.	140 lbs		
				FALL	30"		
				WH=Wt of Hammer	WR=Wt of Rods		

GROUND ELEVATION:

TOC ELEVATION:

DATE STARTED: 9/2/98

DATE FINISHED: 9/2/98

DRILLER:

GEOLOGIST: D Wazny

REVIEWED BY:

* POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV FOOT %	MATERIAL DESCRIPTION	USCS CLASS	PEN Cone tsf	WELL CONSTRUCTION
0–1	S.S.S	1	SS	2	7			75	0-0.5' Topsoil 0-1': Moist, brown silty SAND. Some roots and grass	SM	<1	Boring back-filled with bentonite chips
2–3	S.S.S	2	SS	4	10	9	7	100	1-3': Moist, dark brown, grading to medium brown, fine silty SAND	SM	<1	
4–5	S.S.S	3	SS	6 5	5 4	4	4	100	3-6'. Moist, mottled brown/some gray, fine silty SAND	SM	<1	
6–7	S.S.S	4	SS	3	3	3	3	100	6-8': Moist to wet, gray, fine silty SAND. Some clay	SM	<1	
8–9	S.S.S	5	SS	2	3	4	5	100	8-10'. Wet, gray, fine silty SAND. Some dark gray organic streaking	SM	<1	
10–11	S.S.S	6	SS	2	2	3	5	100	10-12': Moist, gray, fine sandy SILT grading to silty CLAY	ML CL	<1	
12–13	\\\\\	7	SS	2	4	4	3	100	12-14' Moist, gray, soft plastic CLAY	CL	<1	
14–15	\\\\\	8	SS	2	2	2	3	100	14-16': Moist, gray, plastic CLAY END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER

TEST BORING LOG

BORING NO.	RA-A3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 9/2/98
									DATE FINISHED: 9/2/98
				DIA.		2 in			DRILLER:
				WT.		140 lbs			GEOLOGIST: D Wazny
				FALL		30"			REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV 100%	DESCRIPTION MATERIAL DESCRIPTION	USCS CLASS	KPa Cone ppm	WELL CONSTRUCTION
0–2		1	SS	4	9			75	Brown organic topsoil 0-1': Sandy SILT. Some large gravel in hole	SM	<1	Boring back-filled with bentonite chips
2–4		2	SS	7	9	4	4	100	1-3' Moist, brown, crumbly, fine silty SAND Dark brown poprsible discoloration from 1.5-2'.	SM	1	
4–6		3	SS	5 / 4	4 / 3	3	2	100	3-6'. Moist to wet, brown, fine silty SAND. Trace clay	SM	<1	
6–8		4	SS	6	4	3	4	100	6-8': Wet, brown, fine silty SAND, grading to wet, gray, soft, plastic CLAY with sand	SM CL	<1	
8–10		5	SS	3	3	4	4	100	8-10': Moist to wet, medium gray, sandy SILT grading to clayey SILT Dark gray-black streaking in 1/8" sand seams	SM SC	<1	
10–12		6	SS	1	3	3	4	100	10-12': Same as above. Becoming more stiff. Some dark gray-black organic streaking	SC	<1	
12–14		7	SS	2	4	4	5	100	12-14' Moist, gray, stiff CLAY with silt	CL	<1	
14–16		8	SS	1	2	3	4	100	14-16'. Moist, gray, stiff plastic CLAY. Trace silt END OF BORING	CL	<1	
16–18												
18–20												
20–22												
22–24												
24–26												
26–28												
28–29												

COMMENTS

URS GREINER

TEST BORING LOG

BORING NO.	RA-B1
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

DATE STARTED:	8/27/98
DATE FINISHED:	8/27/98
DRILLER:	
GEOLOGIST:	D Wazny
REVIEWED BY:	

* POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1	S.S.S	1	SS	1	2			75	0-1': Moist, brown silty SAND, grading to brown sand	SM	<1	Boring back-filled with bentonite chips
2–3		2	SS	1	2	1	2	30	1-3': Moist to dry, brown, loose SAND. (Fill)	SP	<1	
4–5		3	SS	2 / 2	3 / 3	3	2	75	3-6': Moist to dry, brown, loose SAND	SP	<1	
6–7		4	SS	1	1	3		30	6-8': Saturated brown SAND	SP	<1	
8–9		5	SS	WH				40	8-10': Saturated gray-green SAND	SP	<1	
10–11		6	SS	1	1/2			40	10-12': Saturated brown/gray, loose SAND	SP	<1	
12–13		7	SS	1	1	1	2	90	12-13.5': Same as above 13.5-14': Gray, plastic CLAY	CL	2	
14–15		8	SS	4	4	4	5	100	14-16': Moist, gray, plastic CLAY END OF BORING	CL	<1	
16–29												

COMMENTS

URS GREINER

TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-B2
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:
	DATE STARTED: 8/31/98
	DATE FINISHED: 8/31/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

* POCKET PENETROMETER READING

DEPTH FT	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–2	1	SS	3	3			75	0-4": Dry, brown sandy SILT 4"-1': Dry, brown, loose SAND	SP	<1	Boring back-filled with bentonite chips
2–4	2	SS	3	4	3	3	30	1-3': Dry, brown, loose SAND	SP	<1	
4–6	3	SS	3 2	2 3	2	4	75	3-6': Dry, brown, loose SAND	SP	<1	
6–8	4	SS	3	2	2	1	30	6-7': Wet brown SAND 7-7.4': Wet, gray sandy CLAY 7.4'-8': Wet gray SAND	SP CL SP	4	
8–10	5	SS	1	1	1	1	80	8-10': Wet to saturated gray-green SAND	SP	<1	
10–12	6	SS	1	2	1	2	100	10-12': Saturated gray-green SAND	SP	<1	
12–14	7	SS	WH				100	12-13.5': Saturated gray-green SAND 13.5-14': Gray, plastic CLAY	SP CL	<1	
14–16	8	SS	2	3	4	5	75	14-16': Wet, gray, plastic CLAY END OF BORING	CL	<1	

COMMENTS

URS GREINER

TEST BORING LOG

BORING NO.	RA-B3
PROJECT NO.	
PROJECT:	NASA PLUM BROOK
CLIENT:	NASA
BORING CONTRACTOR:	Summit Drilling
SHEET NO. 1 OF 1	
GROUND ELEVATION:	
TOC ELEVATION:	
DATE STARTED:	9/1/98
DATE FINISHED:	9/1/98
DRILLER:	
GEOLOGIST:	D Wazny
REVIEWED BY:	

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

* POCKET PENETROMETER READING

DEPTH FT	SAMPLE NO.	TYPE	BLOWS PER 6"	RECOV. %	DESCRIPTION MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–2	1	SS	2 7	75	2-3" gravel at surface 0-1'. Moist, brown sandy SILT	SM	3	Boring back-filled with bentonite chips
2–4	2	SS	8 7 7 7	100	1-3':Dry, dark brown (discolored), crumbly, fine silty SAND	SM	<1	
4–6	3	SS	5 3 7 10 7 10	100	3-6': Dry, mottled brown fine silty SAND, grading to clayey SAND, to sandy CLAY at 5'	SM SC	<1	
6–8	4	SS	3 3 3 3	100	6-8': Moist to wet, brown, fine silty SAND grading to moist, gray silty sandy CLAY	SM CL	<1	
8–10	5	SS	2 3 5 4	90	8-10'. Moist, gray, sandy CLAY. Some fine sand seams spaced 2-4" apart	SC	<1	
10–12	6	SS	2 2 3 3	100	10-12'. Moist, gray, soft to medium stiff CLAY	CL	<1	
12–14	7	SS	2 2 2 3	100	12-14'. Moist gray CLAY. Some sand	CL	<1	
14–16	8	SS	2 2 2 3	100	14-16'. Wet, gray, plastic CLAY END OF BORING	CL	<1	
16–29								

COMMENTS

URS GREINER
TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-C1
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 8/27/98
				DIA.		2 in			DATE FINISHED: 8/27/98
				WT.		140 lbs			DRILLER:
				FALL		30"			GEOLOGIST: D Wazny
									REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV ROD %	MATERIAL DESCRIPTION	USCS CLASS	PID Conc ppm	WELL CONSTRUCTION
0–1		1	SS	2	3			75	0-6": Dry, brown sandy SILT (Topsoil) 6"-1': Dry, brown, loose SAND	SP	<1	Boring back-filled with bentonite chips
2–3		2	SS	2	1	1	3	30	1-3': Dry, brown, loose SAND	SP	<1	
4–5		3	SS	2	3	3	2					
				2	3			90	3-6': Dry, brown SAND	SP	<1	
6–7		4	SS	1	1	1	1	90	6-8': Moist, brown, loose SAND. Wet at 7.25'	SP	<1	
8–9		5	SS	1	2	WH		75	8-10': Saturated gray-green SAND	SP	<1	
10–11		6	SS	WH	3			80	10-11.5': Same as above 11.5-12': Moist, gray, plastic CLAY	SP CL	<1	
12–13		7	SS	2	3	3	4	40	12-14': Gray, plastic CLAY	CL	<1	
14–15		8	SS	2	2	4	4	100	14-16': Same as above END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-C2
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE		
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED:	8/31/98
				DIA.		2 in			DATE FINISHED:	8/31/98
				WT.		140 lbs			DRILLER:	
				FALL		30"			GEOLOGIST:	D Wazny
									REVIEWED BY:	

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOVERY %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0-2	. . . .	1	SS	3	3			75	0-1': Dry, brown, loose SAND. Some grass at top	SP	<1	Boring back-filled with bentonite chips
2-4	. . . .	2	SS	3	4	3	3	30	1-3': Same as above (Fill) 3-4': SAND (Fill)	SP SP	<1	
4-6	. S . S .	3	SS	1 2	2 2	1	1	75	4-6': Dry, dark brown, fine silty SAND. Possible discoloration. No odor	SM	<1	
6-8	. . . .	4	SS	1	1	1	1	30	6-8': Saturated, brown, grading to gray-green SAND	SP	<1	
8-10	. . . .	5	SS	1	1	1	1	75	8-10': Saturated gray-green SAND. Some dark organic streaking	SP	<1	
10-12	. . . . / . S . S .	6	SS	3	1	1	3	100	10-12': Saturated, gray-green SAND. Fine silty SAND, grading to silty CLAY at tip	SP SM	<1	
12-14	\\\\\\	7	SS	3	2	2	3	100	12-14': Moist, gray, plastic CLAY	CL	2	
14-16	\\\\\\	8	SS	2	3	3	3	100	14-16': Moist, gray, very soft, plastic CLAY END OF BORING	CL	<1	

COMMENTS

URS GREINER

TEST BORING LOG

BORING NO.	RA-C3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 9/1/98
	DATE FINISHED: 9/1/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV RQD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–1		1	SS	6	12			75	0-1': 2" brown sandy SILT topsoil, grading to brown, loose SAND. Re-sampled	SP		Boring back-filled with bentonite chips
2–3		2	SS	6	8	7	6	100	1-3': Moist to dry, dark brown, fine silty SAND. Discolored. Becoming mottled light brown in tip	SM	<1	
4–5		3	SS	6	6	7	8					
				12	12			75	3-6': Moist, brown, loose fine silty SAND	SM	<1	
6–7		4	SS	3	3	4	4	100	6-8': Moist to wet, gray, fine clayey SAND, grading to sandy CLAY	SC CL	<1	
8–9		5	SS	4	4	7	6	100	8-10': Moist to wet, gray sandy CLAY. Some 1/8" fine sandy seams	CL	<1	
10–11		6	SS	2	3	4	5	100	10-12'. Moist, gray, plastic silty CLAY. Some sand	CL	<1	
12–13		7	SS	2	2	4	6	100	12-14': Moist, gray CLAY, becoming more stiff	CL	<1	
14–15		8	SS	2	2	3	4	100	14-16': Moist, gray plastic CLAY. Occasional thin sand seam	CL	<1	
16									END OF BORING			
17												
18												
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29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-D1
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods

DATE STARTED:	8/30/98
DATE FINISHED:	8/30/98
DRILLER:	
GEOLOGIST:	D Wazny
REVIEWED BY:	

* POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"	RECOV ROD %	MATERIAL DESCRIPTION	USCS CLASS	PID Conc ppm	WELL CONSTRUCTION
0–2	. S . S	1	SS	2 5	75	0-3": Topsoil 3"-1': Brown, loose SAND	SP	<1	Boring back-filled with bentonite chips
2–4	. S . S	2	SS	4 4 5 6	30	1-3': Dry, dark brown, organic silty SAND. Some roots near top	SP	<1	
4–6	. S . S	3	SS	3 2 3 3 / 4 3	75	3-5.5': Same as above 5.5-6': Moist, light brown, silty SAND, trace clay	SM	<1	
6–8		4	SS	2 2 2 6	30	6-8': Wet to saturated, brown SAND, grading to gray silty CLAY with interbedded sand seams	SP CL	<1	
8–10		5	SS	1 1 4 5	40	8-10': Wet, gray, soft plastic CLAY. Some interbedded sand seams	CL	<1	
10–12		6	SS	1 1 2 4	40	10-12': Moist to wet, gray CLAY with interbedded fine sands	CL	<1	
12–14		7	SS	1 2 3 3	90	12-14': Moist, gray with trace earthen red, soft CLAY	CL	<1	
14–16		8	SS	2 3 3 4	90	14-16': Moist, gray, plastic CLAY END OF BORING	CL	<1	

COMMENTS

URS GREINER

TEST BORING LOG

PROJECT: NASA PLUM BROOK	BORING NO. RA-D2
CLIENT: NASA	PROJECT NO.
BORING CONTRACTOR: Summit Drilling	SHEET NO. 1 OF 1
	GROUND ELEVATION:
	TOC ELEVATION:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE	
Date	Time	Level	TYPE	TYPE		SS			DATE STARTED: 8/31/98
									DATE FINISHED: 8/31/98
				DIA.		2 in			DRILLER:
				WT.		140 lbs			GEOLOGIST: D Wazny
				FALL		30"			REVIEWED BY:

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	PID (ppm)	WELL CONSTRUCTION
0–1	S.S.S	1	SS	4	16			75	0-1': Moist, brown, sandy SILT. Some gravel-size fragments	SM	<1	Boring back-filled with bentonite chips
2–3	S.S.S	2	SS	9	4	12	12	30	1-3': Moist to dry, brown, crumbly fine sandy SILT turning dark brown. Possible stain at 2.5'	SM	<1	
4–5	S.S.S /	3	SS	6 / 4	6 / 2	7	6	75	3-4.5': Same as above 4.5-6': Moist, light brown fine silty SAND. Saturated, medium-brown SAND at 5.5'	SM SP	<1	
6–7	.... / S.S.S	4	SS	3	2	4	3	30	6-7.5': Same as above 7.5-8': Grades to sandy SILT. Gray plastic CLAY in tip	SP SM	<1	
8–9	\\\\\\	5	SS	2	4	5	5	95	8-10': Wet, gray CLAY with sand. Interbedded 1/8" sand seams spaced 2-3" apart	CL	<1	
10–11	\\\\\\	6	SS	2	4	5	6	100	10-12': Moist to wet, gray plastic CLAY. Some sand in thin seams	CL	<1	
12–13	\\\\\\	7	SS	2	3	4	5	100	12-14': Moist, gray, soft plastic CLAY	CL	<1	
14–15	\\\\\\	8	SS	2	3	3	3	100	14-16': Same as above END OF BORING	CL	<1	
16–17												
18–19												
20–21												
22–23												
24–25												
26–27												
28–29												

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-D3
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 9/1/98
	DATE FINISHED: 9/1/98
	DRILLER:
	GEOLOGIST: D Wazny
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"	RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–2	S	1	SS	3, 8	75	0-1': 2-3" asphalt. Moist, mottled brown SILT 1-2': Dark brown sandy SILT. Discoloration	ML SM	<1	Boring back-filled with bentonite chips
2–4	S	2	SS	4, 6, 7, 5	100	2-3': Brown silty SAND. Less discoloration	SM	1	
4–6	S	3	SS	4, 4, 4, 4, 5, 6	75	4-6': Moist, brown, fine silty SAND. Wet at 5.5'	SM	1	
6–8	SC/CL	4	SS	4, 3, 3, 4	100	6-8': Brown, fine silty, clayey SAND, grading to wet to moist, plastic soft, silty, sandy CLAY	SC CL	<1	
8–10	S	5	SS	3, 3, 5, 7	100	8-10': Wet, gray, fine silty SAND grading to wet, gray clayey sandy SILT	SM	<1	
10–12	CL	6	SS	1, 1, 3, 4	100	10-12': Wet, gray plastic CLAY. Some sand	CL	<1	
12–14	CL	7	SS	2, 2, 2, 2	100	12-14': Moist, gray, plastic CLAY with silt	CL	<1	
14–16	CL	8	SS	2, 2, 2, 3	100	14-16': Moist to wet, gray plastic CLAY END OF BORING	CL	<1	

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO. RA-E1.5
PROJECT NO.

PROJECT: NASA PLUM BROOK
CLIENT: NASA
BORING CONTRACTOR: Summit Drilling

SHEET NO. 1 OF 1
GROUND ELEVATION:
TOC ELEVATION:
DATE STARTED: 02/16/99
DATE FINISHED: 02/16/99
DRILLER:
GEOLOGIST: J. Anderson
REVIEWED BY:

GROUND WATER LEVEL					CAS.	SAMP.	CORE	TUBE
Date	Time	Level	TYPE	TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV ROD %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–10												Boring back-filled with bentonite chips
10–12		1	SS	6	7	8	10	90	10-12': Moist, gray sandy, clayey SILT	ML	<2.5	
12–14		2	SS	8	6	6	7	90	12-14': Moist, gray, plastic sandy silty CLAY	CL		
14									END OF BORING			

COMMENTS

URS GREINER
TEST BORING LOG

BORING NO.	RA-E2.5
PROJECT NO.	
PROJECT: NASA PLUM BROOK	SHEET NO. 1 OF 1
CLIENT: NASA	GROUND ELEVATION:
BORING CONTRACTOR: Summit Drilling	TOC ELEVATION:
	DATE STARTED: 02/16/99
	DATE FINISHED: 02/16/99
	DRILLER:
	GEOLOGIST: J. Anderson
	REVIEWED BY:

GROUND WATER LEVEL

Date	Time	Level	TYPE		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2 in		
				WT.		140 lbs		
				FALL		30"		

WH=Wt of Hammer WR=Wt of Rods * POCKET PENETROMETER READING

DEPTH FT	STRATA	SAMPLE NO.	TYPE	BLOWS PER 6"				RECOV %	MATERIAL DESCRIPTION	USCS CLASS	HNu Conc ppm	WELL CONSTRUCTION
0–10												Boring back-filled with bentonite chips
10–12	\\\\\	1	SS	3	5	6	8	100	10-12': Moist to wet, gray sandy SILT some clay	ML	<2.5	
12–14	\\\\\	2	SS	3	3	4	5	100	12-14': Wet, gray, plastic silty CLAY	CL	<2.5	
14									END OF BORING			

COMMENTS

APPENDIX A

SECTION 13

2001 Environmental Baseline Survey

(Tetra Tech, 2001)

Final
Environmental Baseline Survey Report For The Plum Brook Reactor Facility Decommissioning Project

February 28, 2001

Prepared for:
The U.S. Army Corps of Engineers
Huntington District

Prepared by:
Tetra Tech, Inc.
5205 Leesburg Pike, Suite 1400
Falls Church, Virginia 22041

TABLE OF CONTENTS

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LIST OF ABBREVIATIONS AND ACRONYMS

ACM	Asbestos Containing Material
ASTM	American Society for Testing and Materials
BG	Block Group
CFR	Code of Federal Regulations
CIB	Community Information Bank
CRP	Community Relations Plan
Ea.	Each
EA	Environmental Assessment
EBS	Environmental Baseline Survey
EBSR	Environmental Baseline Survey Report
FUDS	Formerly Used Defense Site
GRC	Glenn Research Center
H-3	Tritium
LBP	Lead-Based Paint
LF	Linear Feet
MPCs	Maximum Permissible Concentrations
NASA	National Aeronautics and Space Administration
NRC	Nuclear Regulatory Commission
OPDES	Ohio Pollutant Discharge Elimination System
PBOW	Plum Brook Ordnance Works
PBRF	Plum Brook Reactor Facility
ppm	parts per million
RBC	Risk-Based Concentration
PCBs	Polychlorinated Biphenyl's
SF	Square Feet
RCRA	Resource Conservation and Recovery Act
SVOCs	Semivolatile Organic Compounds
TSCA	Toxic Substances Control Act
TLD	Thermoluminescent Detector
USAEC	United States Army Corps of Engineers
UST	Underground Storage Tank
VOCs	Volatile Organic Compounds

EXECUTIVE SUMMARY

The National Aeronautics and Space Administration (NASA), Glenn Research Center (GRC), has no further need for the Plum Brook Reactor Facility (PBRF) in support of its mission. The NASA PBRF is located at the Plum Brook Station in Sandusky, Ohio, and was defueled and shut down in 1973. At that time, the U. S. Nuclear Regulatory Commission (NRC) license for the facility was changed to "possess but do not operate" status. NASA proposes to terminate the license, which is still in effect for the facility.

This Environmental Baseline Survey Report (EBSR) was prepared to support the PBRF Decommissioning Project by identifying and inventorying all known environmental conditions at and near the PBRF that affect, or could be affected by, the Decommissioning Project. As such, this document contains an overview of the environmental setting at the PBRF and includes a comprehensive audit of the PBRF and adjacent areas within a one-half mile radius of the facility. This survey was performed in accordance with the American Society for Testing and Materials Standard D6008-96, *Standard Practice for Conducting Environmental Baseline Surveys.*

As part of this survey, documents concerning the environmental condition of the property were reviewed, personnel who work/worked at the facility were interviewed, and a visual inspection of the property was conducted. Any data gaps present that would prevent a complete property characterization were identified. A brief summary of the results of the EBS is presented below.

Due to the nature of the facility, environmental monitoring conducted while the facility was active focused solely on radiological aspects. Comprehensive radiological characterization efforts conducted in 1985 and in 1998 appear to have adequately characterized the radiological status of the buildings and structures at the PBRF.

Since the facility has been shut down, sampling for environmental contaminants other than radionuclides has occurred. This sampling has been conducted in three separate investigations: underground storage tanks located adjacent to the Services Equipment Building; a former explosive manufacturing facility that was present in what is now the southwestern part of the PBRF; and recent environmental characterization efforts in various areas associated with the decommissioning project. Sampling and analyses conducted at the former two areas appears to have adequately characterized the nature and extent of the related environmental contamination, while the most recent soil sampling effort identified several areas of low-level contamination. The concentrations detected were well below available Risk Based Concentration (RBC) screening guidance levels, except for one sample that contained an estimated concentration of a semi-volatile organic compound above the RBC.

Various data gaps were identified during preparation of this EBSR. Most of these data gaps are due to a lack of data on certain types of potential contaminants (based on site activities and history), while others are lack of sampling in certain areas. One was identified during the review of historic aerial photographs. A plan has been developed to fill these data gaps that includes sampling the areas of concern for the appropriate parameters. By collecting these additional data, a complete characterization of the environmental condition of the property will be accomplished. In addition, installing monitoring wells near the southern boundary of the PBRF will address potential contaminant migration from adjacent areas onto the PBRF.

1.0 PURPOSE OF THE ENVIRONMENTAL BASELINE SURVEY

The National Aeronautics and Space Administration (NASA), Glenn Research Center (GRC), has no further need to use the Plum Brook Reactor Facility (PBRF) in support of its mission. The NASA PBRF is located at the Plum Brook Station in Sandusky, Ohio, and was shut down in 1973. At that time, the U. S. Nuclear Regulatory Commission (NRC) license for the facility was changed to "possess but do not operate" status. This license is still in effect for the facility. NASA proposes to terminate the license according to the NRC's regulations radiological criteria for license termination (10 Code of Federal Regulations [CFR] Part 20, Subpart E).

This Environmental Baseline Survey Report (EBSR) was prepared to support the PBRF Decommissioning Project by identifying and inventorying all known environmental conditions at and near the PBRF that affect, or could be effected by, the Decommissioning Project. As such, this document contains an overview of the environmental setting at the PBRF and includes a comprehensive audit of the PBRF and its surrounding environs.

The proposed action of the Decommissioning Project is to decontaminate the PBRF to levels consistent with NRC's unrestricted release criteria, to take measurements to verify that decontamination is complete, to request that NRC terminate the license without restrictions, and then to demolish the buildings and regrade the area. NASA will retain the land as buffer area within the Plum Brook Station. As part of this action, NASA is preparing other documents concerning the environmental aspects of the Decommissioning Project, including an environmental assessment (EA) as required by the *National Environmental Policy Act.*

1.1 BOUNDARIES OF THE PROPERTY AND SCOPE OF SURVEY

The PBRF is located in the northern portion of the 2,950 ha (6,400 acre) Plum Brook Station, located about 6 km (4 miles) south of Sandusky, Ohio (Figure 1.1-1). The PBRF includes 21 buildings/structures located on approximately 11 ha (27 acres) of nearly level land. The topography in the area slopes gently northward toward Lake Erie. The average slope of the land is less than 6%. Elevation ranges from about 191 to 207 m (625 to 680 ft) above sea level. The elevation at the PBRF is about 191 m (625 ft) above sea level (Ref. #53). The site layout is shown on Figure 1.1-2.

Two buildings and a water storage tower located in the northwest area of the PBRF (not shown on Figure 1.1-2) are outside the scope of this document because they were removed from the NRC license in accordance with NRC regulations in 1979.

Adjacent properties within the scope of this Environmental Baseline Survey (EBS) are those within an approximately one-half mile radius of the PBRF boundary. These areas include a wooded area to the north within the Plum Brook Station boundary, residential areas adjacent to the northern boundary of the Station, and a mixture of open fields and wooded areas to the east, west, and south. With the exception of the residential area to the north, all other adjacent areas are within the boundaries of Plum Brook Station. Aerial photos of the PBRF and surrounding areas are provided in Appendix B.

2.0 SURVEY METHODOLOGY

2.1 APPROACH AND RATIONALE

This EBS was performed in accordance with the American Society for Testing and Materials (ASTM) Standard D6008-96, *Standard Practice for Conducting Environmental Baseline Surveys*. The approach outlined in this standard practice involves several activities:

- A site visit that includes a visual inspection of the condition of the parcel and adjacent areas;
- Detailed search and review of records produced by the facility, including an inventory of hazardous substances used or stored at the facility;
- Review of Federal and state databases on releases of hazardous substances and various other environmental data concerning the parcel and adjacent areas;
- Review of property tax files or similar resources documenting the past uses of the parcel ;
- Review of historic aerial photographs to aid in documenting past uses of the parcel;
- Interviews with persons knowledgeable about the activities carried out at the facility;
- Identification of ongoing response actions that have been taken at or adjacent to the parcel; and
- Identification of sources of contamination at the parcel, or at adjacent areas which could migrate to the parcel in question.

The overall goal of the EBS is to determine the environmental condition of the property in question - in this case, the approximately 11 ha (27 acres) and 21 buildings/structures that comprise the PBRF. In this process any data gaps present that would prevent a complete property characterization are identified.

The primary effort involved in creating this Environmental Baseline Survey Report (EBSR) was collecting and reviewing the various records collected as part of the survey. Records were searched and reviewed during the site visit to the PBRF and also during a visit to the U.S. Army Corps of Engineers offices in Huntington, West Virginia to review the Administrative Record for the Formerly Used Defense Site (FUDS) activities at the PBS. As discussed in Section 3.1 of this document, the U.S. Army originally annexed the land now comprising the Plum Brook Station in 1940 in order to establish the Plum Brook Ordnance Works (PBOW). The PBOW operated from 1941 to 1945.

Interviews were also conducted with some PBRF personnel. Physical walk-through site inspections were accomplished for all accessible facilities at the PBRF. Certain areas at the facility are not accessible to personnel without specialized safety training due to radiological contamination. The project team visited not every space used as typical offices. Facilities inspected and personnel interviewed/contacted are summarized below in Section 2.1.2.

A title search is also normally conducted as part of an EBS. For this EBSR, however, a title search was not performed due to the well-documented history of the property (see Section 3.1).

2.1.1 List and Description of Documents Reviewed

Table 2.1.1-1 provides a listing of the documents reviewed during this EBS. These references are numbered in the table and are referred to by number elsewhere in this document. In addition, NASA GRC maintains a Community Information Bank (CIB) containing relevant information on the Decommissioning Project in the Firelands College Library in Huron, Ohio. The documents included in the CIB are varied, and include technical reports, historical information, and project management plans.

Table 2.1.1-1. ***List of Documents Reviewed for the EBS***

Ref. No.	Document
1	Information for Experiment Sponsors for NASA Plum Brook Reactor Facility, NASA Glenn Research Center, October 1968
2	NASA Technical Memorandum, Beryllium Behavior in the NASA Plum Brook Reactor, Document # NASA TM X-67894, NASA Lewis Research Center, August 1971
3	An Evaluation of the Options for Further Decommissioning of the Plum Brook Reactor Facility, NASA Lewis Research Center, July 1978
4	Final Radiological Survey for the Release of Buildings 1121, 1142 and Structure 1156 at the Plum Brook Reactor Facility, NASA Lewis Research Center, November 1980
5	Environmental Report, Plum Brook Reactor Dismantling, Amendment 1, NASA Lewis Research Center, February 1981
6	Memorandum from Teledyne Isotopes to General Manager of Plum Brook Operations – Subject: Off-Site Radiological Environmental Monitoring Around PBRF, June 1981
7	Letter from Teledyne Isotopes, John Ross, General Manager, Plum Brook Operations to Mr. Earl C. Boitel, Jr. PBRF Manager, NASA Lewis Research Center; Re: Additional Information regarding Water Infiltration of the PBRF-HRA Structure, May 16, 1985
8	Environmental Compliance Audit Report, Plum Brook Station, Sandusky, Ohio, NASA Lewis Research Center, April 1986
9	An Evaluation of the Plum Brook Reactor Facility and Documentation of Existing Conditions, Study Organization, NASA Lewis Research Center, December 1987
10	An Evaluation of the Plum Brook Reactor Facility and Documentation of Existing Conditions, (Volumes 1, 2,3 and 6 a 6 Volume Series), NASA Lewis Research Center, December 1987
11	Environmental Resources Document, NASA Lewis Research Center, Cleveland, Ohio, NASA Lewis Research Center, August 1990
12	Plum Brook Station, Preliminary Assessment, Volume I-IV, NASA Lewis Research Center, June 1991
13	NASA Plum Brook Station Underground Storage Tank Corrective Actions, Remedial Investigation/Feasibility Study, Phase I Report, NASA Lewis Research Center, November 1991
14	Site Inspection Report, Plum Brook Station, Sandusky, Ohio, Volume I-II, NASA Lewis Research Center, January 1994
15	NASA Plum Brook Station Reactor Facility Risk Assessment, Final Draft, NASA Lewis Research Center, February 1994
16	NASA Plum Brook Garage and Maintenance Area, Final Report, NASA Lewis Research Center, February 1994
17	RCRA Closure Plans, Plum Brook Ordnance Works, Sandusky, Ohio, U.S. Army Corps of Engineers, Huntington District, February 1994
18	County and City Data Book, 1994 – A Statistical Abstract Supplement, U.S. Department of Commerce, August 1994
19	Biological Inventory of Plum Brook Station, 1994, NASA Lewis Research Center (Office of Environmental Programs), February 1995

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20	Draft Records Review Report, Plum Brook Ordnance Works Sandusky, Ohio, U.S. Army Corps of Engineers, Huntington District, April 1995
21	Site Management Plan, Plum Brook Ordnance Works, Sandusky, Ohio; Part B, Areas of Concern, U.S. Army Corps of Engineers, Huntington District, September 1995
22	Closure Work Plan, Reactor Area NASA Plum Brook Station, Sandusky, Ohio, NASA Lewis Research Center, September 1995
23	Environmental Justice Implementation Plan For NASA Lewis Research Center, NASA Lewis Research Center, April 1996
24	Soil Screening Guidance: Technical Background Document, Second Edition, EPA/540/R95/128, US Environmental Protection Agency, May 1996
25	Records Review Final Report, Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio, U.S. Army Corps of Engineers, Huntington District, April 1997
26	Red Water Ponds Focused Remedial Investigation Final Report for Plum Brook Ordnance Works, Plum Brook Station/NASA, Sandusky, Ohio, U.S. Army Corps of Engineers, Nashville District/Huntington District, April 1997
27	Recommended Approach to the Update of the 1985 PBRF Engineering Study; Phase I, NASA Plum Brook Operations, NASA Glenn Research Center, December 1997
28	Smear Survey Record of Cold Retention Pond, NASA Lewis Research Center, February 1998
29	Second Quarterly Groundwater Level Measurements and First Semi-Annual Groundwater Sampling Event, Site-Wide Groundwater Investigation, Former Plum Brook Station/NASA, Sandusky, Ohio; Revision 0, U.S. Army Corps of Engineers, Nashville District, May 1998
30	Smear Survey Record of Cold Retention Pond, NASA Lewis Research Center, October 1998
31	Draft, Refined Analysis of Alternatives for License Termination of the Plum Brook Reactor Facility, NASA Lewis Research Center, November 1998
32	NASA/Lewis Plum Brook Reactor Facility, Confirmatory Survey, Volume I-II, NASA Lewis Research Center, November 1998
33	Site Investigation of Acid Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio; Revision 1, U.S. Army Corps of Engineers, Nashville District, December 1998
34	Draft Report, Risk Assessment and Direct-Push Investigation of Red Water Pond Areas, Former Plum Brook Ordnance Works, Sandusky, Ohio, Volume; 1, Revision 1, U.S. Army Corps of Engineers, Nashville District, March 1999
35	Final Summary Report, Site-Wide Groundwater Monitoring (1997-1998), Former Plum Brook Ordnance Works, Sandusky, Ohio; Volume 1, Revision 1, U.S. Army Corps of Engineers, Nashville District, June 1999
36	Limited Site Investigation Draft Final Report,Former Plum Brook Ordnance Works, Pentolite Area Waste Lagoons, Sandusky, Ohio, U.S. Army Corps of Engineers, Louisville District, August 1999
37	Sediment Sample Data from October 1999, NASA Lewis Research Center, October 1999
38	Decommissioning Plan for the Plum Brook Reactor Facility; Revision 0, NASA Glenn Research Center, December 1999
39	Amended Closure Plan, Garage and Maintenance Area, Building 7121 and Building 7131, Internal Draft, NASA Glenn Research Center, December 1999
40	Reactor Area Building 1131, Amended Closure Plan, NASA Glenn Research Center, March 2000
41	Letter with attachment; Re: Laboratory Validation, Final Results of Analyses Conducted of 12 Soils Samples collected by NASA on the Plum Brook Reactor Facility site in October 1999, U.S. Army Corps of Engineers, Huntington District, March 2000
42	Amended Closure Plan, Reactor Area, NASA Plum Brook Station, Sandusky, Ohio, Volume I, NASA Glenn Research Center, March 2000
43	Procedures Manual, Protected Safe Storage Mode, Plum Brook Reactor Facility, NASA Glenn Research Center, March 2000
44	Office of Safety and Assurance Technologies, Plum Brook Reactor Facility Decommissioning Project Plan, NASA Glenn Research Center, April 2000
45	Limited Site Investigation Final Report for the former Plum Brook Ordnance Works, Ash Pits Numbers 1 and 3, Sandusky, Ohio, U.S. Army Corps of Engineers, Louisville, District, July 2000

Ref. No.	Document
46	Limited Site Investigation Final Report for the former Plum Brook Ordnance Works, Garage Maintenance Area, Sandusky, Ohio, U.S. Army Corps of Engineers, Louisville, District, July 2000
47	Fluorescent Light Fixtures and Battery Summary (PCB Ballasts), Plum Brook Reactor Facility, NASA Glenn Research Center, August 2000
48	General Engineering Laboratories – Certificate of Analysis (Fission and Activation Products – Hot Cell Swipes, July 2000), NASA Glenn Research Center, August 2000
49	NASA Plum Brook Reactor Facility Decommissioning and Decontamination Pre-Design Investigation Plan, NASA Glenn Research Center, August 2000
50	NASA Plum Brook Reactor Facility Decommissioning and Decontamination Pre-Design Investigation Soil Sampling Analytical Data, NASA Glenn Research Center, August 2000
51	Water Sample Record, July and August 2000 Samples, NASA Glenn Research Center, September 2000.
52	SAIC-FASS Team Asbestos Containing Materials/Lead Based Paint/PCB Survey Plum Brook Reactor Facility Buildings, NASA Glenn Research Center, September 2000
53	Environmental Assessment for the Decommissioning of the Plum Brook Reactor Facility, Plum Brook Station, NASA Glenn Research Center, October 2000
54	Memo: Risk-Based Concentration Table, United States Environmental Protection Agency, Region III, October 2000
55	Conversation with Dave Stith regarding naturally occurring BTEX compounds in limestone in Sandusky, Ohio area, Department of Geochemistry, Ohio Division of Geological Survey, November 2000.
56	Conversation with Dave Stith regarding background levels of heavy metals in Sandusky, Ohio area, Department of Geochemistry, Ohio Division of Geological Survey, February 2001.

2.1.2 Inspections of Properties Conducted and Personnel Contacted

The specific buildings/areas at PBRF that were inspected during the site visit and the personnel interviewed/contacted are shown in Tables 2.1.2-1 and 2.1.2-2, respectively.

Table 2.1.2-1. *Facilities Inspected*

Building Number	Facility Description
Main Buildings	
1111	Reactor Building
1112	Hot Laboratory Building
1131	Service Equipment Building
1132	Fan House Building
1133	Waste Handling Building
1134	Primary Pump House
1136	Compressor Building
1141	Office and Laboratory Building
Support Buildings and Structures	
1135	Gas Service Building
1156	Water Tower
1157	Cooling Tower Platform
1158	Sludge Basins
1159	Cold Retention Basins
1160	Hot Retention Area
1158	Precipitator Tank
1161	Substation
1191	Security Building
1192	Water Effluent Monitoring Station
1195	Cryogenic and Gas Supply
1196	Gas Storage Structure

Table 2.1.2-2. *Personnel Interviewed/Contacted*

Name	Position/Subject Area Specialty	Years at PBRF
Hank Pfanner	Reactor Manager/General Operations, Site History	1963-present
Don Young	Radiation Technician/General Operations, Site History	1963-present
Lee Early	Lab Technician and Maintenance/Lab Operations, Site History	1965-present
Len Homyak	Project Manager/General Operations, Site History	1962-1995
Timothy Polich	Decommissioning Project Manager/ General Operations, Site History, Environmental Sampling	1999-present
Keith Peecook	Construction Manager/ General Operations, Site History, Environmental Sampling	1995-present

3.0 PLUM BROOK REACTOR FACILITY SITE HISTORY

This section describes the history of the PBS, including the 11 ha (27-acre) parcel that is now the PBRF and the adjacent areas within the scope of this EBSR. Also provided is a technical description of the overall facility processes when the reactor was active. This includes a description of each building/structure at the facility and its purpose and activities carried out there. Utilities present, waste generation and handling practices, and environmental monitoring conducted are also described.

3.1 PAST USES

The original PBS site was acquired by the Department of Defense (DoD) in 1940 and consisted of approximately 9,010 acres. Prior to 1940, it was suspected that this land and the area surrounding it had only been used for either agriculture or was undisturbed open fields or woodlands. In order to verify the suspected lack of development of the area prior to 1940, several avenues were pursued. Historical topographic and land use maps were reviewed, and PBRF personnel who grew up in the area were interviewed. In addition, there are no Sanborn Fire Insurance Maps for the area (discussed further in Section 4.8.7). This indicates that the area was not developed. Based on these data, it is apparent that prior to 1940 the area that became the PBS was privately owned and was used for agriculture, or remained undeveloped fields or wooded areas. According to Mr. Hank Pfenner, the current Reactor Manager whose family owned the land comprising what is now the PBRF prior to 1940, the land was only used for agriculture until its purchase by the DoD.

In the 1941, the Plum Brook Ordnance Works (PBOW) was established and the U.S. Army contracted with the Trojan Powder Company to manufacture TNT, DNT and pentolite at the PBOW. Production began on December 16, 1941 and continued through late 1945, ceasing two weeks after V-J Day. During this production period, over 900 million pounds of these materials were manufactured at PBOW. After the operation ceased, the area was turned over to the Army Ordnance Department and was renamed Plum Brook Depot and used for ammunition storage (Ref. #19).

During the PBOW era, the area comprising the western half of the current PBRF was known as the Pentolite Area. The high explosive pentolite was manufactured in this area. The wastewater generated as part of this process was disposed of in the Pentolite Area Waste Lagoons, which were located in what is now the southwestern portion of the PBRF. Historic aerial photos of the Pentolite Area and waste lagoons are provided in Appendix B.

The wastewater generated from the pentolite manufacturing process potentially contained nitroaromatics including pentaerythritol (PE), pentaerythritol tetranitrate (PETN), trinitrotoluene (TNT), and the solvent acetone.

Included in the adjacent areas within the scope of this EBSR are five PBOW sites located south of the former Pentolite Area: the Pentolite Road Red Water Ponds, the Garage Maintenance Area, the Rail Car Unloading Area/Sellite Area, Ash Pit #1 and Acid Area #3. These areas and the activities carried out there are described in detail in Section 4.8 of this EBSR.

The PBOW was placed in standby condition from 1945 to 1946. During this time, the Army conducted decontamination and decommissioning (D&D) of many of the buildings and structures associated with the manufacturing of ordnance (Ref. #12). D&D included removal and relocation of all explosives to burning grounds for incineration. Where possible, remaining structures and buildings were burned in place. Decontamination of pentolite manufacturing lines was halted during the last quarter of 1945, and it was estimated the 65% of the necessary decontamination of the PBOW had been completed by December 1945 (Ref. #14).

No information is available regarding decontamination of surrounding soils in the Pentolite Area or the removal of the waste lagoon structures (Ref. #22). However, during construction of the PBRF the entire area was filled and graded; the waste lagoon structures were likely removed at that time. A memo dated 1958 states that the "Pentolite Area of approximately 117.3 acres was decontaminated, demolished, and cleared for use as the Lewis Laboratory Reactor Facility" (Ref. #22).

In December 1945, custody of the PBOW was transferred from the Trojan Powder Company to the U.S. Army Ordnance Department, and the U.S. Army Corps of Engineers (USACE) assumed responsibility for maintenance and custodial duties at the PBOW from January 1 through June 30, 1946. In August 1946, PBOW was transferred to the War Assets Administration. Additional decontamination efforts were undertaken by Ravena Arsenal from 1954 to 1958 (Ref. #19).

In 1956, the National Advisory Committee for Aeronautics (NACA) began leasing sections of PBS from the Army. An agreement was made in 1956 for a lease of 500 acres of the north portion of the site to construct and operate the PBRF. The PBRF was designed and built from 1957 through 1961, and the facility was tested until April 1962 when full power operation began.

In 1958, NACA became the National Aeronautics and Space Administration (NASA). By 1963, approximately 6,400 acres of the PBOW had been acquired by NASA for various aerospace research activities, plus an additional 2,000 acres to serve as a buffer zone. Research and test activities were conducted by NASA throughout the site from the 1960s and early 1970s.

In 1978, NASA declared approximately 2,150 acres of land as excess. The Perkins Township Board of Education uses 46 of the excess acres as a bus transportation center. Much of the remaining excess property was reclaimed for farmland. NASA also transferred Parcel #59 to the General Services Administration (GSA) in 1978 for subsequent disposal. The efforts of the GSA to dispose of the property have been futile largely due to the presence of the wastewater ponds resulting from PBOW activities. The current site consists of approximately 6,400 acres.

NASA controls the land known as the PBS through ownership of title, use of easements, leases, permits, and ownership of development rights.

3.2 DESCRIPTION OF THE FACILITY WHEN IT WAS ACTIVE

The PBRF is located within an 11-ha (27-acre) fenced area on the PBS and includes the following facilities and areas (see Figure 1.1-2):

- A Reactor Building (Building 1111) with a 60-megawatt research test reactor and 100-kilowatt swimming-pool type thermal mock-up reactor
- A seven cell Hot Laboratory complex (Building 1112)
- Reactor and laboratory operations support facilities that include the Reactor Office and Laboratory Building (Building 1141), Primary Pump House (Building 1134), Fan House (Building 1132), Waste Handling Building (Building 1133), Hot Retention Area (1155), Cold Retention Area (1154), Hot and Cold Pipe Tunnels, and the Cooling Tower (#1152) which was removed in the early 1980s
- The effluent drainage system, which includes catch basins/drainage culverts, the Water Effluent Monitoring Station (Building #1192), which drains into Pentolite Ditch outside the PBRF fence, and the Emergency Retention Basin
- General support facilities which include the Reactor Services Equipment Building (Building 1131), Substation (#1161), and the Security Building (#1191)
- Raw water treatment facilities including the Water Tower (#1151), Precipitator (#1157), Sludge Basins (#1153), and Drying Basins located just outside the fence in the northern portion of the PBRF
- Cryogenic support facilities including the Cryogenic and Gas Supply Farm and Building (#1195 and #9837 – both removed), the Gas Storage Structure (#1196 - removed), Compressor Building (#1136), and the Gas Services Building (#1135).

During its operating life, the PBRF was used to perform nuclear irradiation testing of fueled and unfueled experiments for space program applications. The facility was designed to segregate processes involving radioactive materials ("hot" areas or equipment) from all other processes and operations ("cold" areas). As a result, hot areas were contaminated with radionuclides. A brief description of the facilities/areas and their function, during the period of operation of the PBRF, is provided below. Process flow charts for the various systems can be found in Appendix E.

Major Facilities

Reactor Building (Building 1111)

The Reactor Building is a four-story structure (two basements and main and second floor levels) that houses the 9-foot diameter, 31-foot high reactor tank encased in a concrete biological shield varying in thickness of up to 2.7-m (9-ft). It consists of the following:

- Reactor tank and internal components
- Primary cooling water and primary cooling shutdown systems
- Biological shield
- Quadrants and canals and pump-out, recirculation, and drain systems
- Reactor building rooms
- Hot drains, sumps, pumps, and valves

The core of the research reactor contains uranium/aluminum alloy fuel elements with aluminum alloy arranged in a 3x9 lattice with five fueled cadmium controls rods in the center row of the lattice. The reactor was light-water cooled and moderated with a primary beryllium reflector and secondary water reflector. Experiments were inserted using two horizontal through tubes, six horizontal beam tubes, and two vertical experiment tubes all made of aluminum alloy.

The reactor tank and concrete biological shielding are surrounded by four quadrants (Quadrants A–D), three (A, C, and D) of which could be flooded with water for additional biological shielding and one which served as a dry area (Quadrant B). The reactor and quadrants are enclosed within a 30-m (100-ft) diameter, 1.9-cm (¾-in) thick steel containment vessel extending from 17-m (56-ft) belowgrade and 16-m (53-ft) abovegrade. A system of canals that were used to move irradiated fuel and targets to and from the reactor tank, fuel storage area, and the adjacent Hot Laboratory (Building 1112) surround the quadrants. The reactor tank was used as a pressurized container for the building and was an important component of the primary cooling water system. The reactor tank also supported the reactor core, reactor controls, and experimental facilities.

The PRBF quadrant and canal recirculation system is a closed loop recirculation system. The quadrant and canal recirculation system were used to recirculate water from Quadrants A, C, and D through two filter units and two mixed resin deionizers located in the Fan House. The water was recirculated to maintain clean and optically clear quadrant water.

The quadrant and pump-out system were used to pump water from Quadrants A, C, and D and Canals E through K into the Cold Retention Basins for storage. This water could be returned through a filter in the Fan House back to the quadrants and canals.

The hot drain system, which consisted primarily of sumps, pumps, and valves, served as the drainage collection system for all wastewater that came from a radioactively contaminated area.

Primary cooling water piping, embedded in concrete, extends from the reactor tank to the primary pump house (Building 1134). The primary cooling water piping was used to remove heat from the reactor core and transfer the heat to the secondary cooling loop.

The mock up reactor is also located in the reactor building in Canal H. This reactor was used to calibrate fuel elements and other experiment components and to test rigs before insertion in the test reactor.

In addition to the facilities and equipment described above, the Reactor Building contains work space used to set-up experiment assemblies, a personnel decontamination facility, a change room, and a control room for remote operation of experiment rigs. More detailed discussion of the facilities of the Reactor Building is available in the *Decommissioning Plan for the Plum Brook Reactor Facility* (Ref. #38).

Hot Laboratory (Building 1112)

The Hot Laboratory is a two-story structure consisting of a basement and main level and is attached to the south side of the Reactor Building (Building 1111). The hot dry storage area in the Hot Laboratory is the area closest to the reactor building and is a shielded room used to store irradiated reactor and experiment components and tools (e.g., core fuel element handling tools). The hot laboratory also contains seven hot cells, a storage canal, a decontamination room, repair shop area, an office, and work areas.

Reactor and Laboratory Operations Support Facilities

The reactor and laboratory operations support facilities includes both hot and cold facilities. The hot facilities/areas include the Reactor Office and Laboratory Building (Building 1141), Primary Pump House (Building 1134) and associated primary cooling water system, Fan House (Building 1132), Waste Handling Building (Building 1133), Hot Retention Area (1155), Cold Retention Area (1154), Hot Pipe Tunnel, and the effluent drainage system. The cold facilities include the cold pipe tunnel, the secondary cooling water system; the Reactor Services Equipment Building (Building 1131), except for an analytical laboratory; the raw water treatment system, the cryogenic facilities, the Substation (1161), and the Security Building (1191). These facilities are described below.

Reactor Office and Laboratory Building (Building 1141). This is a three-story building (basement, main and second story level) attached to the west side of the Reactor Building (Building 1111). During the operation of the PBRF, this facility housed offices (e.g., engineering and health physics), repair shops, a first aid facility, and radiochemistry laboratories.

The radiochemistry laboratories in this building analyzed the substances with the highest levels of radioactivity, including the primary cooling water and some materials used in experiments. Solid radioactive waste from these laboratories was placed into closed stainless steel containers for pick-up by health and safety personnel. The low-level solid waste was stored in the Waste Handling Building (1133) until it was shipped for disposal. Liquid wastes generated at these laboratories, including waste chemicals and solvents (including chloroform, carbon tetrachloride, acetone, toluene, trichloroethylene, 1,1,1-trichloroethane, and fuming nitric acid), were disposed of in drains that lead to the Hot Retention Area (Building 1155). In addition, 1,1,1-trichloroethane (brand name NA-500) was stored in 55-gallon drums in the basement of this building.

Primary Pump House (Building 1134). This is a one-story building attached to the eastside of the Reactor Building (Building 1111). It contains the reactor primary cooling water pumps, heat exchangers, and ion exchangers for the primary cooling water system, primary coolant strainers, resin pits, and a hot sump.

The primary cooling water system consists of four loops: the main loop, the by-pass cleanup loop, the instrument and test hole cooling loop, and the shutdown loop. The main loop contained 26,000 gallons of deionized water and is connected to the reactor tank. The by-pass cleanup loop is a secondary loop on the main loop used to control the purity of the water in this system. There are two mixed bed deionizers that each contain 41 cubic feet of mixed bed resin that removed radioactive ions from the cooling water. The typical life of the resin bed was 8 months. Spent resin was stored at the Waste Handling Building (1133) for shipment to the disposal facility. The instrument cooling loop supplied cooling water to the test holes and the shutdown loop was used for decay heat removal after shutdown.

Fan House (Building 1132). This is a two-story building that houses the filtration and exhaust systems for all hot areas at the PBRF, including the Reactor Building and the Hot Laboratory complex. In the Fan House, room air from PBRF buildings was filtered through absolute filters and exhausted through the Fan House stack. Air emissions at the stack were monitored according to the requirements in the facility's Atomic Energy Commission (AEC) license; no exceedances of the Maximum Permissible Concentrations (MPCs) occurred during operation of the PBRF. Monitoring equipment included: a gaseous activity monitor and scintillation detector, a radioiodine activity monitor filter and scintillation detector, and particulate activity monitor filter and GM tube, and a gross beta-gamma GM tube read out.

Waste Handling Building (Building 1133). This is a two-story building that contains the liquid waste evaporator system, laundry equipment, waste packaging equipment, a small analytical laboratory, and low-level solid waste storage facilities. Low-level solid radioactive waste stored here included personal protective equipment, air filters from the air handling system, and other miscellaneous solids such as rags, etc. Liquid effluent from the laundry equipment was piped to the hot drain system. The evaporator was used to treat liquids from the Hot Retention Area, described below; sludge from the evaporator was stored in this building and shipped offsite for disposal with the other low-level waste at the radioactive waste disposal facility in Maxey Flats, Kentucky.

Hot Retention Area (1155). This area has eight 230,000-L (60,000-gal) and four 28,000-L (7,500-gal) steel underground storage tanks. This area is located south of the Fan House and during operation of the PBRF facility received radioactively contaminated water from the hot drain systems. All radioactively contaminated water was sent to the larger tanks, and the smaller tanks were used as holding tanks. The contaminated water was treated, monitored and then discharged to the Cold Retention Area (1154), the quadrant and canal recirculating system, or the Water Effluent Monitoring Station (Building 1192).

Cold Retention Area (1154). This area has two 1,900,000-L (500,000-gal) below-grade storage basins that were used to store low-level radioactive water primarily from the quadrants and canals in the Reactor Building.

Cold PipeTunnel. This contains the piping system that was used during PBRF operation to transport uncontaminated process water from the Reactor Water Tower (1151) to the Reactor Services Equipment Building (Building 1131) and then onto the Primary Pump House (Building 1134).

Secondary Cooling Water System. The Secondary Cooling Water System is composed of five loops, which contained a total of 225,000 gallons: the main, auxiliary, test, filter, and shutdown loops. This system was used to remove heat from the Primary Cooling Water System.

Effluent Drainage System

Drainage System

The drainage system for the PBRF is a series of open ditches, covered culverts, and catch basins used for collecting and transporting all liquid effluent from the 11-ha (27-acre) PBRF from its source to the WEMS. This includes surface water and roof-top runoff, building sump discharges, and during operation, low-level liquid wastes.

Water Effluent Monitoring Station (Building 1192)

The Water Effluent Monitoring Station (WEMS) was used to monitor all PBRF liquid effluents for radioactivity prior to being discharged to Pentolite Ditch. The station is located in the southeast corner of the PBRF and is comprised of a metal building and concrete trench with metal sluice gates and flumes. Effluent flow rate and radiological quality was monitored continuously at the WEMS. If any permitted limits were exceeded, the sluice gates would automatically shut and the water would be diverted to the Emergency Retention Basin, described below.

Emergency Retention Basin

The Emergency Retention Basin is a 76x107-m (250x350-ft), 38 million-L (10 million-gal) aboveground, brown clay earthen-diked basin located in the southeast corner of the PBRF. It was used as emergency storage for radioactively water that exceeded the allowable discharge criteria and was used several times during the operation of the PBRF.

Pentolite Ditch

The Pentolite Ditch received all water discharged from the WEMS during PBRF operation. The ditch is located south of Pentolite Road and flows from the area of the WEMS approximately 2,750-ft eastward to Plum Brook.

General Support Facilities

Reactor Services Equipment Building (Building 1131). This is located east of the Primary Pump House and contains the water processing equipment, air compressors, boilers, electrical control equipment, diesel generators for emergency electrical power, and the health physics radiochemistry/analytical laboratory. All areas but the latter were cold areas. Samples analyzed in the laboratory were environmental samples collected as part of the extensive monitoring program carried out during operation of the PBRF. Soil, water, air, crop, and animal tissue samples were collected and analyzed periodically to ensure that the PBRF was in compliance with AEC permit limits. In addition, 1,1,1-trichloroethane (brand name NA-500) was stored in 55-gallon drums in this building.

Substation (Building 1161). Electrical service to the PBRF enters the facility at the substation. Step-down transformers are located here.

Security Building (Building 1191). This building was and is used strictly as the ingress/egress point to the PBRF. Monitoring equipment, including personnel scanning equipment, is used/stored here. All personnel exiting the PBRF were/are screened for radiological contamination prior to exiting the facility.

Raw Water Treatment Facilities

All these facilities were cold facilities and treated water to be used in the reactor operations. Domestic drinking water was supplied by the local municipal water authority and was distributed in an isolated system. An engineering drawing of this system is provided in Appendix D.

Water Tower (Building 1151). Raw water from Lake Erie was stored in this structure prior to its release to the treatment facilities described below. Approximately 1 million gallons per day of water was used while the PBRF was active.

Precipitator (Building 1157). Raw water from the water tower flowed directly to the precipitator (a 42-foot diameter, 125,000-gallon unit), where it was treated with lime-alum to precipitate metals and make process water. Chlorine and possibly an algaecide or similar chemical was also added. Some of this water was then diverted to the Secondary Cooling Water System. The remaining water then continued on in the process water system to gravity-type sand filters. Water was then directed either to the Cooling Tower (Building 1152) where it was further treated with an antifoulant, to various auxiliary systems, or to the deionized water system. Deionized water was used in the hot areas, primarily the Primary Cooling Water System. Sludge from the precipitator was directed to the Sludge Basins, described below.

Sludge Basins (Building 1153). These basins (2) are approximately 15 m x 9 m (50 ft x 30 ft) x 3 m (9 ft) deep and received the sludge from the precipitator. When they approached capacity, the material was pumped to the Drying Basins located in the northernmost portion of the PBRF.

Drying Basins. As mentioned above these areas (2), each approximately 30 m x 30 m (100 ft x 100 ft) in size (the depth is unknown, but is assumed to be shallow – 0.3 – 0.6 m [1-2 ft]), received sludge from the Sludge Basins when they approached capacity. The frequency of this is unknown. From the name, it can be assumed that the sludge was allowed to dry in the Drying Basins. It is not known if the dried sludge was ever cleaned out of the Drying Basins.

Cryogenic Support Facilities

In order to better simulate conditions in space for testing of materials in the reactor, it was equipped with a cryogenic loop. These facilities were also cold (non-radioactive) facilities.

Cryogenic and Gas Supply Farm and Building (Buildings 1195 and 9837). This area was where the helium gas supply was stored. The building was removed during shutdown of the PBRF.

Gas Storage Structure (Building 1196). This structure was used to hold the recovered liquid helium after it had exited the reactor facility. It was removed during shutdown of the PBRF.

Compressor Building (Building 1136). Compressors used to compress the helium gas are housed in this building.

Gas Services Building (Building 1135). This building contains gauging equipment used to monitor the pressure of the cryogenic system.

Environmental Monitoring

Point source air and water monitoring conducted at the PBRF during operation was discussed above in the sections on the Fan House and the WEMS. Other environmental monitoring was conducted at the facility and at locations outside the PBS boundaries. At the PBRF, the Remote Area Monitoring System used several types of detectors to monitor radioactivity up to 100 locations within the facility.

Airborne activity (particulate and gaseous) was monitored both within the buildings and outdoors within the fenced area. Water in the canals and quadrants and other areas was monitored for beta-gamma radiation, while direct radiation measurements were taken in various areas with neutron monitors, pulse detectors, and G-M tubes for beta-gamma radiation. If any monitors detected levels above allowable limits, warning lights were illuminated on a display located in the Health-Safety Operations Office in Building 1141 (see photo in Appendix C).

In addition to on-site monitoring, samples of air, soil, fallout/precipitation, surface water, vegetation, and animal tissue were collected periodically within an approximately 5-mile radius of the PBRF.

4.0 SUMMARY OF DATA FOR ON-SITE PROPERTIES

This section describes the current activities carried out at the PBRF, and the current environmental setting and condition of the area. Also discussed are the community relations efforts during the Decommissioning Project, environmental justice, and the categorization of the property according to the ASTM standard. Finally, the adjacent properties are discussed with regard to the potential for contamination at those areas to migrate to and affect the PBRF.

4.1 CURRENT ACTIVITIES

The PBRF has been inactive since 1973 when the reactor fuel was removed and the facility was put into "standby" mode. In 1979 the status was changed to "mothballed" and the PBRF was put into protected safe storage mode. As part of the NRC license requirements, NASA personnel prepared a Procedures Manual that specifies the activities necessary to safely maintain the facility in its current status. The following procedures are detailed in the manual:

- Emergency;
- Health Physics;
- Response to Abnormal Conditions;
- Administrative; and
- Operations and Maintenance.

Activities at the site currently consist primarily of Operations and Maintenance procedures such as routine inspections and security checks (3 shifts per day). A complete discussion of these activities is beyond the scope of this document. Discussed below are ongoing activities at the PBRF that are environmentally related.

In order to keep the reactor tank in an inert environment, dry nitrogen gas is purged through the tank and vented to the atmosphere via the exhaust stack at the fan house (Building #1132). Because the tank is radioactive, it emits decay products, primarily tritium (H-3). The stack emissions are monitored continuously and compared to the Maximum Permissible Concentrations (MPCs) allowed under the current NRC license. No exceedances of the MPCs have occurred.

Sump pumps are located in the basements of the major buildings at the PBRF to prevent groundwater infiltration into the buildings. This water is discharged to the drainage system leading to the Water Effluent Monitoring Station (#1192), then it drains to Pentolite Ditch and on to Plum Brook (see Sections 4.2.2.2 and 4.2.2.4 for a complete discussion on surface water and process water, respectively). During the site visit, discharge from the sump pumps into the Water Effluent Monitoring Station was approximately 5-7 gallons per minute. NASA personnel stated that this is approximately the average flow rate. This is the only water discharged from the PBRF, other than storm water. Storm water is routed through catch basins and into the same drainage system leading to the Water Effluent Monitoring Station, so during times of rain the discharge into the monitoring station increases proportional to the amount of rainfall.

Environmental monitoring is conducted quarterly, in accordance with the NRC license. Table 4.1-1 shows the locations and media sampled.

TABLE 4.1-1.—*Quarterly Environmental Sampling Media and Locations*

Media	Location
Water	• Cold Retention Basins (#1154) • 1 of the 4 deep wells surrounding the Reactor Building (#1111) • Water Effluent Monitoring Station (#1192) • Emergency Retention Basin Sump (if water is present)
Water/Sediment	• Plum Brook Downstream of Pentolite Ditch (1 location) • Plum Brook Upstream of Pentolite Ditch (1 location) • Pipe Creek - Background Sample (1 location)
Sediment	• Pentolite Ditch (4 locations between WEMS outfall and Plum Brook)
Air	• Thermoluminescent Detector (TLD) inside Building 1111 (4 locations); changed once every quarter • TLD outside on PBRF fence (4 locations – N, S, E, W); changed once every quarter • TLD in Hot Laboratory (Building #1112) (3 locations); changed once every quarter • TLD outside PBRF fence, on Plum Brook Station fence (4 locations – N, S, E, W); 24-hour test once per quarter • Air samples at PBRF fence (5 day duration, once per quarter)
Swipe/Direct Readings	• Radiation surveys of all zoned areas

Another environmental monitoring activity occurring at the PBRF concerns radon gas in the Containment Vessel. Monitoring equipment runs continuously; this is discussed in detail in Section 4.2.15.

4.2 ENVIRONMENTAL SETTING

4.2.1 Land Use

Plum Brook Station is located primarily in Perkins and Oxford townships and covers approximately 2,950 ha (6,400 acres). Most of the land at Plum Brook Station consists of forestland and open fields, and the areas surrounding the Station are primarily rural and agricultural (Ref. #53).

The PBRF encompasses 11 ha (27 acres) in the northern portion of the Plum Brook Station. The area adjacent to the PBRF to the north of the facility is a wooded area maintained by NASA as a buffer zone between the PBRF and the residences along Bogart Road, located approximately 1,500 feet north of the northern edge of the PBRF. The adjacent areas south, east, and west of the PBRF currently consist of open fields and forestland. The immediate area has changed little from that shown in the aerial photos provided in Appendix A.

4.2.2 Water Quality and Management

Current conditions related to water quality and management are discussed below for groundwater, surface water, storm water, process water, and sewer systems. Water quality and management issues concerning the facility when it was active were discussed in Section 3.2.

4.2.2.1 *Groundwater*

Plum Brook Station is underlain by a shallow overburden aquifer and deeper bedrock aquifers. Two principal bedrock aquifers underlie Plum Brook Station. A fractured limestone aquifer occurs in the western portion of Erie County, and groundwater flow in this aquifer is to the north. The PBRF overlies this limestone bedrock aquifer. Wells completed in this aquifer have yields ranging from 19 to 95 liters (5 to 25 gallons) per minute (Ref. #12).

Unconsolidated deposits of glacial origin overlie the bedrock aquifer and comprise the overburden aquifer. The thickness of the overburden ranges from less than 1.5 meters (5 feet) to greater than 8 meters (25 feet). The overburden is the thickest in the vicinity of the PBRF where it is thought to fill in a low in the underlying bedrock surface (Ref. #31).

There are eleven overburden monitoring wells at the PBRF. In addition, four bedrock monitoring wells were installed near the Reactor Building (#1111) when the facility was constructed. See Figure 4.2.2.1-1 for the locations of the wells at the PBRF.

A groundwater investigation is being conducted under the *Resource Conservation and Recovery Act* (RCRA) program in the PBRF area at the former underground storage tank (UST) location shown on Figure 4.2.2.1-1. Three USTs were removed from a common excavation near Building 1131 in the vicinity of the PBRF in 1989 and groundwater remediation has been proposed (Ref. #42). These USTs are further described in Section 4.2.13, Storage Tanks and Pipelines.

The elevation of the groundwater surface is measured quarterly and the groundwater quality is measured semi-annually as part of an ongoing sitewide groundwater investigation. Groundwater flow in both the bedrock and overburden aquifers in the vicinity of the PBRF is thought to be affected by the eight sump pumps located in this area. The pumping in this area has created a localized cone of depression in the groundwater surface. Water levels in bedrock wells completed in this area have fluctuated as much as 8 meters (25 feet) (Ref. #35).

Nature and Extent of Groundwater Contaminants at the PBRF

As part of the Focused RI conducted at the Pentolite Road Red Water Ponds in 1995, Reactor Well 2 at the PBRF was sampled and analyzed for nitroaromatics, nitrates, VOCs, SVOCs, and metals. The nitroaromatics 3-NT and 3,4-DNT were found at levels of 23 ug/l and 13 ug/l, respectively. Three VOCs were also detected (ug/l): benzene (1.8), ethyl-benzene (1.2), and xylenes (8.0). Only benzene was above the EPA Region III Risk Based Concentration (RBC).

Five groundwater monitoring wells were installed as part of the RCRA actions at the UST location. These wells were sampled for VOCs, SVOCs, pesticides, polychlorinated biphenyls, and metals. Dissolved phase VOCs were detected at concentrations above remediation standards in the overburden aquifer. No contamination was detected in the soils (Ref. #38). The groundwater contamination will be addressed by a pump-and-treat remediation system consisting of one groundwater recovery well shown on Figure 4.2.2.1-1.

4.2.2.2 *Surface Water*

There are no surface water bodies within the 11 hectare (27 acre) PBRF. The closest surface water body is Ransom Ditch, located just west of the PBRF. This feature has been intensively modified for drainage and is characterized by steep banks (2 to 1 slope) vegetated with a mixture of grasses, herbaceous weeds, and shrubs. The stream channel is relatively straight because of past dredging activities. Surface water flow is intermittent in the summer and fall with small isolated pools (Ref. #53).

Also near the PBRF is Pentolite Ditch. This intermittent stream is located just south of Pentolite Road, which is at the southern boundary of the PBRF. As discussed below in Section 4.2.2.3, Storm Water, all storm water from the PBRF is routed to catch basins and through the Water Effluent Monitoring Station which discharges to Pentolite Ditch. Pentolite Ditch joins Plum Brook approximately 850 meters (2,800 feet) downstream of the PBRF. A National Pollutant Discharge Elimination System (NPDES) monitoring station is located on Plum Brook, just downstream of the confluence with Pentolite Ditch. The PBRF sumps are a listed source for the Plum Brook outfall in the existing NPDES permit.

The Water Effluent Monitoring Station includes a metal building and a concrete trench with metal gates and flumes. The trench itself, silt entrapped behind the flumes, and an area of soil adjacent to the trench are radioactively contaminated.

The 1985 characterization survey (Ref. #10) measured contamination in the Water Effluent Monitoring Station building and in the silt in the Water Effluent Monitoring Station trench. The 1998 confirmatory survey (Ref. #32) also measured concrete surfaces in the building and found contamination levels consistent with those measured in 1985. Isotopic analysis of gamma emitters in the 1998 survey (excluding naturally occurring gamma emitters) indicated the dominant nuclides were Cs-137 (4 to 11 pCi/g) and Co-60 (1 to 4 pCi/g). Table 4.2.2.2-1 compares the 1985 and 1998 survey results for the Water Effluent Monitoring Station building.

The Pentolite Ditch received all water from the Water Effluent Monitoring Station. Up to 30 cm (12 in.) of silt and soil in some areas along the Pentolite Ditch are radioactively contaminated. The contamination occurs primarily at the western end (near the Water Effluent Monitoring Station outfall), with a smaller amount near the eastern end (near the confluence with Plum Brook).

TABLE 4.2.2.2-1. —*Summary of Survey Results for the Water Effluent Monitoring Station (Building #1192)*

Building/ Structure	Summary of 1985 Characterization Survey Results	1998 Confirmatory Survey	
		No. of Survey Measurements	Results
Water Effluent Monitoring Station (1192)	• Loose alpha contamination ranging from 0 to 2 dpm/100 cm^2 • Loose beta-gamma contamination ranging from 0 to 48 dpm/100 cm^2 • Direct radiation levels ranging from 0.004 to 0.04 mR/hr	• 8 direct beta measurements • 8 smears	• Three measurements were about 15,000 dpm/100 cm^2 • All others were less than 5000 dpm/100 cm^2

For the 1985 characterization, the Pentolite Ditch was divided into 9.1- × 9.1-m (30- × 30-ft) grids. A contact beta-gamma survey was performed at the center and four surrounding points in each grid. A silt sample was then collected at the center point and a soil sample was collected at the surrounding point that had the highest contamination level. The survey results indicated that portions of the ditch nearest the Emergency Retention Basin (i.e., the west end) and nearest Plum Brook (i.e., the east end) were contaminated with higher levels of contamination than in the other portions of the ditch. Samples from four shallow (3 m [10-ft]) cores indicated that contamination was confined to depths less than 15 cm (6 in).

Sampling indicated that soil from the bottom and the banks of the Pentolite Ditch had average gross beta activities of 40 and 110 pCi/g, respectively.

During the 1998 confirmatory survey, eight sediment samples were collected along the Pentolite Ditch. The analytical results showed that the total activity in the samples ranged from 10 to 30 pCi/g. Most of the activity is from natural K-40; the residual activity from Cs-137 ranged from 2 to 15 pCi/g and from Co-60 from 0 to 1 pCi/g. The 1998 average concentration (about 20 pCi/g) is lower than that measured in 1985 (75 pCi/g). This decrease could be due to several factors, including decay, fewer sample locations, and irregular distribution of the contamination.

4.2.2.3 *Storm Water*

As mentioned above, storm water from the entire 11 hectare (27 acre) is routed to catch basins that lead to the Water Effluent Monitoring Station, which then discharges to Pentolite Ditch. Also as mentioned in Section 3.2, all process water from the facility was routed through this system once radioactivity levels were within permissible standards. This drainage system consists of a series of open ditches, covered culverts, and catch basins (ditches and culverts are shown as dotted lines on Figure 1.1-2). Underground piping and silt deposits in the catch basins are radioactively contaminated.

The 1985 characterization effort (Ref. #10) reported that accumulated silt in the catch basins had gross beta activity ranging from 7 to 330 pCi/g, with an average of 44 pCi/g. Depths and areas of contamination were not reported.

The catch basins were reexamined in the 1998 confirmatory survey (Ref. #32). The beta survey showed that one sample had a maximum concentration of 5000 dpm/100 cm^2, and the remaining samples had an average concentration of less than 1200 dpm/100 cm^2. The 1998 gross beta activity measurements are on the order of 15 to 20 pCi/g, similar to the average 1985 measurements (44 pCi/g). The 1998 sampling effort also showed that the activity in the catch basins is predominantly naturally occurring K-40, at concentrations ranging from 7 to 14 pCi/g. The concentration of Cs-137 and Co-60 ranged from 1 to 11 pCi/g and from 1 to 5 pCi/g, respectively.

4.2.2.4 *Process Water*

Because the PBRF is non-operational, there is no process water at the facility. When the facility was active, however, large quantities of process water were utilized. A complete description of the process water system was provided in Section 3.2.

4.2.2.5 *Sewer Systems*

Because the PBRF is non-operational, the sewer system is not used. In fact, most drains have been blocked to prevent usage. A discussion of the sanitary sewer system was provided in Section 3.2.

4.2.3 Air Quality and Management

Plum Brook Station is located in Erie County, which is in attainment for all National Ambient Air Quality Standards primarily because of the rural character of the area. A 1991 report stated that the Ohio EPA operates one monitoring station for total suspended particulates in the county that consistently in compliance with particulate standards (Ref. #12). Because of the limited operation of facilities at Plum Brook Station, there are limited emissions to the atmosphere and the site is not classified as a major emission source under the Clean Air Act Title V permitting program. There are no permitted emission sources at the PBRF (Ref. #53).

In order to keep the reactor tank in an inert environment, dry nitrogen gas is purged through the tank and vented to the atmosphere via the exhaust stack at the fan house (Building #1132). Because the tank is radioactive, it emits decay products, primarily tritium (H-3). The stack emissions are monitored continuously and compared to the Maximum Permissible Concentrations (MPCs) allowed under the current NRC license. No exceedances of the MPCs have occurred.

Air quality management practices observed when the facility was active were discussed in Section 3.2.

4.2.4 Noise

Noise sources at Plum Brook Station include an airstrip, transient noise blasts from test facilities, construction activities, and traffic noise. The Army Reserves and the Ohio Air National Guard also discharge pyrotechnic devices at Plum Brook Station. None of these activities is a significant noise source (Ref. #53).

Since the PBRF was shut down in 1973 and is currently inactive and uninhabited, there are essentially no noise sources at the facility.

4.2.5 Energy

Electricity is currently available at the PBRF. It is obtained from the Ohio Edison Company's local power grid and enters the PBRF through the substation (#1161). Infrastructure for natural gas service is in place at the facility and is used for facility unit heaters.

4.2.6 Hazardous Materials Management

Because the PBRF is not operational, no hazardous materials are used at the facility; *Emergency Planning and Community Right-to-Know Act* requirements currently do not apply to the PBRF. Hazardous materials management practices when the facility was active were discussed in Section 3.2.

4.2.7 Asbestos Containing Materials, Lead-Based Paint, and PCBs

During the site visit, peeling paint was noticed to be present throughout the PBRF buildings, in addition to material suspect to contain asbestos. A survey for asbestos containing material (ACM), lead-based paint (LBP) and polychlorinated biphenyls (PCBs) was not within the scope of this EBSR because comprehensive surveys for these materials in all buildings at the PBRF were conducted in the summer of 2000. The surveys consisted of a visual inspection and sampling/laboratory analysis for asbestos, lead in paint, and PCB content in both paint and in miscellaneous items; estimates on the total quantities of ACM, LBP, and PCBs at each PBRF building. The accessibility (height) of the material was also noted. The results of these comprehensive surveys are summarized below.

ACM Survey

The materials considered to have asbestos are listed in Table 4.2.7-1. The types, quantities, and locations of ACM by building are detailed in Table 4.2.7-2. Note that the report recommended that all quantities are estimates and should be checked by the Abatement Contractor prior to bidding.

TABLE 4.2.7-1. --*Materials Considered to Contain Asbestos*

ACM Detected
Fiberglass piping and systems insulation with canvas covered and tar paper (foil) covered fiberglass
All insulated valves, fittings (elbows, tees, etc.), air ducts, service equipment, and vibration cloth
All floor tile, linoleum, and mastics
All base moldings and ceiling tiles or panels (their mastics were acm)
Joint tape used on the cellulose panels in Building #1112 (Reactor Hot Lab), Room 9
All window caulking
All joint areas of drywall
All roof materials under the foam cover
Radioactive exclusion zones not tested, but should be considered suspect ACM
ACM Not Detected
All Plaster and Wall Board (Ceilings)
All Drywall Only

TABLE 4.2.7-2. —*Type and Quantity of Asbestos Containing Materials by Building*

Building #	Type and Quantity of ACM (SF, LF, Ea.)
1111	45,281 SF (floor tile, linoleum, base molding, roofing, caulking, insulation) 6,818 LF (pipe insulation) 60 Ea. 2" Mudded Fitting 6 Ea. 2.5" Mudded Fitting 224 Ea. 3" Mudded Fitting 213 Ea. 3.5" Mudded Fitting 94 Ea. 4" Mudded Fitting 107 Ea. 4.5" Mudded Fitting 105 Ea. 5" Mudded Fitting 20 Ea. 5.5" Mudded Fitting 44 Ea. 6" Mudded Fitting 85 Ea. 6.5" Mudded Fitting 8 Ea. 7" Mudded Fitting 36 Ea. 8" Mudded Fitting 16 Ea. 8.5 Mudded Fitting 59 Ea. 9" Mudded Fitting 20 Ea. 10" Mudded Fitting 14 Ea. 12" Mudded Fitting 2 Ea. 15" Mudded Fitting 2 Ea. 10" Mudded Valve 5 Ea. 12" Mudded Valve 15 Ea. 16" Mudded Valve 2 Ea. 14" Mag Valve Insulation
1112	20,064 SF (floor tile, base molding, roofing, caulking, wall paneling) 435 LF (pipe insulation) 12 Ea. 3" Mudded Fitting 2 Ea. 6" Mudded Fitting 3 Ea. 7" Mudded Fitting 3 Ea. 9" Mudded Fitting
1131	17,379 SF (floor tile, base molding, ceiling tile, insulation, roofing, miscellaneous packing and gaskets, caulking) 1,616 LF (pipe insulation) 2 Ea. 2.5" Mudded Fitting 70 Ea. 3" Mudded Fitting 54 Ea. 3.5" Mudded Fitting 40 Ea. 4" Mudded Fitting 20 Ea. 4.5" Mudded Fitting 49 Ea. 5" Mudded Fitting 11 Ea. 6" Mudded Fitting 8 Ea. 8" Mudded Fitting 6 Ea. 16 Mudded Valve

Building #	Type and Quantity of ACM (SF, LF, Ea.)
1132	20 SF (insulation, roofing, caulking) 675 LF (pipe insulation) 27 Ea. 3" Mudded Fitting 13 Ea. 3.5" Mudded Fitting 4 Ea. 4.5" Mudded Fitting 11 Ea. 5" Mudded Fitting 7 Ea. 7" Mudded Fitting
1133	11,210 SF (floor tile, base molding, caulking, insulation, roofing, vibration cloth, in boiler and piping system) 1,622 LF (pipe insulation) 6 Ea. 2" Mudded Fitting 149 Ea. 3" Mudded Fitting 94 Ea. 3.5" Mudded Fitting 30 Ea. 4" Mudded Fitting 49 Ea. 4.5" Mudded Fitting 11 Ea. 5" Mudded Fitting 6 Ea. 5.5" Mudded Fitting 5 Ea. 6" Mudded Fitting 6 Ea. 6.5" Mudded Fitting 5 Ea. 7" Mudded Fitting 2 Ea. 10" Mudded Valve
1134	61,143 SF (roofing, insulation, caulking) 398 LF (pipe insulation) 9 Ea. 2.5" Mudded Fitting 25 Ea. 3" Mudded Fitting 40 Ea. 3.5" Mudded Fitting 32 Ea. 4" Mudded Fitting 45 Ea. 4.5" Mudded Fitting 16 Ea. 5" Mudded Fitting 5 Ea. 5.5" Mudded Fitting 3 Ea. 6.5" Mudded Fitting 7 Ea. 9" Mudded Fitting
1136	228 LF (pipe insulation) 4 Ea. 4" Mudded Fitting 1 Ea. 6" Mudded Fitting 4 Ea. 8" Mudded Fitting
1141	102,900 SF (floor tile, base molding, ceiling tile, insulation, roofing, vibration cloth, caulking, drying board) 55,62 LF (pipe insulation) 77 Ea. 2.5" Mudded Fitting 306 Ea. 3" Mudded Fitting 174 Ea. 3.5" Mudded Fitting 137 Ea. 4" Mudded Fitting 109 Ea. 4.5" Mudded Fitting 81 Ea. 5" Mudded Fitting

Building #	Type and Quantity of ACM (SF, LF, Ea.)
1141 (cont'd)	39 Ea. 5.5" Mudded Fitting 4 Ea. 6" Mudded Fitting 18 Ea. 6.5" Mudded Fitting 24 Ea. 7.5" Mudded Fitting 7 Ea. 8" Mudded Fitting 7 Ea. 9" Mudded Fitting 2 Ea. 10" Mudded Fitting 2 Ea. 12" Mudded Fitting 1 Ea. 10" Mudded Valve 18 Ea. 12" Mudded Valve 80 Ea. Tar Coated Hangers
1191	1,200 SF (floor tile)

LF = linear feet; SF = square feet; Ea. = each

LBP and PCBs in Paint Survey

All structural steel (columns, beams, stairs, railings, etc.) should be considered high in lead. The source of the lead seems to be the primer, which is integrated into the steel. The various color paints that are peeling from the structural steel are mainly low in lead content (< 1% by weight), while the primer is intact and integrated into the steel. The Services Equipment Building (#1131); a diesel fuel above ground storage tank immediately north of Building #1131; the Precipitator (#1157); the Water Tower (#1151); and the remaining valve posts at the existing foundation of the Cooling Tower (#1152) also have high lead content (this conclusion for Buildings 1157 and 1151 is based on direct X-ray fluorescence readings, as opposed to laboratory analysis). The paint on Precipitator is damaged and peeling. All four samples in the Primary Pump House (#1134) also tested positive for lead. The majority of paint containing high amounts of lead is gray and peach colored. The quantities and locations of LBP per building are detailed in Table 4.2.7-3.

Paint samples were also tested for PCBs. All of the paint bulk sample analytical results for PCBs were < 50 parts per million (ppm). There was an analytical result of 49 ppm, 50 ppm, and 18 ppm PCB on a peach colored overhead door in Building #1134 (Primary Pump House). Because the analytical results did not have a suitable margin of error to determine this paint to be non hazardous for PCBs (<50 ppm), additional PCB sampling and analysis was conducted on the peach paint. This additional sampling and analysis showed the peach colored paint to be <50.0 ppm in all the PBRF Buildings. Although the additional sampling showed this paint to be non-hazardous for PCBs, the report recommended that the suspect interior peach colored overhead door in Building #1134 be wiped down with a proper cleaning agent to remove any suspect oily material.

The report notes that all peeling paint quantities are estimates due to the deteriorating condition of the paints; quantities of LBP should be checked by the Abatement Contractor prior to bidding.

Results of PCB Survey of Miscellaneous Items

The majority of the PCBs found were in fluorescent light fixtures and batteries. Table 4.2.7-4 details the types and quantities of each per building. There are damaged and leaking fluorescent light fixture ballasts throughout the PBRF Buildings. There are two (2) known PCB Ballast Oil Spill Areas in Building #1141 (Reactor Office and Laboratory Building) on the floor in Rooms #112 and #117.

In the early 1980's all transformers at the PBRF were tested for PCBs. Two were found to contain PCBs at levels greater than 50 ppm. One was located at the substation (#1161) and the other was adjacent to Building 1112. These transformers were removed and properly disposed of according to *Toxic Substances Control Act* (TSCA) regulations.

4.2.8 Waste Management

Since the PBRF was shut down in 1973, there have been no NASA personnel working at the PBRF on an 8-hour per day basis, but only checking on the facility daily. The PBRF is in mothball status. Without personnel regularly on the site, there is no solid waste generated. With the exception of the water supply to the fire hydrant system, all water systems have been abandoned; as stated in Section 4.2.2.5, no wastewater is generated at the PBRF.

The only waste noted during the site visit was 11 55-gallon drums, holding approximately 7 ½ cubic feet per drum, of disposable personnel protective equipment used during the routine environmental sampling and maintenance activities. This waste is considered Class A low-level radioactive waste. NASA personnel stated that a licensed transporter is called periodically to transport the drums to a licensed Class A low-level radioactive waste disposal facility.

Waste management practices when the facility was active were discussed in Section 3.2.

4.2.9 Radioactive Materials Management/Current Radiological Status of the PBRF

Other than residual radioactive contamination at the PBRF, radioactive materials remaining at the PBRF are primarily the reactor tank and the activated equipment remaining in Hot Dry Storage (Building 1112). These areas, as well as other areas that are contaminated by radionuclides, are secure and are only able to be accessed by specially trained personnel. The following discussion of the radiological status of the PBRF is taken primarily from the *Decommissioning Plan for the Plum Brook Reactor Facility*, Rev 0, December 1999 (Ref. #38).

A major characterization survey for the entire PBRF was conducted in 1985, and a confirmatory survey was conducted in 1998. Section 4.2.9.1 summarizes the characterization information from the two surveys. The results from the two surveys indicate that most of the residual radioactivity at the PBRF is confined generally within equipment and piping, with limited environmental contamination. The reactor tank internals and waste in the Hot Dry Storage Area contain most of the radioactivity.

TABLE 4.2.7-3. —*Quantity of Lead-Based Paint by Building*

Location	Paint Color	Est. Quantity Peeling Paint SF, LF, Ea	Accessibility (Elevation) 0-6 ft	6-12 ft	>12 ft	Sample #	Lab Results	Remarks
Building 1111								
Building 1111 elev. -25'-0" Area 21	Green	100 SF	X			N/S: REF. 1131-Pb-006	0.63% by WT. 0.14 mg/cm^2	Equipment
Building 1111 First Floor Area 1 West	Peach	100 SF	X	X		1111-Pb-036	1.2% by WT.	Overhead Door
Building 1112								No Samples with LBP
Building 1131								
Building 1131 Basement Aux. Eq. Room 20	Gray	12 SF, 25 LF	X			1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	South Wall, Piping
Building 1131 Basement Water Treatment Pump Room 21	Gray	75 SF, 15 LF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls, Piping, Valves, Pumps NOTE: Paint is peeling from insulation.
Building 1131 Basement Stairway to Battery Room	Gray	85 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Water Treatment Room 13	Gray	135 SF	X	X		N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Wall, Pipe, Equipment
Building 1131 First Floor Control Room 11	Gray	38 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Janitor Closet	Gray	4 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Office Room 5	Gray	5 SF	X	X		N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Boiler Room 15	Gray	26 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Boiler Room 15	Peach	70 SF		X		N/S: REF. 1134-Pb-032	2.2% by WT. 1.1 mg/cm^2	Rolling Doors

TABLE 4.2.7-3. —*Quantity of Lead-Based Paint by Building (continued)*

Location	Paint Color	Est. Quantity Peeling Paint SF, LF, Ea	Accessibility (Evaluation) 0-6 ft	6-12 ft	>12 ft	Sample #	Lab Results	Remarks
Building 1131 First Floor Boiler Room 15	Green	200 SF	X	X	X	N/S: REF. 1131-Pb-006	0.63% by WT. 0.14 mg/cm^2	Boilers, Equipment and associated Piping
Building 1131 First Floor Elevator Room 17	Gray	3 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Engine Room 18	Gray	83 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls
Building 1131 First Floor Engine Room 18	Green	100 SF	X			1131-Pb-006	0.63% by WT. 0.14 mg/cm^2	Machinery
Building 1131 First Floor Engine Room 18	Yellow	50 SF			X	N/S	POSITIVE LBP XRF 4.4 mg/cm^2	Crane
Building 1131 First Floor Engine Room 18	Peach		X	X	X	1131-Pb-035	1.6% by WT.	Overhead Door
Building 1131 First Floor Shop and Equipment Area 1	Yellow	50 SF	X			N/S	POSITIVE LBP XRF 4.4 mg/cm^2	Cabinet
Building 1131 First Floor Shop and Equipment Area 1	Green	40 SF	X			N/S: REF. 1131-Pb-006	0.63% by WT. 0.14 mg/cm^2	Cabinet
Building 1131 First Floor Shop and Equipment Area 1	Gray	130 SF	X			N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Walls, Assorted Metal/ Wood Cabinets
Building 1131 Mezzanine WTP- Top of Stairs	Gray	20 SF			X	N/S: REF. 1131-Pb 002	1.00% by WT. 0.34 mg/cm^2	Tank
Building 1131 Exterior	Peach	20 SF	X			N/S: REF. 1134-Pb-032	2.2% by WT. 1.1 mg/cm^2	Overhead Doors
Building 1131 Exterior	Beige	200 SF	X	X	X	N/S	No Lab Positive LBP XRF 2.6 mg/cm^2	Precipitor Tank, Stairs, ETC.
Building 1132								
Building 1132 First Floor Operating Area Room 1	Peach	N/A	X			1132-Pb-038	0.85% by WT.	Entry Door-Eastside

TABLE 4.2.7-3. —*Quantity of Lead-Based Paint by Building (continued)*

	Paint	Est. Quantity	Accessibility (Evaluation)					
		Peeling Paint						
Location	Color	SF, LF, Ea	0-6 ft	6-12 ft	>12 ft	Sample #	Lab Results	Remarks
Building 1133								
Building 1133 First Floor Boiler Room 14	Green	100 SF	X	X		N/S: REF. 1131-Pb-006	0.63% by WT. 0.14 mg/cm^2	Boiler and Associated Equipment
Building 1133 First Floor Boiler Room 14	Peach	10 SF	X	X		N/S: REF. 1134-PB-032	2.2% by WT. 1.1 mg/cm^2	Doors
Building 1133 First Floor Operating Area Room 1	Peach	30 SF	X	X		N/S: REF. 1134-PB-032	2.2% by WT. 1.1 mg/cm^2	Overhead Rolling Door Note: See Pcb Data
Building 1134								
Building 1134 First Floor Room 8	Peach	50 SF	X	X		1134-PB-032	2.2% by WT. 1.1 mg/cm^2	Rolling Door Note: 49 ppm PCB result
Building 1134 Mezzanine	Gray	25 SF	X			N/S: REF. 1131-PB-002	1.00% by WT. 0.34 mg/cm^2	Walls, Piping, Equipment, and Debris on Floor
Building 1136								
Building 1136 Ground Floor Main Area-Interior	Gray/Various Colors	1000 SF	X	X		N/S: REF. 1131-Pb-002	1.00% by WT. 0.34 mg/cm^2	Paint Debris on Floor Bird Feathers and Feces present
Building 1136 Ground Floor Main Area-Interior	Peach	150 SF	X	X		N/S: REF. 1134-Pb-032	2.2% by WT. 1.1 mg/cm^2	Overhead Rolling Door
Building 1136 Ground Floor Exterior	Gray	50 SF		X		N/S: REF. 1131-Pb-002	1.00% by WT. 0.34 mg/cm^2	East and West Sides around Gutters
Building 1136 Ground Floor Exterior	Peach	150 SF	X	X		N/S: REF. 1134-Pb-032	2.2% by WT. 1.1 mg/cm^2	Overhead Rolling Door
Building 1141								No Samples with LBP

TABLE 4.2.7-4. —*Type and Quantity of PCBs by Building*

Location	Fluorescent Lights Size and Quantity (Each)	Accessibility (Elevation) 0-6 ft	6-12 ft	>12 ft	Remarks
Building 1111: 1st Floor & Mezzanine Rooms, Offices, Etc.	8'-62 Ea.; 4'-122Ea.; 1'-6 Ea.		X	X	Batteries: 1-5 Cell Emerg. Light
Building 1112: 1st Floor	8'-35 Ea.; 4'-1 Ea.		X	X	Batteries: 2-5 Cell Emerg. Light
Building 1131: 1st Floor & Mezzanine Rooms, Offices, Labs, Exhaust Hoods, Etc.	8'-7 Ea.; 4'-285 Ea.	X	X	X	Batteries: Water Treatment: Rm 13-(1-3'x6') Batteries Basement: Rm 25-(2-3'x8') Batteries & 1-5 Cell Emerg. Light
Building 1132/1133: 1st Floor & Basement Rooms, Offices, Common Areas, Etc.	8'-20 Ea.; 4'-40 Ea.		X	X	Batteries: 1-5 Cell Emerg. Light
Building 1136: Interior	4'-1 Ea.	X	X		
Building 1141: 1st Floor & 2nd Floor Rooms, Offices, Labs, Common Areas Etc.	8'-174 Ea.; 4'-103 Ea.		X		Batteries: Basement: Rm 7- 1-5 Cell Emerg. Light

Sections 4.2.9.2, 4.2.9.3, and 4.2.9.4 summarize radiological characterization information collected in 1985 (Ref. #10) and in 1998 for the major facilities, contaminated support facilities, and areas expected to be non-radiologically contaminated, respectively.

Residual contamination in the PBRF buildings and environment is from activation products (i.e., H-3 and Co-60) and fission products (i.e., Cs-137 and Sr-90). The background concentrations of these radionuclides are essentially negligible. Radionuclides such as K-40 and Ra-226 are naturally occurring and were measured during the 1985 PBRF characterization. A summary of background radionuclide concentrations is presented in Section 4.2.9.1.

4.2.9.1 *Radiological Characterization of the PBRF*

Two radiological characterization efforts have been conducted at the PBRF. A radiological survey of the PBRF was conducted in 1985. A confirmatory survey was conducted in September 1998 to verify the 1985 results and to provide additional isotopic data to use for estimating doses for license termination. During the 1998 confirmatory survey, buildings that were not expected to require decontamination were surveyed because contamination in these areas could impact decommissioning planning and costs. Two areas of environmental contamination, the Emergency Retention Basin and the Pentolite Ditch were also sampled to confirm the 1985 data.

Most of the inventory at the PBRF is contained in the reactor tank internals and the waste in the Hot Dry Storage Area. Tritium (H-3) is the primary radionuclide of concern in these areas. Outside of the reactor tank and Hot Dry Storage Area, the radionuclides of concern consist of both mixed fission products and activated materials, with the primary radionuclides expected to be Co-60, Cs-137, and Sr-90.

1985 Characterization Survey

The first survey in 1985 (Ref. #10) characterized the buildings and ground surface around the PBRF. The floor and inside wall surfaces at all elevations (including basements) were surveyed in the Reactor Building, the Hot Laboratory, the Waste Handling Building, the Fan House, the Primary Pump House, the hot pipe tunnel, and the Reactor Office and Laboratory Building. The exterior surfaces of the containment vessel dome and roofs were not surveyed because both were resurfaced. The grounds within the fenceline were also surveyed, including soil surfaces, paved areas, and the Pentolite Ditch from the PBRF to Plum Brook.

Background samples were collected and analyzed for eight categories of soil and six buildings that were not affected by plant operations (Ref. #10). The background characterization consisted of measuring gross alpha and gross beta activity levels for all samples and direct radiation levels for a portion of the samples.

For soils, the majority of the samples had gross alpha and gross beta activity levels of 6 to 10 pCi/g and 30 to 40 pCi/g, respectively. Direct radiation levels were approximately 6 μR/hr. These levels are consistent with background levels in other areas of the U.S. One set of background soil samples was collected from a location containing an outcropping of shale. These samples had average gross alpha and gross beta activity levels three times higher than the balance of the background soil samples.

For building surfaces, background characterization included collection of smear samples and static measurement of gross alpha and gross beta activity levels. The average gross alpha activity level was 3 cpm, which is consistent with gross alpha levels reported for similar materials. The average gross beta activity level was 30 cpm, which is lower than gross beta levels reported for similar materials. For typical equipment characteristics, the reported count rates correspond to gross alpha and gross beta activity levels of approximately 25 and 250 dpm/100 cm^2, respectively.

The outdoor area and buildings were surveyed on grids for gross alpha and gross beta activity within the PBRF fenceline. Direct radiation measurements were taken with a micro-roentgen meter. Surface and deep soil samples were analyzed for gross alpha and gross beta activity.

Isotopic analyses were performed on all samples containing significant quantities of radioactive material when those samples represented the systems or structures from which they came. Radioisotopes were identified by gamma pulse height analysis using germanium detectors networked in multichannel analyzer systems. Strontium-90 was analyzed by chemical separation of strontium, holding for ingrowth of the Y-90 daughter and subsequent counting and analysis. Low energy gamma or pure beta emitters, such as Fe-55 or Ni-63, were not measured during the isotopic analysis.

The 1985 characterization survey estimated the radiological inventory of the reactor tank and internals. Three core samples from the biological shield were analyzed for gross alpha and gross beta activity; some portions of the core samples were analyzed for Co-60. Piping and drain systems were also characterized. External contamination and direct dose rates were measured and corrosion films were collected. The water handling systems, including the Hot Retention Area and

Cold Retention Basins, also were analyzed. External contamination and direct dose rates were measured and sludge samples were collected and analyzed.

The major conclusions from the 1985 characterization survey were:

- The majority of the radionuclide inventory at the PBRF is in two locations: (1) the reactor tank and its internals and (2) in stored waste in the Hot Dry Storage Area (in the Hot Laboratory).
- Most of the contamination inside the buildings is inside piping and equipment. Other than the internal piping and equipment contamination, residual contamination in the facilities is limited to locations where piping or equipment has leaked (e.g. the hot pipe tunnel and evaporator in the Waste Handling Building).
- In the reactor tank (exclusive of reactor internals) and the primary cooling system, Co-60 was the dominant gamma-emitting nuclide based on analysis of corrosion film samples. Europium isotopes detected were associated with activation of gadolinium from the injection system during reactor operations. The absence of fission products in the primary cooling system is consistent with the historical information.
- The isotope Co-60 and fission products Cs-137 and Sr-90 were detected in the canal and quadrant drains, hot sumps, resin pits, Hot Retention Area, and Cold Retention Basins.
- Areas of environmental contamination contain Co-60 and fission products.

1998 Confirmatory Characterization Survey

In 1998, a confirmatory radiological survey was conducted at portions of the PBRF to support the planning for decommissioning and license termination activities. For the confirmatory survey, only the easily detected radionuclides were analyzed (by gamma spectroscopy) and quantified. As a result, beta emitters and radionuclides that are difficult to detect (i.e., Sr-90, Fe-55, Ni-63, and other low energy beta emitters) were not identified and quantified. The analysis for the primary gamma emitters (i.e., Co-60, Cs-137, and europium isotopes) was determined to be adequate to verify the 1985 characterization data. Where possible, the sampling techniques and locations used for the 1998 survey duplicated those of the 1985 survey to ensure consistency. However, because exact locations could not be duplicated, the sampling results from the 1998 investigation were compared with the 1985 investigation results primarily to identify any significant differences.

The results from the 1998 confirmatory survey generally confirmed the findings from the 1985 survey. Gamma scans of outdoor areas showed exposure rates of 5 to 10 μR/hr, which are typical for background levels. The 1998 confirmatory survey examined the Emergency Retention Basin, Water Effluent Monitoring Station, Pentolite Ditch, PBRF grounds, PBRF paved areas, catch basins, Cold Retention Area, Reactor Building outside the reactor containment vessel, Reactor Office and Laboratory Building, Service Equipment Building, Fan House, Waste Handling Building, and the cold service tunnels. The areas were surveyed to measure gross beta activity (pCi/100 cm^2) and direct radiation exposure rates. In addition, soil, sediment, and concrete samples were analyzed for gamma-emitting radionuclides.

In general, the 1998 confirmatory survey confirmed the contaminated and uncontaminated areas identified during the 1985 characterization survey. The 1998 confirmatory survey identified six additional contaminated areas: four laboratories (Rooms 207, 209, 210, and 213A) in the Reactor Office and Laboratory Building; an area of contamination on the -4.6-m (-15-ft) basement level of the Reactor Building; and on the PBRF pavement near the entrance to the Reactor Building. Within the Emergency Retention Basin, the 1998 confirmatory survey identified a high Cs-137 concentration of 200 pCi/g while the 1985 high concentration of Cs-137 was 90 pCi/g. These findings are not expected to impact the degree of remediation required at these areas.

The gamma characterization information from the 1998 survey shows that the dominant gamma sources are Cs-137 and Co-60. Other gamma-emitting nuclides are only small contributors (less than 1 percent). With the exception of a single sample from canal F, gamma activity is dominated by Cs-137 at all PBRF areas (e.g., environmental contamination, sumps, floors in the Reactor Building). In canal F, the activity is dominated by Co-60.

4.2.9.2 *Major Facilities at the PBRF*

This section summarizes radiological characterization information for the major facilities at the PBRF.

Reactor Building (Building 1111)

The majority of the radioactivity at the Reactor Building is contained inside the reactor tank. The biological shield and several piping systems are also radioactively contaminated. Radioactivity was detected on the surfaces of the quadrants, canals, and drains. The following paragraphs summarize characterization data for the parts of the Reactor Building.

Reactor Tank and Internal Components

The reactor tank has the highest radionuclide inventory of all the areas at the PBRF. Radionuclide inventory estimates of the reactor tank and its internal components were presented in the 1980 environmental report (Ref. #5). To calculate the radionuclide inventory of the reactor tank, separate calculations were performed for each of the major components of the core box and beryllium reflector. Large pieces, such as through tubes, thermal shields, and the reactor tank, were analyzed as several segments. The calculations were built on estimates of integrated neutron exposure, activation cross section for the nuclides of interest in each component, the radioisotope half-life, and the decay time. Table 4.2.9.2-1 identifies the isotope of interest (first column), the June 30, 1978, inventory estimates (second column), and the 1978 inventories decayed to December 31, 2003 (third column). (Year 2003 was assumed because this is a time during which decontamination of the PBRF and waste removal is currently expected to occur.) As shown in Table 4.2.9.2-1, H-3 dominates the inventory.

TABLE 4.2.9.2-1. ***—Estimated Inventory in the Reactor Tank and Internal Components***

Nuclide	Inventory (curies) as of 6/30/1978[a]	Inventory (curies) as of 12/31/2003[b]
H-3	156,800	37,266
Co-60	2,640	92
Fe-55	7,340	10.5
Ni-63	45	37
Ni-59	0.5	0.5
Zn-65	115	0.0
Al-26	1.4	1.4
Cd-113m	0.8	0.2
Total	**166,943**	**37,408**

a. From Ref. #5.
b. Calculated by decaying the 1978 inventory estimates to the year 2003.

Reactor Primary Cooling Water System and Primary Cooling Shutdown System

Two corrosion film samples from valves in the primary cooling water system were analyzed in 1985. The two samples showed similar levels of activity (256 and 375 dpm/100 cm^2). A gamma pulse height analysis conducted on the sample with higher activity identified the specific nuclides Co-60, Eu-152, Eu-154, and Eu-155. No fission products, such as Cs-137, were identified. Cobalt-60 had the highest activity of the gamma-emitting radionuclides. The lack of cesium is consistent with the historical information, indicating that there was no fuel leakage. The presence of europium is suspected to be from irradiated gadolinium that was accidentally injected by a safety system (Ref. #10). Except for special equipment (e.g., strainers and some valves), 1985 exposure rates from piping and equipment in this area were less than 30 mR/hr.

Reactor Biological Shield

The biological shield surrounding the reactor tank was activated by neutrons that entered the concrete and interacted with elements. Three core samples were taken from the biological shield in 1985 and analyzed for gross alpha, gross beta, and gamma emitters. The samples were analyzed for europium, but only Co-60 was detected. The average Co-60 concentration in the biological shield within 25 cm (10 in.) of the reactor tank was 17.5 pCi/g. A sample of the reinforcing steel in the concrete was also analyzed for gross alpha, gross beta, and gamma emitting nuclides. Cobalt-60 was detected at a concentration of 325 pCi/g in the reinforcing steel.

Reactor Quadrants and Canals, and Their Pump-out and Recirculation Systems

The 1985 characterization data for the quadrants, canals, and their pump-out recirculation systems included alpha- and beta-gamma radiation measurements of the building wells, direct radiation readings, and collected crud samples. The characterization showed:

- Reliable direct radiation measurements from the canals and quadrants were difficult to obtain because of the radiation field from the reactor tank and biological shield.
- The average concentration of loose alpha contamination, loose beta-gamma contamination, and direct radiation readings in the canals was approximately 2 dpm/100 cm^2, 1000 dpm/100 cm^2, and 0.1 mR/hr, respectively.
- Overall, the pump-out and recirculation system were contaminated internally, but they have little or no external contamination. External dose rates from piping and valves ranged from 0.01 to 0.6 mrem/hr. Drain crud samples contained 0.1 to 1 pCi/g of gross alpha activity and up to 20,000 pCi/g of gross beta activity. Cobalt-60 was the dominant gamma-emitting radionuclide.
- Direct radiation measurements in the canals ranged from 0.001 to 0.3 mR/hr.
- Deep underground soil samples were collected, and the analytical results verified that the canals (G and K) did not leak contaminated water into the ground.

As part of the 1998 confirmatory survey, a 10 cm (4-in.) diameter concrete core sample approximately 8 cm (3 in.) deep was taken from canal F, located outside the containment that connects to both the mock-up reactor and the canals going into the Hot Laboratory. Cs-137 and Co-60 were detected at concentrations of 2.7 pCi/g and 156 pCi/g, respectively.

Reactor Building Rooms

The Reactor Building rooms were surveyed in both 1985 and 1998. Loose and fixed contamination and direct radiation measurements both inside and outside the containment vessel in 1985 showed:

- Inside the containment vessel, loose alpha contamination levels ranged from 0 to 5 dpm/100 cm^2, loose beta-gamma contamination levels ranged from 0 to almost 200 dpm/100 cm^2, and direct radiation readings ranged from 0.006 to a maximum of 500 mR/hr in the sub-pile room. The average direct radiation reading in the other areas ranged from 0.01 to 0.045 mR/hr.
- Outside the containment vessel, loose alpha contamination levels ranged from 0 to 5 dpm/100 cm^2, loose beta-gamma contamination levels ranged from 0 to almost 350 dpm/100 cm^2, and direct radiation readings ranged from 0.005 to 0.230 mR/hr.

The Reactor Building rooms outside the containment vessel were also surveyed during the 1998 confirmatory survey. A total of 105 direct beta measurements and smears were taken along with a single concrete core sample at the -4.6-m (-15-ft) elevation where a hot spot was identified at the -15 ft level near the east wall (location RB056). One of the 105 beta measurements had a count rate of about 43,000 dpm/100 cm^2. Another measurement had a count rate of about 7000 dpm/100 cm^2. The remaining 103 beta measurements had count rates less than 2000 dpm/100 cm^2, and the average rate was about 100 dpm/100 cm^2.

A 10 cm (4-in.) diameter concrete core sample approximately 8 cm (3 in.) deep was taken at the hot spot (43,000 dpm/100 cm^2). Cobalt-60 and Cs-137 were detected at concentrations of 0.1 pCi/g and 0.2 pCi/g, respectively.

Hot Drains, Sumps, Pumps, and Valves

The 1985 characterization data for the hot drain system included alpha and beta-gamma radiation measurements, direct radiation readings, and collected crud samples. Direct radiation readings from the hot drain system sumps ranged from 0.007 to 2 mR/hr. Ten of the 12 sumps had average readings of 1.2 mR/hr. Crud samples from the hot sumps had elevated alpha and gamma radiation readings, with alpha activity levels ranging from 15 to 9500 pCi/g, and gamma activity levels ranging from 580 to 130,000 pCi/g. The dominant gamma-emitting radionuclides were Co-60 and Cs-137.

Hot Laboratory (Building 1112)

Most of the radioactive contamination in the Hot Laboratory is from stored waste in the Hot Dry Storage Area. Contamination has also been identified in the hot cells and rooms surfaces.

Hot Dry Storage Area

The waste in the Hot Dry Storage Area of the Hot Laboratory has the second highest estimated radionuclide inventory of all the contaminated areas at the PBRF. This waste consists of radioactively contaminated items similar to that in the reactor tank (e.g., beryllium pieces and control rod sections). Estimates of radionuclide inventories in the Hot Dry Storage Area were presented in the 1981 environmental report (Ref. #5 and also in Ref. #10). The method for estimating the inventories is discussed in Appendix A of the 1980 environmental report and involves separate calculations for each of the major components. The calculations were built on estimates of integrated neutron exposure, activation cross section for the nuclides in the various components, the half-life of the active isotopes, and the decay time. These inventory estimates, as of June 30, 1978, are presented in the second column of Table 4.2.9.2-2. The 1978 inventories were decayed to December 31, 2003, a time during which decontamination of the PBRF and waste removal is currently expected to occur (third column). As shown in Table 4.2.9.2-2, H-3 dominates the inventory.

During the 1985 characterization, TLDs were lowered into the Hot Dry Storage Area to obtain dose rate measurements. No smear samples, which indicate surface contamination levels, were taken inside the Hot Dry Storage Area.

TABLE 4.2.9.2-2. —*Estimated Radionuclide Inventory of the Waste in the Hot Dry Storage Area*

Nuclide[a]	Inventory (curies) as of 6/30/1978[b]	Inventory (curies) as of 12/31/2003[c]
H-3	34,600	8,223
Co-60	16,100	559
Fe-55	14,600	16
Zn-65	1	0.0
Total	**65,301**	**8,798**

a. Other nuclides were calculated to be less than 1 percent of the total.
b. From Ref. #5.
c. Calculated by decaying the 1978 inventory estimates to the year 2003.

Hot Cells

The seven hot cells in the Hot Laboratory were surveyed in 1985 using instrument scans and wipe samples. Loose alpha contamination in the cells ranged from 0 to 370 dpm/100 cm^2, and loose beta-gamma contamination ranged from 200 to 173,000 dpm/100 cm^2. Direct radiation ranged from 1 to 450 mR/hr. Isotopic analyses of wipe samples with the highest contamination levels indicated that Co-60 and Cs-137 dominate the measured activity.

Rooms

The rooms in the Hot Laboratory include the decontamination room, repair shop, storage room, mezzanine, cold work area, hot work area, and hot handling area. The floors, walls, and ceilings of the rooms were surveyed in 1985 using instrument scans and wipe samples. The 1985 characterization data show that contamination levels in the Hot Laboratory rooms, exclusive of the decontamination room, were similar to those in the Reactor Building rooms outside of the containment vessel. For areas other than the decontamination room, the loose alpha contamination ranged from 0 to 8 dpm/100 cm^2 and loose beta-gamma contamination ranged from 0 to 18,852 dpm/100 cm^2. Direct radiation levels in these same areas ranged from 0.003 to 1 mR/hr. The decontamination room had loose alpha contamination as high as 208 dpm/100 cm^2, loose beta-gamma contamination as high as 337,000 dpm/100 cm^2, and dose rates as high as 8 R/hr.

4.2.9.3 *Support Facilities and Other Areas at the PBRF*

Radiological characterization information for the contaminated support facilities at the PBRF are briefly discussed in the following paragraphs. The support facilities are smaller and have lower levels of contamination than the major facilities described in Section 4.2.9.2. The contamination generally is in readily removable equipment or in areas that are more simply decontaminated. The structures themselves have limited contamination. A summary of characterization information for the contaminated support facilities is presented in Table 4.2.9.3-1. Also discussed in this section are areas of contaminated pavement.

The highest contamination levels found in the support facilities during the 1985 survey were in the hot pipe tunnels (shown in Figure 1.1-2). The piping in the tunnel, which was used to handle radioactive liquid and gasses, contains radioactive contamination, and the tunnel floor is radioactively contaminated in one area.

The next highest contamination levels were in an evaporator in the basement of the Waste Handling Building (#1133). Other equipment and piping in this building contain radioactive contamination, and surface contamination has been identified throughout the building. In the Fan House (#1132), equipment (e.g., ducts and piping) contains measurable radioactive contamination, and contamination has been identified throughout the basement floor. In the Reactor Office and Laboratory Building (#1141), radioactive contamination has been found on laboratory hoods, in piping, and on the floors of some of the radiochemistry laboratories. In the Primary Pump House (#1134), equipment and piping, as well as pits and sumps, contain radioactive contamination.

At the Hot Retention Area (#1155), the storage tanks and associated piping and equipment are radioactively contaminated, and low levels of contamination (i.e., less than the levels in Regulatory Guide 1.86 [USAEC 1974], according to Ref. #10) have been identified in the concrete vault. At the Cold Retention Basins (#1154), the basin liners, concrete structures, and the silt deposits on the liners are radioactively contaminated. Underground soil samples collected in 1985 verified that the Hot Retention Area and Cold Retention Basins did not leak contaminated water into the ground.

The areas examined in the 1998 survey generally confirmed the results. For the Fan House, Waste Handling Building, and Reactor Office and Laboratory Building, the 1998 results are consistent with the 1985 results. In general, the more extensive 1985 survey and the 1998 verification survey showed that there was only localized contamination in the support structures.

Areas of Contaminated Pavement

Two areas of known low-level waste spills have been identified: one near the Waste Handling Building (#1133) concrete pad and one in the vicinity of the Primary Pump House (#1134) resin pits (see Figure 1.1-2). The 1985 characterization effort involved collecting deep and shallow cores near the concrete pad at the Waste Handling Building. Samples from the cores showed radiological contamination to a depth of 1.8 m (6 ft). At the same location, gross beta activity measurements were 1500 pCi/g at a depth of 0.3 m (1 ft) and 100 pCi/g at a depth of 1.8 m (6 ft). Gross alpha activity measurements at the same depths were 90 and 7 pCi/g, respectively. No radiological concentration was reported for the second spill area in the vicinity of the Primary Pump House (#1134) resin pits. The 1998 survey confirmed the presence of contamination near the Waste Handling Building, but no contamination was detected at the previously identified spill area near the Primary Pump House.

During the 1998 survey, an additional contaminated location was identified on the pavement near the entrance to the Reactor Building, where total beta activity up to 42,000 dpm/100 cm^2 was measured.

Table 4.2.9.3-1. *Summary of Survey Results for Support Facilities at the PBRF*

Building/ Structure	Summary of 1985 Characterization Survey Results	1998 Confirmatory Survey	
		No. of Survey Measurements	Results
Reactor Office and Laboratory Building (1141)	• Loose alpha contamination ranging from 0 to 4 dpm/100 cm^2 • Loose gamma-beta contamination ranging from 0 to 137 dpm/100 cm^2 • Average direct radiation less than 0.02 mR/hr	• 120 direct beta measurements • 120 smears	• Two measurements were about 50,000 dpm/100 cm^2 • Three measurements were between 5000 and 10,000 dpm/100 cm^2 • All others were less than 2000 dpm/100 cm^2
Primary Pump House (1134)	• Loose alpha contamination ranging from 0 to 2 dpm/100 cm^2 • Loose gamma-beta contamination ranging from 0 to 29 dpm/100 cm^2 • Direct radiation about 0.01 mR/hr	None	None
Fan House (1132)	• Loose alpha contamination ranging from 0 to 2 dpm/100 cm^2 • Loose gamma-beta contamination ranging from 0 to 102 dpm/100 cm^2 • Direct radiation less than 1 mR/hr	• 60 direct beta measurements • 60 smears	• One measurement was about 7000 dpm/100 cm^2 • All others were less than 2500 dpm/100 cm^2
Waste Handling Building (1133)	• Loose alpha contamination ranging from 0 to 5 dpm/100 cm^2 • Loose gamma-beta contamination ranging from 0 to 11797 dpm/100 cm^2 (the highest value is in the basement; the next highest value is 2000 dpm/100 cm^2) • Direct radiation ranges from 0.02 to than 3 mR/hr	• 60 direct beta measurements • 60 smears	• One measurement was about 7000 dpm/100 cm^2 • Most others were less than 2500 dpm/100 cm^2
Hot Retention Area (1155)	• Tanks are contaminated; concrete vault contamination was less than the levels in Regulatory Guide 1.86 (USAEC 1974) • Direct radiation ranged from 0.044 to 2.8 mR/hr	None	None
Cold Retention Basins (1154)	• Alpha contamination ranged from 0 to 3 dpm/100 cm^2 • Beta contamination ranged from 25 to 1061 dpm/100 cm^2 • Direct radiation less than 0.1 mR/hr	• 8 direct beta measurements • 8 smears	Wipe samples range from 1000 to 5000 dpm/100 cm^2
Hot pipe tunnel	• Activity primarily in the 4-in. polyethylene piping. Contact dose rates range from 6 to 2200 mR/hr • Loose alpha contamination ranged from 0 to 17 dpm/100 cm^2 • Loose beta-gamma contamination ranged from 0 to 47,363 dpm/100 cm^2 with a hot spot from line leak • Direct radiation ranged from 2 to 85 mR/hr	None	None

4.2.9.4 *Facilities Expected to be Clean*

Based on the 1985 and 1998 characterization information, several support facilities within the PBRF fence were determined to be uncontaminated. These facilities are the:

- Service Equipment Building (#1131)
- Gas Services Building (#1135)
- Compressor Building (#1136)
- Substation (#1161)
- Security Building (#1191).

Based on historical knowledge, at the time of the 1985 characterization survey, the following facilities were considered to be uncontaminated and were not surveyed. This assessment was not revisited as part of the 1998 confirmatory survey:

- Cold pipe tunnel
- Water tower (#1151)
- Sludge basins (#1153)
- Precipitator (#1157)
- Cryogenic and Gas Supply Farm and Building (#1195 & #9837)
- Gas Storage Structure (#1196).

These facilities will be surveyed as part of the final status survey of the Decommissioning Project.

4.2.10 Hazardous Waste Management

No hazardous waste is currently generated at the PBRF because it is not utilized. Hazardous waste management practices when the facility was active were discussed in Section 3.2.

4.2.11 Pollution Prevention and Recycling

No pollution prevention and recycling activities occur at the PBRF because it is non-operational and mothballed. There are no NASA personnel working at the PBRF on an 8-hour per day basis. Hence, no materials are used that would necessitate pollution prevention or recycling actions.

4.2.12 Pesticides/Herbicides

During the site visit, NASA personnel reported that pesticides and herbicides are used at the PBRF on an "as needed" basis to clear vegetation from the foundations of buildings and at the fence line. An outside contractor does all pesticide and herbicide applications. No pesticides or herbicides are stored at the PBRF.

Pesticide/herbicide use when the facility was active was discussed in Section 3.2.

4.2.13 Storage Tanks and Pipelines

Storage tanks and pipelines at the PBRF can be divided into three groups: those used to manage low-level contaminated water, and those associated with water treatment or fuel storage.

Low-level Contaminated Water

The Hot Retention Area (#1155) contains eight 227,100 liter (60,000 gallon) underground storage tanks within a concrete vault that were used to contain radioactively contaminated water from the hot drain system, and the canals and quadrants of the reactor. The Cold Retention Basins (#1154) each held approximately 1.9 million liters (500,000 gallons) of water and were also used to store water from the quadrants and canals. The existing radiological contamination at both of these areas was discussed in Section 4.2.9.

Water Treatment

The Water Tower (#1151) held both raw and treated water. It is not expected to be radiologically contaminated. Similarly, the Precipitator (#1157) was used as part of the water treatment process and is expected to be radiologically clean.

Several caustic and acid above ground storage tanks have been removed (removal dates unknown). Each was about 760 liters [200 gallons]. One pair (one of each) were associated with the water treatment system and were located just west of the Precipitator. Another pair were located just west of the Fan House (#1132). Similarly, an above ground storage tank containing acid was present adjacent to the Cooling Tower (#1152), but it too has been removed.

Fuel Storage Tanks

There is one above ground fuel storage tank currently at the PBRF. It holds approximately 1,325 – 1,500 liters (350 – 400 gallons) and was used to store diesel fuel for the boilers. It is located just off the northeast corner of the Service Equipment Building (#1131). During the site visit it was noted that the tank has a plate on the side dated 1942 and that stained soil was present beneath the east end of the tank. NASA personnel interviewed reported that this tank had a significant overflow during filling in about 1975. Diesel fuel flowed to the catch basin located approximately 18 meters (60 feet) north of the tank and a substantial quantity reached the Water Effluent Monitoring Station. NASA personnel constructed a dike to prevent the fuel from entering Pentolite Ditch. When enough fuel was present, it was ignited. NASA personnel were unable to estimate the quantity of fuel released.

Three underground storage tanks were located just off the southwestern-most corner of the Services Equipment Building (#1131). Two of these were diesel fuel tanks; they were removed in 1989 according to state regulations. The third tank was used to store waste solvents and oils. It was also removed in 1989. However, residual contamination remains in site soils and groundwater. Corrective actions under the *Resource Conservation and Recovery Act* are necessary to address dissolved phase VOCs in groundwater in the immediate vicinity of this former tank. A remediation system, consisting of a groundwater recovery and treatment system, has been designed to treat the contaminated groundwater. A recovery well will be installed near existing monitoring well EB-RA-05 (see Figure 4.2.2.1-1). The current plan is to house the groundwater treatment system inside Building 1131 (Ref. #42).

4.2.14 Surface Impoundments

Surface impoundments present at the PBRF are the Emergency Retention Basin in the southeast part of the facility, the Sludge Basins (#1153) in the northeast corner of the fenced area, and the Drying Basins in the northern part of the site, outside the fence. The Emergency Retention Basin is known to be contaminated by radionuclides, as discussed below. Neither the Sludge Basins nor the Drying Basins are thought to contain radiation above background levels because they were part of the raw water treatment system and therefore should not have been in contact with radioactive substances.

Emergency Retention Basin

As discussed in Section 3.2, during operations the Emergency Retention Basin was used for emergency storage of radioactively contaminated water, and the stored water could evaporate, percolate into the soil, decay off and be discharged, or be diluted and discharged. Therefore, the soil in the basin was contaminated with radionuclides. This area was characterized during both the 1985 and 1998 studies; the contaminants are Cs-134, Cs-137, and Sr-90. Surface soil in the Emergency Retention Basin (i.e., from 0 to 15 cm [0 to 6 in] below the surface) and soil from 15 to 30 cm (6 to 12 in.) below the surface in specific areas is radioactively contaminated.
The 1985 characterization of the Emergency Retention Basin included collecting shallow (0 to 3.0-m [0 to 10-ft]) cores, near-surface (5 to 15-cm [2 to 6-in.]) soil samples, and surface (0 to 5-cm [0 to 2-in.]) soil samples. The shallow cores were analyzed for gross alpha and gross beta activity and the results indicated that the residual activity was confined to the upper 15 cm (6 in.) of soil. Near-surface soil samples collected from the Emergency Retention Basin indicated that gross beta activity averaged 78 pCi/g. Surface soil samples collected at locations where the near-surface samples showed the highest activity levels were also analyzed for gross beta activity. Radionuclide concentrations in the surface soil samples were 10 to 20 times greater than that in the near-surface samples.

The near-surface samples having the highest activity also were analyzed to determine the isotopic distribution. The average Co-60, Cs-137, and Sr-90 concentrations in the near surface samples were 22, 32, and 2.4 pCi/g, respectively.

During the 1998 confirmatory survey, a gamma scan was conducted (about 1.3 cm [0.5 in.] from the surface) and five soil samples were collected. The gamma scan showed peak exposure rates of about 50 μR/hr, with average exposure rates ranging from 20 to 30 μR/hr. These exposure rates are generally similar, but they are slightly less than those reported in the 1985 survey. The soil samples taken in 1985 were from the southern portion of the Emergency Retention Basin (the most contaminated area in the 1985 survey). The decay-adjusted 1985 concentrations and the 1998 concentrations are within a factor of 3 of each other. The differences could be due to the different sample locations and the contamination not being homogenous. The lower concentrations at the 0 to 5-cm (0 to 2-in.) depth and the higher concentrations at the 5 to 15-cm (2 to 6-in.) depth may indicate downward contaminant migration.

Sludge Basins and Drying Basins

As mentioned above, the Sludge Basins and Drying Basins were part of the raw water treatment system. Raw water was obtained from Lake Erie and treated onsite by adding alum, lime, chlorine, and an acid or caustic to adjust pH as necessary. During the records review conducted as part of this EBS, a process flow diagram was found that showed "3 chemical feed lines and chlorine line." However, no records were found that identified exactly the "3 chemicals." Although chlorine was used, it is possible that an algaecide or similar chemical was also used to control microorganism growth in the process water.

Interviews with personnel that worked at the PBRF when it was active found that periodically the water and/or sludge from the Sludge Basins was sampled and analyzed at the onsite laboratory in the Services Equipment Building (#1131). Although the exact analytical parameters analyzed for are unknown, it was stated that if the results were acceptable, the water and/or sludge from the Sludge Basins would then be pumped to the Drying Basins. Engineering drawings of the facility show a 3-inch sludge discharge line connecting the Sludge Basins and the Drying Basins.

During the site visit, it was noted that the Sludge Basins are currently holding water and that the Drying Basins are overgrown with vegetation and not distinguishable from the surrounding natural landscape.

4.2.15 Radon

A 1987 study of radiological contamination at the PBRF discovered elevated concentrations of radon- 222 (a radioactive daughter product from the decay of radium-226) (Ref. #9). Radon 222 is a naturally occurring isotope that persists as a radioactive gas with a half-life of 3.8 days. The study found elevated concentrations of radon present throughout the containment vessel in building #1111, with high concentrations particularly noticeable at the lower elevations. The report noted that since the containment vessel is sealed off from the subterranean structures by means of the steel shell and massive concrete, the source of the radium is not likely to be from the earth itself. Instead, it was determined that the radon gas must be emanating from the massive concrete structures of the containment vessel. Large amounts of local stone (gray shale) are present as aggregate in this concrete. Tests of the gray shale, referred to in geological circles as Huron or Mentor shale, which underlie the entire Plum Brook Station, have shown that it contains naturally high levels of radium-226, which is a decay product of the natural uranium present in these formations (Ref. #9).

During operations, normal air turnover in the facility purged the radon-222 from the facility; however, the ventilation system has not operated since the shutdown in 1973. As a result, radon gas has and will continue to accumulate in the containment vessel. For radon concentrations in the range of 4 to 20 pCi/1, the EPA requires temporary and/or permanent remedial action to be taken to reduce levels below 4 pCi/l (Ref. #9).

During the site visit, continuous radon monitoring equipment was observed within the containment vessel. When the radon levels approach 4 pCi/1, NASA personnel take measures to instigate the normal turnover of air to vent the area. This is done on a regular basis, approximately once per month.

4.2.16 Onsite and Offsite Transportation of Solid Waste, Hazardous Waste, and Radioactive Waste

There is no onsite or offsite transportation of solid or hazardous waste from the PBRF. The PBRF was shut down in 1973 and has been mothballed since then. No NASA personnel work at the PBRF on an 8-hour per day basis, but only check on the facility daily. Therefore, there are no personnel on site to generate solid or hazardous waste that would need to be transported on (within) or off the site.

There is no onsite transportation of radioactive waste on the PBRF, but there is offsite transportation. As stated in Section 4.2.8, Waste Management, there is a small amount of low-level radioactive waste consisting of disposable personnel protective equipment generated by NASA personnel during routine maintenance and environmental sampling activities. This waste is stored in 55-gallon drums that hold approximately 7 ½ cubic feet of material per drum. During the site visit, 11 55-gallon drums of this waste was stored onsite in the Waste Handling Building (#1133).

NASA personnel stated that they periodically call a licensed transporter to transport the drums to a licensed Class A low-level radioactive waste facility for disposal. Transportation of waste when the facility was active was discussed in Section 3.2.

4.2.17 Traffic and Parking

Since there is no regular activity at the PBRF, traffic and parking is currently not an issue. During operation, PBRF employees used a large parking lot approximately 500 feet southwest of the Reactor Building (#1111). During the site visit, the parking surface was observed have multiple fractures with vegetation growing through fractures.

4.2.18 Natural and Cultural Resources

The information in this section has been primarily summarized from References #19 and #53.

4.2.18.1 *Biological Resources*

Plum Brook Station is part of a regional ecosystem encompassing Sandusky, parts of Lake Erie, and several Lake Erie islands. The station contains significant areas of grassland, bushland, and woodlands. A biological survey conducted in 1994 determined that no significant plant communities were located at Plum Brook Station (Ref. #19). A total of 327 vascular plant species were collected or observed during the 1994 survey, and, of these, 251 species are indigenous to the area. The plant species number was considered low due to a history of disturbance and the predation of deer. A number of wildflowers prevalent throughout other areas in Erie County are absent from the PBS because of excessive browsing. Areas of greatest plant diversity are in the central and southern portion of Plum Brook Station and not near PBRF (Ref. #19).

The 1994 Survey found 116 bird species during the summer birding season on the PBS (Ref. #19). Of these, 92 species were either confirmed or likely nesters. Five species were considered to be late migrants and nine species visitors only. Common birds at the PBS include the American robin, the red-winged blackbird, the European starling, the song sparrow, and the common grackle. The amphibian and reptile survey found 2 species of salamanders, 7 species of frogs and toads, 6 species of snakes and 4 species of turtles. None of these amphibian or reptile species were listed as Federal or state endangered or threatened species (Ref. #19). Several streams, ponds and artificial water bodies exist on the PBS. The 1994 Survey found 14 species of fish, which are common State-wide and tolerant of water quality and habitat degradation, except for the brook stickleback (Ref. #19). Forty-one species of butterfly and 385 species of moth were recorded in the 1994 Survey. Mammals at Plum Brook Station include white tailed deer, raccoons, woodchucks, moles, and coyotes. Large populations of deer and coyotes are reported to be on the PBS. The 1994 Survey suggests that while coyotes feed mainly on small mammals and birds, the large deer population also provides a food source for the coyote (Ref. #19).

4.2.18.2 *Wetlands and Floodplains*

Portions of Plum Brook Station lie within the 100-year and 500-year floodplains. The PBRF is located neither in the 100-year or 500-year floodplain, nor have wetlands been delineated in the immediate vicinity of the PBRF, based on review of floodplain and national wetlands inventory maps, respectively (Ref. #53). Most of the identified wetlands are small, isolated palustrine emergent, scrub shrub, or forested. Past PBRF site development including the construction of drainage ditches to prevent the accumulation of standing water have reduced the potential for wetland formation (Ref. #53).

4.2.18.3 *Endangered and Threatened Species*

The biological survey conducted in 1994 noted that a number of vascular plants species that were once common to the area had become rare on the PBS, surviving only as individual populations rather than in intact communities. This pattern reflects the fragmented nature of the area and its history of disturbance (Ref. #19). Table 4.2.18.3-1 lists those species ranked by the Division of

Natural Areas and Preserves as Ohio Rarities as endangered (E), threatened (T) and potentially threatened (P).

TABLE 4.2.18.3-1.—*Endangered, Threatened and Potentially Threatened Vascular Plant Species at Plum Brook Station*

Type	Species	Common Name
Endangered	*Carex cephaloidea*	Thin-leaf sedge
	Hypericum gymnanthum	Least St. John's-wort
Threatened	*Arenaria laterifolia*	Grove sandwort
	Carex conoidea	Field sedge
	Helianthus mollis	Ashy sunflower
Potentially Treatened	*Baptisia lactea*	Prairie false indigo
	Carex alata	Broad-winged sedge
	Gratiola virginiana	Round-fruited hedge-hyssop
	Hypericum majus	Tall St. John's-wort
	Rhexia virginiana	Virginia meadow-beauty
	Scleria triglomerata	Tall nut-rush
	Viola lanceolata	Lance-leaved violet

One Federally-listed species, the bald eagle (*Haliaeetus leucocephalus*), was observed during the 1994 Survey near one of the reservoirs. While this species did not nest on the PBS at the time, it is likely that it is a sporadic visitor to the area (Ref. #19). A 1991 report stated that approximately four breeding pairs of the bald eagle occur within 5 to 10 miles of Plum Brook Station (Ref. #12). The Indiana bat (*Myotis sodalis*) is also listed as a Federal and state-endangered species in Erie County, where the Station is located. The 1991 report notes that no survey has been conducted to identify habitats of the Indiana bat in the Plum Brook area (Ref. #12); it is not known if such a survey has been conducted in the meantime.

Several state-listed rare and endangered bird species were found on the PBS during the 1994 survey: Cooper's hawk, upland sandpiper, alder flycatcher, least flycatcher, sedge wren, marsh wren, Brewster's warbler, black-throated green warbler and Henslow's sparrow (Ref. #19).

Three species of special concern were identified at Plum Brook Station: Blanding's turtle, eastern fox snake and the smooth green snake. None of these protected or special status species were identified at the PBRF (Ref. #19).

Three species of state-endangered moth (*Papaipema silphii*, *Spartiniphaga inops*, and *Hypocoena enervata*) have been found in nature preserves within 5 miles of the Plum Brook Station and their associated habitats (wetlands and Prairie Dock) exist at Plum Brook Station (Ref. #12).

During the site visit for this EBSR, it was noted that the only vegetation within the fenced PBRF area is grass.

4.2.18.4 *Historic, Archaeological, and Cultural Resources*

The Spacecraft Propulsion Research Facility (B-2 Facility) is the only building at Plum Brook Station that has been designated a National Historic Landmark. Native American archaeological sites have been identified in the Plum Brook Station area, but only outside of the Plum Brook Station fence line (Ref. #53).

Currently, no facilities at the PBRF have been identified as historic resources, and no archaeological or cultural resources have been identified at the facility. Due to the extensive grading and other earth-disturbing activities that occurred during construction of the PBRF, it is unlikely that any intact subsurface archaeological or cultural resources would be present at the site. However, as part of the pre-decommissioning activities, a letter initiating the Section 106 Consultation Process regarding the potential historical status of the PBRF has been sent to the State Historic Preservation Officer (SHPO) (Ref. #53). The SHPO has responded with a "no interest" determination.

4.3 FORMER PENTOLITE AREA WASTE LAGOONS

As discussed in Section 3.1, Past Uses, the area that is now the PBRF was originally part of the Plum Brook Ordnance Works known as the Pentolite Area. Pentolite, a high explosive, was manufactured here. The Pentolite Area Waste Lagoons were located in what is now the southwestern portion of the PBRF.

In 1999, a Limited Site Investigation of the Pentolite Area Waste Lagoons was conducted as part of the DERP/FUDS program. As part of this investigation, five soil borings were installed in the area of the former waste lagoons. No groundwater samples were collected. The soil samples were analyzed for VOCs, Target Analyte List Metals, and explosives. No explosives were detected in any of the samples, nor were any RBCs exceeded for any of the other analytes. The report concluded that contamination was not revealed by the field activities and therefore it appears that the operation and decommissioning activities associated with the waste lagoons did not release significant contaminants into the environment.

4.4 PRE-DECOMMISSIONING ENVIRONMENTAL CHARACTERIZATION

In August 2000, surface and subsurface (1-5 feet) soil samples were collected at various locations around the PBRF in accordance with the *Decommissioning Pre-Design Investigation Plan* (Ref. #49). Several areas of low-level VOC, SVOC, and PCB soil contamination were identified. However, except for 1 sample that contained an estimated concentration of an SVOC above the RBC, the concentrations detected were well below available RBCs (Ref. #50).

4.5 COMMUNITY RELATIONS

As part of the decommissioning project of the PBRF, NASA has created a Community Relations Plan (CRP) to lay out the mechanisms for informing and involving the public in activities and decisions related to the project. The plan meets the requirements for Public Participation outlined by the Nuclear Regulatory Commission's (NRC) Final Rule of License Termination, FR

Vol. 62, No. 139, 7/21/97. The goals and methods of community outreach are broad. The methods of community outreach include: news releases; media advisories; public services announcements; direct mailings; exhibits; fact sheets; web site; community/public information sessions; open house/tour of the Plum Brook Station; videotape presentations; briefings/presentations to local officials; public meetings; community information bank/center; newsletter, and so on. The CRP indicates that many of these activities are to occur when the decommissioning of the PBRF begins.

A number of community outreach activities have occurred and are on-going. These include the posting of a web site (http://www.lerc.nasa.gov/WWW/pbrf/), the establishment a Community Information Bank (CIB) at the Firelands College Library in Huron, Ohio, the institution of. Community Workgroup, and regular meetings between the NASA Decommissioning Project Manager and local township and county officials. The CIB is a repository of information on the decommissioning of the PRBF and is continually updated and available to the public upon request. The Community Workgroup consists of fourteen men and women of Erie and Huron counties that participate in a variety of community activities and professions, including the area's educational, environmental and minority communities. The Workgroup meets quarterly, and the meetings are open to the public with public service announcements aired on local radio stations in advance of the meetings. The Workgroup meeting minutes are available on the web site. The Workgroup's most recent meeting occurred October 17, 2000. Informal meetings between various local township and county officials and the NASA Decommissioning Project Manager and a NASA GRC Public Affairs Specialist to discuss NASA's plans for decommissioning have occurred since July 1999.

An upcoming community involvement activity is the 30-day public review of the Draft EA NASA is preparing on the PBRF Decommissioning Project. When the Draft EA is completed, an availability announcement will be published in the local newspaper and media and the document will be made available for public review and comment for 30 days. Copies of the document will be available in the CIB at Firelands College. In addition, a summary presentation will be given to the Community Work Group during the 30-day comment period.

Previous community outreach activities that included the decommissioning of the PBRF include an Open House and Tour of the Plum Brook Station on October 30, 1999, and a community information session on the decommissioning of the PBRF on November 3, 1999. The Open House and Tour was of the entire Station, with a drive-by of the PBRF site and question and answer session on future decommissioning plans for the site. The NASA GRC and Plum Brook Station have sponsored a number of other educational and outreach activities in the community on other work done at the Station contributing to space exploration.

4.6 ENVIRONMENTAL JUSTICE

From 1990 Census data, the *Environment Justice Implementation Plan for NASA Lewis Research Center* identified a total of 30,500 persons, of whom approximately 4,200 are black and 450 are Hispanic (15.25% of the population) that live within a 5-mile radius of the PBS, including the entire City of Sandusky.

For this EBSR, a search of 1990 Census data was conducted to determine the number of people living within a one-mile radius of the PBRF site. As of 1990, a total of 761 persons lived within 1 mile of the PBRF and 0 persons lived within 0.5 mile of the facility. To determine the minority population within the one-mile radius, Census Block Group data were reviewed. Figure 4.6-1 shows the four Census Block Groups that intersect the one-mile radius of the PBRF and their minority and below poverty population percentages.

All of the Block Groups (BGs) except 6004 extend beyond the boundaries of the figure. BG 5002 and 6001 extend northward, while BG 6003 extends to the west. Only 1.1% of BG 5002 and 20.1% of BG 6001 lie within the one-mile radius. While the entire BG 6004 is within the boundaries of the figure, only 35.2% of it is within the one-mile radius. BG 6003 covers the remainder of the radius.

The percentages of minority and below poverty populations listed on the figure for each BG are for the entire BG. For example, BG 5002 has 2.3% minority and a 2.7% below poverty populations, but only 1.1% of the entire BG 5002 is within the one-mile radius. Similarly, BG 6001 has 2.3% minority and 0.7% below poverty populations with only 20.1% of the entire BG within the one-mile radius. BG 6004 has 6.0% minority and 4.7% below poverty populations with 35.2% of the BG within the one-mile radius. And while BG 6003 shows 1.2% minority and 2.8% below poverty populations, these populations are located in areas not shown on the figure, as no one lives on the PBS. The 716 persons found within the one-mile radius live north of Bogart Road and east of the PBS boundary on Columbus Avenue in BGs 5002, 6001 and 6004.

The standard used to determine environmental justice impacts on minority and below poverty populations is based on county percentages. The PBRF is in Erie County. Census data from 1990 identified 76,799 persons in the Erie County, of whom 7,907, or 10.23%, compose the minority population of Erie County. The percentage of the Erie County population below poverty is 9% (Ref. 18). The data from BG 5002, 6001 and 6004 have a combined minority population percentage of is 10.6% and a combined below poverty percentage of 8.1%. Because only a portion of each BG is within the one-mile radius, it is unlikely that the entire minority and below poverty populations of each BG are found within the portion covered by the one-mile radius.

4.7 ENVIRONMENTAL CONDITION OF PROPERTY AT THE PBRF

Since this EBS was conducted in accordance with ASTM Standard 6008-96, *Standard Practice for Conducting Environmental Baseline Surveys*, the Property Categorization Scheme identified in that standard is being used. Table 4.7.1 shows the property category definitions.

Most buildings at the PBRF have some type of contamination that requires remediation and are therefore included in category 6. The categorization of the buildings and land at the PBRF is discussed below and summarized in Table 4.7-2. The environmental condition of property map is shown in Figure 4.7-1.

Category 1 Areas

The open space at the PBRF that is not placed into another category as shown on Figure 4.7-1 is classified as Category 1 property. These areas have either been sampled and shown to be free of contamination, or they are areas for which no data has been identified indicating that a release or migration of hazardous substances or petroleum products has occurred.

TABLE 4.7-1.—*ASTM Property Categorization*

Type No.	Environmental Condition of the Property (ECP) Area Category Definitions
1	Areas where no storage, release, or disposal of hazardous substances or petroleum products has occurred (including no migration of these substances from adjacent areas)
2	Areas where only storage of hazardous materials, hazardous substances or petroleum products has occurred (but no release, disposal, or migration from adjacent areas has occurred)
3	Areas where storage, release, disposal, and/or migration of hazardous substances or petroleum products has occurred, but at concentrations below action levels
4	Areas where storage, release, disposal, and/or migration of hazardous substances or petroleum products has occurred, and all remedial actions necessary to protect human health and the environment have been taken
5	Areas where storage, release, disposal, and/or migration of hazardous substances or petroleum products has occurred, removal and/or remedial actions have been selected and may be underway, but all required remedial actions have not yet been taken
6	Areas where storage, release, disposal, and/or migration of hazardous substances or petroleum products has occurred at concentrations above action levels, but required response actions have not yet been implemented.
7	Areas that are unevaluated or require additional evaluation

TABLE 4.7-2.—*Facility Categorization Matrix*

Building No.	Building Name	Type of Contamination Identified	EBS Category Number
1111	Reactor Building	Radiological, ACM, LBF, PCBs	6
1112	Reactor Hot Laboratory	Radiological, ACM, PCBs	6
1131	Reactor Services Equipment Building	Radiological, ACM, LBP, PCBs, Diesel Fuel	6
1132	Reactor Fan House	Radiological, ACM, LBP, PCBs	6
1133	Reactor Waste Handling Building	Radiological, LBP, PCBs	6
1134	Reactor Primary Pump House	Radiological, LBP	6
1135	Reactor Gas Services Building	N/A	1
1136	Reactor Compressor Building	LBP, PCBs, Oil	6
1141	Reactor Office and Laboratory	Radiological, PCBs	6
1151	Reactor Water Tower	LBP (X-Ray Fluorescence)	6
1152	Reactor Cooling Tower (Removed); foundation and valve posts remain	LBP (X-Ray Fluorescence)	6
1153	Reactor Sludge Basins	N/A	7
1154	Reactor Cold Retention Basins	Radiological	6
1155	Reactor Hot Retention Area	Radiological	6
1157	Reactor Precipitator	LBP (X-Ray Fluorescence)	6
1161	Reactor Substation	PCBs removed	4
1191	Reactor Security Building	N/A	2
1192	Reactor Water Effluent Monitoring Station	Radiological	7
1195 & 9837	Reactor Cryogenic and Gas Supply Farm and Building	N/A	1
1196	Reactor Gas Storage Structure (Removed)	N/A	1
N/A	Drying Basins	N/A	7
Open space	N/A	Various	See Figure 4.7-1

The *Reactor Gas Storage Structure (#1196)* was used strictly to store hydrogen gas and was removed when the PBRF was shutdown. The cement foundation is currently present and the area is now covered with grass. While it is near the Reactor Compressor Building that has LBP, PCBs and oil contamination, it is not likely that any of that contamination has migrated to the former Gas Storage Structure area. It is equally not likely that any radiological contamination has migrated to the structure.

The *Reactor Cryogenic and Gas Supply Farm and Building (#1195 and #9837)* were part of the same system as the Gas Storage Structure described above. The building was removed and this area is currently overgrown with vegetation. For the same reasons as discussed above for the Gas Storage Structure, this area is included in Category 1.

Category 2 Areas

The *Reactor Security Building (#1191)* was and is used strictly as the ingress/egress point to the PBRF. There is no known or suspected contamination in this building. But because monitoring equipment is stored here that contains radioactive check sources, this building is classified as an area where only storage of hazardous materials has occurred.

Category 3 Areas

The area of the former Pentolite Area Waste Lagoons, an approximately 5,850 square meter (107 m x 55 m) [63,000 square foot (350 ft x 180 ft)] area in the southwest portion of the PBRF, is classified as Category 3. This is because of its documented history of receipt and storage of nitroaromatic-contaminated wastewater and recent characterization of no identified contamination remaining in the soils.

During the latest environmental characterization effort at the PBRF, soil samples from several areas were found to contain trace levels of VOCs, SVOCs, and PCBs (all less than 100 parts per billion). Because the concentrations detected were estimated values and all but one were well below available RBCs, these areas are included in Category 3. Although the extent of these areas of apparently very minor contamination is not delineated, the trace levels found indicate that no further investigation is necessary.

Category 4 Areas

Transformers present at the *Reactor Substation (#1161)* were found to contain PCBs and were removed in the early 1980s.

Category 5 Areas

The only Category 5 area at the PBRF is the area adjacent to the southwest corner of Building 1131 where the former waste solvent UST was located. This area is being addressed under the state RCRA program. Contaminated soils have been removed and the Ohio EPA has approved the installation of a groundwater pump-and-treat system as the remedial action. This treatment system is currently in the final design stage.

Category 6 Areas

All areas discussed below are contaminated with various substances and are planned for decontamination as part of the Decommissioning Project. They are therefore included in Category 6.

The *Reactor Building (#1111)* that housed the nuclear reactor remains a source of radiological contamination despite the fact that it was defueled in 1973. A recent Asbestos Containing Materials/Lead Based Paint/PCB Survey (ACM/LBP/PCB Survey) (Ref. #52) also discovered all three of these contaminant sources in the Reactor Building as well. The ACM/LBP/PCB Survey results were discussed in Section 4.2.7.

The *Reactor Hot Laboratory (#1112)* was used to handle irradiated materials and contains radiological contamination. In addition, the ACM/LBP/PCB Survey found ACM and PCB present in the building.

The *Reactor Services Equipment Building (#1131)* housed an active radiochemistry/analytical lab as well as currently housing diesel generators, a battery bank, and air compressors (Appendix C, Photos 5, 6, and 7). During the site visit, diesel fuel stains were observed on air compressors and surrounding concrete (Appendix C, Photo 8). The building also contains ACM, LBP and PCBs (Ref. #52).

The *Reactor Fan House (#1132)* contains pumps and compressors used in handling air from the hot areas. The 1987 Evaluation of the PBRF (Ref. #10) tested for radiological contamination throughout the facility and noted slight radiological contamination in the Fan House. The ACM/LBP/PCB Survey also found all three materials in the building.

The *Reactor Waste Handling Building (#1133)* houses the liquid waste evaporator system and a waste storage facility. The 1987 report stated that some low-level radiological contamination was found in the basement evaporator room. The ACM/LBP/PCB Survey also found LBP and PCBs in the building. Photo 18 in Appendix C shows only a single example of the long strips of peeling paint visible throughout the building.

The *Reactor Primary Pump House (#1134)* contains the primary cooling water pumping system and components, a pump pit, a hot sump, and resin pits (Appendix C, Photo 17). The Evaluation notes that the building contained radiological contamination and that a low-level radiological spill occurred near the resin pits, contaminating soil there. The ACM/LBP/PCB Survey also found LBP in the building.

The site visit to the *Reactor Compressor Building (#1136)* revealed oil staining on the compressors and concrete. LBP and PCBs were also found in the building during the survey (Ref. #52). Because radioactive materials were not handled in this building, it was not tested for radiological contamination during the 1987 Evaluation (Ref. #10).

The *Reactor Office and Laboratory Building (#1141)* contained repair shops, hot and cold sumps, offices and a radiochemistry lab. The 1987 Evaluation reports small radiological spills on the floor of rooms 212 and 214 that penetrated the cracks between the floor tiles (Ref. #10, #35). PCBs were also found in the building during the ACM/LBP/PCB Survey.

Both the *Cold Retention Basins (#1154)* and the *Hot Retention Area (#1155)* contain low levels of radiological contamination (Ref. #10).

The ACM/LBP/PCB Survey discovered LBP on the *Reactor Water Tower (#1151)*, the *Precipitator (#1157)*, and the remaining valve posts at the foundation of the removed *Reactor Cooling Tower (#1152)* through X-Ray Fluorescence tests, but did not take samples of the paint chips for further laboratory analysis (Ref. #52). Therefore, it is known that the paint contains lead, but the actual percent-by-weight is still unknown. This loose paint must be removed as LBP and disposed of as lead-containing waste prior to demolition of these structures. Analytical testing of the paint waste will be required at that time to determine if this waste is hazardous under RCRA (i.e., toxicity characteristic for lead, D008 waste).

Category 7

The Decommissioning Plan states that the *Reactor Water Effluent Monitoring Station (WEMS) (#1192)* has a small amount of silt, possibly with radiological contamination, accumulated between the weirs (Ref. #38). In addition, there is a potential for solvent contamination of these sediments as discussed in Section 5.2. This area therefore requires additional evaluation.

The *Reactor Sludge Basins (#1153)* and the *Drying Basins* (located outside the fence in the northern portion of the PBRF) were part of the raw water treatment system. For this reason, no radiological contamination is suspected. However, as discussed in Section 5.2, these areas have never been sampled. There is potential for water treatment chemicals such as algaecides to have accumulated in these areas and they therefore require further evaluation.

During the review of data conducted for this EBS, no information was found on the extent of the area of contamination from the 2 areas of low-level waste spills (just south of Building #1134 and south of Building #1133). Soils were sampled to a depth of 10 feet in the area south of the Waste Handling Building (#1133) in the 1985 characterization study, and contamination was reported to a depth of 6 feet. No direct indication of the areal extent of the contamination was given (It was stated that soil should be removed to a depth of 8 feet and that a total of 185 cubic yards of soil should be removed. Assuming a square excavation, this would imply an area of 25 feet on each side). No radiological concentration was reported in the 1985 study for the second spill area near the Primary Pump House (#1134). The 1998 survey confirmed the presence of contamination near the Waste Handling Building, but no contamination was detected at the previously identified spill area. The lateral extent of the spill near Building #1133 should be determined, and the presence or absence of contamination associated with the second spill should be verified.

4.8 ADJACENT PROPERTIES

As discussed in Section 1.1, the adjacent properties within the scope of this EBS are those within an approximately one-half mile radius of the PBRF boundary. These areas include a wooded area to the north within the Plum Brook Station boundary, residential areas adjacent to the northern boundary of the Station, and a mixture of open fields and wooded areas to the east, west, and south. With the exception of the residential area to the north, which is located about 0.6 miles from the Reactor Building at PBRF, all other adjacent areas are within the boundaries of Plum Brook Station. Aerial photos of the PBRF and surrounding areas are provided in Appendix B.

In addition to conducting a records search of existing data on the adjacent properties within the one-half mile radius, a "Vista Check" Federal and state database search for known sites within 1.5 miles of the PBRF was conducted. This report is customized to be in compliance with ASTM Standard E1527 (Phase I Environmental Site Assessments) and is attached as Appendix F of this EBSR.

A portion of the PBRF property and the area south of Pentolite Road was part of the Plum Brook Ordnance Works (PBOW) where 2,4,6-trinitrotoluene (TNT), dinitrotoluene (DNT) and pentolite were manufactured from 1941 to 1945. The activities conducted at the PBOW were discussed in detail in Section 3.1 of this EBSR. Within the adjacent properties one-half mile radius, five contaminated former PBOW sites are present. These sites, located south and southwest of the PBRF, are the Pentolite Road Red Water Ponds, the Garage Maintenance Area, the Rail Car Unloading Area/Sellite Area, Ash Pit #1 and Acid Area #3 (Figure 4.8-1).

Because the general groundwater flow direction at the PBS is towards the north, contaminated groundwater at these areas could potentially affect the environmental condition of the PBRF. In addition, contaminated soils present at these areas can act as an on-going source for groundwater contamination. The available data on these areas and conclusions on the likelihood of these areas affecting the PBRF are discussed below.

Methodology

Each of the contaminated sites within the PBRF adjacent area has been the subject of at least one environmental investigation. Different contractors or agencies, however, completed these investigations, in different years. In order to make the results easily readable, comparable and meaningful, this report compares all soil results to screening levels presented in EPA Region III's most recent (October 5, 2000) Risk Based Concentration (RBC) table. Contaminants included are VOCs, SVOCs, nitroaromatic compounds, and inorganics (Ref. #54). All surface and subsurface soil sample results are compared to $1/10^{th}$ of the RBCs for residential soil for noncarcinogenic contaminants. For example, a noncancer RBC for residential soil of 1 will be reduced to 0.1. This $1/10^{th}$ reduction is consistent with EPA Region III's risk screening criteria for potential Superfund sites and is done to ensure that chemicals with additive effects are not prematurely eliminated during screening (Ref. #54).

In order to estimate the potential for migration of contaminants in soil to groundwater, all surface and subsurface soil sample results are also compared to EPA Region III's Soil Screening Levels (SSLs) with a Dilution Attenuation Factor (DAF) of 1. As contaminants in soil percolate through soil to groundwater, they are subjected to physical, chemical and biological processes that tend to reduce their concentrations over time. According to EPA documentation, for waste areas of 10 acres or greater, a DAF of 10 or less is an appropriate threshold point (Ref. #24). SSLs with a DAF of 1 are used in this report and represent the most stringent threshold for which to measure sample results against. Only those sample results above 1/10th RBCs or SSLs are discussed in this section.

All surface and groundwater sample results are compared to 1/10th RBCs for tap water for noncarcinogenic contaminants. This comparison is made for the same reason as discussed above for soils. Only those sample results above 1/10th RBCs are reported.

4.8.1 Pentolite Road Red Water Ponds

The Pentolite Road Red Water Ponds (PRRWPs) are located upgradient of the PBRF south of Pentolite Road (Figure 4.8-1). This site is approximately 425 feet from the southern boundary of the PBRF. It is the closest and most contaminated site to the PBRF in the adjacent area.

The PRRWPs initially consisted of two distinct basins or ponds, but the original shapes of the two ponds have shrunk significantly since they were originally constructed in 1941 and used in PBOW operations. Both ponds were subsequently filled in and little physical evidence of their former configuration remains (See Photos 8 and 9 in Appendix B). There are no buildings on the PRRWPs site.

4.8.1.1 *History*

PBOW Operational Period: 1941-1945

During the operational years of the PBOW, the PRRWPs received wastewater from TNT Manufacturing Areas A and B. This wastewater, referred to as "red water" because of its color, contained byproducts of the TNT manufacturing process, including nitroaromatic compounds. The PRRWPs consisted of two adjacent basins, a western and an eastern basin, each measuring approximately 100 feet wide by 140 feet long. The basins were constructed with precast 15 by 9-foot 9-inch blocks of concrete with asphaltic-filled expansion joints. The concrete was placed on 4 to 6 inches of gravel or #4 stone. A 1941 construction drawing for the PRRWPs indicated a one-foot high levee surrounding the basin (Ref. #26).

Review of historical site drawings indicate that wastewater from the wastewater settling basins at TNT Manufacturing Areas A and B flowed through wooden flumes and pipes to a wastewater treatment and incineration area (Waste Water Disposal Plant #1), then to the PRRWPs disposal area via an elevated 12-inch diameter discharge pipe (Figure 4.8.1.1-1) The Pentolite Road Red Water Ponds had a maximum capacity of 182,000 cubic yards of wastewater (approximately 36.9 million gallons) (Ref. #26).

Post PBOW Operational Period: 1945 to Present

Following World War II, the PBOW was in standby condition from 1945 to 1946. During this time, the Army began decontaminating and decommissioning many of the buildings and structures associated with the manufacturing of ordnance.

Removal and decontamination of TNT and DNT lines was conducted in 1945. Drain lines and steam lines were flushed and dismantled; PBOW historical records, however, do not indicate where they were flushed or where the water used for flushing was disposed (Ref. #21). Previous documentation does not state whether the limestone beds of the two basins were removed. From 1954 to 1958, Ravenna Arsenal, Inc. continued the decontamination efforts on the PBOW that the Army had begun in 1945 (Ref. #14). A letter to Ravenna Arsenal, Inc. from the U.S. Army Ammunition, Procurement, and Supply Agency in Joliet, Illinois describes work to be accomplished by Ravenna Arsenal, including apparent decontamination and decommissioning activities. Item 2 of this letter states: "Examine leaching bed near Reservoir #1, destroy some of the contaminants and re-route drainage to reduce amount of red water flowing into Plum Brook." The leaching bed referred to in this letter may be the Pentolite Road Red Water Ponds (Ref. #26).

An aerial photograph taken in October 1950 shows a disturbed area where the PRRWPs were located (Ref. #26). The eastern basin of the PRRWPs resembles the rectangular shape of the original wastewater basin and appears to be predominately dry. The western basin of the PRRWPs is irregularly shaped with its western corner overgrown with vegetation. The remainder of the western basin appears to contain water. An aerial photograph taken in 1956 shows a similarly shaped area for both the eastern and western basin of the PRRWPs, but the western basin, unlike in the 1950 photograph, appears to be predominately dry (Ref. #26).

4.8.1.2 *Physical Characteristics of the PRRWPs*

The terrain at the PRRWPs is relatively flat with an approximate elevation between 625 and 629 feet above MSL (Ref. #21). During field reconnaissance of the area conducted in March 1994 and fall 1994, the actual ponds were no longer present and the area consisted of thick masses of cattails with bare areas which seasonally contain ponded water (Ref. #19). Areas of stressed vegetation were also observed. Ponded water within this area, which occurs in topographical depressions, particularly after heavy rains, was observed to have a reddish tint (Ref. #21, #26).

A ditch, running southwest to northeast, traverses the PRRWPs area to the east. The ditch is approximately 10-feet deep. The water in the ditch flows in a northeasterly direction into Pentolite Ditch, which parallels Pentolite Road. According to information provided by NASA PBS employees, an underground clay pipe ("drainage tile") drains the PRRWPs area and discharges into the second ditch that parallels Pentolite Road (Ref. #26).

Groundwater flow in the PRRWPs area in both the overburden and bedrock aquifers has been documented to flow north (Ref. #26). The unconsolidated overburden, composed of glacial outwash material, varies in thickness from a few feet to over 40 feet. The bedrock consists of both limestone and shale. However, because of the shallow bedrock and thin veneer of overburden materials overlying the bedrock aquifer in the PRRWPs area, it is likely that the vertical, or downward, flow of groundwater from the overburden into the bedrock predominates over the horizontal flow in the overburden (Ref. #26). This flow pattern would facilitate migration of contaminants in the overburden soils and groundwater into the bedrock aquifer (Ref. #26).

4.8.1.3 *Contaminant Response Actions*

Four contaminant response actions by PBS personnel to incidents at the PRRWPs occurred. Prior to any specific environmental investigation of the PRRWPs, those contaminant response actions are summarized below.

1977 Actions

The first response action occurred in April 1977 when PBS personnel reported localized pockets of reddish brown water in the small surface ditch east of, and adjacent to, the PRRWPs (Ref. #26). The source was discovered to be a broken drain tile on the southeast corner of the ditch. Retention dikes and sump pits were promptly excavated to prevent leakage of the material to surface streams. From April 13, 1977 to May 3, 1977, a private disposal contractor removed approximately 60,000 gallons of the "red" water. Grading and drainage improvements were made to the area to alter surface runoff patterns (Ref. #26).

The local Air National Guard backfilled the original settling basin to bring it higher in elevation than the surrounding area. A new drainage ditch was dug approximately 300 feet east of the original ditch, which was then backfilled. The intent of these activities was to eliminate ponding in the area, thus reducing the amount of surface water that could mix with the red water residue, producing red-colored water (Ref. #26). A 1995 site management plan states that standing water still occurs in topographical depressions in the PRRWPs area (Ref. #21).

Surface water samples were collected from the surface drain tile pool and the retention trench that was dug to prevent runoff to surface streams. The samples were reported to be deep red in color and odorless, with a pH of 7.3 (Ref. #26). A flame test of the samples suggested the presence of sodium, which was subsequently verified by atomic absorption spectrophotometry to be present in a ratio of 2 to 1 to sulfate. This indicated that the major inorganic constituent is sodium sulfate, a by-product of the TNT process and a constituent of red water (Ref. #26).

Tannin and significant amounts of iron were also detected in the samples. The presence of tannin was attributed to an acid reaction with wooden vats and plumbing from PBOW structures. The presence of iron, in the range of 20 parts per million (ppm) was attributed to an acid/chemical reaction with iron plumbing from the PBOW structures. Phenols were also detected in the two samples but their source could not be explained (Ref. #26).

Surface and subsurface soil samples were collected in the drainage tile area. The depth of the surface soil sample was 0-1 foot. A thin layer (approximately 1/8-inch) of salt-like crystalline material was noted on the surface sample. The topsoil samples were dispersed in water and the water turned red in color. Subsurface samples of the clay sub-strata were also taken but the report does not give the depth of the sample. The subsurface samples did not cause discoloration of water. Analysis of the salt-like surface strata samples had the highest concentration of sulfate and the clay sub-strata apparently did not absorb the chemical spoils (Ref. #26).

1989 Actions

In 1989, NASA personnel observed reddish-brown water emanating from the drainage tile into Pentolite Ditch. Water samples were collected and analyzed for chemical oxygen demand (COD), pH, chromium, copper, lead, iron and zinc. The iron and COD concentrations were approximately 6 to 10 times higher at the discharge pipe than at the National Pollutant Discharge Elimination System (NPDES)-regulated sampling weir (outfall 003) located downstream on Plum Brook (Ref. #26).

1990 Actions

In April 1990, NASA personnel again observed rust-colored water discharging into Pentolite Ditch from the drainage tile that originates in the PRRWPs. Water samples were collected and analyzed for total chromium, COD, metals, and nitroaromatic compounds including cyclotrimethylene trinitranime (RDX) and cyclotetramethlene tetranitramine (HMX) known to be used in the manufacture of TNT during World War II. None of the NPDES limits for outfall 003 were exceeded as a result of the discharge. However, levels of iron, nickel, nitrate, sulfate and zinc at the outfall were significantly higher than the upstream levels as a result of the discharge. Concentrations of nitroaromatic compounds were below the detection limit of the analytical method (Ref. #22). The amount of red water released into the Pentolite Ditch is unknown, but the estimated flow rate during the 1990 release was five gallons per minute (Ref. #21).

1991 Actions

In April 1991, NASA personnel found a third discharge of rust-colored water into Pentolite Ditch from the drainage tile. Analysis of a NPDES sample collected 2 days later at a downstream location indicated levels for COD, suspended solids, nitrate, zinc, copper and pH to be within daily NPDES permit levels (Ref. #26).

The red water ponds are not inspected on a routine basis for overflow or discharge into streams or ditches (Ref. #21).

4.8.1.4 *Previous Environmental Investigations*

Two documented environmental investigations have been conducted at the PRRWPs: a Focused Remedial Investigation (RI) in 1997 (Ref. #26), and a Risk Assessment and Direct-Push Investigation in 1999 (Ref. #34). The PRRWPs were also included in the Site-Wide Groundwater Monitoring Report (Ref. #35).

In addition to the documented investigations, in 1994 a Site Inspection (SI) (Ref. #14) was conducted as a PBS-wide investigation. The PRRWP area was not specifically targeted, but a previous investigation is mentioned in this document. It is referred to as the site investigation conducted in 1990 by IT Corp. However, no reference list is provided in the 1994 SI, but data from the 1990 study are reproduced. It is reported that several nitroaromatics, including DNT, 2,4-DNT, and TNT were found in surface soils at the PRRWPs at concentrations up to 11,000 ppb. Trace volatile organic contamination was also noted. The 1990 study by IT was not located during the conduct of this EBS.

For the purposes of this report, a general comparison of soil samples from the 1997 Focused Remedial Investigation and the 1999 Risk Assessment and Direct-Push Investigation is given below to show changes in the prevalence of contaminants in the soil. A comparative review of groundwater samples is summarized from the 1999 Site-wide Groundwater Monitoring Report that compared overburden and bedrock groundwater samples from 1997 and 1998.

Sample Results

Comparison of Soil Samples for Nitroaromatic Compounds from the 1997 Focused RI and the 1999 Investigation

Soil samples for the 1997 investigation were taken in the fall of 1994 and the spring of 1995 and samples for the 1999 investigation were taken in 1998. The three-and-a-half to four-year time span between the two soil sample investigations seems to have made a difference in the number and concentrations of nitroaromatic compounds found in the soil in the PRRWPs area.

Each investigation examined a comparable number of soil samples: 18 surface (0 to 0.5 foot and 0 to 3 foot intervals) and 24 subsurface (3 to 5 foot and 5 to 10 foot intervals) soil samples in 1997 and 20 surface (0 to 2 foot interval) and 39 subsurface (4 to 6 foot and 8 to 10 foot) soil samples in 1999. For the discussion below, the general soil sample intervals are compared. For example, the 1997 3 to 5 foot samples were compared to the 1999 4 to 6 foot samples. Also, the samples are averaged so a single reading of a particular nitroaromatic compound is given for a particular soil interval. For the entire list of samples and their specific concentrations, see the source material, the 1997 Focused Remedial Investigation (Ref. #26) and the 1999 Risk Assessment and Direct-Push Investigation (Ref. #34).

The most common nitroaromatic compounds found in all intervals in both investigations were 2,4-dinitrotoluene (2,4-DNT), 2,6- dinitrotoluene (2,6-DNT), 1,3,5-trinitrobenzene (1,3,5-TNB), 1,3-dinitrobenzene (1,3-DNB) and 2,4,6-trinitrotoluene (2,4,6-TNT). In general, the number of samples containing nitroaromatic compounds increased with the depth of the sample. The concentrations of nitroaromatic compounds increased from the surface to the first subsurface sample, then decreased from the first subsurface sample to the second subsurface sample. This pattern indicates that the compounds have been migrating vertically through the soil, and are naturally degrading over time. The results are summarized in Table 4.8.1.4-1 below.

TABLE 4.8.1.4-1 — *A Comparison of Nitroaromatic Compounds found in Surface and Subsurface Soil Samples above RBC and SSLs from the 1997 and 1999 Investigations of the PRRWPs Area*

Nitroaromatic Compounds	RBC (1/10th) [mg/Kg]	# of samples detected 1997	# of samples above RBC	High 1997 [mg/Kg]	# of samples detected 1999	# of samples above RBC	High 1999 [mg/Kg]	SSLs (DAF 1) [mg/Kg]	# of samples above SSLs
Surface									
1,3-dinitrobenzene	0.78	5	3	1.6	0	NA	NA	0.0018	**All**
2,4-dinitrotoluene	16	9	0	2.1	2	0	1.2	0.029	**All**
2,6-dinitrotoluene	7.8	2	0	0.4	0	NA	NA	0.012	**All**
1,3,5-trinitrobenzne	230	5	0	1.7	0	0	NA	NA	NA
2,4,6-trinitrotoluene	2.1	0	NA	NA	1	0	0.3	NA	NA
First Subsurface									
1,3-dinitrobenzene	0.78	7	7	3.4	2	2	9.3	0.0018	**All**
2,4-dinitrotoluene	16	8	0	8.7	3	1	25	0.029	**All**
2,6-dinitrotoluene	7.8	4	0	3.6	2	0	0.29	0.012	**All**
1,3,5-trinitrobenzne	230	9	0	58	3	0	43	NA	NA
2,4,6-trinitrotoluene	2.1	1	1	12,000	0	NA	NA	NA	NA
Second Subsurface									
1,3-dinitrobenzene	0.78	11	11	6.6	3	3	5.8	0.0018	**All**
2,4-dinitrotoluene	16	10	1	19	6	0	15	0.029	**All**
2,6-dinitrotoluene	7.8	6	0	2.9	3	0	1.7	0.012	**All**
1,3,5-trinitrobenzne	230	12	0	23	6	0	18	NA	NA
2,4,6-trinitrotoluene	2.1	2	1	340	1	0	0.4	NA	NA

NA = Not Applicable

As the table details, only 2,6-DNT and 1,3,5-TNB are below RBC in all soil intervals. 1,3-DNB is above RBC in 3 out of 5 surface samples and in all subsurface samples. 2,4-DNT is above RBC only in 1 out of 10 second subsurface samples. The single sample of 2,4,6-TNT at 12,000 mg/Kg in the first subsurface interval was several orders of magnitude above its RBC of 2.1 mg/Kg. The sample was taken from the area believed to be where the red water entered the pond. No samples in this first subsurface interval with 2,4,6-TNT were detected in the 1999 investigation. Another sample of 2,4,6-TNT, measuring 340 mg/Kg, was above RBC in the second subsurface interval. This sample was also taken from where the red water entered the pond. The 1999 investigation only found a single reading of 2,4,6-TNT in this second subsurface interval, but it was below RBC.

When comparing the soil sample results to SSLs, it can be seen that all samples exceed SSLs for 1,3-DNB, 2,4-DNT and 2,6-DNT, indicating that it is likely these contaminants have migrated to groundwater. There are no SSLs for 1,3,5-TNB and 2,4,6-TNT.

It should be noted that 4-Am-DNT, a biologically transformed byproduct of dissolved TNT (by plants), was also found in three first interval and three second interval subsurface soil samples in the 1997 Focused Remedial Investigation (Ref. #26). This indicates that 2,4,6-trinitrotoluene is being transformed and broken down in the soil.

Additional Soil Testing in the 1999 Investigation

The 1999 investigation tested soil samples for PCBs, cyanide and metals. No PCBs or cyanide were found in any soil samples. A total of 59 surface and subsurface soil samples were taken to test for inorganic compounds. The surface soil samples were taken from the 0 to 2-foot range; the first subsurface samples were taken from the 4 to 6 foot range; and the second subsurface samples were taken from the 8 to 10 foot range. Twenty-one inorganic compounds were detected in at least one soil sample collected. Only those samples above RBC and SSLs are listed below in Table 4.8.1.4-2.

TABLE 4.8.1.4-2 — ***Inorganics Found in Surface and Subsurface Soil Samples Above RBCs and SSLs from the 1999 Investigation of the PRRWPs Area***

Inorganic Compounds	RBC (1/10th) [mg/Kg]	# of samples above RBC	Low	High	SSLs (DAF 1) [mg/Kg]	# of samples above SSLs
Surface						
Arsenic	0.43	20 (all)	2.3	14.1	0.0013	20 (all)
Chromium	23	None	NA	NA	2.1	20 (all)
Iron	2300	20 (all)	8330	22900	NA	NA
Manganese	1600	None	NA	NA	48	20 (all)
Selenium	39	None	NA	NA	0.95	2
First Subsurface						
Antimony	3.1	2	7.9	9.3	0.66	2
Arsenic	0.43	20 (all)	2.6	42.8	0.0013	20 (all)
Barium	550	None	NA	NA	110	4
Chromium	23	None	NA	NA	2.1	20 (all)
Iron	2300	20 (all)	9480	43700	NA	NA
Manganese	1600	2	2230	2270	48	20 (all)
Selenium	39	None	NA	NA	0.95	3
Second Subsurface						
Antimony	3.1	2	7.7	7.8	0.66	2
Arsenic	0.43	19 (all)	4.1	17.6	0.0031	19 (all)
Barium	550	None	NA	NA	110	1
Chromium	23	None	NA	NA	2.1	19 (all)
Iron	2300	19 (all)	8940	28700	NA	NA
Manganese	1600	None	NA	NA	48	19 (all)
Selenium	39	None	NA	NA	0.95	2

NA = Not Applicable

As the table details, all soil samples contained arsenic and iron above RBCs in all intervals. However, on-site background levels of arsenic, as measured during the 1997 Focused Remedial Investigation (Ref. #26), range between 3.5 mg/Kg to 23 mg/Kg, far above the arsenic RBC of 0.43 mg/Kg. While all surface and second subsurface samples were within the background arsenic range, four samples in the first subsurface level - 25.3mg/Kg, 27.3mg/Kg, 27.9mg/Kg and 42.8mg/Kg – were above the background range (Ref. #34).

Background levels for iron were not measured during the 1997 Focused RI, but in discussions with personnel at the Ohio Division of Geological Survey (Ref. #56), typical background levels for iron in northern Ohio can range from 10,000 mg/Kg to 50,000 mg/Kg, depending on the geology of the area. While a truly representative background level for iron should be determined from samples on-site, the background levels for iron given above would mean all iron concentrations detected are within the typical background range.

Antimony and manganese were detected in a limited number of samples above RBC in the subsurface soil. On-site background levels of antimony and manganese were established during the 1997 Focused RI with antimony ranging from 5.9 mg/Kg to 7.6 mg/Kg and manganese ranging from 86 mg/Kg to 1,500 mg/Kg (Ref. #26). First subsurface soil samples for both inorganic compounds exceed on-site background levels.

The inorganic compounds barium, chromium, selenium, while not above RBCs, were above SSLs, and therefore are likely to migrate to groundwater. Antimony, arsenic and manganese were also above SSLs. There is no SSLs for iron.

Overburden and Bedrock Groundwater Sample Results

According to the Site-Wide Groundwater Monitoring Report (Ref. #35), there are four overburden monitoring wells and one bedrock monitoring well in the PRRWPs area that were sampled for VOCs, SVOCs, nitroaromatic compounds, PCBs, metals (total and dissolved) and cyanide in 1997 and 1998. Figure 4.8.1.4-1 shows the location of the 5 monitoring wells in the PRRWPs area. Table 4.81.4-3 lists those samples above RBCs for both overburden and bedrock aquifers.

As the table details, only two VOCs in the overburden aquifer were detected at low concentrations. The bedrock aquifer sample, however, detected benzene at a concentration three orders of magnitude above RBC, and also had elevated levels of ethyl benzene and toluene. While BTEX compounds are known to naturally occur in the Delaware Limestone in central Ohio, and particularly in the Sandusky area (Ref. #55), the Site-Wide Groundwater Monitoring report concludes that BTEX concentrations found in the bedrock groundwater samples are above background levels (Ref. #35).

Elevated levels of SVOCs, nitroaromatic compounds, and metals, both in unfiltered and filtered samples, were detected in the overburden aquifer. The majority of the high concentrations were detected in two overburden monitoring wells, PR-MW7 and PR-MW8 (See Figure 4.8.1.4-1); these wells are located upgradient of the remaining two overburden monitoring wells, and are farthest from the PBRF. Those nitroaromatic compounds that exceeded SSLs for all soil samples, particularly 1,3-dinitrobenzene and 2,4-dinitrotoluene, were detected in high concentrations in the overburden aquifer in both the 1997 and 1998 samples. The inorganic compound manganese, which exceeded SSL for all soil samples, was also detected at high concentrations in all groundwater samples in both 1997 and 1998.

TABLE 4.8.1.4-3 — *A Comparison of Overburden and Bedrock Groundwater Samples above RBCs from 1997 and 1998*

Parameter	RBC (1/10th) [µg/L]	Overburden Aquifer: # of samples above RBC	Overburden Aquifer: 1997 Sample High	Overburden Aquifer: 1998 Sample High	Bedrock Aquifer: 1997 Sample High	Bedrock Aquifer: 1998 Sample High
VOCs						
1,1,2-Trichloroethane	0.19	0	NA	NA	NA	4.9
Benzene	0.32	1	NA	0.47	570	780
Bromodichloromethane	0.17	1	NA	0.23	NA	NA
Chlorobenzene	11	0	NA	NA	NA	5.5
Ethyl benzene	130	0	NA	NA	130	140
Toluene	75	0	NA	NA	490	550
SVOCs						
2,4-Dinitrophenol	7.3	3	6000	3800	NA	NA
3-Nitroaniline	11	2	450	NA	NA	NA
4,6-Dinitro-2-methylphenol	0.37	5	2300	20000	NA	NA
4-Nitrophenol	29	1	NA	42	NA	NA
Dibenzofuran	2.4	1	NA	620	NA	NA
Nitrobenzene	0.35	2	NA	13	NA	NA
Bis(2-Ethylhexyl)phthalate	4.8	NA	NA	NA	37	NA
Nitroaromatic Compounds						
1,3-dinitrobenzene	0.37	6	1500	2100	NA	NA
2,4-dinitrotoluene	7.3	6	1300	2400	NA	NA
2,6-dinitrotoluene	3.7	2	190	NA	NA	NA
1,3,5-trinitrobenzne	110	4	2000	2800	NA	NA
Metals (Unfiltered)						
Aluminum	3700	4	8960	15800	NA	NA
Arsenic	0.045	2	11.5	14.3	NA	NA
Barium	260	0	NA	NA	605	1710
Chromium	11	1	NA	22.6	NA	20.6
Cobalt	220	5	7270	7150	NA	NA
Copper	150	3	3790	3740	NA	NA
Iron	1100	3	22000	32600	NA	4810
Manganese	73	8 (all)	34100	43900	NA	139
Nickel	73	5	7600	6950	NA	NA
Metals (Filtered)						
Arsenic	0.045	1	12.5	NA	NA	NA
Barium	260	0	NA	NA	555	1390
Cobalt	220	5	6770	7450	NA	NA
Copper	150	5	3390	3900	NA	NA
Iron	1100	5	12200	9560	NA	NA
Manganese	73	8 (all)	29700	45500	NA	NA
Nickel	73	5	6820	7310	NA	NA
Thallium	0.26	0	NA	NA	NA	50.8
Cyanide	73	4	1710	1900	NA	NA

NA = Not Applicable

Note: Only one bedrock aquifer sample was collected in 1997 and 1998.

Bedrock groundwater samples for SVOCs, nitroaromatic compounds, and unfiltered and filtered metals either did not detect those contaminants or detected them below RBC. Only one SVOC, bis(2-Ethylhexyl)phthalate, was detected in the 1997 bedrock sample. Four inorganic compounds were detected in the unfiltered bedrock samples, but only barium was detected in the filtered sample as well. While barium was above its SSL for soil, it was not found in the overburden groundwater samples.

While the Site-Wide Groundwater Monitoring Report (Ref. #35) did not indicate finding any of the breakdown products of 2,4,6-dinitrotoluene, the 1997 Focused RI (Ref. #26) did report three biotransformation products, 4-Am-2-NT, 4-Am-DNT, and 2-Am-DNT, detected in overburden groundwater samples.

4.8.1.5 *Conclusions*

All previous environmental investigations into the PRRWPs concur that the area is heavily contaminated with significant levels of nitroaromatic compounds in both the soil and shallow groundwater. While extensive soil testing has delineated the extent of contamination in the PRRWPs soil, the number and placement of groundwater monitoring wells is inadequate to delineate the full extent of groundwater contamination in the overburden aquifer and the potential movement of contaminants toward the PBRF.

As shown in Figure 4.8.1.4-1 shows, there are no overburden monitoring wells located between the PRRWPs area and the PBRF, and overburden groundwater flow is north-northeast towards the PBRF. As discussed in Section 4.2.2.1, the overburden wells in the central portion of the PBRF were installed in association with the USTs at Building 1131 and have therefore not been sampled for nitroaromatics. There is no data on overburden aquifer quality between the PBRF and the PRRWPs. We therefore recommend that overburden monitoring wells be placed along the south side of Pentolite Road to determine if nitroaromatic contamination is migrating from the PRRWPs to the PBRF.

Additionally, there are no bedrock monitoring wells in the PRRWPs area. The bedrock monitoring well sampled in all groundwater studies is not on the PRRWPs site, but is located north of Pentolite Road (BED-MW15) and to the southeast of the PBRF (see Figure 4.8.1.4-1). We recommend that bedrock monitoring wells be placed in the PRRWPs area to delineate the extent of bedrock aquifer contamination in that area. As with the overburden aquifer, there is no data on bedrock aquifer quality between the PBRF and the PRRWPs. Since the PBRF is downgradient of the PRRWPs, we therefore recommend that bedrock monitoring wells be nested with the overburden wells along the south side of Pentolite Road to determine if contaminants are migrating in the bedrock aquifer from the PRRWPs to the PBRF. Suggested locations for these wells are presented in Section 4.8.6.

4.8.2 Garage and Maintenance Area

The Garage and Maintenance Area (GMA) is located upgradient of the PBRF in the southern-most portion of the adjacent area. It is approximately 2,000 feet from the southern boundary of the PBRF. The GMA consists of 4 buildings: Building # 7121 (Maintenance Shop) #7122

(Carpenter Shop), #7131 (Garage) and #7132 (Vehicle Service Station). The GMA is located in the central portion of the PBS with Maintenance Shop located along Maintenance Road and Garage located at the end of Garage Road. Railroad tracks from the TNT Rail Car Loading Area to the west of the GMA travel through the GMA and in front of Building 7121 (see Figure 4.8.2-1).

4.8.2.1 *History*

PBOW Operational Period: 1941-1945

The GMA was constructed in 1941 for PBOW operations and was likely used by the Army for maintenance of equipment and vehicles, possibly including rail cars (Ref. #19). Five underground storage tanks (USTs) were installed in the GMA in 1942 to support maintenance work. The USTs contained gasoline, solvents and waste oil. The GMA, as part of the PBOW, was shut down in September 1945.

Post PBOW Operational Period: 1945 to Present

The GMA was in a standby condition from 1945 to 1946. When NASA acquired the PBS in 1963, it reopened the GMA and continues to use it today as a vehicle maintenance area. In 1964, NASA installed 3 USTs (#29, #30 and #31) at the GMA for the storage of solvents (acetone, TCE and TCA), and a fourth (#36) UST in 1982 for the storage of diesel fuel (Ref. #21).

4.8.2.2 *Physical Characteristics of the GMA*

The terrain at the GMA is flat with an average elevation of approximately 635 feet above MSL. The GMA is located partly in grassland and partly in a "structured" paved area (Ref. #21). Surface water runs off of the GMA either toward the east flowing into Plum Brook or toward the west flowing into Ransom Brook. The Site-Wide Groundwater Monitoring investigation found that groundwater in both overburden and bedrock flows to the north-northeast, which is toward the PBRF (Ref. #35). Groundwater flow was calculated to be 1.9 to 3.4 feet per year (Ref. #13).

4.8.2.3 *Previous Environmental Investigations*

Three environmental investigations have occurred at the GMA; two under RCRA and one under the DERP/FUDS program. A UST Corrective Actions Remedial Investigation/Feasibility Study (RI/FS) was conducted under RCRA in 1991, as was a site investigation/risk assessment supporting closure of the UST sites in 1999. A Limited Site Investigation was also conducted in 1999 under the DERP/FUDS program. These investigations are summarized below.

<u>1991 UST Corrective Actions RI/FS</u>

The 1991 UST Corrective Actions RI/FS was conducted for the entire PBS site and included tank removals from the GMA (Ref. #13). A total of 8 USTs were removed from the GMA area in 1989. Table 4.8.2.3-1 below lists the GMA tanks removed. The location, size, contents and final disposition of the ninth UST #36, installed in 1982, is unclear from a review of previous documentation on the GMA (Ref. #s 12, 13, 16, 21).

The RI/FS specifically tested the soil surrounding, and water in the former tank area and also tested soil and groundwater over the entire GMA site. Gasoline and diesel fuel tank-related samples were compared to Ohio EPA standards for benzene, toluene, ethylbenzene and xylene (BTEX) and total petroleum hydrocarbons (TPH) concentrations. VOC concentrations are measured against EPA Region III 1/10th RBC standards. Results and remedial actions are summarized below.

TABLE 4.8.2.3-1 — *Relevant Information Relating to the Removal of 8 USTs from the GMA*

Date of Installation	Date of Removal	Building #	Tank #	Tank Capacity and Material	Tank Contents	Tank Status at Time of Removal
1942	9/18/89	7121	28	3,000-gallon steel tank	Waste oil and solvents	No information provided
1964	9/18/89	7121	29	700-gallon steel tank	Solvents	Tank found to contain water prior to removal
1964	9/18/89	7121	30	700-gallon steel tank	Solvents	Tank found to contain water prior to removal
1964	9/18/89	7121	31	700-gallon steel tank	Solvents	Tank found to contain water prior to removal
1942	9/18/90	7131	32	1,500-gallon steel tank	Waste oil and solvents	No information provided
1942	7/5/89	7132	33	9,000-gallon steel tank	Gasoline	Tank removed from service earlier due to suspected leakage
1942	7/5/89	7132	34	9,000-gallon steel tank	Gasoline	In service prior to week of removal
1942	7/5/89	7132	35	9,000-gallon steel tank	Diesel Fuel	Tank removed from service earlier due to suspected leakage

Sample Results

Tank Samples – Soil, Surface Water and Groundwater
Building 7132, Vehicle Service Station - Tanks #33, #34, #35

The tanks (#33, #34, and #35) for the Vehicle Service Station were suspected of leaking prior to removal and inspection of the tanks and sampling of the area proved this true. Visible areas of corrosion were noted on the three tanks removed from the Vehicle Service Station that held gasoline and diesel fuel. Three soil samples from the tank pit bottom, and one sample from walls, excavated piles, and adjacent Pump Island were tested for BTEX, TPH, EP Toxicity Lead and ignitability. Surface and groundwater samples were also taken from the tank pit bottom and tested. Only those results above Ohio EPA standards are presented in Table 4.8.2.3-2 below. For a review of all results, see Ref. #13.

The most prevalent BTEX contaminant detected was benzene, found not only at concentrations several orders of magnitude above its Ohio EPA standard in the pit bottom and Pump Island soil samples, but also above the standard in the soil borings and standing water samples. All pit bottom and Pump Island samples were above the standard for BTEX and TPH. Based on these findings, 13 additional feet of soil was removed from bottom of the already excavated tank pit, as well as soil from the tank pit walls, and soil around the former location of the Pump Islands to prevent further contamination of the area (Ref. #13). A subsequent soil sample from the tank area contained benzene at 420 μg/L. After discussions with the Ohio State Bureau of Underground Storage Tank Regulation, it was determined that an additional 1-1.5 feet of soil would be removed from the tank pit bottom before the excavation was backfilled. This additional excavating was completed and the tank pit was backfilled (Ref. #13).

TABLE 4.8.2.3-2 — *Soil and Standing Water Samples Taken From the Excavation Pit at Vehicle Service Station Tank Area*

		Pit Bottom Soil Samples		Pump Is. Soil Samples	Soil Pile Samples		Soil Borings Samples		Standing Water Samples	
Parameter	Ohio EPA Stnds	Sample Low	Sample High	Sample	Sample Low	Sample High	Sample Low	Sample High	Sample High	Sample Low
BTEX [µg/Kg]										
Benzene	6	120	43000	2800	NA	NA	14.42	15.03	NA	55
Toluene	4000	8700	30000	54000	NA	NA	NA	NA	NA	NA
Ethylbenzene	6000	NA	11000	47000	NA	NA	NA	NA	NA	NA
Xylene	28000	NA	96000	400000	NA	NA	NA	NA	NA	NA
TPH [mg/Kg]										
TPH	40*	48.5	616.6	2817	67	621	NA	51	NA	56.2

*Standard at the time of this investigation.

Building 7121, Maintenance Shop - Tanks #28, #29, #30 and #31

Three soil samples from the tank pit bottom, and one sample from walls and excavated piles were taken after the removal of the four tanks (#28, #29, #30 and #31) from the Maintenance Shop that held waste oil and solvents. Soils around the tanks were tested for VOCs, TPH, EP Toxicity Lead and ignitability. The soils around the area of Tank #28 revealed a greater number of contaminants and at higher concentrations than the soils around Tanks #29, #30, and #31. Trichloroethene, 1,1,1-trichloroethane and tetrachloroethene were the VOCs with the highest concentrations in all samples, but all detected levels were below RBC (Ref. #13). They were, however, above SSLs. The documentation does not indicate that any soils were removed from the area.

Building 7131, Garage – Tank #32

Three soil samples from the tank pit bottom, and one sample from walls and excavated piles were taken after the removal of the one tank (#32) from the garage that held waste oil and solvents. Soils around the tanks were tested for VOCs, TPH, EP Toxicity Lead and ignitability.

All samples were below RBC for VOCs. The TPH level of 244 mg/Kg was above the Ohio EPA standard of 40 mg/Kg that was applicable at that time (Ref. #13). The documentation does not indicate that any soils were removed from the area.

Samples for Entire GMA

Soil Gas Survey

A soil gas survey of the GMA was done in 1989 at the time of the UST removals. A total of 76 samples were collected and analyzed. Most areas sampled showed measurable levels of one or more of the target compounds: dichloroethene (DCE), benzene, trichloroethene (TCE), toluene, tetrachlorethene (PCE) and xylene. The highest concentrations were found near the former UST locations and along building foundations, railroad tracks and buried utility lines. The report theorizes that these structures and features could be serving as preferential migration pathways for the movement of contaminants (Ref. #13).

Soil samples ranging in depth from 4 to 12 feet below the ground surface were collected north and northwest of the GMA. Sample results indicated low levels of contamination from fuel products, TCE and PCE. The distribution of the contaminants detected appears to be sporadic, indicating that low-level soil or groundwater contamination may be present (Ref. #13).

Groundwater

Two groundwater samples were taken. It is unclear from the report whether the groundwater samples were taken from the overburden or bedrock aquifer (Ref. #13). Samples were tested for VOCs, SVOCs, pesticides, PCBs and TPH. No SVOCs above RBCs were detected in the samples. Only two VOCs were detected above RBCs: 1,1-dichloroethene was detected at 20 μg/L (RBC 0.04 μg/L) and trichloroethene was detected at 7 μg/L (RBC 1.6 μg/L). Trace levels of Beta-BHC were detected in both samples. Beta benzene hexachloride (BHC) is a common insecticide. The detection of Beta BHC is not linked to the contents of former USTs (Ref. #13).

Sediment

Two sediment samples were taken from drainage ditches, one east of the northeast corner of the Maintenance Shop and one north of the Garage. These drainage ditches channel water from the former UST areas toward the east (Ref. #13). Samples were tested for VOCs, SVOCs, pesticides, PCBs and TPH. Two VOCs, methylene chloride and acetone, were detected about 1/10th RBC for tap water, but the RI/FS concludes that these VOC concentrations were probably laboratory contaminants, not contaminants from past activities at the site (Ref. #13). One VOC, 1,1-dichloroethane, was found in one sample but below RBC. The report states this in an uncommon finding and attributes it to ice and moisture contained in the sediment sample. The report does point out, however, that 1,1-dichloroethane was detected in both the groundwater and surface soil samples (Ref. #13).

Several SVOCs were detected in both sediment samples but were below RBC and SSLs. The RI/FS concludes that these SVOCs, polycyclic aromatic hydrocarbons (PAHs), were from roadway run-off, gasoline and diesel vehicle tailpipe emissions, not from the contents of the former USTs. Two pesticide compounds, Beta BHC at 82 μg/Kg and Delta BHC at 370 μg/Kg, were also detected in the sediment samples. Sediment samples showed TPH at 2620 mg/Kg, two orders of magnitude above the Ohio EPA standard for TPH of 40 mg/Kg that was applicable at that time.

1997/1998 Site-Wide Groundwater Monitoring Investigation

Since the RI/FS study was conducted almost a decade ago, more recent groundwater results from the Site-Wide Groundwater Monitoring Report (Ref. #35) were reviewed to determine current contaminant levels. One overburden and one bedrock monitoring well were installed in the GMA. The groundwater samples were tested for VOCs, SVOCs, metals (unfiltered and filtered), nitroaromatic compounds, PCBs, and cyanide. Only those results above RBCs are discussed below.

In the overburden aquifer, only one VOC, 1,1-dichloroethene, was detected above RBC (0.044 μg/L) in both the 1997 (3.4 μg/L) and 1998 (2.2 μg/L) samples. Seven unfiltered metals (aluminum, arsenic chromium, iron, lead, manganese and vanadium) were detected above RBCs in the overburden aquifer in the 1998 samples. The metals were not detected in the 1997 overburden aquifer (Ref. #35).

In the bedrock aquifer, one VOC, benzene, was detected at 19 μg/L in the 1998 sample, well above its RBC of 0.32 μg/L. Similarly, one nitroaromatic compound, 1,3-dinitrobenzene at 0.86 μg/L, was detected above its RBC of 0.37 μg/L. Barium and manganese were detected above RBCs in both the unfiltered and filtered 1997 and 1998 samples. The 1997 sample also showed unfiltered iron above its RBC (Ref. #35).

Limited Site Inspection in 1999

A Limited Site Inspection was conducted in 1999 at the GMA as part of the DERP/FUDS program (Ref. # 46). The purpose of this study was to evaluate the potential contamination specifically at the Locomotive Shop within the GMA due to past Army activities.

One soil sample was taken in a work pit within the Locomotive Shop and one soil sample was taken outside the Locomotive Shop near the wastewater junction box. The samples were analyzed for SVOCs, PCBs, and metals. The only detects of note in the sample from the pit were the PCB Aroclor 1260 at a concentration of up to 450 mg/kg, lead up to 1,330 mg/kg, antimony at 10.9 mg/kg, and chromium up to 148 mg/kg. The sample near the wastewater junction box had no significant detects.

Water samples were collected from the sump inside the Locomotive Shop and the wastewater junction box outside the Locomotive Shop. Surface water samples and a sediment sample from an open ditch to the east of the building were also taken. The samples taken within the sump were found to have iron levels of 29,300 ug/L, lead levels of 177 ug/L, and arsenic levels of 20.6 ug/L. No evidence of contamination was found outside the building.

No groundwater samples were taken as part of this site inspection.

Studies Conducted in 1999 Associated with Closure of the USTs

As part of the closure process for the UST sites at the GMA, another site investigation was conducted in 1999. The objective was to determine the presence and extent of chemical contamination, and use this data to conduct a human health risk assessment. The results of these studies were summarized in an Amended Closure Plan (Ref. # 39).

Soil samples from borings detected 59 organic chemicals of potential concern at the Building 7121 location and 35 at the Building 7131 location. The borings also detected levels of lead higher than normal background levels for the area. Therefore, lead was also identified as an inorganic chemical of potential concern for Building 7131.

Excess cancer risk estimates were calculated from the estimated daily intakes and cancer slope factors and compared to the OEPA's recommended risk guideline of 1E-05. Excess cancer risks for populations evaluated for the Building 7121 exposure area ranged from 1E-05 for a child to 2E-05 for an adult, and from 1E-06 for a child to 2E-05 for an adult for the Building 7131 exposure area. Non-cancer health effects were determined to be below one (ranging from 0.004 to 0.2 at both sites) on the OEPA Hazard Index and thus did not require remediation.

Cancer risks were found to be above the OEPA action level for polynuclear aromatic hydrocarbons detected along the Garage Road in shallow soil. However, these detections are not attributable to UST releases, and were attributed to the historical use of oil along the roadways at PBS. Therefore soil remediation under this program was not warranted.

It was determined, however, that corrective action was required to address the presence of dissolved-phase VOCs in shallow groundwater in the vicinity of the Building 7121 USTs. The selected remediation system will consist of a vacuum-enhanced groundwater recovery system, with groundwater discharged to the sanitary sewer and extracted vapors discharged to the atmosphere. The effectiveness of the system will be assessed by soil and groundwater sampling.

4.8.2.4 *Conclusions*

The removal of USTs and contaminated soils surrounding the tanks from the GMA eliminated the majority of the sources of contamination in GMA soils and groundwater. It is specifically the groundwater contamination, and its subsequent movement toward the PBRF, that is relevant to this report. The groundwater treatment system discussed above should aid both in reducing organic contaminant levels and also in preventing the migration of contaminated groundwater.

While the 1991 RI/FS (Ref. #13) detected little groundwater contamination in GMA, the 1997/1998 Site-Wide Groundwater Monitoring Report (Ref. #35) detected a number of metals at levels above RBCs in both the overburden and bedrock aquifers. However, metals are naturally occurring in groundwater and there are no data on typical background levels of metals in groundwater at the PBS. Therefore, it is uncertain whether the concentrations detected reflect contamination from past activities or are naturally occurring.

As recommended in the previous section on the PRRWPs, the installation and sampling of overburden and bedrock monitoring wells just south of Pentolite Road, upgradient of the PBRF, would confirm if contaminant migration from the GMA toward the PBRF is occurring.

The 1991 RI/FS concluded from the soil gas survey that migration of contaminants has occurred along preferential flow pathways associated with man-made structures on the GMA. According to sitewide PBS engineering drawings, a sanitary sewer line is present approximately 300 feet west of the GMA. This line runs north to the PBRF (see Appendix D for the utility line drawings). It is possible that contaminants could migrate along this pathway to the PBRF. We recommend soil and groundwater screening sampling along this sanitary sewer line to ascertain if contaminants are migrating towards the PBRF.

4.8.3 Rail Car Unloading Area/Sellite Area

The Rail Car Unloading Area/Sellite Area (RCUA/SA) is located upgradient of the PBRF, directly west of the GMA approximately 2,000 feet from the southern boundary of the PBRF. It is located on the north side of Maintenance Road between Ransom and Taylor Roads (see Figure 4.8.2-1). The RCUA/SA has been described as covering an area of 1 acre (Ref. #12) to 5 acres (Ref. #14). The Rail Car Unloading Area and Sellite Area are separate areas. The Sellite Area is located adjacent to the west side of the Rail Car Unloading Area. The 1995 Site Management Plan (Ref. #19) states that the Sellite Area may have contributed to the contamination of the site and therefore is included with the Rail Car Unloading Area.

There are no buildings currently on the RCUA/SA. Broken timbers found near the Sellite Area suggest the former presence of a wooden structure, which has been confirmed by historic photographs (Ref. #21). An abandoned single railroad track is located on the northern and western portions of the site.

4.8.3.1 *History*

PBOW Operational Period: 1941-1945

The RCUA/SA was constructed in 1941 and actively used until the production of TNT ceased two weeks after V-J Day (September 2, 1945). The RCUA received and unloaded more than 400 million pounds of toluene (Ref. #12). It is suspected that additional chemicals may have been unloaded or stored at the RCUA (Ref. #21).

The Sellite Area was used for the production and storage of sellite used in the manufacture of TNT. Sellite, more commonly known as sodium sulfate, was added to crystalline TNT because it forms a water-soluble salt with unwanted TNT isomers that are removed in the water wash process.

Post PBOW Operational Period: 1945 to Present

The RCUA/SA was in a standby condition from 1945 to 1946 after TNT manufacturing ceased. While decommissioning on the entire PBOW site began in 1946, it is believed that the RCUA, with its proximity to the GMA, may have led to its use for informal staging of equipment and supplies (Ref. #21). Based on historic photographs, the building on the RCUA/SA site was removed sometime after 1958, but remnants of the site remain, including cinders (slag) and sulfur (Ref. #21).

4.8.3.2 ***Physical Characteristics of the RCUA/SA***

The terrain at the RCUA/SA is relatively flat with a gentle northward slope. Elevation is approximately 635 feet above MSL. The RCUA/SA is located on grassland with lush vegetation surrounding the area. The 1991 Preliminary Assessment found approximately a quarter acre of bare area that supported little vegetation. The report hypothesized that the area may be bare due to toluene spills during the unloading process in the Operational Period (1941-1945) (Ref. #12). A subsequent 1994 field reconnaissance found extensive areas of bare soil in the Sellite Area with pieces of sulfur and slag on the ground (Ref. #20).

Surface runoff at the RCUA generally flows north to drainage ditches or streams. A tributary of Ransom Brook passes west of the site and flows northward toward the edge of the PBRF and then off the PBS. A shallow surface water ditch, located to the east, receives run-off from the Sellite Area (Ref. #21). Groundwater in the overburden aquifer was measured to flow in a northerly direction under the RCUA/SA. No aquifer tests have been conducted at the RCUA/SA (Ref. #21).

4.8.3.3 ***Previous Environmental Investigations***

The 1994 Site Inspection is the only investigation conducted that covers the RCUA/SA (Ref. #14). The RCUA/SA was only a small part of that investigation. The results of the samples that were taken on the RCUA/SA are summarized below. The Site-wide Groundwater Monitoring Report (Ref. #32) does not indicate there are any monitoring wells on the RCUA/SA.

Sample Results

Surface and Subsurface Soil

Two surface soil samples were collected near the RCUA west of the GMA, north of Maintenance Road and three surface soil samples were collected from the SA just west of the RCUA near the intersection of Maintenance Road and the abandoned rail spur. One subsurface soil sample was taken in the RCUA but the depth of the sample was not given in the report (Ref. #19). No subsurface soil samples were taken in the SA. The samples were tested for VOCs and SVOCs. Table 4.8.3.3-1 below details only those contaminants found above RBCs and SSLs.

TABLE 4.8.3.3-1 — *Results of Surface and Subsurface Soil Samples Taken From the RCUA and SA Sites*

	RBC (1/10th) [µg/Kg]	RCUA above RBC samples	SA above RBC samples	SSLs DAF 1 [µg/Kg]	RCUA above SSLs samples	SA above SSLs samples
Surface Soil						
Benzo(a)anthracene	870	NA	920	73	NA	220 / 920 /89
Benzo(a)pyrene	87	NA	680	19	22	130 / 920
Benzo(b)fluoranthene	870	NA	2400	23	34	310 / 2400
Dibenzo(a,h)anthracene	87	NA	91	70	NA	91
Indeno(1,2,3-cd)pyrene	870	NA	NA	64	NA	85 / 430
Toluene	1,600,000	NA	NA	44	NA	54 / 82
Trichloroethene	5800	NA	NA	0.7	NA	1 / 1
		RCUA Sample	**SA Samples**			
Acenaphthylene	No RBC	NA	98	No SSL		
Phenanthrene	No RBC	25	110 / 460 /48	No SSL		
Subsurface Soil						
Benzo(a)pyrene	87	230	No SA samples	19	230	No SA samples
Benzo(b)fluoranthene	870	NA		23	340	
		RCUA Sample				
Acenaphthylene	No RBC	60	No SA samples	No SSL		
Phenanthrene	No RBC	220		No SSL		

NA = Not Applicable

As Table 4.8.3.3-1 shows, the SA has more contaminants and contaminants at higher concentrations than the RCUA. While there were no surface soil samples from the RCUA above RBCs, four samples were detected above RBCs in the SA. Similarly, while only two surface soil samples were detected above SSLs in the RCUA, fourteen samples were detected above SSLs in the SA. The single subsurface soil sample in the RCUA detected only two contaminants above RBCs and SSLs, but these contaminants were found at higher concentrations than in the surface soil samples.

Groundwater

One groundwater sample was taken from the overburden monitoring well installed along the western edge of the GMA near the RCUA. Solvents and SVOCs were detected in the sample but are believed to be related to the UST leakage on the GMA, not from any contamination on the RCUA/SA. Only one solvent, 1,1-dichloroethene at 8 μg/L, was detected above the EPA Region III tap water RBC of 0.044 μg/L.

Sediment and Surface Water

One sediment sample and one surface water sample were collected in Ransom Brook adjacent to the RCUA. Based on topography, this location was selected as a possible entry to surface water for contaminants from surface water runoff from the RCUA (Ref. #21). No organic compounds were detected in the surface water samples. VOCs and SVOCs were detected in the sediments but most were estimated values below the potential quantitation limit (Ref. #21).

4.8.3.4 *Conclusions*

Because of the limited scope of the 1994 Site Investigation at the RCUA/SA, no conclusions were made regarding this site in that report (Ref. #14). The 1991 Preliminary Investigation (Ref. #12) conducted a hazard ranking on the RCUA. It scored between 3.84 to 9.70 for the various transport pathways, well below the EPA-designated hazard ranking score of 28.5, the point at which a site becomes eligible for inclusion in the National Priorities List (NPL) (Ref. #21).

Because so few soil or groundwater samples were taken, it is difficult to come to any conclusions about the RCUA/SA and the possible effect that it could have on the PBRF. Given that contaminated groundwater is the most likely contaminant source on the RCUA/SA to affect the PBRF, it is likely that the groundwater monitoring wells recommended to be installed upgradient of the PBRF would be sufficient to determine if contaminant migration is occurring from the RCUA/SA and if it is likely to affect the PBRF.

4.8.4 Ash Pit #1

Ash Pit #1 is located upgradient of the PBRF in the southern-most portion of the adjacent area of the PBRF. Ash Pit #1 is just south of Maintenance Road, southeast of the GMA and north of the railroad tracks and Building #8531 (Power House #1) (Figure 4.8.4-1) (Ref. #21). It is approximately 2,025 feet from the PBRF boundary. The northern and southern boundaries of Ash Pit #1 are still somewhat defined by berms or rises in elevation approximately 3 to 5 feet higher than ground level. The northern and southern berms transverse in an east/west direction along Maintenance Road and Power House #1, respectively (Figure 4.8.4-1) (Ref. #45). The eastern and western boundaries of Ash Pit #1 are not clearly defined by a berm or rise in elevation but have been identified from historic aerial photographs and drawings (Ref. #21, #45).

4.8.4.1 *History*

PBOW Operational Period: 1941-1945

During the PBOW operational period, Ash Pit #1 served as a disposal area for ash generated at the on-site power plant, Power House #1 (Ref. #21). Power House #1 consisted of a main powerhouse, a coal storage area, and a diked area containing fuel oil in above ground storage tanks (ASTs). The main powerhouse consisted of two to four large coal burning boilers, several steam driven or electric air compressors, a turboelectric generator, and a feed water treatment system. Water was added to the coal ash generated from each of the boilers. The water/ash slurry flowed through a sluice trench to the ash sump located at the end of the building. From the ash sump, the ash traveled through a pipeline to a nearby surface impoundment known as Ash Pit #1 (Ref. #45).

Post PBOW Operational Period: 1945 to Present

Information concerning the status or use of Ash Pit #1 following the end of the TNT manufacturing operation is limited (Ref. #21). Unlike other areas of the PBOW, the railroad tracks and Power House #1 were not destroyed during the decommissioning of the PBOW but remain abandoned at the site. Based on topographical quadrangles (dated 1959 and 1969), aerial photographs, and a visual site survey, the area of Ash Pit #1 has essentially remained unchanged since the PBOW operational period (Ref. #45).

4.8.4.2 *Physical Characteristics of Ash Pit #1*

The terrain of Ash Pit #1 is relatively flat with an average elevation of approximately 635 feet above MSL. The elevated berms that define the northern and southern boundaries of Ash Pit #1 are approximately 640 feet MSL (Ref. #45). A visual survey on July 8, 1999 found Ash Pit #1 covered with thickets of grass, weeds and small trees ranging from 5 to 8 feet tall (Ref. #45).

Two drainage ditches were found near Ash Pit #1. The first drainage ditch, approximately 5 feet north of Ash Pit #1 on the northern boundary of the pit, runs in a northerly direction and under Maintenance Road by means of a concrete culvert. The visual survey report notes that the ditch was overgrown with vegetation and that access was limited (Ref. #45). The ditch did not appear to contain any water. A second, larger drainage ditch located northwest of Ash Pit #1 did contain water that was flowing in a northeastern direction (Ref. #45).

Groundwater flow under Ash Pit #1 is in a north to northeast direction (Ref. #21).

It should be noted that a high voltage utility line runs through Ash Pit #1 in a north-south direction. There is also an underground telephone line running approximately 5 feet south of Maintenance Road in an east-west direction just north of Ash Pit #1 (Ref. #45).

4.8.4.3 *Previous Environmental Investigations*

In July 2000, a Limited Site Investigation was conducted on Ash Pit # 1 (Ref. #45). The Site-wide Groundwater Report (Ref. #35) does not indicate there are any monitoring wells the Ash Pit #1 area. No groundwater samples have been collected at Ash Pit #1.

Sample Results

Surface and Subsurface Soil

A total of one surface sample and 6 subsurface samples were taken. The subsurface samples ranged from 1 to 4 feet in depth. All samples were analyzed for SVOCs and target analyte metals (TAL) metals (Ref. #45). No SVOCs were found in any of the soil samples. Several metals above RBC and SSLs were detected and are listed below in Table 4.8.4.3-1.

TABLE 4.8.4.3-1 — *TAL Metals Found in Surface and Subsurface Soil Samples above RBCs and SSLs From Ash Pit #1*

TAL Metals	RBC (1/10th) mg/Kg	# of samples above RBC	Low	High	SSLs DAF 1 mg/Kg	# of samples above SSLs
Surface						
Aluminum	7800	1		16600	NA	NA
Arsenic	0.43	1		31.2	0.0013	1
Chromium	23	None	NA	NA	2.1	1
Iron	2300	1		73200	NA	NA
Manganese	1600	None	NA	NA	48	1
Selenium	39	None	NA	NA	0.95	1
Subsurface						
Aluminum	7800	4	8310	12700	NA	NA
Arsenic	0.43	6 (all)	6.2	19.6	0.0013	6 (all)
Barium	550	None	NA	NA	110	1
Chromium	23	None	NA	NA	2.1	6 (all)
Iron	2300	6 (all)	18500	95100	NA	NA
Manganese	1600	2	2230	2270	48	6 (all)
Selenium	39	None	NA	NA	0.95	4

NA = Not Applicable

As the table details, aluminum, arsenic and iron were found above RBC in both the surface and subsurface samples. Manganese was above RBC only in the subsurface sample. Arsenic, chromium, manganese, and selenium were above SSLs in surface and subsurface samples, increasing in concentration in the subsurface samples. Additionally, barium was found above SSLs in the subsurface sample. Again, it is likely that contaminants above SSLs will be found in groundwater (Ref. #45).

Surface Water and Sediment

One surface water and one sediment sample were collected from the drainage ditch northwest of Ash Pit #1. The samples were analyzed for SVOCs and target analyte metals (TAL) metals (Ref. #45). No SVOCs were found in the water or sediment samples. Several TAL metals were found in both sediment and surface water samples above RBCs and are shown in Table 4.8.4.3-2 below.

As with the soil samples, aluminum, arsenic and iron were found in the sediment samples above RBCs and SSLs. Additionally, chromium, manganese and vanadium were detected above SSLs in the sediment sample. The surface water sample detected only two metals, iron and manganese, above RBCs (Ref. #45).

TABLE 4.8.4.3-2 — *TAL Metals Found in Sediment and Surface Water Samples above RBCs and SSLs From Ash Pit #1*

TAL Metals	RBC (1/10th) [mg/Kg]	SSLs (DAF 1) [mg/Kg]	Sample
Sediment			
Aluminum	7800	NA	11400
Arsenic	0.43	0.0013	41.5
Chromium	23	2.1	NA
Iron	2300	NA	80900
Manganese	1600	48	1730
Vanadium	55	260	73.5
	RBC (1/10th) [μg/L]		**Sample**
Surface Water			
Iron	1100		1390
Manganese	73		78.8

4.8.4.4 *Conclusions*

With findings of elevated metals at Ash Pit #1, the Limited Site Investigation concludes that it is possible that past DoD activities at the Ash Pit have negatively impacted the environment (Ref. #45). Given the limited number of samples collected and the lack of groundwater data, it is not possible to determine if contaminants at Ash Pit #1 may affect the PBRF.

As ash slurry (coal ash and water) was the only waste stream put into Ash Pit #1, it is unlikely that there are any contaminants other than TAL metals in the soil or groundwater. SVOCs and VOCs are burned off when the coal was burned to produce energy. All sample results were negative for SVOCs, supporting this fact. While metals are generally not mobile in soil, more than 50 years have past since the ash pit was active; metals may have migrated into the groundwater, particularly arsenic and manganese that were found at concentrations above the SSLs.

However, natural background levels of certain metals are known to be elevated in northern Ohio. Background levels for iron range between 10,000 mg/Kg and 50,000 mg/Kg (Ref. #56) and for manganese range from 86 mg/Kg to 1,500 mg/Kg (Ref. #26). The subsurface soil sample for iron was 95,100 mg/Kg and the manganese subsurface soil sample was 2,270 mg/Kg, both above RBC and background levels. Arsenic was found in soil surface and sediment samples above RBC and SSL. On-site background levels for arsenic range between 3.5 mg/Kg to 23 mg/Kg (Ref. #26). The surface sample was 31.2 mg/Kg and the sediment sample 41.5 mg/Kg, both above RBC and background levels. Thus, it appears that these elevated concentrations of metals may be related to past activities at Ash Pit #1.

The monitoring wells we recommended to be installed just south of Pentolite Road and upgradient of the PBRF would detect contamination migrating toward the PBRF and potentially impacting that facility.

4.8.5 Acid Area #3

Acid Area #3 (AA3) is located upgradient of the PBRF in the western-most portion of the adjacent area of the PBRF (see Figure 4.8-1). The area is a rectangular shape and it covers approximately 10 acres (Ref. #21). It is approximately 2,100 feet from the PBRF boundary. AA3 is located along Ransom Road with approximately three-quarters of the AA3 area north of Maintenance Road and one-quarter of the AA3 area south of Maintenance Road (see Figure 4.8.5-1). Abandoned single-track rail spurs cross the area in a north/south direction. The foundations of buildings and other structures also currently exist on the site (Figure 4.8.5-2) (Ref. #21). Building #9215 (Warehouse D-9) is currently located on the AA3 site and is used for storage by NASA (Ref. #21).

4.8.5.1 *History*

PBOW Operational Period: 1941-1945

AA3 was constructed in 1941 as part of the PBOW for the production of oleum (sulfuric acid) and nitric acid that were used in the production of TNT and pentolite (Ref. #21). A number of buildings existed on the site during this period. AA3 was shut down when the entire PBOW was shut down in mid-December 1945.

Post PBOW Operational Period: 1945 to Present

Decommissioning and decontamination of the acid, pentolite and DNT processing lines began after the plant was shut down in late 1945. Decontamination was completed in the 1960s in accordance with Department of Defense (DoD) standards at that time (Ref. #33). Buildings and structures were removed from AA3 but the date of their removal is unknown (Ref. #21).

4.8.5.2 *Physical Characteristics of Acid Area #3*

The terrain of AA3 is relatively flat with an average elevation of approximately 635 feet above MSL. AA3 is located on grassland and the site area is covered with trees and bushes (Ref. #33). Surface runoff in AA3 flows west toward a tributary of Pipe Creek (Ref. #21). Exact direction of groundwater flow has not been established at AA3. In general, groundwater flow at the PBS is in a northerly direction, towards Lake Erie, in both the overburden and bedrock aquifers. On the western side of the PBS, however, groundwater in the overburden flows to the northwest, while groundwater in the bedrock flows to the northeast toward the PBRF (Ref. #33).

4.8.5.3 *Previous Environmental Investigations*

In 1998, a Site Investigation was conducted at AA3 (Ref. #33). The Site Investigation also examined two other areas associated with AA3: the former Maintenance Shop Area (MNT), located in the west central portion of the AA3, and the former Power Substation (PSS), located across Ransom Road, just north of Maintenance Road (see Figure 4.8.5-2). Overburden and bedrock groundwater samples at AA3 were collected in the Site-wide Groundwater Investigation (Ref. #33).

Sample Results

Surface Soil

A total of 20 surface soil samples were taken at AA3 including 2 surface samples at the PSS and 3 surface samples at the MNT area. The depth of the surface samples was 0-1 foot. The surface soil samples were tested for VOCs, SVOCs, explosive compounds, PCBs and metals (Ref. #33). Table 4.8.5.3-1 below summaries the results above RBC and SSLs for AA3 surface soil samples.

TABLE 4.8.5.3-1 — *Results Of Surface Soil Samples at Acid Area #3*

	RBC (1/10th) [µg/Kg]	# of samples above RBC	Low	High	SSLs (DAF 1) [µg/Kg]	# of samples above SSLs
SVOCs						
2,4-Dinitrotoluene	16,000	None	NA	NA	29	1
2,6-Dinitrotoluene	7,800	None	NA	NA	12	1
2-Methylnaphthalene	160,000	None	NA	NA	110	1
Benzo(a)anthracene	870	2	2100	3500	73	7
Benzo(a)pyrene	87	7	2200	3300	19	9
Benzo(b)fluoranthene	870	2	2400	3400	230	6
Carbazole	32,000	None	NA	NA	23	2
Dibenz(a,h)anthracene	87	None	NA	NA	7	1
Indeno(1,2,3-cd)pyrene	870	2	1200	1400	640	2
Naphthalene	160,000	None	NA	NA	7.7	1
PCBs						
Aroclor 1260	320	4	330	3200	NA	NA
Metals						
	RBC (1/10th) [mg/Kg]				**SSLs (DAF 1) [mg/Kg]**	
Aluminum	7800	6	7940	11800	NA	NA
Arsenic	0.43	20 (all)	2.5	9.6	0.0013	20 (all)
Barium	550	None	NA	NA	110	1
Chromium	23	None	NA	NA	2.1	20 (all)
Iron	2300	20 (all)	6810	26600	NA	NA
Manganese	160	18	182	922	48	20 (all)

NA = Not Applicable

Three VOCs were detected in surface soil samples, but concentrations were well below their respective EPA Region III RBCs for residential soil and SSLs.

As the table above details, only four SVOCs - Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, and Indeno (1,2,3-cd) pyrene - were detected above RBCs. Six other contaminants were detected above SSLs. The majority of the samples above RBCs were found in the AA3 area. Only one sample from the PSS with exceeded RBC, while no samples were detected above RBCs in the MNT (Ref. #33).

A polychlorinated biphenyl (aroclor 120) was detected in five of the 15 samples from AA3, in both of the samples from the PSS, and in one of the three samples in the MNT (Ref. #29). Of these, three AA3 samples exceeded RBC, two PSS samples exceeded RBC, but no MNT samples exceeded RBC (Ref. #33).

A total of 14 metals were detected in surface soil samples within the AA3 and associated PSS and MNT areas. Aluminum, arsenic iron and manganese were detected above RBCs and SSLs (Ref. #33). One sample contained barium and all samples contained chromium at levels above SSLs.

Subsurface Soil

A total 18 subsurface soil samples were taken at AA3 including 3 subsurface samples at the MNT area. The subsurface samples were taken in 2 foot intervals and ranged from 2-4 ft, 6-8 ft and 8-10 ft. The subsurface soil samples were tested for VOCs, SVOCs, explosive compounds, and metals (Ref. #33). Table 4.8.5.3-2 below summaries the results for all those contaminants above RBCs and SSLs.

TABLE 4.8.5.3-2 — *Results of Subsurface Soil Samples at Acid Area #3*

	RBC (1/10th) [µg/Kg]	# of samples above RBC	Low	High	SSLs (DAF 1) [µg/Kg]	# of samples above SSLs
VOCs						
Methylene Chloride	85,000	None	NA	NA	0.95	1
SVOCs						
2,4-Dinitrotoluene	16,000	None	NA	NA	29	1
2,6-Dinitrotoluene	7,800	None	NA	NA	12	1
Benzo(a)anthracene	870	None	NA	NA	73	1
Benzo(a)pyrene	87	1	NA	340	19	1
Benzo(b)fluoranthene	870	None	NA	NA	230	1
Naphthalene	160,000	None	NA	NA	7.7	1
Metals						
Aluminum	7800	10	8350	11900	NA	NA
Antimony	3.1	2	7.4	8	0.66	2
Arsenic	0.43	18 (all)	2.5	32.2	0.0013	18 (all)
Barium	550	None	NA	NA	110	1
Chromium	23	None	NA	NA	2.1	18 (all)
Iron	2300	18 (all)	5720	34300	NA	NA
Manganese	160	17	173	1180	48	20 (all)

A total of six VOCs were detected in subsurface soils within AA3. Three VOCs were detected in the MNT area. All detected VOC concentrations, however, were below their respective RBCs for residential soil (Ref. #33). Methylene chloride was detected above SSL in a single sample in the AA3 area.

Twenty SVOCs were detected in the subsurface soil samples. Of these, only 1, benzo(a)pyrene, was detected above RBCs (Ref. #33). A total of six VOCs were detected above SSLs.

Fifteen metals were detected in the subsurface soil samples collected within the AA3 and associated MNT and PSS areas. Five metals – aluminum, antimony, arsenic chromium, iron and manganese – were detected above RBC. Barium and chromium were detected above SSLs (Ref. #33).

Groundwater

For the Site-Wide Groundwater Monitoring Report (Ref. #35), one well was installed in 1997 and another adjacent to it in 1998, and samples were taken for both overburden and bedrock groundwater. The wells are located north of Maintenance Road and east of Ransom Road across from the northern top third of AA3.

The samples in the overburden were tested for VOCs, SVOCs, nitroaromatic explosives, metals (total and dissolved), and cyanide. No VOCs, SVOCs, nitroaromatic explosives or cyanide were detected. Six unfiltered samples and one filtered sample were above 1/10th RBC for tap water. Results are detailed below in Table 4.8.5.3-3 (Ref. #33).

TABLE 4.8.5.3-3 — *Results of 1997 and 1998 Overburden Groundwater Samples from Acid Area #3*

	RBC (1/10th) [μg/L]	1997 Sample	1998 Sample
Metals			
Aluminum (unfiltered)	3700	11600	ND
Arsenic (unfiltered)	0.045	10.3	ND
Chromium (unfiltered)	11	22.8	ND
Iron (unfiltered)	1100	27300	ND
Lead (unfiltered)	15	16.6	ND
Manganese (unfiltered)	73	816	123
Manganese (filtered)	73	78.8	139

ND = Non Detect

Groundwater samples in the bedrock were tested for VOCs, SVOCs, nitroaromatic explosives, metals (total and dissolved), and cyanide. Two VOCs and two SVOCs were detected in the 1997 sample but only bis(2-ethlhexyl)phthalate was above its RBC of 4.8 μg/L at a concentration of 5.8 μg/L. The 1998 sample showed no concentrations of VOCs or SVOCs. Nitroaromatic explosives and cyanide were not detected in the sample for either year. Aluminum, iron, manganese and zinc were detected in the unfiltered and filtered samples, but only manganese was detected above its RBC of 73 μg/L at 74.6 μg/L in 1997, and 83.8 μg/L in 1998 (Ref. #35).

4.8.5.4 *Conclusions*

The Site Investigation of AA3 concludes that while surface soil sampling reveals a limited amount of SVOCs and PCBs in the AA3 and PSS areas (not the MNT area), the SVOCs were less prevalent in the subsurface soil samples, probably due to reduced mobility of the detected compounds (Ref. #33).

The Site-wide Groundwater Monitoring Report concludes that results from the overburden and bedrock groundwater samples in the AA3 area indicate the groundwater has not been impacted by past site activities. Although elevated levels of manganese were found in both the overburden and bedrock groundwater samples, the report states that these concentrations are low compared to other areas of the PBOW and that manganese is not believed to be a site-related contaminant (Ref. #35). Neither does the report attribute the sporadic detection of low levels of VOCs and SVOCs to be site-related contaminants (Ref. #31).

It is unlikely that the low levels of contamination in this area will affect the PBRF. If monitoring wells are installed just south of Pentolite Road as previously recommended, samples from those wells would indicate if any contamination is migrating towards the PBRF.

4.8.6 Overall Conclusions for the PBOW Sites

Of all the adjacent areas to the PBRF reviewed above, the PRRWPs remain the closest and most contaminated area of concern. The other PBOW sites discussed could also potentially contribute to contamination migrating towards the PBRF. With the installation of nested overburden and bedrock monitoring wells just south of Pentolite Road and upgradient from the PBRF, it will be possible to determine if contaminants are migrating from all of the areas of concern in the adjacent area to the PBRF. Figure 4.8.6-1 shows the approximate recommended locations of these wells. During the review of available data, nothing was found that would indicate that any NASA activities at the PBS have caused contamination in the adjacent areas that could migrate to the PBRF; all such contamination appears to be related to the former PBOW activities.

4.8.7 Summary of the Vista Check Database Search

A search of Federal and state environmental databases for known sites within 1.5 miles of the PBRF was conducted through the Vista Check Database System. The ASTM Site Assessment Plus Report is included as Appendix F of this EBSR. In addition to the database searches, the report includes Sanborn Fire Insurance Maps, and a U.S. Department of the Interior land use and land cover map (from source materials dated 1980 and 1983). However, no historic fire insurance maps (Sanborn maps) are available for the PBS area. This indicates that the area was undeveloped in the late 19th and early 20th centuries. As discussed in Section 3.1, historically, the area was used for agriculture until the DoD obtained the property in 1940.

As shown in Appendix F, several sites of interest were identified in the Federal and state database searches (see the figure on page 3 of Appendix F). These are located between ¾ and 1 mile from the PBRF and all but one are located on the PBS. A state-registered inactive leaking UST (LUST) is located 0.82 miles northeast of the PBRF at the Perkins Board of Education on E. Bogart Road. This site is listed as "No Further Action" in the database and is downgradient of the PBRF.

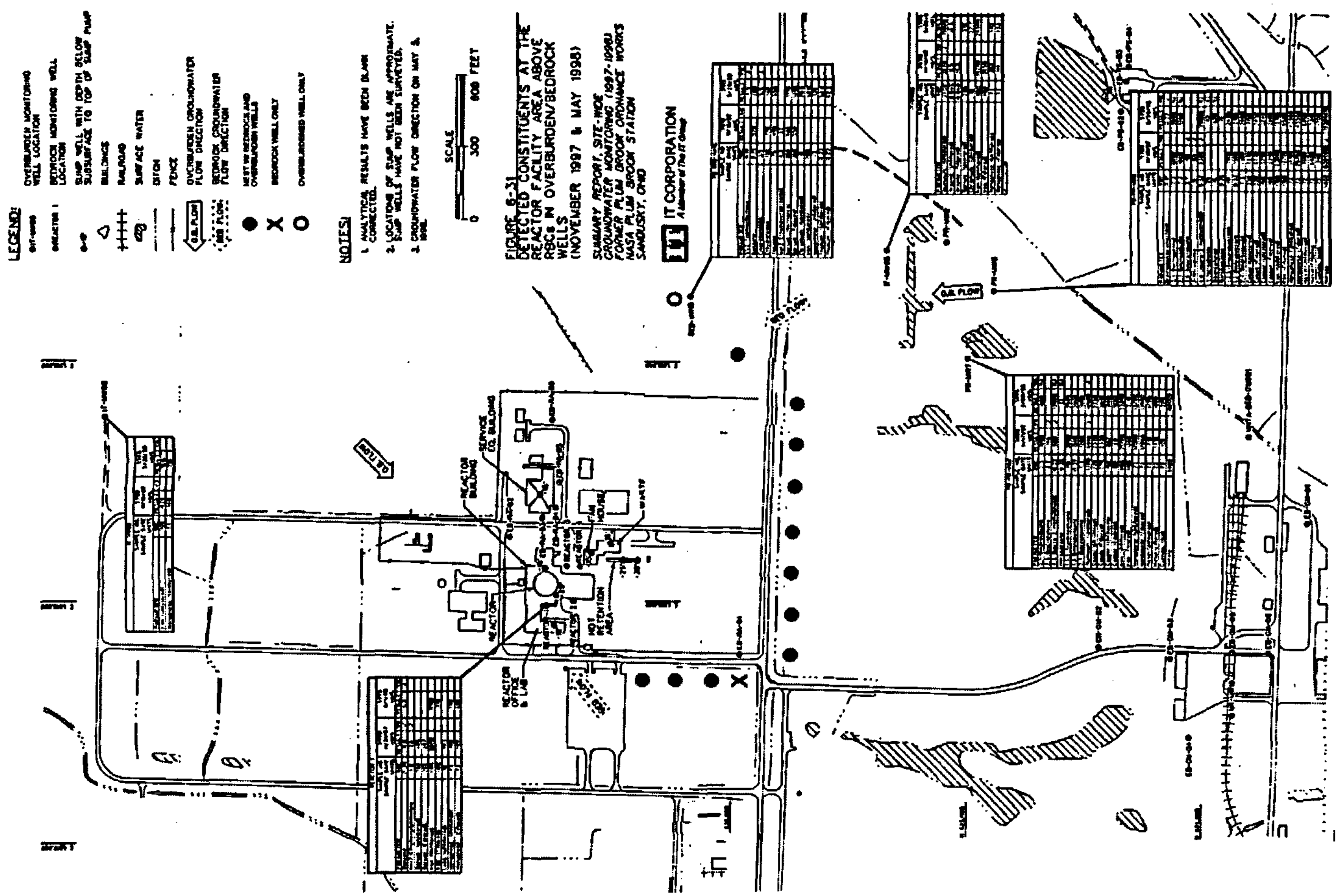


Figure 4.8.6-1.—Recommended Locations of Overburden and Bedrock Monitoring Wells Upgradient of the PBRF.
(Source: Ref#35 modified)

All other sites identified are within the boundary of the PBS. Four sites are identified with building numbers. The LUSTs at Buildings #8951, #5231, and #7132 are listed as inactive and require no further action. The LUST at Building #7121 is listed as active and also requires no further action.

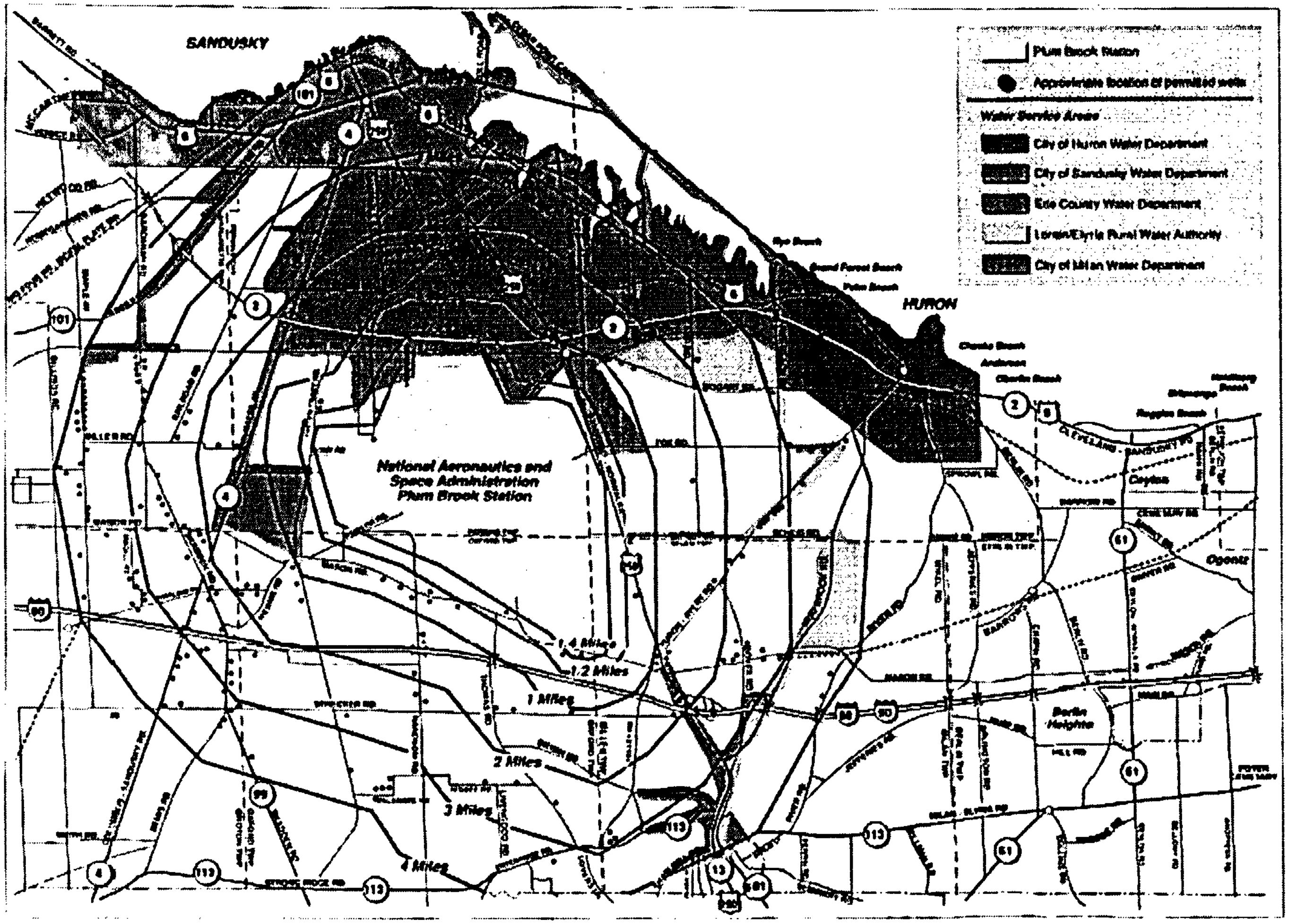
The database also identified PBS as a large quantity generator under RCRA, as a site undergoing RCRA corrective actions, and also as a site that has undergone Federal discovery, preliminary assessment, and screening site inspection activities.

The report also identifies seven unmapped sites, 5 of which are LUSTs and 2 are solid waste landfill facilities. All areas upgradient of the PBRF that could affect that facility are located on the PBS. These unmapped sites are not located on the PBS. Therefore, it is expected that these 7 sites could not adversely affect the PBRF.

Similarly, the overall results of the ASTM Site Assessment Plus Report do not indicate any additional sources of contamination that could affect the PBRF. As discussed above in Section 4.8.6, the former PBOW sites located upgradient of the PBRF are the areas of concern within the adjacent areas.

4.8.8 Private Groundwater Wells

The 1991 Preliminary Assessment detailed water utilization for the PBS and all other users within 15 miles of the Station (Ref. #12). Within a 4-mile radius of the PBS, there are 179 permitted private drinking water wells on record at the Erie County Health Department. The Erie County Health Department does not require a permit for wells intended for agricultural use. Figure 4.8.8-1 shows the permitted drinking water wells and those areas served by rural, city or county water authorities. As the figure shows, permitted private wells are located side-gradient to the entire PBS. The area downgradient from the PBS are serviced by the various local water authorities which obtain their water from surface water supplies including Lake Erie and reservoirs fed by the Huron River (Ref. #12).



(Source: Ref#12)

FIGURE 4.8.8-1.—*Permitted Drinking Water Well Locations Within a Four-Mile Radius of PBS, and Water Service Areas.*

5.0 CONCLUSIONS AND RECOMMENDED COURSES OF ACTION

This section presents conclusions and also discusses current data gaps and future recommended investigations.

5.1 CONCLUSIONS

Upon analyzing data collected during the conduct of this EBS, the following conclusions can be made:

Due to the nature of the facility, environmental monitoring conducted while the facility was active focused solely on radiological aspects. The radiological characterization efforts conducted in 1985 and in 1998 appear to have adequately characterized the radiological status of the buildings and structures at the PBRF. However, during this EBS, no information was obtained on the extent of the contamination associated with the former spill area south of the Waste Handling Building (#1133).

Since the facility has been shut down, sampling for environmental contaminants other than radionuclides has occurred. This has been associated with the USTs adjacent to the Services Equipment Building (#1131), the former Pentolite Area Waste Lagoons that were present in what is now the southwestern part of the PBRF, and recent environmental characterization efforts associated with the decommissioning project.

Sampling and analyses conducted at the former UST area appears to have adequately characterized the nature and extent of the contamination associated with these tanks. Future remedial actions involving the groundwater contamination in this area should reduce contaminant levels.

Although soil sampling conducted to date in the former Pentolite Area Waste Lagoons is somewhat limited, the available data indicate that there is no nitroaromatic soil contamination remaining in the area. In fact, the state EPA representative overseeing the DERP/FUDS work at the PBRF has indicated that the request for "no further action" at the former Pentolite Area Waste Lagoons will be approved (personal communication w/ Ms. Lisa Humphreys, December 2000).

The most recent soil sampling effort at the PBRF (Ref. #50) identified several areas of low-level VOC, SVOC, and PCB soil contamination. However, except for 1 sample that contained an estimated concentration of an SVOC above the RBC, the concentrations detected were well below available RBCs.

The environmental condition of the PBRF appears to be adequately characterized, with the exception of the data gaps discussed below in Section 5.2.

5.2 DATA GAPS AND RECOMMENDED INVESTIGATIONS

Various data gaps have been identified during conduct of this EBS. Several of these gaps concern lack of data on certain types of potential contaminants (based on site activities and history), others are lack of sampling in certain areas, and one was identified during the review of historic aerial photographs. The specific data gaps identified are discussed below.

During interviews with personnel who worked at the PBRF when it was active, it was noted that the analytical laboratories at the PBRF used typical solvents associated with laboratories, such as carbon tetrachloride, acetone, and methylene chloride. Waste solvents were disposed of by pouring them down the drains at the laboratories. Because the laboratories handled radioactive materials, these drains are part of the hot drain system that discharged to the tanks in the Hot Retention Area (#1155). Liquids stored in this area were allowed to "cool" and were then diluted with non-radioactive water and discharged through the Water Effluent Monitoring Station (WEMS) (#1192). Although the solvents disposed of were certainly diluted greatly in this process, in addition to the dilution that occurred in the Hot Retention Area, it is possible that the sediments at the WEMS may have been contaminated by volatile organic compounds. Sediment and subsurface (to a depth of 5-feet) sampling/volatile organic analyses should be conducted at the WEMS to verify that no VOC contamination exists. Three sediment samples collected from random locations should be sufficient to determine if this area has been impacted by solvent contamination.

There is another potential source of VOC contamination being introduced into the WEMS. This source is the current discharge of water from the sumps in the basements of the major buildings at the PBRF. Due to the depths of the wells at the sumps, it is safe to assume that this water is from the bedrock aquifer. The RCRA investigation conducted at the former waste solvent tank site found that the sump at Building 1131 has caused a radial depression of the groundwater table towards the sump. Although the former waste solvent tank site could be contributing to the VOC contamination, the sump effluent is monitored quarterly for radioactive constituents only; VOCs are not an analyte.

During the sitewide groundwater monitoring study (Ref. #35), benzene was detected in Reactor Well #1 (a bedrock well) at a concentration of up to 8.8 ug/l (the RBC is 0.36 ug/l). Although benzene is known to be naturally occurring in the area and has been found in most bedrock monitoring wells across Plum Brook Station, it is not know to naturally occur in surface water. The sump effluent is discharged through the WEMS, into Pentolite Ditch and then into Plum Brook. Since the sump effluent is from the bedrock aquifer, there is potential for it to be contaminated with VOCs, particularly benzene. A grab sample of the sump effluent at the WEMS should be collected when it is not raining (to avoid dilution by storm water) and analyzed for VOCs.

Although not specifically identified during either the records search or interviews, there is another potential source of contamination associated with the laboratory drainage system. Because of the nature of the laboratory operations, potential exists for substances such as mercury from broken thermometers to have been disposed of in sink or floor drains. Therefore, during demolition of the laboratory areas, sludge present in the laboratory floor drains and sink traps, and any material present between floor sub-surfaces should be sampled and analyzed for a complete set of analytical parameters (i.e, VOCs, SVOCs, Target Analyte List metals, and pestcides/PCBs).

The Sludge Basins (#1153) in the northeast corner of the PBRF and the associated Drying Basins in the northern area outside the PBRF fence have never been sampled. This is because these basins were part of the raw water treatment system and thus are not suspected to have radiological contamination. However, the potential use of algaecides or similar substances to control microorganism growth in the process water leads to the possibility that the sludge/sediment in the Sludge Basins and what is now soil in the Drying Basins may be contaminated with these substances. Several sediment and soil samples should be collected in each of these areas at random locations and analyzed for pesticides/herbicides and metals. If any contaminants are detected, a sampling grid system should be established over each basin and an appropriate number of random samples should be collected in accordance with EPA guidance.

As discussed in Section 4.2.13, the diesel fuel above ground storage tank just north of the Services Equipment Building (#1131) was overfilled in about 1975. Soil sampling of the impacted area was never conducted. In addition, stained soil was observed below the tank during the site visit. This area and the soils between the tank and the catch basin located approximately 60 feet north of the tank should be sampled and analyzed for diesel range organics and total petroleum hydrocarbons. Composite samples should be collected from a depth of 0 – 2 feet from beneath the tank and then at 10-foot intervals to the catch basin.

Based on the data reviewed for this EBS, it appears that the overburden groundwater in the central portion of the PBRF has not been analyzed for nitroaromatics. Reactor Well 2, a bedrock well, was sampled in 1995 during the Focused RI at the Pentolite Road Red Water Ponds, and 3-NT and 3,4-DNT were found at levels of 23 ug/l and 13 ug/l, respectively. The Limited Site Investigation of the former Pentolite Area Waste Lagoons (Ref. #36, 1999) did not identify nitroaromatic contamination in soils, and concluded that the potential for groundwater contamination was therefore low. Groundwater, however, was not sampled as part of this investigation. Overburden groundwater at the PBRF should be analyzed for nitroaromatics in order to verify that the former Pentolite Area Waste Lagoons did not impact groundwater at the facility.

During the review of data conducted for this EBS, no information was found on the extent of the area of contamination from the 2 areas of low-level waste spills (just south of Building #1134 and south of Building #1133). Soils were sampled to a depth of 10 feet in the area south of the Waste Handling Building (#1133) in the 1985 characterization study, and contamination was reported to a depth of 6 feet. No direct indication of the areal extent of the contamination was given (It was stated that soil should be removed to a depth of 8 feet and that a total of 185 cubic yards of soil should be removed. Assuming a square excavation, this would imply an area of 25 feet on each side). No radiological concentration was reported in the 1985 study for the second spill area near the Primary Pump House (#1134). The 1998 survey confirmed the presence of contamination near the Waste Handling Building, but no contamination was detected at the previously identified spill area. The lateral extent of the spill near Building #1133 should be determined, and the presence or absence of contamination associated with the second spill should be verified.

During the review of historic aerial photographs taken during construction of the PBRF, piles of unknown material were observed in what is now the parking lot (see photo in Appendix B). This material appears to be fill, but its origin is unknown. It is possible that this material was obtained onsite. Given the history of the Plum Brook Ordnance Works, the area beneath and immediately south of the parking lot may have been filled with soil contaminated by nitroaromatics. Although this area is outside the fenced portion of the PBRF, it is recommended that ten soil samples (composites from 0 – 2 feet) be collected in these areas and analyzed for nitroaromatics.

Finally, as discussed in Section 4.8.6, since the PBRF is downgradient of several former PBOW sites located in the adjacent areas south of the PBRF, there is potential for groundwater contamination from these sites to migrate towards the PBRF. With the installation of monitoring wells just south of Pentolite Road and upgradient from the PBRF, it will be possible to determine if contaminants are migrating from all of the areas of concern in the adjacent area to the PBRF. The approximate recommended locations of these wells were presented in Figure 4.8.6-1.

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CERTIFICATION OF
FINAL ENVIRONMENTAL BASELINE SURVEY
FEBRUARY 2001
FOR PLUM BROOK REACTOR FACILITY,
SANDUSKY, OHIO

I certify that the property conditions stated in this report are based on a thorough review of available records, visual inspections, and sampling and analysis as noted, and are true and correct, to the best of my knowledge and belief.

________________________________ ________________

Preparer/Affiliation Date

I have reviewed the preparer's methodology and report, and concur with the methodology and findings to the best of my knowledge and belief.

________________________________ ________________

Chief, NASA GRC Environmental Management Office Date