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REPORT

GROUNDWATER REPORT

FEED MATERIALS PRODUCTION CENTER
FERNALD, OHIO

REMEDIAL INVESTIGATION AND FEASIBILITY STUDY

VOLUME 1 OF 13

December 1990

U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE

Property of
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DRAFT

1.0 INTRODUCTION

The Feed Materials Production Center (FMPC) is a government-owned, contractor-operated federal facility for the production of pure uranium metals for the U.S. Department of Energy (DOE). The FMPC site is located on 1,050 acres in a rural area approximately 18 miles northwest of downtown Cincinnati, Ohio. The Production Area is limited to an approximate 136-acre tract near the center of the FMPC site. The villages of Fernald, New Baltimore, Ross, New Haven, and Shandon are all located within a few miles of the plant (Figure 1-1).

On March 9, 1985, the U.S. Environmental Protection Agency (EPA) issued a Notice of Noncompliance to the DOE identifying EPA's major concerns over potential environmental impacts associated with the FMPC's past and present operations. Between April 1985 and July 1986, conferences were held between DOE and EPA representatives to discuss the issues and to identify the steps the DOE proposed to achieve and maintain environmental compliance.

On July 18, 1986, a Federal Facility Compliance Agreement (FFCA) was jointly signed by DOE and EPA pertaining to environmental impacts associated with the FMPC. The FFCA was entered into pursuant to Executive Order 12088 (43CFR47707) to ensure compliance with existing environmental statutes and implementing regulations such as the Clean Air Act, the Resource Conservation and Recovery Act (RCRA), and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In particular, the FFCA was intended to ensure that environmental impacts associated with past and present activities at the FMPC are thoroughly and adequately investigated so that appropriate remedial response actions can be formulated, assessed, and implemented.

In response to the FFCA, a Remedial Investigation and Feasibility Study (RI/FS) was initiated pursuant to CERCLA, as amended by the Superfund Amendment and Reauthorization Act (SARA). All RI/FS activities are being conducted in conformance with EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (EPA/540/G-89/004 October 1988). The 1986 FFCA was amended by a Consent Agreement under Section 120 and 106(a) of CERCLA (Consent Agreement) in order to achieve consistency with changing regulations and guidance, the operable unit concept, and the current commitments of the RI/FS program without modifying the underlying objectives. The Consent Agreement was signed on April 9, 1990 and became effective on June 29, 1990.

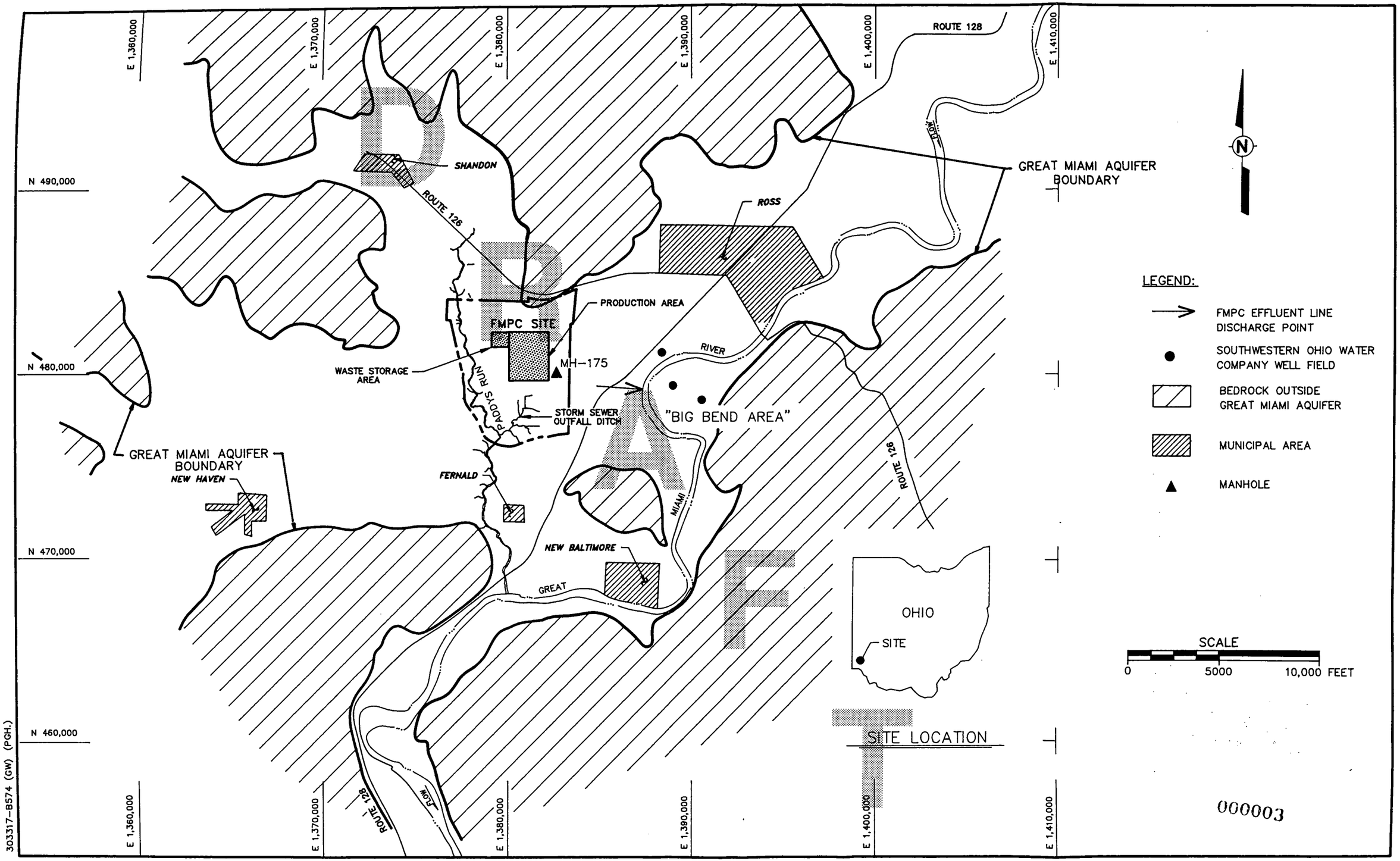

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FIGURE 1-1
STUDY AREA AND VICINITY

1.1 OBJECTIVES

The overall objective of the Remedial Investigation (RI) is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances, pollutants, or contaminants, and to gather all necessary data to support the FS. The groundwater program was designed to determine the effect that the operations and waste disposal practices at the FMPC have had on the groundwater. The overall objectives of the groundwater program are as follows:

- Determine the hydrogeology for the area under and adjacent to the site
- Determine if subsurface water-bearing zones below the FMPC have been contaminated
- Determine the sources of contaminants on site and the resultant concentrations in groundwater both on and off the FMPC Reservation
- Characterize the rate and direction of contaminant transport away from the FMPC
- Determine the effects on groundwater flow and contaminant transport that result from groundwater pumping

The purpose of this report is to present the results of the hydrologic investigation and groundwater data analysis that have been completed under the RI and to provide a comprehensive interpretation for the entire site.

1.2 RELATIONSHIP TO RI/FS

The RI/FS for the FMPC was initially designed to address the entire site and to focus on various environmental media that could be potentially impacted by past and present operations at the FMPC. The purpose of the RI is to determine the nature and extent of any release, or threat thereof, of hazardous or radioactive substances and to gather the necessary data to support the evaluation of remedial action alternatives in the Feasibility Study (FS).

A Work Plan for the site-wide RI/FS, based on the requirements of the FFCA, was originally submitted to EPA in December 1986. After a series of technical discussions, the Work Plan was modified and resubmitted in March 1988. It received EPA approval in May 1988.

The Work Plan prepared for the site-wide RI/FS provided the overall technical approach, identified a number of investigative areas, developed objectives for each of the specified investigations, and established overall objectives for the evaluation of data collected during the RI activities. The Work Plan also involved the preparation of a number of detailed plans to establish specific

procedures to be followed in the completion of the RI/FS for the FMPC. These plans included the following:

- Sampling Plan
- Health and Safety Plan
- Community Relations Plan
- Data Management Plan
- Quality Assurance Project Plan

The Sampling Plan, which was submitted in March 1988 in conjunction with the RI/FS Work Plan, contained objectives, sampling locations, and sampling procedures for the following:

- Radiation measurement
- Surface soils
- Groundwater
- Subsurface soils
- Surface water and sediment
- Biological resources

The Work Plan identified 27 units of the FMPC to be investigated in the RI/FS. Several modifications to the list eventually increased this total to 39 units. In the course of the investigation, it became apparent that for technical and program management purposes, these 39 units needed to be categorized and grouped together. The concept of operable units was introduced into the program to accommodate separate schedules for each operable unit. This allowed the remedial action process to proceed to completion for the most well-defined or problematic units, while data collection and analysis continued for other operable units.

Under the RI/FS Work Plan, the 39 candidates for remedial action are categorized into five operable units as follows (Figure 1-2):

- Operable Unit 1 - Waste Pits 1 through 6, Clearwell, and Burn Pit
- Operable Unit 2 - Other Waste Units
- Operable Unit 3 - Production Area and Suspect Areas
- Operable Unit 4 - Silos 1, 2, 3, and 4
- Operable Unit 5 - All Environmental Media

Operable Unit 5 includes those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FMPC contaminants. The Operable Unit 5 media are linked to the four "source control" operable units, but in and of themselves represent sources of contaminant release only in terms of serving as a transport pathway from one environmental medium to another. The environmental media for Operable Unit 5 are defined separately below:

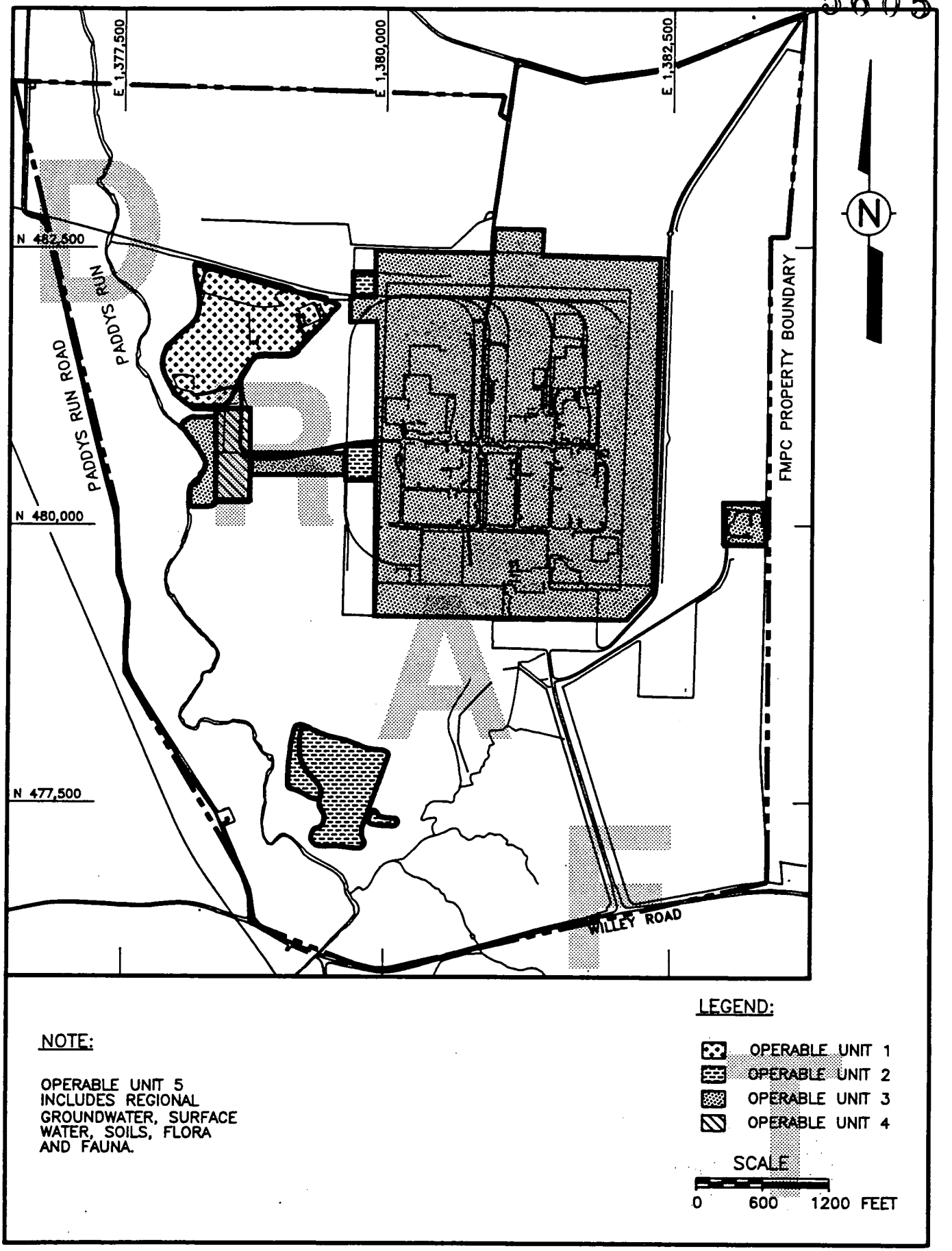

FIGURE 1-2

OPERABLE UNITS LOCATIONS

- Surface Water/Sediments:

  - Great Miami River: Addresses the sediments in the Great Miami River and their role as a potential source of contaminants to the overlying water column and the aquatic community; does not include source control, which is the focus of other operable units.

  - Paddys Run: Similar to the Great Miami River, with the additional consideration of the effects of leakage from Paddys Run into the regional aquifer.

  - Storm Sewer Outfall Ditch: Similar to Paddys Run.

- Groundwater: Limited to the Great Miami Aquifer (i.e., the regional aquifer) throughout the study area, with appropriate consideration given to the South Plume, which is the subject of a separate removal action; does not include source control, which is the focus of other operable units.

- Soils: Includes all surface soils not accounted for in other operable units; specifically, all off-FMPC soils and soil areas outside of the Production Area, other controlled areas of the site, and suspect areas.

The objectives of the groundwater investigation demonstrate the direct relationship between the groundwater program and Operable Unit 5. In fact, this groundwater report serves as the primary source document for the Operable Unit 5 RI and related reports. By utilizing this groundwater report as a source document that contains detailed presentations of the investigations, procedures, analysis, models, and results, the Operable Unit 5 RI/FS reports can be streamlined to more clearly focus on the most significant issues and concerns.

Operable Units 1, 2, 3, and 4 are identified as possible source areas of contamination to the glacial overburden and/or the underlying sand and gravel aquifer.

The information contained in this report is directly transferable to those portions of the RI/FSs for Operable Units 1, 2, 3, and 4 that pertain to environmental releases and their current and potential effects. For example, Chapter 17.0 is dedicated to the analysis of the hydrogeologic settings associated with each of the four operable units, and Chapter 22.0 addresses the long-term potential for environmental releases and migration from these operable units.

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2.0 SITE SETTING

2.1 SITE DESCRIPTION AND HISTORY

The U.S. Atomic Energy Commission (AEC), predecessor to DOE, established the FMPC for processing uranium and its compounds from natural uranium ore concentrates and recycled recoverable residues for government needs. This integrated production complex began operations in conformance with AEC Orders in the early 1950s. In 1951, National Lead Company of Ohio (now NLO, Inc.) entered into contract with the AEC as Operations and Maintenance (O&M) Contractor. This contractual relationship lasted with AEC, and eventually DOE, until January 1, 1986. Westinghouse Materials Company of Ohio (WMCO), a wholly owned subsidiary of Westinghouse Electric Corporation, then assumed management responsibilities of the site operations and facilities for a minimum of five years.

Production peaked in 1960 at approximately 10,000 metric tons of uranium (mtu) per year. A product decline began in 1964, to a low in 1975 of about 1230 mtu. During the 1970s, consideration was given to closing the FMPC; therefore, capital improvements and staffing were minimized. The staffing level, which peaked at 2891 in 1956, slowly declined from 662 in 1972 to 538 in 1979. In 1981, the FMPC began planning to accommodate increased production requirements. Production levels significantly increased and there was a rapid staff buildup in many areas for several years. Implementation of a major facilities restoration program followed. Then production ceased in the summer of 1989 to focus plant resources on the restoration program. Currently, the FMPC remains in an inactive status; however, the environmental studies and restoration activities continue.

A variety of chemical and metallurgical processes are utilized at the FMPC for the manufacture of uranium products. During the manufacturing process, high quality uranium compounds are introduced into the FMPC processes at several points. Impure starting materials are dissolved in nitric acid and the uranium is purified through solvent extraction to yield a solution of uranyl nitrate. Evaporation and heating convert the nitrate solution to uranium trioxide (UO_3) powder. This compound is reduced with hydrogen to uranium dioxide (UO_2) and then converted to uranium tetrafluoride (UF_4) by reaction with anhydrous hydrogen fluoride. Uranium metal is produced by reacting UF_4 and magnesium metal in a refractory-lined vessel. This primary uranium metal is then remelted with scrap uranium metal to yield a purified uranium ingot. Various uranium metalworking processes are also housed on the FMPC.

From 1953 through 1955, the FMPC Refinery processed pitchblende ore from the Belgian Congo. Pitchblende ore contains all daughter products of the uranium decay chains and is particularly high

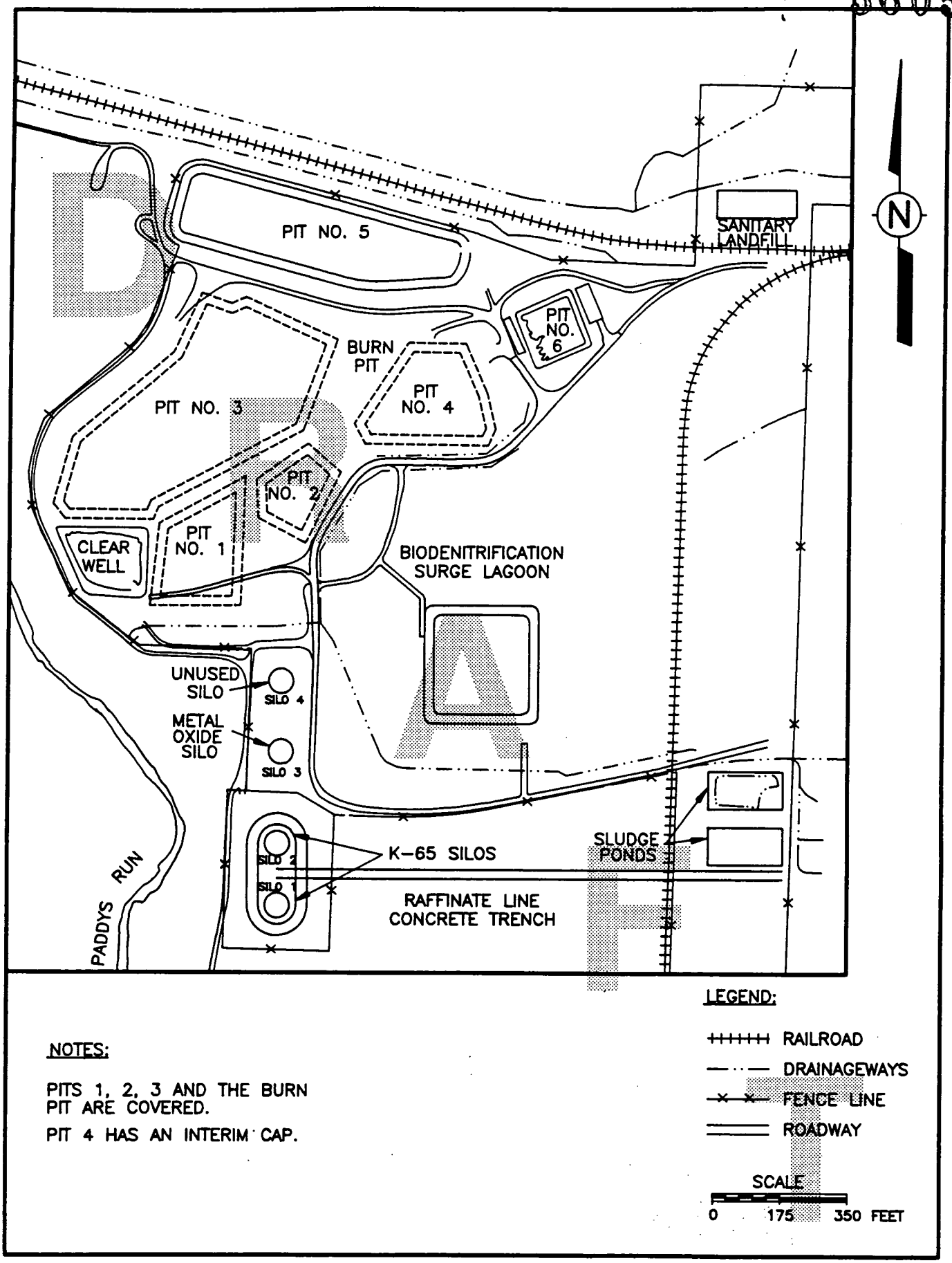
in radium content. No chemical separation or purification was performed on the ore prior to arrival at the FMPC. Beginning in 1956, the refinery feedstock consisted of uranium concentrates (yellowcake) from Canada and the United States. Canadian concentrates were not processed after 1960. In the production of these concentrates, most of the uranium daughters had been removed. However, radium-226 (Ra-226) remained in the yellowcake in amounts that varied with the process.

Small amounts of thorium were produced at the FMPC on several occasions from 1954 through 1975. Thorium operations were performed in the metals fabrication plant, the recovery plant, the special projects plant, and the pilot plant. The FMPC currently serves as the thorium repository for DOE and maintains long-term storage facilities for a variety of thorium materials.

Large quantities of liquid and solid wastes were generated by the various operations at the FMPC. Before 1984, solid and slurried wastes from FMPC processes were disposed of in the on-property Waste Storage Area. This area, which is located west of the production facilities (Figure 2-1), includes six low-level radioactive waste storage pits; two earthen-bermed concrete silos containing K-65 residues which are high-specific activity, low-level radium-bearing residues resulting from the pitchblende refining process; one concrete silo containing metal oxides and one unused concrete silo; two Lime Sludge ponds; and a sanitary landfill. The Waste Storage Area is addressed under Operable Units 1 and 4.

Solid waste materials associated with uranium metals production are presently stored on-FMPC in steel drums awaiting further processing or off-site disposal at approved facilities. These wastes include oils, sludges, contaminated combustibles, filter cake, off-spec UF_4 or thorium tetrafluoride (ThF_4), and reject UO_3. The drums sit on various pads and in warehouses and are inspected weekly. Contents of deteriorated drums are repackaged. Other wastes, stored in drums on contained surfaces, include spent degreasing solvents and material contaminated with polychlorinated biphenyls (PCBs).

An Inactive Fly Ash disposal area and an Active Fly Ash pile, addressed under Operable Unit 2, are located approximately 3000 feet south-southeast of the waste storage area. One pile remains active for the disposal of fly ash from the FMPC coal-fired boiler plant. An area between and adjacent to the fly ash areas, known as Southfield, is believed to be the disposal site for construction debris and possibly other types of solid wastes from FMPC operations. Southfield is also being addressed as a solid waste unit under Operable Unit 2.



NOTES:

PITS 1, 2, 3 AND THE BURN PIT ARE COVERED.

PIT 4 HAS AN INTERIM CAP.

303317-A208 (GW) (PGH)

FIGURE 2-1

WASTE STORAGE AREA

Surface water runoff from the Waste Storage Area, fly ash piles, and other affected areas within the western portion of the FMPC enters Paddys Run, a tributary of the Great Miami River. Paddys Run originates just north of the FMPC and flows south-southeast along the western edge of the site. For most of the year it is a dry stream bed with occasional rainfall-induced flows.

Leachate from these same areas can potentially migrate vertically through a till layer of varying thickness to the regionally important Great Miami Aquifer which underlies the site. This aquifer serves as a principal source of domestic, municipal, and industrial water throughout the region. A portion of the flow in Paddys Run is also known to enter this aquifer as a result of leakage through the stream bottom. Leakage occurs over the length of Paddys Run, beginning at a point west of the Waste Storage Area, and extending to the Great Miami River.

Liquid waste effluent generated from FMPC process operations is sent to a general plant sump for treatment and analysis prior to release to the Great Miami River through the main effluent line. The main effluent line to the Great Miami River is the permitted discharge point for wastewater from the FMPC. The discharge is regulated by a National Pollutant Discharge Elimination System (NPDES) permit and DOE Orders, with compliance monitoring performed at Manhole 175 before the effluent leaves the FMPC boundary.

Storm water runoff from the production area is collected in storm water retention basins, located on the south side of the Production Area, to allow for solids removal prior to being analyzed and released to the Great Miami River through the same effluent line. During extreme storm events, if the storm water retention basins overflow, storm water is discharged through the Storm Sewer Outfall Ditch to Paddys Run.

2.2 SURFACE FEATURES

The FMPC lies on the boundary between the southernmost extent of Pleistocene Glaciation and the ancient unglaciated upland. The advance and retreat of continental glaciers not only shaped the topography, but determined the hydrogeologic setting for the site.

2.2.1 Physiographic Province

The FMPC lies in the Till Plains section of the Central Lowland physiographic province, characterized by structural and sedimentary basins and domes. Among these features, the Cincinnati Geoanticline is structurally significant in this region. The underlying bedrock in the region is shale and fossiliferous limestone of Middle and Late Ordovician age (Fenneman 1916). It outcrops on steep valley walls in numerous waterfalls. In some areas, it is overlain by glacial deposits that range in thickness to as much as 400 feet.

The main physiographic features in the area are gently rolling uplands, steep hillsides along the major streams, and the Great Miami River Valley, which is a relatively broad, flat-bottomed valley flanked on either side by bluffs that rise to a maximum of 300 feet above the general level of the valley floor.

2.2.2 Topography

Maximum elevation along the northern boundary of the FMPC property is a little more than 700 feet above mean sea level. The Production Area and Waste Storage Area rest on a relatively level plain at an approximate elevation of 580 feet. The plain slopes from 600 feet along the eastern boundary of the FMPC to 570 feet at the K-65 silos, and then drops off toward Paddys Run at an elevation of 550 feet. All drainage on the FMPC is from east to west into Paddys Run, with the exception of the extreme northeast corner which drains east toward the Great Miami River.

2.3 SURFACE WATER HYDROLOGY

The FMPC is located within the Great Miami River Basin drainage, but above the river's present day flood plain. The Great Miami River is the receiving stream for the FMPC effluent discharge and represents the main surface water feature in the vicinity of the FMPC (Figure 2-2). The river flows generally to the southwest and has a drainage area of approximately 3360 square miles at the Hamilton gage, which is located about 10 miles upstream from the FMPC discharge outfall.

The river exhibits meandering patterns that result in sharp directional changes over distances of less than 3000 feet. Directly east of the FMPC and within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 2-2). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FMPC point of discharge.

The average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3305 cubic feet/second (ft^3/s). Using drainage area scaling, the corresponding average flow at the FMPC point of discharge has been estimated to be 3460 ft^3/s. The maximum discharge ever recorded for the Great Miami River at Hamilton occurred on March 26, 1913 and was estimated to be 352,000 ft^3/s. The maximum discharge since the construction in 1922 of five retarding basins, located approximately seven miles upstream of Ross, was 108,000 ft^3/s and occurred on January 21, 1959. The ten-year-flood discharge has been calculated to be 81,455 ft^3/s for the site reach. The minimum daily discharge of 155 ft^3/s was recorded on September 27, 1941. This value is approximately half of the seven-day, ten-year low flow value (Q_{7-10}) of 267 ft^3/s, as computed by the U.S. Geological Survey (USGS) for the Hamilton gage. This translates to 280 ft^3/s at the site reach.

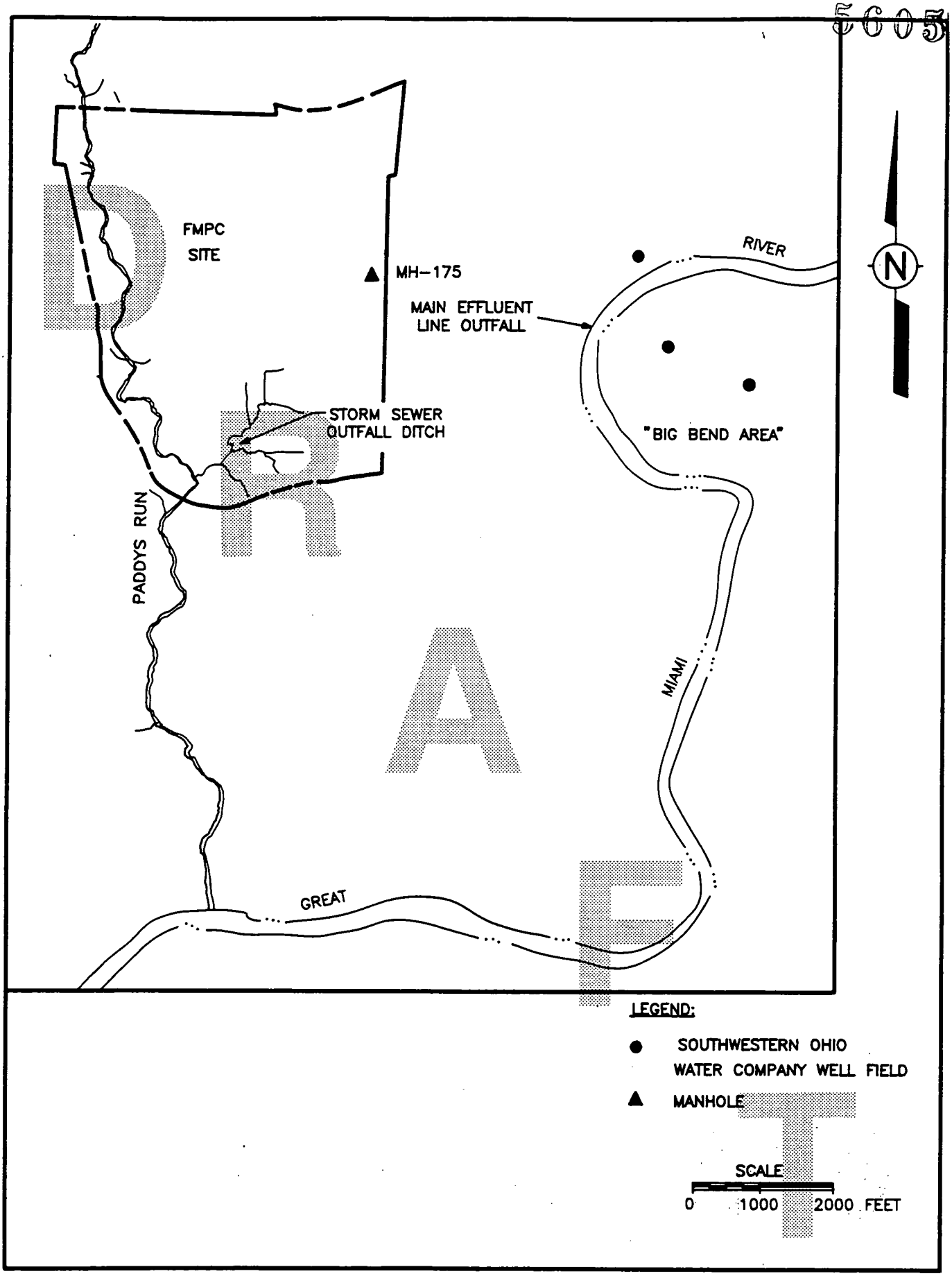


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FIGURE 2-2

SURFACE WATER HYDROLOGY

Natural surface drainage from the FMPC is primarily to Paddys Run. Paddys Run originates north of the site, drains southward along the west side of the FMPC, and eventually enters the Great Miami River approximately 1.5 miles south of the FMPC (Figure 2-2). This stream loses flow to the underlying aquifer along much of its course due to its highly permeable channel bottom which is carved into the Great Miami Aquifer. Paddys Run is an ungaged, intermittent stream that flows primarily between January and May, with an estimated discharge for this period ranging between 0.2 and 4.0 ft^3/s. Peak flows have not been measured.

A principal drainage feature of the FMPC is a tributary to Paddys Run known as the Storm Sewer Outfall Ditch. This drainage course originates east of the Production Area, flows southwest across the southern portion of the site, and enters Paddys Run near the southwest corner of the property (Figure 2-2). Much of the stream bottom of this drainage course, which also collects runoff from an area east of the Production Area, is composed of sand and gravel. Vertical seepage rates through the stream bottom are similar to Paddys Run. This drainage course is generally dry throughout most of the year, with flows occurring during and immediately after precipitation.

The Storm Sewer Outfall Ditch historically conveyed surface water runoff from the Production Area directly to Paddys Run when the capacity of the storm sewer lift station, which diverts low flow storm water to Manhole 175, was exceeded. Storm water retention basins were constructed in October 1986 and December 1989 at the head of the Storm Sewer Outfall Ditch. Storm water runoff from the production area is now conveyed to these retention basins. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out of the basins to the Great Miami River via the FMPC's main effluent line. The basins are designed to retain the runoff from a 10-year, 24-hour rainfall event; only in the event of an overflow would storm water from the Production Area enter the outfall ditch.

2.4 GEOLOGY

The following provides a summary of the geologic history and hydrogeologic setting of the area surrounding the FMPC.

The FMPC is located within a two- to three-mile-wide subterranean valley known as the New Haven Trough. This valley formed as a result of Pleistocene Glaciation and subsequently filled with glacial outwash materials and till. The geological history of the FMPC area, as presented by Fenneman (1916), is summarized in the following paragraphs.

In Late Ordovician time, approximately 450 million years ago, sediments which would become a predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale is the relatively impermeable bedrock which now underlies the FMPC area and forms the adjacent highlands.

Prior to Pleistocene Glaciation, the area was relatively flat and sloped in a northward direction. This level plain contained a northward flowing drainage system. This system was referred to as the Teays River System and consisted of two major streams with many tributaries. At some time during the early Pleistocene period, this north-flowing river system was disrupted by the advance of Nebraskan and Kansan Glaciation to the north of the Cincinnati area. The drainage system that developed south of the advancing ice sheets is known as the Deep Stage Drainage System (Figure 2-3a).

The Deep Stage Drainage System was composed of three major rivers: the Miami River, the East Fork of the Little Miami River, and the Licking River. The Miami River followed much the same channel as the present-day Great Miami River from Middletown to Ross. The East Fork of the Little Miami River entered the area from the northeast. The Licking River came in from the south in essentially its present-day channel, but continued to the north of the present day Ohio River.

These three rivers combined to form what is known as the ancestral Ohio River, which entered the area from the east along the present-day channel of the Ohio River, then turned northeast through the valley now occupied by the Little Miami River. There it was joined by the East Fork and flowed west through the Norwood Trough to the Mill Creek Valley, where it joined the Licking River. The stream then flowed north through the Mill Creek Valley and turned west to join the Miami River south of Hamilton. It continued to the southwest through the New Haven Trough to near Harrison, where it turned and flowed south through what is now the Whitewater River Valley (Figure 2-3a).

Several tributary streams of later importance entered the main stream in the vicinity of the FMPC. Two streams originated near Miamitown: one flowed north to join the main stream between Shandon and Fernald and the other flowed south following the course of the present-day Great Miami River. Two other small streams originated near New Baltimore and flowed north to the main stream. The Dry Fork of the Whitewater River, which now lies to the west of the area, formerly turned east to Shandon and then flowed south through what is now the Paddys Run Valley (Figure 2-3a).

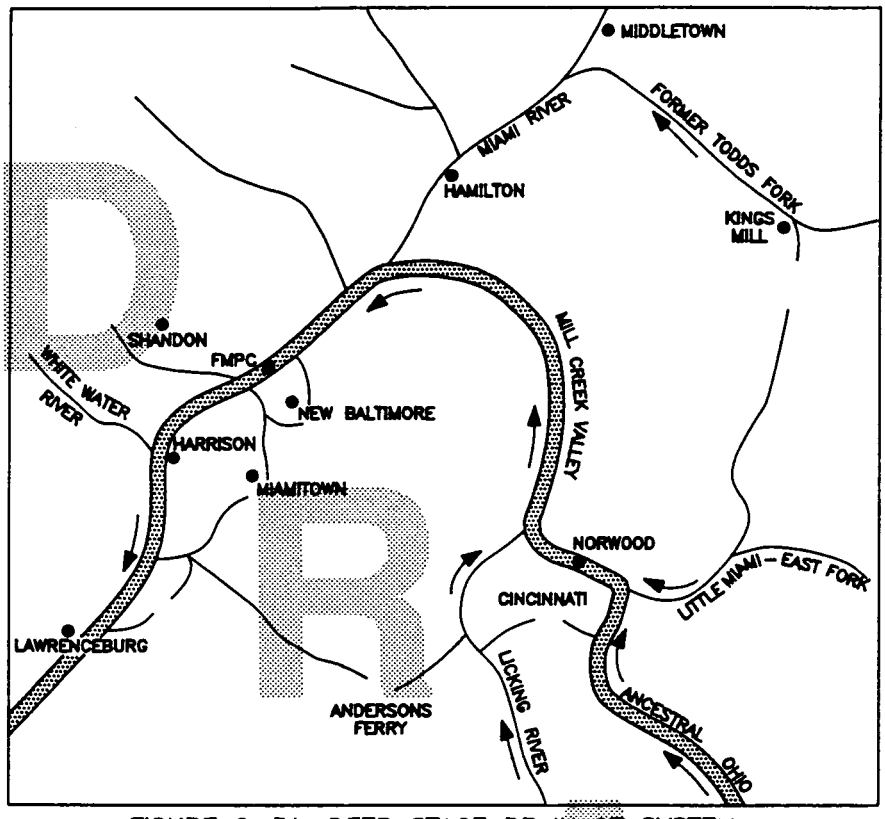


FIGURE 2-3A. DEEP STAGE DRAINAGE SYSTEM

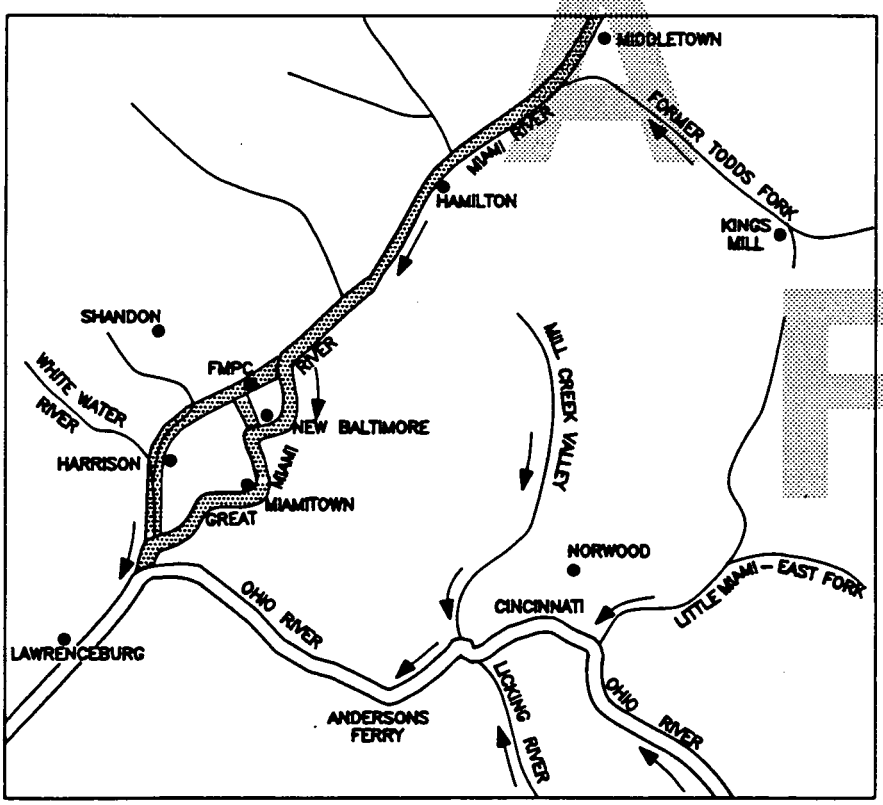


FIGURE 2-3B. PRESENT DRAINAGE SYSTEM

LEGEND:

- DIRECTION OF FLOW
- ANCESTRAL OHIO

LEGEND:

- DIRECTION OF FLOW
- GREAT MIAMI AQUIFER
- PRESENT OHIO RIVER
- NEW HAVEN TROUGH

SOURCE:

FENNEMAN, N.M., 1916 "THE GEOLOGY OF CINCINNATI AND VICINITY", GEOLOGICAL SURVEY OF OHIO, BULLETIN 19.

NOT TO SCALE

303317-A209 (GW) (PGH)

FIGURE 2-3

SCHEMATIC DIAGRAM OF THE DEEP STAGE DRAINAGE SYSTEM AND THE PRESENT DRAINAGE SYSTEM

During the time of Deep Stage Drainage and the early stages of Illinoisan Glaciation (300,000 to 400,000 years ago), the river valleys cut deeply into the shale bedrock to depths up to 200 feet below current land elevations. As the Illinoisan ice sheet advanced into the area, ice began to block the Miami River and its confluence with the ancestral Ohio River. This caused water to pond in the Mill Creek Valley. For a time, water still flowed to the west along the front of the advancing ice sheet and carved the present-day Great Miami River Valley along the tributary system near Miamitown (Figure 2-3a).

When the confluence of the Miami River and the ancestral Ohio River was completely blocked, the ponded water in the Mill Creek Valley rose until it overflowed low divides and carved outlets at Anderson's Ferry and at what is now downtown Cincinnati. This created the present-day channel of the Ohio River. As the ice retreated, the valleys of the Deep Stage Drainage were filled with well-sorted sand and gravel outwash deposits, and the Great Miami River and the Ohio River were established in their present-day channels (Figure 2-3b).

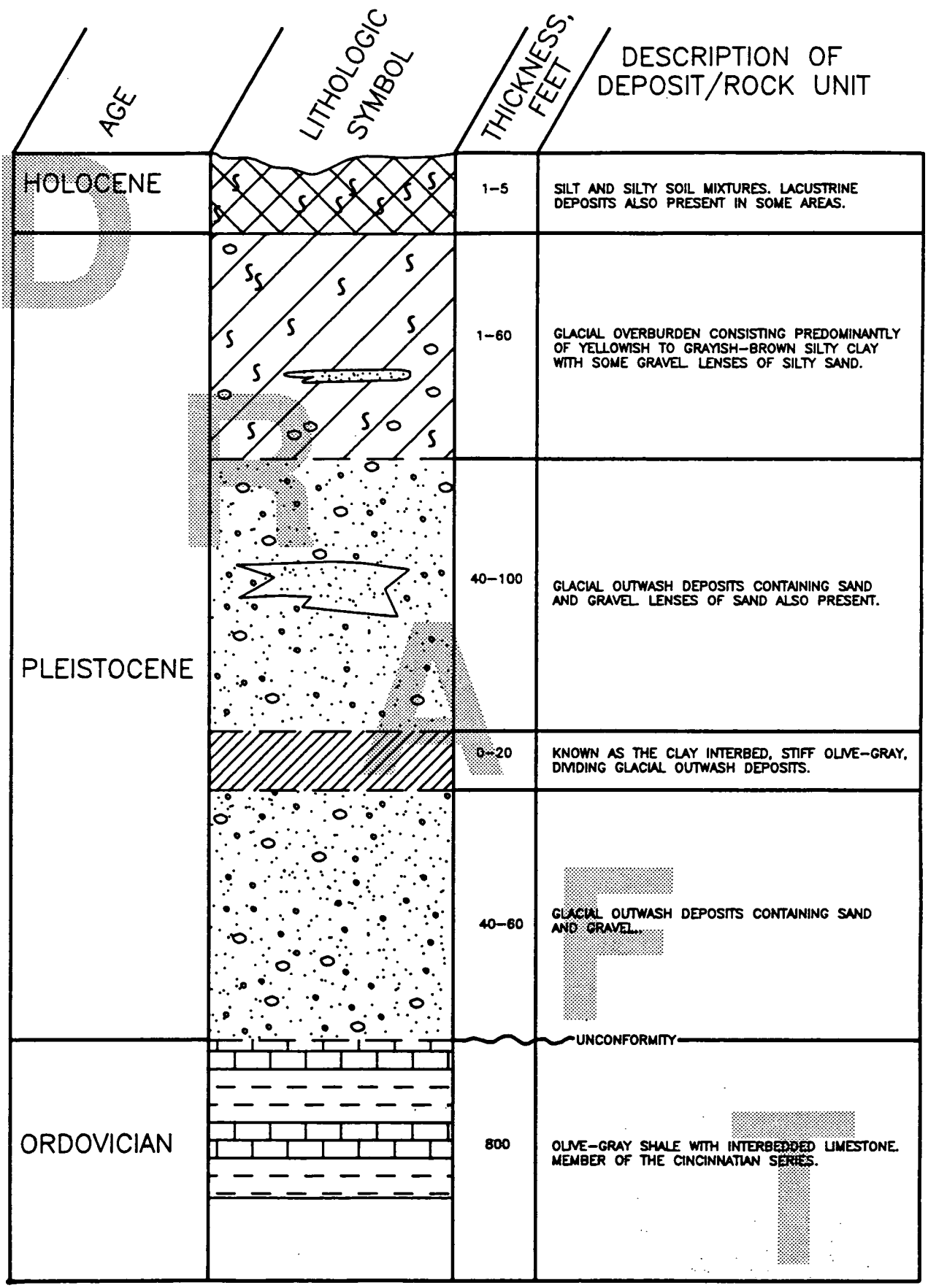
The last stage of glaciation, the Wisconsin, was much less disruptive to the drainage in the area. The ice sheet advanced only as far as the south side of the FMPC. The main effect of this glacial advance in the area was the displacement of the Dry Fork of the Whitewater River from its historic channel into its present-day channel. As it retreated, the ice deposited a moraine in the historic channel which formed a dam. The dam was breached two times, with the final breach draining the lake permanently. The lake basin is now occupied by Paddys Run.

Since the last retreat of continental glaciers, the streams in the area have removed much of the glacial overburden and lacustrine mantle left by the ice sheets. The Great Miami River has eroded through the glacial overburden and is now in direct contact with the glaciofluvial outwash deposits that comprise the buried valley aquifer. Paddys Run is also in contact with these deposits in its lower reaches. The FMPC itself is located on a dissected till plain and lacustrine deposits left by Wisconsin Glaciation.

2.5 HYDROGEOLOGY

The bedrock in the vicinity of the FMPC consists of predominantly flat-lying olive-gray Ordovician shales with thin, interbedded layers of limestone. This shale forms the floor and valley walls of the New Haven Trough. The buried valley is generally carved into this shale between 60 and more than 200 feet below the pre-erosional land surface in the vicinity of the FMPC.

Unconformably overlying the shales in the bedrock channel are approximately 150 feet of regionally extensive Pleistocene glacial valley fill deposits. Figure 2-4 is a generalized stratigraphic column of



303317-A168 (GW) (PGH)

FIGURE 2–4
GENERALIZED STRATIGRAPHIC COLUMN OF THE FMPC REGION

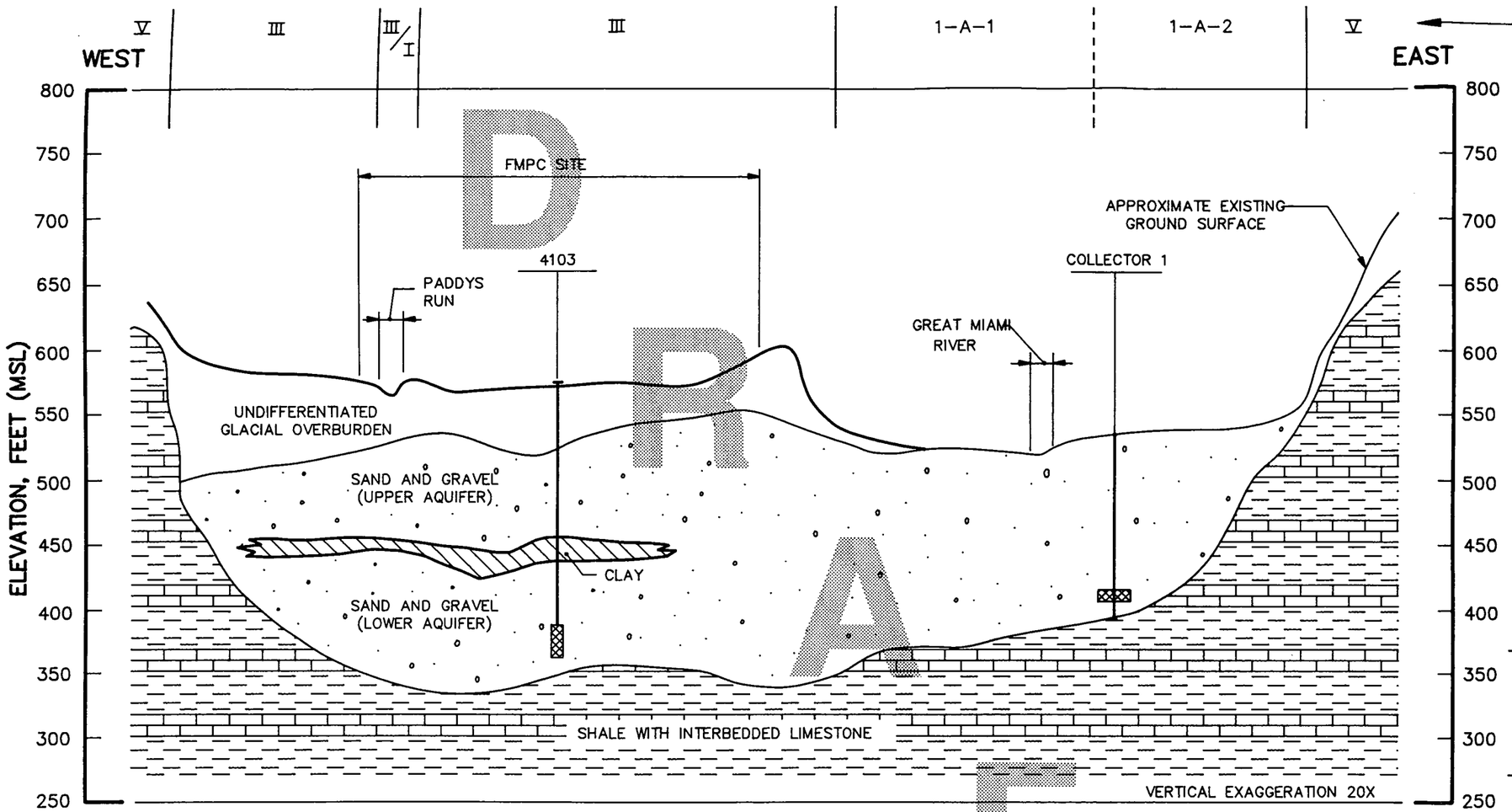
the valley fill deposits. As indicated by the generalized hydrogeologic cross sections, (Figure 2-5), the buried valley is about one-half to over two miles wide and is U-shaped, having a broad, relatively flat bottom and steep valley walls. Interbedded glacial till deposits occur within the outwash deposits, but in most cases are of limited lateral extent. The till deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix.

Within some areas, glacial overburden deposits overlie the bedrock uplands and portions of the outwash materials where they form the thick unconsolidated sediment layers beneath the soil zone. This glacial overburden is composed of dense, silty clay that varies in composition vertically and laterally. The glacial overburden contains lenses of poorly sorted fine- to medium-grained sand and gravel, silty sand, and silt with layers of silty clay.

Regional hydrogeologic environments of the buried channel aquifer have been investigated and reported by the USGS. A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of the aquifer in adjacent areas. Five major hydrogeologic environments have been identified and mapped in the Great Miami River Valley (Figure 2-6). Type I, III, and V environments generally describe the hydrogeologic conditions in the vicinity of the FMPC and are summarized in the following paragraphs.

The Type I hydrogeological environment is found along the flood plain of the Great Miami River to the south and east of the FMPC facility. The lithology of the aquifer consists principally of sand and gravel. Scattered lenses of clay and other fine-grained material may exist anywhere in this environment. However, these lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to otherwise affect groundwater movement. The potential for induced stream infiltration exists in these areas. Transmissivity values generally range from 40,000 to 67,000 square feet per day (ft^2/day). The Type I aquifer may be classified with a storage coefficient of about 0.2. Individual wells can yield as much as 3000 gallons per minute (gpm).

The Type III hydrogeologic environment is characterized by 50 or more feet of clayey glacial overburden overlying the main buried channel aquifer. In the region of the FMPC, the buried channel aquifer is further divided into an upper and lower part by a semipervious clay layer approximately 10 to 20 feet thick, occurring approximately 120 feet below land surface. Hence, the lower aquifer is classed as a semiconfined or leaky confined aquifer. A coefficient of storage of 0.001 was estimated for the lower sand and gravel aquifer. Estimated transmissivities range from 4700 to 40,000 ft^2/day.



GENERALIZED CROSS SECTION

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO, THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

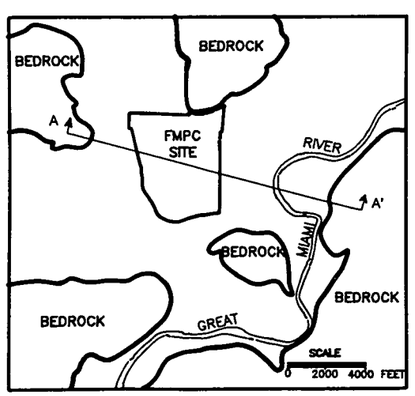
OPEN OR SCREENED INTERVAL

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605-A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

NOTE:

REFER TO FIGURE 2-7 FOR DESCRIPTION OF HYDROGEOLOGIC ENVIRONMENT



LOCATION OF CROSS SECTION

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FIGURE 2-5
GENERALIZED GEOLOGIC CROSS SECTION
STUDY AREA

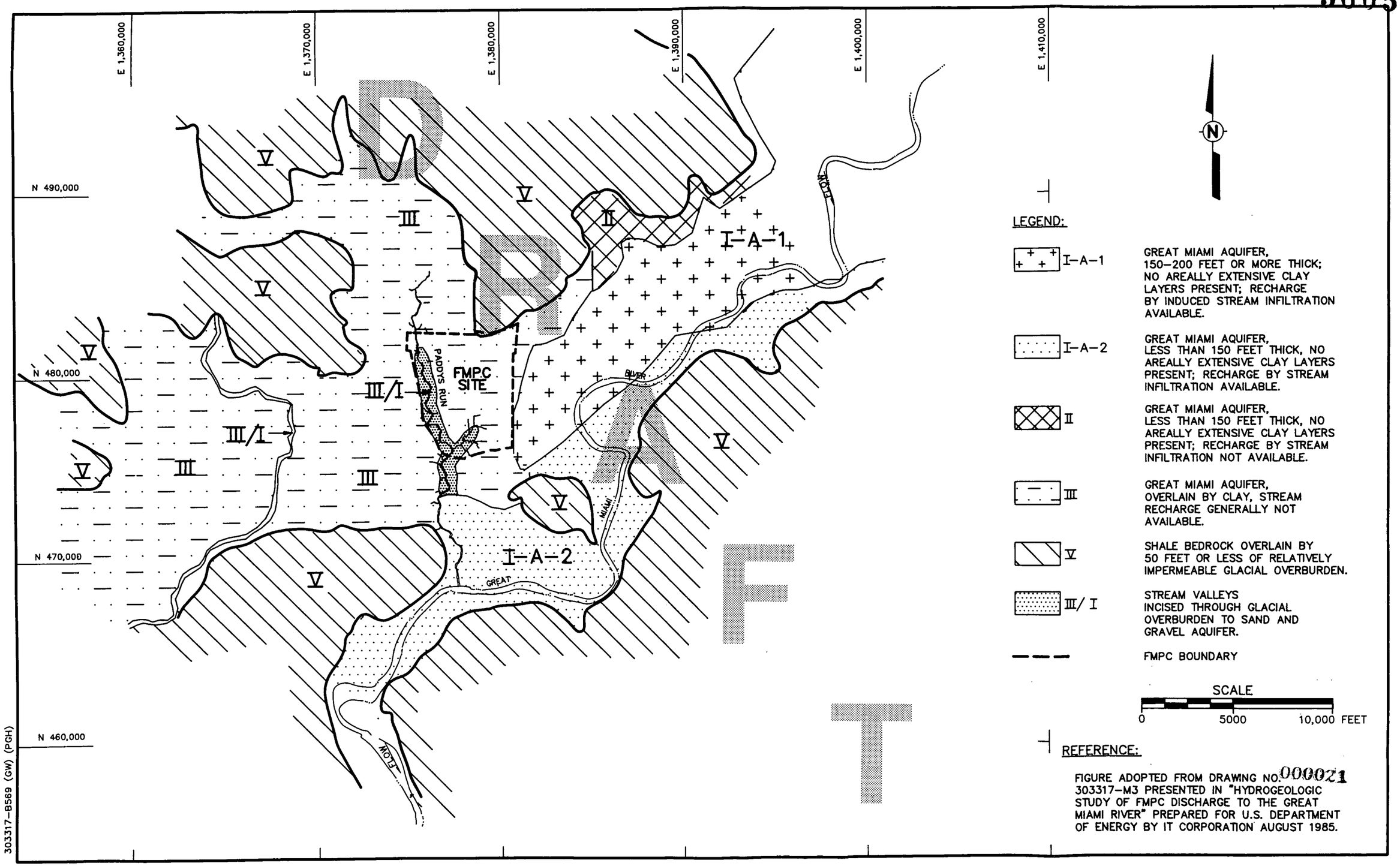

FIGURE 2-6
HYDROGEOLOGIC ENVIRONMENTS

The Type V hydrogeologic environment includes all of the area outside of the buried channel. These areas are uplands and consist of shale with interbedded limestone overlain by 50 or less feet of clay-rich glacial overburden. Large quantities of groundwater are not generally transported through this material. Well yields vary widely, typically ranging from near 0 to 10 gpm. However, because sand and gravel lenses are erratically distributed throughout the overlying glacial overburden, wells completed in these units may yield up to 50 gpm.

Large groundwater supplies occur in the outwash deposits of the buried channel aquifer and are recharged by three principal sources: recharge from bedrock, precipitation recharge, and recharge by stream infiltration. Although the shales and limestones have a low permeability, small amounts of water occur in erratically distributed joints and cracks and produce seepage into the glacial deposits. The average hydraulic conductivity of the bedrock has been estimated to be very low and on the order of 10^{-7} ft/day (10^{-10} cm/s) of contact with the glacial deposits. Recharge by precipitation amounts to approximately 570,000 gpd per square mile of catchment area (12 in/yr) and represents the dominant source of recharge on a regional basis. Under natural conditions, the gradient of groundwater flow is from the aquifer to the Great Miami River, except during dry periods when the gradient is reversed. Intermittent recharge to the aquifer also occurs along Paddys Run.

The groundwater in the regional aquifer enters the FMPC study area from the buried valleys on the west, north, and east. Natural gradients cause the groundwater to exit the FMPC study area by either flowing to the east to the Great Miami River upstream from New Baltimore, or by flowing south through the branch of the bedrock channel west of New Baltimore.

In either case, the Great Miami River is the ultimate receptor of all groundwater in the study area (Figure 2-7). The large pumping wells of the Southwestern Ohio Water Company (SOWC) in the "Big Bend" meander of the Great Miami River east of the FMPC produce a pronounced and persistent cone of depression in the potentiometric surface centered on the pumping wells. Groundwater elevation maps indicate that the resultant cone of depression from the collector wells influences groundwater flow patterns beneath the FMPC. In particular, a groundwater flow divide is created such that groundwater underlying the northern portion of the FMPC, including those areas underlying the waste storage area and the production area, flows to the east toward the collector wells and the Great Miami River. Groundwater from the southern and southwestern portion of the FMPC continues to flow along the natural gradient to the south-southwest through the buried valley. Near the southwest corner of the FMPC, a groundwater component from the west is also present due to the western leg of the buried channel (Figure 2-7). This causes the recharge from certain

reaches of Paddys Run to flow east-southeast until the regional southern component of flow is encountered.

2.6 CLIMATE

Data from the Greater Cincinnati International Airport have been shown to satisfactorily characterize the climatic regime of the FMPC area. The regional climate is defined as continental, with temperatures ranging from a monthly average of 29.0 degrees Fahrenheit in January to 75.5 degrees Fahrenheit in July. The highest temperature recorded from 1950 through 1984 was 102 degrees Fahrenheit in August 1962, and the lowest was minus 25 degrees Fahrenheit in January 1977. The average number of days per year with a minimum temperature of 32 degrees Fahrenheit or less is 110 days, and the average number of days with a maximum temperature of 90 degrees Fahrenheit or above is 20 days per year. Frost depth ranges from 30 to 36 inches.

The average annual precipitation for the period of record is 40.14 inches (National Oceanic and Atmospheric Administration 1989). The highest precipitation occurs during the spring and early summer; precipitation is lowest in late summer and fall. The average annual snowfall is 24.0 inches, with heaviest snowfall in January. The period from late 1987 through October of 1988 was characterized by average monthly precipitation significantly below normal, as shown in Figure 2-8. The 1989 precipitation data indicate above-normal precipitation.

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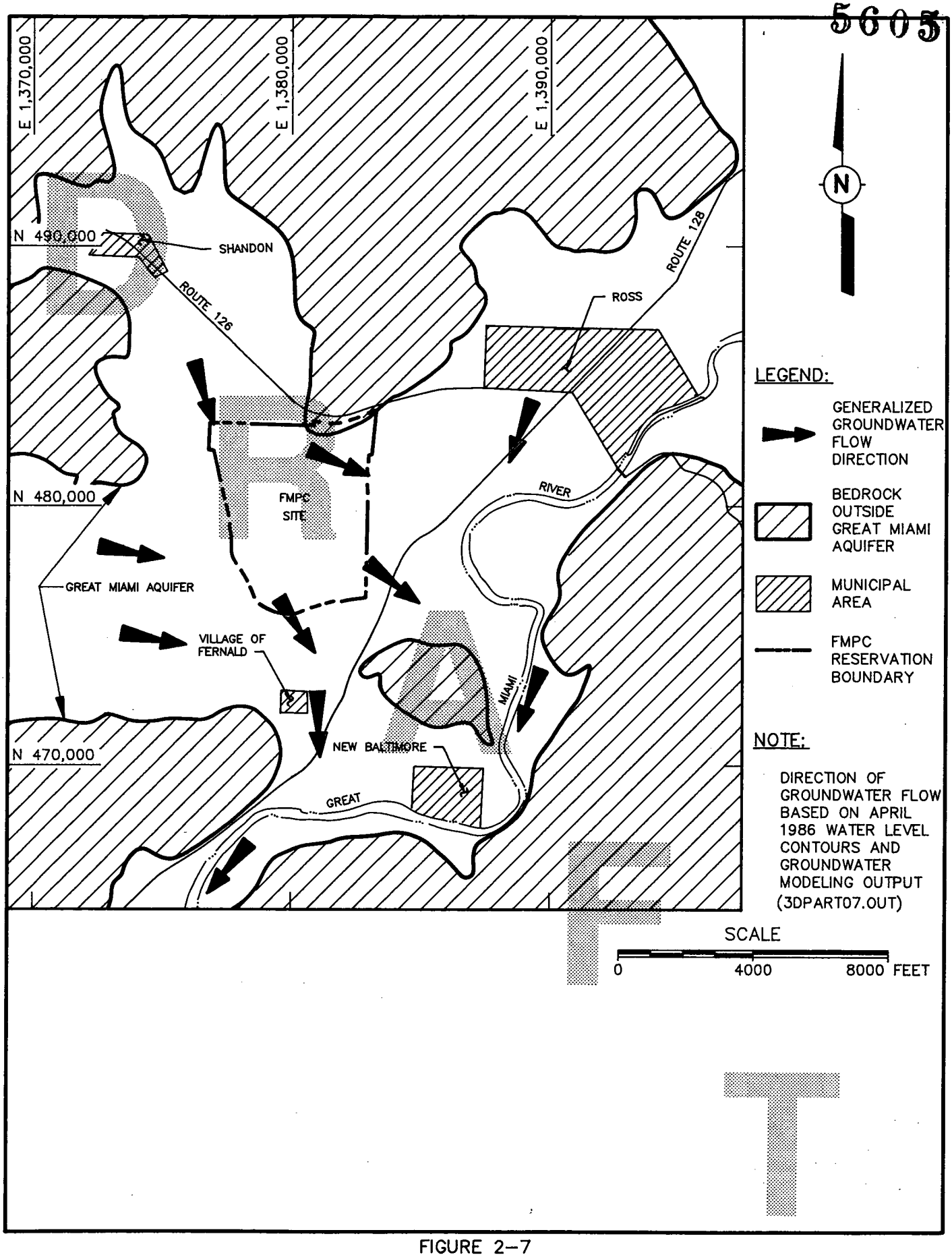

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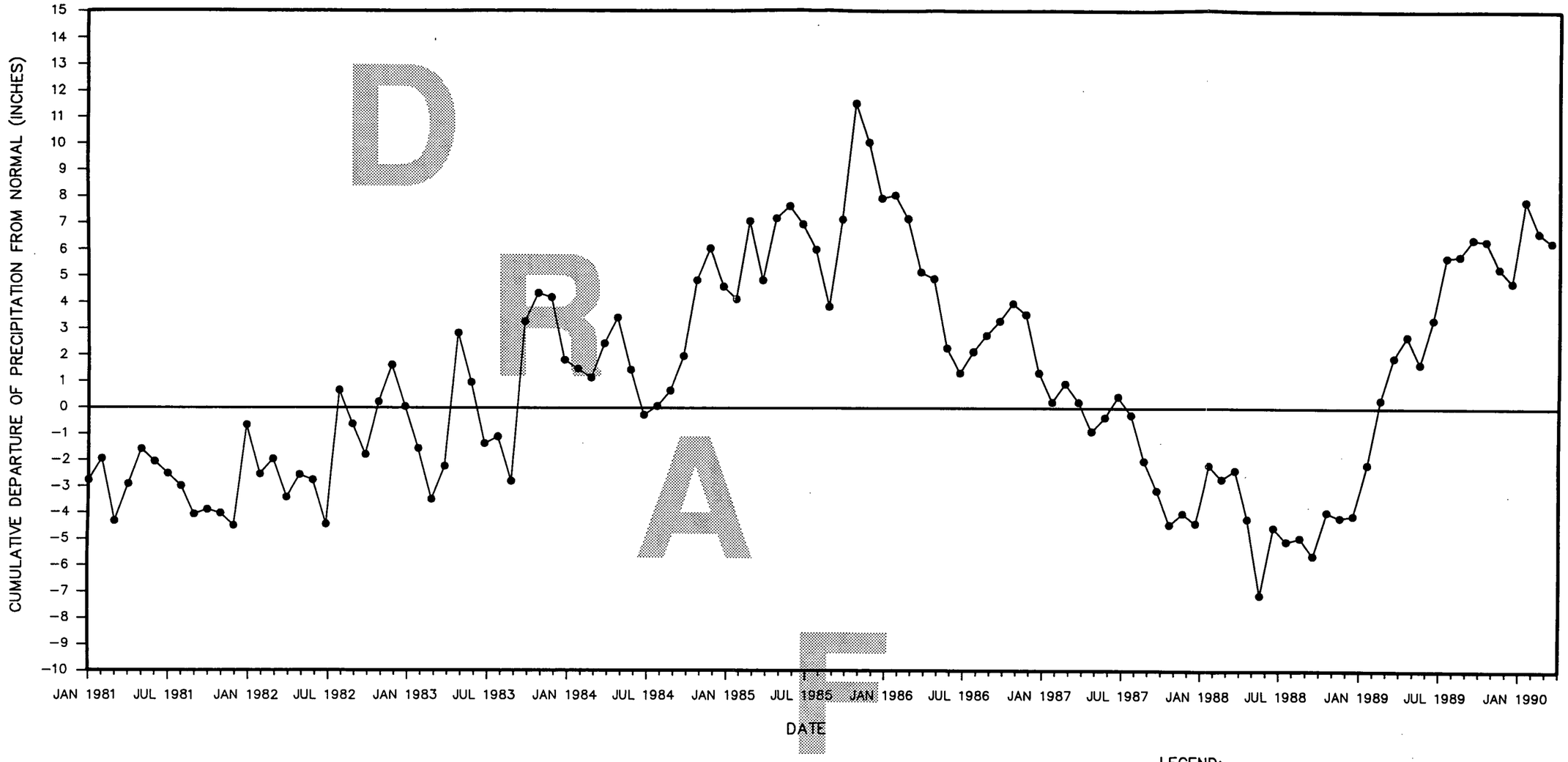
FIGURE 2-7
GENERALIZED GROUNDWATER FLOW DIRECTION
IN GREAT MIAMI AQUIFER



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LEGEND:

● CUMULATIVE DEPARTURE OF PRECIPITATION RECORDED FROM NORMAL

NOTES:

1. DATA USED ARE FOR THE GREATER CINCINNATI AIRPORT, BOONE COUNTY, KY STATION.
2. DATA FROM LOTUS 1-2-3, FILE PRECIP WEEK 1

REFERENCE:

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE
NATIONAL CLIMATIC DATA CENTER
ASHEVILLE, NORTH CAROLINA

303317-B573 (GW) (PGH)

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FIGURE 2-8
CUMULATIVE DEPARTURE FROM NORMAL PRECIPITATION
JANUARY 1981 THROUGH APRIL 1990

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LIST OF ACRONYMS

ASI	Advanced Sciences, Inc.
ASTM	American Society for Testing and Materials
ATC	automatic temperature control
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CIS	Characterization and Investigation Study
CLP	Contract Laboratory Program
CRQL	Contract Required Quantitation Limit
CV	Coefficient of Variation
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ERDA	U.S. Energy Research and Development Administration
FFCA	Federal Facility Compliance Agreement
FMPC	Feed Materials Production Center
FS	feasibility study
GPR	ground penetrating radar
HSL	hazardous substance list
ICP	Inductively Coupled Argon Plasma Spectrometry
IT	IT Corporation
MDL	minimum detection limits
ND	nondetect
NISM	National Institute of Standard Measures
NLO	National Lead Company of Ohio
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
ODH	Ohio Department of Health
OEPA	Ohio Environmental Protection Agency
ORAU	Oak Ridge Associated Universities

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LIST OF ACRONYMS
(continued)

PC	personal computer
PCB	polychlorinated biphenyl
PVC	polyvinyl chloride
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAPP	Quality Assurance Project Plan
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
SARA	Superfund Amendments and Reauthorization Act
SEM	scanning electron microscopy
SOWC	Southwestern Ohio Water Company
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEGD	Technical Enforcement Guidance Document
TOC	total organic carbon
TOX	total organic halides
USGS	U.S. Geological Survey
UTL	upper tolerance limit
VOA	volatile organic analysis
WMCO	Westinghouse Materials Company of Ohio
XRD	X-ray diffraction

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GLOSSARY

1000 Series Wells	Wells or piezometers screened in water-bearing zones within the glacial overburden (see Figure 6-2).
2000 Series Wells	Wells screened over an interval from five feet above to ten feet below the water table in the Great Miami Aquifer (see Figure 6-3).
3000 Series Wells	Wells screened over a 10-foot interval just above the clay interbed or at an equivalent elevation in the Great Miami Aquifer (see Figure 6-4).
4000 Series Wells	Wells screened over a 10-foot interval ending 10 feet above the bedrock bottom of the Great Miami Aquifer (see Figure 6-5).
Adsorption	Process whereby a dissolved ion or molecule becomes attached to the surface of a pre-existing solid substrata.
Anions	Negatively-charged ions in solution.
Anisotrophy	The geologic units whose properties vary with direction.
Aquiclude	A saturated, but poorly permeable bed, formation, or group of formations that do not yield water freely to a well or spring. However, an aquiclude may transmit appreciable water to or from adjacent aquifers.
Aquifer	A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.
Aquitard	A saturated geologic unit that yields inappreciable quantities of water compared to an aquifer but through which appreciable leakage of water is possible.
Bedrock	Any solid rock exposed at the surface of the earth or overlain by unconsolidated material.
Cations	Positively-charged ions in solution.
Cells	Rectangular parallelepipeds formed by a finite-difference model grid.
Code Verification	Testing computer codes against known solutions to verify that they produce the correct results.

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(continued)

Cone of Depression	A depression in the groundwater surface that has the shape of an inverted cone and develops around a well from which water is being withdrawn.
Confined Aquifer	An aquifer that is confined under pressure by overlying and underlying aquitards or aquicludes; water levels in wells rise above the top of the aquifer.
Constant Boundary Heads	Hydraulic heads at the cell faces along the external edges of a model which are held constant during model runs.
Contaminant	A substance that when introduced to either surface or groundwater causes a degradation in the water quality.
Darcy Velocity	Volume of groundwater flow per unit area of porous medium.
Data Verification	A procedure by which the available data are tested for validity.
Diffusion	The migration of a chemical species due to a gradient in its concentration.
Discharge Rate	The rate of flow of a certain volume of water per unit of time.
Dispersion	The spreading and mixing of chemical constituents in groundwater caused by diffusion and mixing due to microscopic variations in velocities within and between pores.
Dispersion Coefficient	An approximated numerical value that represents dispersion in a modeled aquifer system.
Dispersivity	A parameter that describes the amount of spreading of a solute plume as the groundwater carries the solute away from its source.
Distribution Coefficient	A parameter that describes the proportion of a solute that is absorbed onto the solids in a porous material. Retardation of solute movement increases as the distribution coefficient increases.
Drawdown	The distance between the water level surrounding a well before pumping started and the surface of the cone of depression.
Effective Porosity	The volume of void spaces through which liquids can travel divided by the total volume of the solid material.

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(continued)

Evapotranspiration	Loss of water in an area due to evaporation from soils or transpiration of plants.
Finite-Difference Method	A numerical method used to solve the groundwater flow equation. In this method, the study area is divided into rectangular grids.
Geochemical Modeling	Mathematical techniques used to simulate chemical behavior in the subsurface, including chemical speciation, precipitation, and possibly adsorption and ion exchange.
Glacial Overburden	Silt, sand, gravel, and clay deposited by glacial action on top of the Great Miami Aquifer and surrounding bedrock highs.
Glaciofluvial	Pertaining to the meltwater streams that flow from retreating glaciers and to the deposits and landforms produced by such a stream.
Great Miami Aquifer	Glaciofluvial sand and gravels deposited by the meltwaters of Pleistocene glaciers within the entrenched ancestral Ohio and Miami rivers. This is also termed as a buried channel or sand and gravel aquifer.
Groundwater	Water that exists in pore spaces in the subsurface.
Groundwater Contour	A line that connects equal groundwater elevations on a map.
Groundwater Elevation	The height of the groundwater surface above mean sea level.
Groundwater Model	A mathematical representation of a groundwater system that behaves in a manner similar to the real system.
Homogeneous	Uniform in structure or composition throughout an area of interest.
Hydraulic Conductivity	A parameter that describes the rate at which water can move through a porous medium. May vary with the direction of the flow.
Hydraulic Gradient	The rate of change of hydraulic head per unit of distance of flow in a given direction.
Hydraulic Head	The height above mean sea level to which water will rise in a well screened at a specific depth.

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(continued)

Hydrodynamic Dispersion	The process by which groundwater containing a solute is diluted with uncontaminated groundwater as it moves through the aquifer.
Hydrogeology	The science that deals with subsurface waters and related geologic materials and their interaction with surface water.
Hydrograph	A graph showing a characteristic of water, such as surface water flow or groundwater levels, versus time.
Induced Infiltration	Infiltration from a stream bed caused by pumping wells near the stream.
Infiltration	The natural flow of water downward from the land surface or stream into and through the upper soil layers or stream bed.
Interbed	A relatively thin layer of material contained within a thicker layer of material of different composition.
Isoconcentration Map	A contour map showing lines of equal concentration. Depicts the concentrations in a plume.
Isotopes	Atoms of an element that have the same number of protons but different members of neutrons in the atomic nucleus.
Isotropic	Said of a medium whose properties are the same in all directions.
Kriging	A statistical method of interpolating values between points on a map.
Lacustrine	Deposits produced by or formed in a lake.
Leaky Aquifer	An aquifer which is separated from overlying or underlying aquifers by a confining layer of lower permeability (aquitard) which allows the movement of water out of the aquifer.
Loess	A widespread homogeneous fine-grained blanket deposit believed to be windblown dust of Pleistocene Age.
Lower Aquifer	The portion of the Great Miami Aquifer below the clay interbed elevation.
Mass Loading	The mass of material added to a system per unit of time.

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GLOSSARY
(continued)

Model Calibration — The adjustment of parameter input to a mathematical model, within an acceptable range, until the model is an adequate representation of the real system. It involves selecting parameters for successive trial computer runs until the known hydraulic heads and/or solute concentrations are adequately matched with observed values.

Model Verification — Testing a groundwater model against hydrologic input that was not used in the original calibration to verify that it may be used for predictive purposes.

Monitoring Well — A well that is used to collect groundwater samples to monitor the water quality. It may be used to monitor groundwater level fluctuations.

New Haven Trough — Buried channel of the ancestral Ohio River which forms the portion of the Great Miami Aquifer directly beneath and to the west of the FMPC.

Normalized Concentration — Contaminant concentration at a given point divided by the concentration at the source.

Operable Unit — Geographic portions of a site, specific site problems, specific media, etc., that may involve discrete remedial actions comprising incremental steps toward a final remedy.

Operable Unit 1 — Includes those facilities utilized for the disposal of radiological and (to a lesser extent) chemical wastes from FMPC operations. Related facilities that now contain similar waste types are included. Within this context, the following facilities are included in Operable Unit 1:

- Waste Pits 1 through 6
- Burn Pit
- Clearwell

Although areas surrounding these facilities are not considered an integral part of Operable Unit 1, an exception could occur if it is decided that inclusion of a given area would lead to a more effective and efficient remedial action program. For example, the berms and the underlying soils may eventually be included under Operable Unit 1 within an overall source control action for a given waste storage unit.

Operable Unit 2 — Includes those facilities designed for the disposal of solid wastes into which low volumes of radiological or chemical wastes may have been co-disposed. In particular, these units include:

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(continued)

- North and South Lime Sludge Ponds
- Active Fly Ash Pile
- Abandoned Fly Ash Pile and Southfield
- Sanitary Landfill

Operable Unit 3

Includes those facilities and suspect areas that are expected to involve localized cleanup actions using straightforward technologies. Three general types of units are involved, including:

- Any area or facility within the Production Area that is identified through the Production Area or suspected area investigation to represent a past, current, or future source of radionuclide or chemical releases to the environment.

- Suspect areas outside the Production Area. The following is a list of the suspect areas currently being considered:

  - Fire Training Area
  - Incinerator Area (East of the Production Area)
  - Area near the Flag Pole
  - K-65 Slurry Line Trench
  - Several Rubble Mounds at Different Locations
  - Main Effluent Line
  - Metal Scrap Piles

- Areas with elevated levels of uranium or other constituents in soil or perched groundwater within controlled site areas.

Operable Unit 4

Has been established to include those facilities that represent unique technical problems and will likely involve specialized technologies. The four units included in Operable Unit 4 are the two K-65 silos (Silos 1 and 2), the metal oxide silo (Silo 3), and the empty silo (Silo 4).

Operable Unit 5

Includes those environmental media that represent pathways and/or environmental receptors presently or potentially affected by FMPC contaminants. Each of the individual environmental media is defined below:

- Soils: Includes all surface soils not specifically accounted for in other operable units.

- Groundwater: Limited to the Great Miami Aquifer throughout the study area. Does not include source control, which is the focus of Operable Units 1 through 4.

GLOSSARY
(continued)

- Great Miami River: Addresses the sediments in the Great Miami River and their role as a potential source of contaminants to the overlying water column and the aquatic community. Does not include source control, which is the focus of Operable Units 1 through 4.

- Paddys Run: The same as the Great Miami River, with the additional consideration of the effects of leakage from Paddys Run into the regional aquifer.

- Storm Sewer Outfall Ditch: Similar to Paddys Run.

- Flora and Fauna: Involves the evaluation of the overall flora and fauna in the regional area, including terrestrial vegetation and animals, aquatic communities in the Great Miami River and Paddys Run, locally grown produce and feed crops.

- Air: Although air is still considered to be an integral part of Operable Unit 5 per the Federal Facility Compliance Agreement, it is anticipated that this media will be eliminated as a separate component of the RI/FS.

Overshoot/Undershoot	Describes erroneously high values of concentration encountered as a sharp concentration front is approached from the upgradient side in a finite-difference model. Analogous behavior on the downgradient side is called undershoot.
Oxidation/Reduction Potential	A measure of the ability of the groundwater environment to bring about an oxidation or reduction reactions. These reactions involve the transfer of electrons.
Parameter	A numerical value that characterizes an element of the system being modeled. Examples are hydraulic conductivity, recharge rate, and stream leakage coefficient.
Pathway	The route along which contamination could move in the environment from a source to a receptor.
Perched Aquifer	A special case of an unconfined aquifer which occurs wherever a groundwater body is separated form the main groundwater by a relatively impermeable stratum of small areal extent and by an unsaturated zone above the main body of groundwater.
Perched Groundwater	Groundwater contained in a perched aquifer which is separated from and at a higher elevation than the groundwater in the regional aquifer.

GLOSSARY
(continued)

Piezometer	Small diameter well used to measure the hydraulic head.
Pleistocene	Period in geologic history when glacial ice covered much of North America, periodically advancing southward and retreating northward.
Porosity	The ratio of the volume of void spaces in a rock or soil to the total volume of the rock or soil.
Potentiometric Surface	An imaginary surface representing the total head of groundwater in an aquifer that is defined by the level to which water will rise in a well.
Proglacial	Refers to any process which occurs immediately in front of or just beyond the outer limits of a glacier or ice sheet; also refers to lakes, streams, deposits, and other features produced in this environment.
Radioactive Nuclides	Atoms that disintegrate by emission of corpuscular or electromagnetic radiations. The rays most commonly emitted are alpha, beta, or gamma rays.
Receptors	Individuals or organisms that are or potentially could be impacted by contamination.
Recharge	The addition of water to the zone of saturation; also, the amount of water added.
Recharge Rate	Rate at which water enters the top of an aquifer due to downward percolation of rainfall or snowmelt.
Remedial Investigation/Feasibility Study (RI/FS)	An investigation process where the vertical and lateral extent of contamination at a facility is determined and the factors controlling the migration of the contaminants are determined, followed by the establishment of the most suitable remedial alternative for the situation.
Regional Aquifer	Great Miami Aquifer.
Retardation/Retardation Factor	A measure of the reduction in the rate of movement of a solute plume due to adsorption of the solute onto solids in an aquifer. Related to the distribution coefficient.
River Leakage Factor	A parameter that describes the rate of transfer of water between a stream and an aquifer in response to the difference between the water level in the stream and the hydraulic head in the aquifer.
Saturated	A condition where all voids in a solid matrix are filled with liquid.

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GLOSSARY
(continued)

Semiconfining Layer	A layer of subsurface material that is much less permeable than the layer above or below and impedes the upward or downward movement of groundwater.
Sensitivity Analysis	The identification and evaluation of variables which, when changed slightly, cause large changes in the result.
Solute	A dissolved constituent.
Source Loading	The rate at which a chemical constituent is added to an environmental system such as groundwater.
Specific Yield	The ratio of the volume of water a rock or soil will yield by gravity drainage to the volume of the rock or soil.
Steady-State	Not varying with time. In steady-state flow models, hydraulic head does not vary with time. Time does not enter the calculations.
Stratigraphic	The arrangement of similar rocks in layers or beds.
Statistical Outlier	An analytical result that has been statistically determined to be inconsistent with results of other samples.
Storage Coefficient	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in hydraulic head.
Till	A mixture of boulders, cobbles, sand, silt, and clay deposited directly from glacial ice. Generally of low permeability.
Tolerance Limit	The upper value of a tolerance interval that would be expected to include 95 percent of observations when randomly taken.
Transient Model	Not a steady-state model. In a transient solute transport model, concentrations vary with time.
Transmissivity	Hydraulic conductivity of an aquifer multiplied by the thickness of the saturated unit (aquifer). Describes the rate at which water can move through a unit width of the aquifer.
Unconfined Aquifer	An aquifer where the water table is exposed to the atmosphere through openings in the overlying materials.
Unsaturated	The condition where the voids in a solid matrix are not 100 percent filled with liquid.
Vadose Zone	The unsaturated zone of a stratigraphic unit.

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GLOSSARY
(continued)

Vertical Seepage	The vertical migration of groundwater from an upper permeability stratigraphic unit to a lower stratigraphic unit.
Water Table	The surface of an unconfined aquifer at which the pressure in the water is equal to the atmospheric pressure. Usually, approximately the top of the saturated subsurface material.
Water Balance	A quantification of all the sources of water and the corresponding discharges with respect to an aquifer, a drainage basin, or a well.
Zone of Influence	The area within an aquifer impacted by pumping from a well placed in the aquifer.

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PART I. BACKGROUND

This report has been prepared to provide a comprehensive description of the groundwater flow regime and nature and extent of contaminants at the Feed Materials Processing Center (FMPC) site. It includes data from the ongoing field investigation being conducted for the Remedial Investigation/Feasibility Study (RI/FS) at the FMPC and contains data collected from August 1987 through April 1990. The investigation is continuing and additional data will be presented in the individual operable unit studies.

This report has been prepared to serve as a foundation for the groundwater portion of Operable Unit 5. However, the information contained in this report is directly transferable to those portions of the RI/FS for Operable Units 1, 2, 3, and 4 that pertain to environmental release and their current and potential effects.

Figure I-1 presents a schematic of the overall structure of the FMPC groundwater report. The figure not only provides a retrospective summary of the planning and data collection phases reported in Parts I and II of this report, but also gives an indication of the method of analysis and the types of modeling as discussed in Parts III and IV. Part V is devoted to the report conclusion. Figure I-1 also presents the logic and systematic organization of the report. The FMPC RI/FS groundwater report has been divided into the following five parts:

- Part I - Background: Provides background information on site geology/hydrogeology and groundwater use.
- Part II - Data Collection: Provides the reasons and rationale for selecting the detailed methods of data collection and documentation used during the field investigation programs.
- Part III - Data Analysis: Provides in-depth site hydrogeologic and geochemical settings, including groundwater quality.
- Part IV - Groundwater Modeling: Provides the formulation, testing, and results of regional and site modeling, as well as the long-term modeling related to each operable unit.
- Part V - Results and Conclusions: Presents the results and conclusions of the groundwater programs emphasizing groundwater flow systems, source-pathway-receptor relationships, and the nature and extent of contamination.

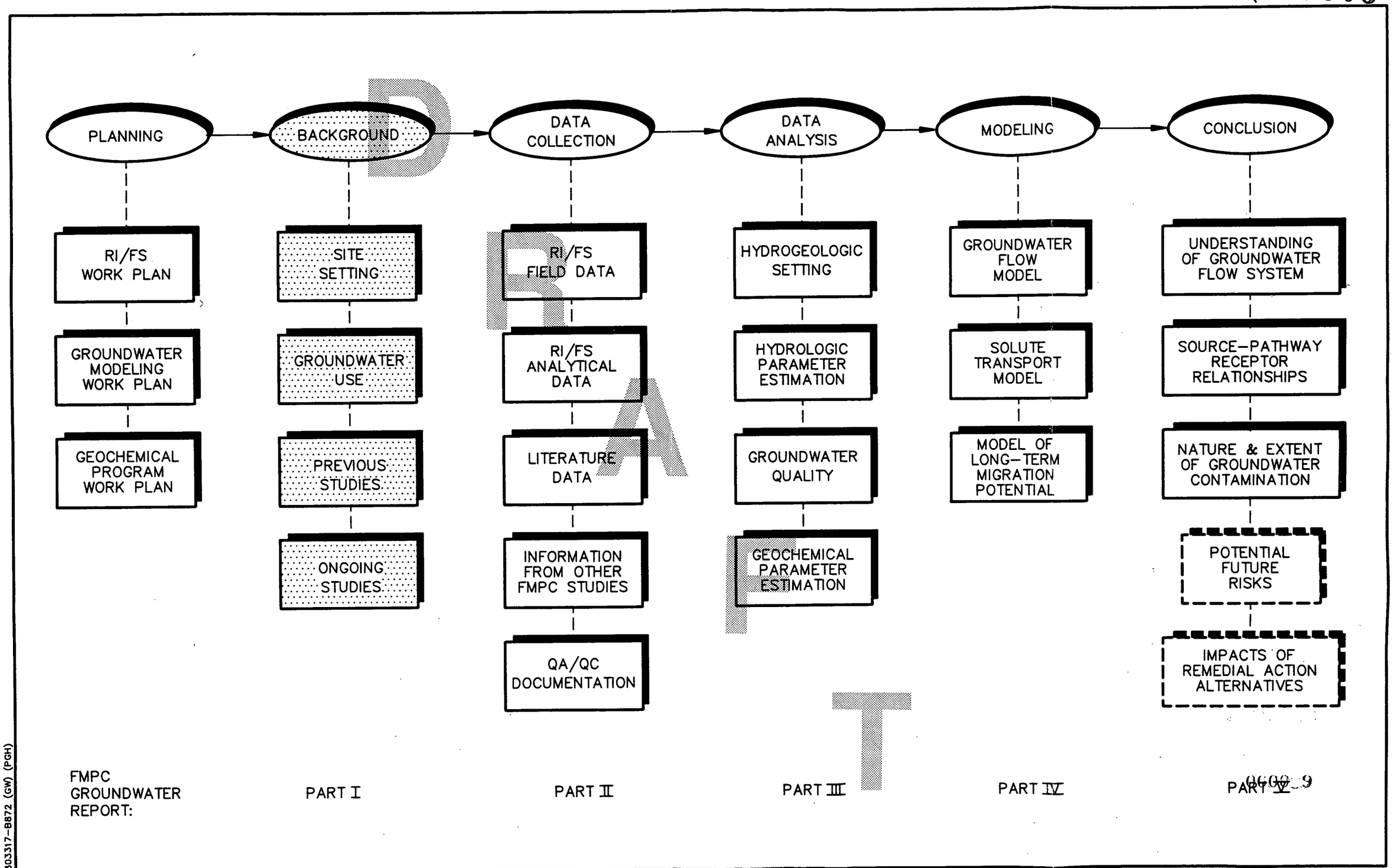

FIGURE I-1

OVERVIEW OF BACKGROUND DATA SOURCES

Part I is divided into five chapters: Chapter 1.0 discusses the objective of the report and its relationship to the FMPC RI/FS. A brief discussion of the site setting such as geology, hydrogeology, and surface water features is presented in Chapter 2.0. A brief discussion of the groundwater use is given in Chapter 3.0. The previous studies pertinent to FMPC groundwater flow regime are identified in Chapter 4.0. Finally, the ongoing studies are presented in Chapter 5.0.

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The only significant pumping centers within the study area are the water supply Well 4103 at the FMPC and the two water supply wells used by the Albright & Wilson Co. The FMPC pumps groundwater from any of three wells located along the southwestern edge of the Production Area. Well 4103 is the most commonly used of the three wells. Each is screened over a ten-foot interval approximately ten feet above the bottom of the aquifer and well below the clay interbed. These wells are sampled routinely; however, there is no evidence of any contamination reaching these wells. The average daily flow from Well 4103 in 290 gpm, although this well is in operation for only part of the day.

The Albright & Wilson Co. uses water from two wells located approximately 2000 feet south of the FMPC. The combined flow from these two wells is approximately 225 gpm. Uranium contamination in the southern Albright & Wilson Co. well has been documented since 1981. As will be discussed in Chapter 20.0, the volume of water extracted from these wells is not large enough to impact flow beyond the immediate property.

3.2 POTABLE WATER USE

The residences in the area use either domestic wells or cisterns for water supplies. Generally, cisterns are used in areas underlain by bedrock. Many residents use bottled water for drinking because of the bad taste and smell of the water from some parts of the aquifer. Figure 3-1 shows the location of domestic and commercial wells that are downgradient from the FMPC to the south and east. With the exception of large volume wells discussed in Section 3.1, the downgradient wells are generally completed in the upper part of the aquifer and pump only when there is a demand for water for domestic washing and sanitation. The presence of these wells, therefore, is insignificant in terms of their impact on groundwater flow.

3.3 AGRICULTURAL USE

There are several large farms in the vicinity of the FMPC. Two known irrigation wells on farms east of the site and northwest of Route 128 are currently being used for field irrigation. One farm on New Haven Road south of the site, between Route 128 and the village of New Baltimore, also is known to irrigate from a well on the property. Those farmers east and south of the FMPC, who are in close proximity to the Great Miami River, irrigate their fields with water from the river (Plummer 1990).

4.0 PREVIOUS STUDIES

In this chapter, previous studies related to the FMPC groundwater regime have been summarized. The summary includes discussion on geology, hydrogeology, surface water, and other pertinent information.

4.1 GEOLOGIC

Geologic investigations of the area that surrounds and includes the FMPC have contributed substantial information to the study. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report is among the first that describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments. Later workers, such as Durrell (1961), supported the earlier observations of Fenneman. The shape of the buried channel aquifer was further refined by Watkins and Spieker (1971) via geophysical surveys of the area around Fernald. Lerch et al. (1980 and 1982), performed soil surveys of Butler and Hamilton counties, Ohio. More recent studies include various geologic maps of Hamilton and Butler counties, Ohio, and some quadrangles that are located in those counties (Leow 1985; Vormelker 1985; Ford 1974; and Swinford, in prep.). Maps showing the extent and age of glacial till in the study area have also been produced (Brockman 1986).

4.2 HYDROGEOLOGIC

Dove (1961) and Spieker (1968a) extensively described the hydrology and hydrogeology of the Great Miami Aquifer in the lower Great Miami River Valley. These studies document recharge rates, permeabilities of various lithologies, and other aquifer characteristics. Both studies specifically discuss groundwater/surface water interactions for the Great Miami River and Paddys Run. Other studies by Spieker deal with increased pumping of the groundwater (1968b) and future development of the groundwater resources (1968c). Other studies of the regional Great Miami Aquifer include a study by the Miami Conservancy District (1985), several studies by the Ohio Department of Natural Resources (Walker 1986; Walton and Schaefer 1956), and various contracted studies (Geotrans 1985; Dames and Moore 1985a; and ATEC Associates, Inc. 1982).

4.3 SURFACE WATER

The Miami Conservancy District has kept precipitation and runoff records for the Miami Valley since the early 1900s (Houck 1921). Precipitation records have also been kept at the Cincinnati Airport. Fluvial activity on most Ohio streams, including the Great Miami River and Paddys Run, has been well documented with respect to flow duration and water quality (Cross and Hedges 1959; Ohio Environmental Protection Agency [OEPA] 1982). Flood information for the Great Miami River and Paddys Run is available from the Federal Emergency Management Agency (1982).

Flow in the drainage basin is monitored using a gaging station on the Great Miami River at Hamilton, Ohio. Flow regulation on the Great Miami River has been studied by Spieker (1968a). Paddys Run data have been compiled by Dames and Moore (1985a). Artificial modifications of Paddys Run and its tributaries on the FMPC reservation have been documented by Dove (1961) and WMCO (1987). Surface water quality data for the FMPC area are available from National Lead Company of Ohio (NLO) (1979 through 1985), WMCO (1986 through 1988), and OEPA (1977 through 1983).

4.4 OTHERS

Dove and Norris (1951) described the possible fate of chemical and radionuclide wastes if they infiltrated the groundwater in the Great Miami Aquifer. Spieker and Norris (1962) investigated radionuclide contamination of the groundwater and the transport of the contaminated water through the Fernald, Ohio area. Publications released in the last five years document radionuclide releases from the FMPC into the groundwater as well as into the air. These studies are from either the DOE (1985) or are internal WMCO documents (Boback et al. 1986a and 1986b). Additionally, the ODH (1988) has documented radionuclide concentrations in private wells in the FMPC area. Sedam (1984) investigated the occurrence of uranium in the groundwater in the vicinity of the FMPC for the DOE. Starkey et al. (1962) and NLO (1983) performed internal investigations to distinguish between FMPC contamination and non-FMPC contamination.

For more than 10 years, the environment in and around the FMPC reservation has been monitored by the DOE (1977, 1985, and 1987), Oak Ridge Associated Universities (ORAU) (1985), various FMPC-related committees (WMCO 1987; Aas et al. 1986; and Fleming et al. 1984 and 1985), and various contracted agencies (IT Corporation [IT] 1986; Weston 1986; and Battelle 1981). The DOE and ORAU documents include environmental impact assessments, RI/FS studies, and environmental surveys. The internal reports include the annual Environmental Monitoring Reports and the Aquifer Contamination Control Reports (various authors 1965-present). These documents are available through WMCO. The material contained in these reports document monthly analyses of groundwater, surface water, and air samples for radionuclides, organic compounds, and metals. A sampling program to comply with RCRA provisions have been under way at the FMPC since 1985. The first five RCRA quarterly samplings were completed by Dames and Moore for the DOE. The fourth quarter 1987 RCRA sampling was completed by the RI/FS sampling team.

Pertinent data derived from these previous studies were selected for use in the RI/FS groundwater program. These data are addressed in Chapter 9.0 of this report.

3.0 GROUNDWATER USE

Large groundwater supplies occur in the deposits that fill the buried valley. The aquifers that occur in these deposits are together known as the Buried Valley Aquifer System of the Great Miami River Basin (Great Miami Aquifer) and have been designated a Sole-Source Aquifer by the EPA under Section 1424(a) of the Safe Drinking Water Act (Federal Register Vol. 53 No. 131 July 8, 1988). Under this designation, the Region V Administrator of the EPA has determined that this aquifer is the sole or principal source of drinking water for this area and that contamination would create a significant hazard to the public health.

Groundwater is the source of water for industrial and domestic use in the area. Groundwater users have been identified in this chapter. Pumping centers downgradient of the FMPC are shown in Figure 3-1. The estimated pumping from the major well fields averages about 18 Mgd. Additionally, there are many smaller industrial, commercial, agricultural, and private groundwater users in the area.

3.1 INDUSTRIAL WATER USE

In 1952, the SOWC installed a large-diameter radial collector well in the sand and gravel glacial outwash deposits east of the Great Miami River near Ross, Ohio. The collector well was pumped for industrial water supply purposes at an average rate of 10 Mgd from 1952 to 1955. Its effective radius is approximately 200 feet. In 1955, a second collector well was installed with an effective radius of 212 feet to establish an adequate water supply for 13 industries in the Mill Creek Valley area. Historical data from the 1950s indicate that the average pumping rate from the collector wells was about 14 to 15 Mgd after completion of the second well. From 1980 through 1986, this pumping rate increased to about 18.4 Mgd (Miami Conservancy District 1987). Spieker (1986b) and Dove (1961) concluded that from 60 to 76 percent of the total flow from the collector wells comes from induced recharge from the Great Miami River.

Water which is pumped from Collector Wells 1 and 2 (Figure 3-1) is piped about 14 miles through a 36-inch-diameter main to a reservoir in the Mill Creek Valley. The water flows by gravity from the reservoir to the industries served by the collector well system. In 1986, a third collector well was installed for emergency use only. Due to the standby status of Collector Well 3, the total flow from the three wells is not expected to exceed the current 18.4 Mgd level. This level is expected to be maintained in the near future.

5.0 ONGOING STUDIES

This report is based on the information available as of May 1, 1990. However, the gathering of additional data still continues. The ongoing studies pertinent to the groundwater investigation are mentioned in this chapter.

5.1 GROUNDWATER FIELD INVESTIGATIONS

RCRA and RI/FS groundwater sampling programs continue at the FMPC. Groundwater elevation measurements are taken and samples are collected from wells placed in both the Great Miami Aquifer and the glacial overburden on a quarterly basis, in accordance with the DOE/WMCO long-term monitoring program. Additional monitoring wells also continue to be installed and monitored to satisfy critical data gaps identified in the RI/FS.

5.2 GROUNDWATER ANALYSIS AND MODELING

The analysis of groundwater flow and quality data continues as the field investigations proceed. Seasonal trends and changes in conditions following the abnormal conditions of 1988 and 1989 are of particular interest.

A series of groundwater modeling studies initiated to support different aspects of the remedial investigation, risk assessment, and feasibility study activities also continue. A regional three-dimensional finite difference groundwater flow model and a local three-dimensional finite difference solute transport model have been constructed. The models are calibrated against existing data and are being used to predict future plume development and movement in support of the evaluation of the feasibility of remedial alternatives.

5.3 SURFACE WATER PROGRAM

Surface water quality in Paddys Run is monitored by WMCO's ongoing monitoring program at WMCO Stations W5, W7, W8, W9, and W10. Station W5 provides an upstream control, Stations W9 and W10 represent upstream and downstream locations with respect to the Waste Storage Area, Stations W11 and W7 provide a similar upstream/downstream pair for the confluence of the Storm Sewer Outfall Ditch with Paddys Run, and Station W8 is a downstream off-FMPC location. Weekly samples are analyzed by WMCO for uranium content and gross alpha and beta activity. Bimonthly composites of weekly samples are analyzed for RA-226 and RA-228.

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PART II. DATA COLLECTION

Part II of the FMPC groundwater report provides the reasons and rationale for selecting the detailed methods of data collection and documentation used during the field investigation program. Figure II-1 presents a schematic of the overall logic and structure of the report. Part I contains the background information on the site hydrogeologic setting; the data analysis, groundwater modeling, and conclusions are presented in Parts III, IV, and V, respectively. Part II contains four chapters, 6.0 through 9.0.

Chapter 6.0 describes the rationale, methodology, and field procedures used in the site-wide program. The field investigation deals with the installation of piezometers, groundwater elevation measurements, and groundwater samplings.

Chapter 7.0 describes the field investigation procedures and methods for the Production and Additional Suspect areas.

Chapter 8.0 discusses the laboratory methods, detection limit requirements, QA/QC procedures, and reporting requirements for each of the laboratories participating in the RI/FS groundwater program. This section does not review the WMCO FMPC laboratory procedures and requirements.

Data collected during previous investigations conducted at the FMPC were used during this study. Chapter 9.0 lists and briefly describes data selected for use from previous investigations and studies. Also listed and described are other sections of the RI/FS that supported this groundwater study.

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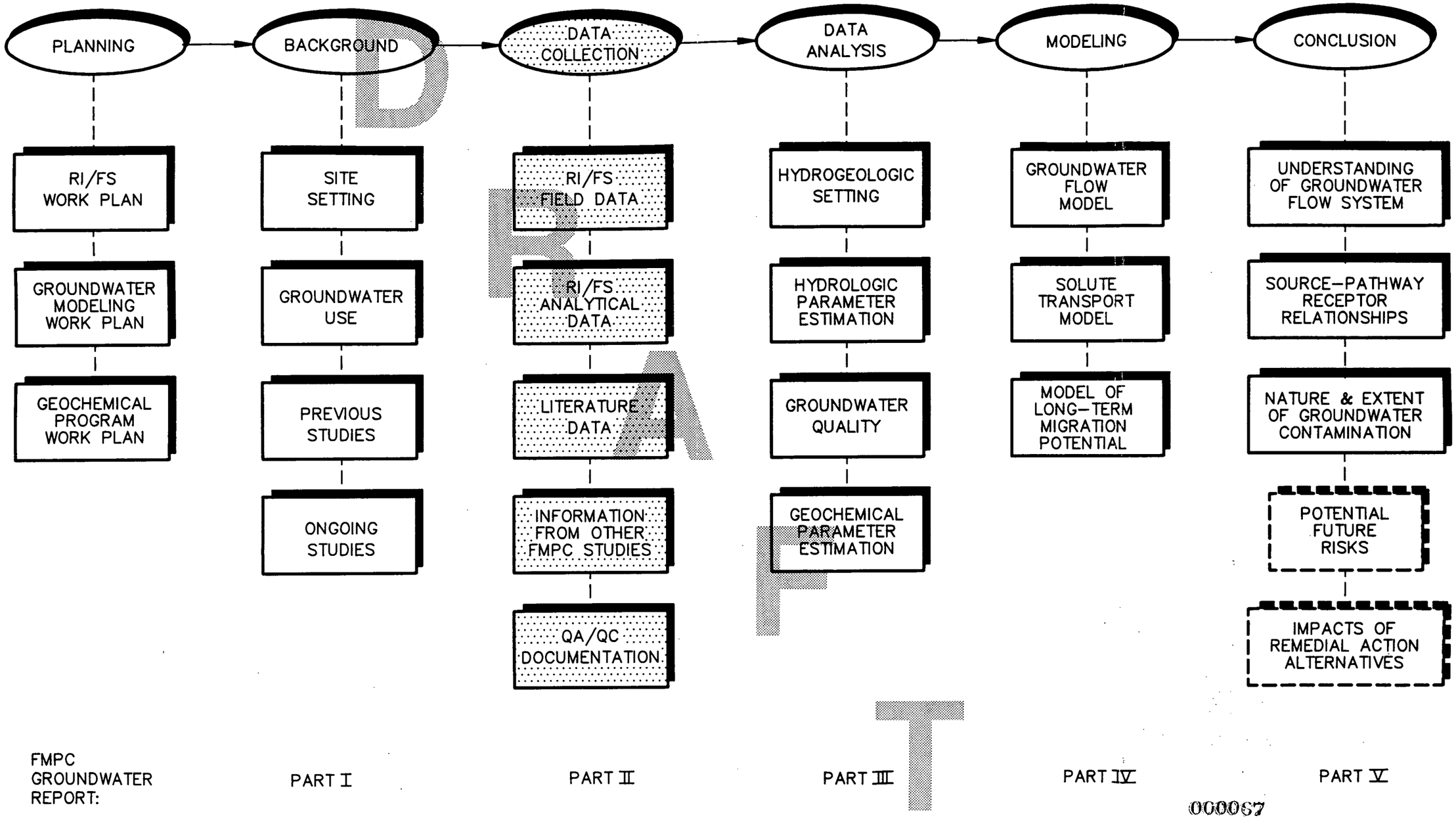

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FIGURE II-1
OVERVIEW OF DATA COLLECTION COMPONENT

6.0 FIELD INVESTIGATION: SITE-WIDE PROGRAM

Part II summarizes the rationale, procedures, and methodology of data collection used in the RI/FS to evaluate the hydrogeology at the FMPC and vicinity. An extensive field investigation program has been developed to obtain site-specific data to characterize the FMPC site geologic and hydrogeologic setting and to determine the surface and groundwater quality. The activities are still ongoing. This report documents the field investigation program through April 1990. The site-wide program is discussed in this chapter. However, the field investigation specific to the Production Area is addressed in Chapter 7.0.

Chapter 6.0 is divided into 7 sections. Section 6.1, "Well Installation Program," describes the rationale and field procedures used to advance soil borings, collect subsurface soil samples, and install wells. Also described in this section are the Quality Assurance/Quality Control (QA/QC) procedures, documentation, audits, and other requirements followed during this investigation. Section 6.2, "Groundwater Elevation Program," describes the investigation procedures followed to measure groundwater levels in the wells and piezometers. Section 6.3, "Groundwater Quality Program," addresses the rationale, procedures and QA/QC performed during groundwater sampling. Analytical field and laboratory requirements are included in this section. Section 6.4, "Hydraulic Conductivity Testing," describes the methodology and results of field hydraulic conductivity tests. Section 6.5, "Geophysical Program," presents the geophysical techniques used during this investigation and summarizes the findings. Section 6.6, "Surface Water and Sediment Program," addresses the rationale and procedures for surface water and sediment quality sampling and surface water elevation measurement. Section 6.7, "Surface Water Elevation Data," discusses the patterns in surface water level changes.

6.1 WELL INSTALLATION PROGRAM

The well installation and groundwater sampling portion of the RI is the principal source of hydrogeologic data from the site. The initial well installation program was developed in the March 1988 RI/FS Work Plan based on data gathered before this investigation was undertaken. The well installation program proceeded in phases. As subsurface soil conditions were evaluated and results of water table measurements and water quality analyses became available, additional wells were added to the program through the approval of Work Plan Addenda.

6.1.1 Objectives

The well installation program focused on identifying the nature and extent of contamination from the FMPC and evaluating sources of groundwater contamination and pathways for contaminant transport. The program was also intended to determine the need for groundwater remediation. The overall objectives of the well installation program were to:

- Determine if subsurface water-bearing zones in the vicinity of the FMPC have been contaminated
- Characterize the site hydrogeology and determine the rate and direction of groundwater flow within each separate hydrogeologic unit
- Determine the concentrations and sources of contaminants on the FMPC site and indicate migration of contaminants to off-FMPC areas
- Determine the effects that pumping has on groundwater flow and contaminant transport
- Define areas of subsurface contaminant migration and groundwater discharge

6.1.2 Scope

To achieve the objectives, a phased approach to field activities was planned. The first major phase of work was to fill identified data gaps to better understand regional groundwater quality and flow patterns. Specific potential sources, pathways, and receptors were also identified. Data collection and evaluation during the execution of the initial phases of the plan resulted in refinements in the understanding of the groundwater system, which in turn defined the need for additional drilling and sampling efforts.

The initial work plan called for the installation of 90 wells during Phase 1 of the RI/FS; however, additional wells were added in three subsequent phases to better define the vertical and lateral extent of contamination. Wells were also added to evaluate the impact of recharge from surface drainage, determine groundwater flow directions, and to refine the understanding of seasonal changes in water table gradients. As of April 1990, 146 monitoring wells have been installed under the RI/FS Work Plan and Addenda. The well installation program is continuing to resolve the detailed interpretation of the groundwater system.

6.1.2.1 Well Numbering System and Logic

Wells were installed to four different depths. Figure 6-1 is a diagram depicting the well installation depth and series numbers. Wells that are screened in the glacial overburden are numbered in the 1000 Series; wells that are screened at the water table in the Great Miami Aquifer are in the

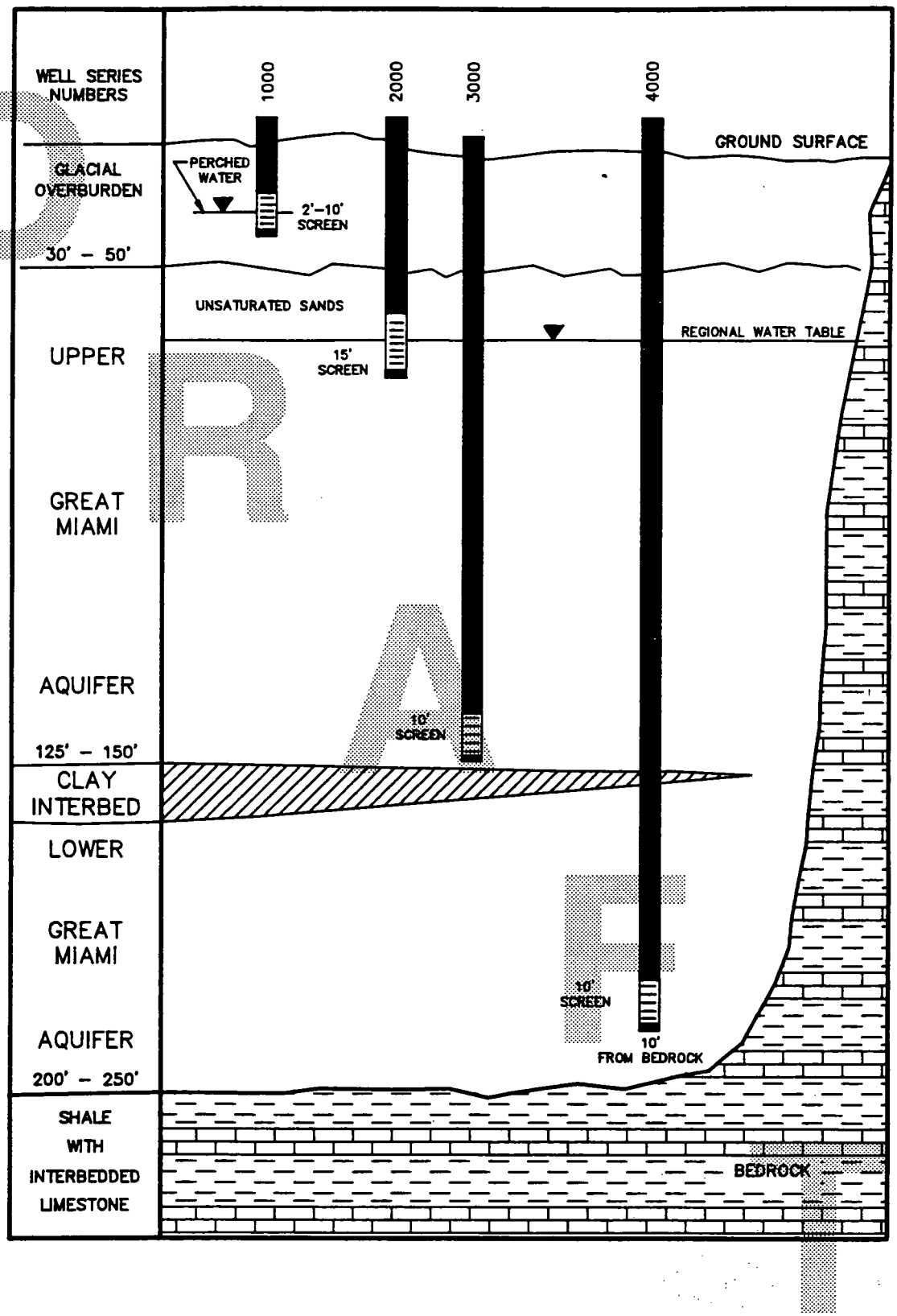

FIGURE 6-1
GROUNDWATER MONITORING WELL COMPLETION DEPTHS

3317-A135 (GW) (PGH)

2000 Series. Wells screened 10 feet above the clay interbed layer sometimes present near the middle of the Great Miami Aquifer, or at the equivalent elevation if the clay was not encountered, are in the 3000 Series; and wells that are screened 10 feet above bedrock at the bottom of the aquifer are in the 4000 Series. The three digits to the right of the thousands number identify the location where the wells are installed. There is no geographic significance to the three-digit location number; they were assigned in sequence with respect to time. Wells installed at different levels in the aquifer at the same location have the same three-digit identifier.

The March 1988 RI/FS Work Plan used 100, 200, 300, and 400 Series numbers. This allowed for only 99 locations. The numbering system was expanded to four digits in September 1988 to allow for additional locations.

On- and off-FMPC wells used in the sampling program that existed prior to the RI/FS were also assigned four-digit well numbers. Table 6-1 lists the previous designation of these wells and the RI/FS numbers assigned. The determination of whether these were 2000 or 3000 Series wells was made from the best records available.

1000 Series Wells

The glacial overburden material, which underlies most of the Production and Waste Storage areas, is the material most likely to be contaminated by direct contact with wastes and by surface water infiltrating through waste areas. The 1000 Series wells were completed in the glacial overburden and were screened either in the first water-bearing zone encountered or, if water was not encountered, the most permeable zone based on field observations. The groundwater encountered in the glacial overburden is perched water. The well screen length varied from 2 to 10 feet in these wells and was based on the thickness of the water-bearing zone. If water was not encountered during boring advancement, 10 feet of well screen was installed. Figure 6-2 shows the location of the 4-inch-diameter 1000 Series wells used for this groundwater report.

2000 Series Wells

The sand and gravel outwash deposits, known as the Great Miami Aquifer, underlie the glacial overburden and are hydrologically less complex than the overburden. These deposits are also more extensive and constitute a regional-scale buried channel aquifer. There are unsaturated outwash sand and gravels between the glacial overburden and the saturated outwash sand and gravels labeled the Great Miami Aquifer.

TABLE 6-1
RENAMED MONITORING WELLS

RI/FS No.	Pre-RI/FS Designation
2124	Cone House
1053	Argonne A-S
3053	Argonne A-D
1054	Argonne B-S
3054	Argonne B-D
1055	Argonne C-S
3055	Argonne C-D
4023[a]	BU-13
2026[a]	BU-101
2036[a]	12-5
1040[a]	RB
2050[a]	Pallet Co.
2056[a]	State 8
2057[a]	State 16
1058[a]	DH
1059[a]	1A
2060[a]	OS-1
1060[a]	OS-1A
2061[a]	OS-2
3062[a]	OS-1
4101	P-1
4102	P-2
4103	P-3
3063[a]	James Dill
3099[a]	Robert James
3100[a]	Charles Young
2121[a]	BU-91
2122[a]	BU-92
2123[a]	12-3
2104[a]	BPH, EM-10, EMR-10
2105[a]	State-10

[a]Private wells.

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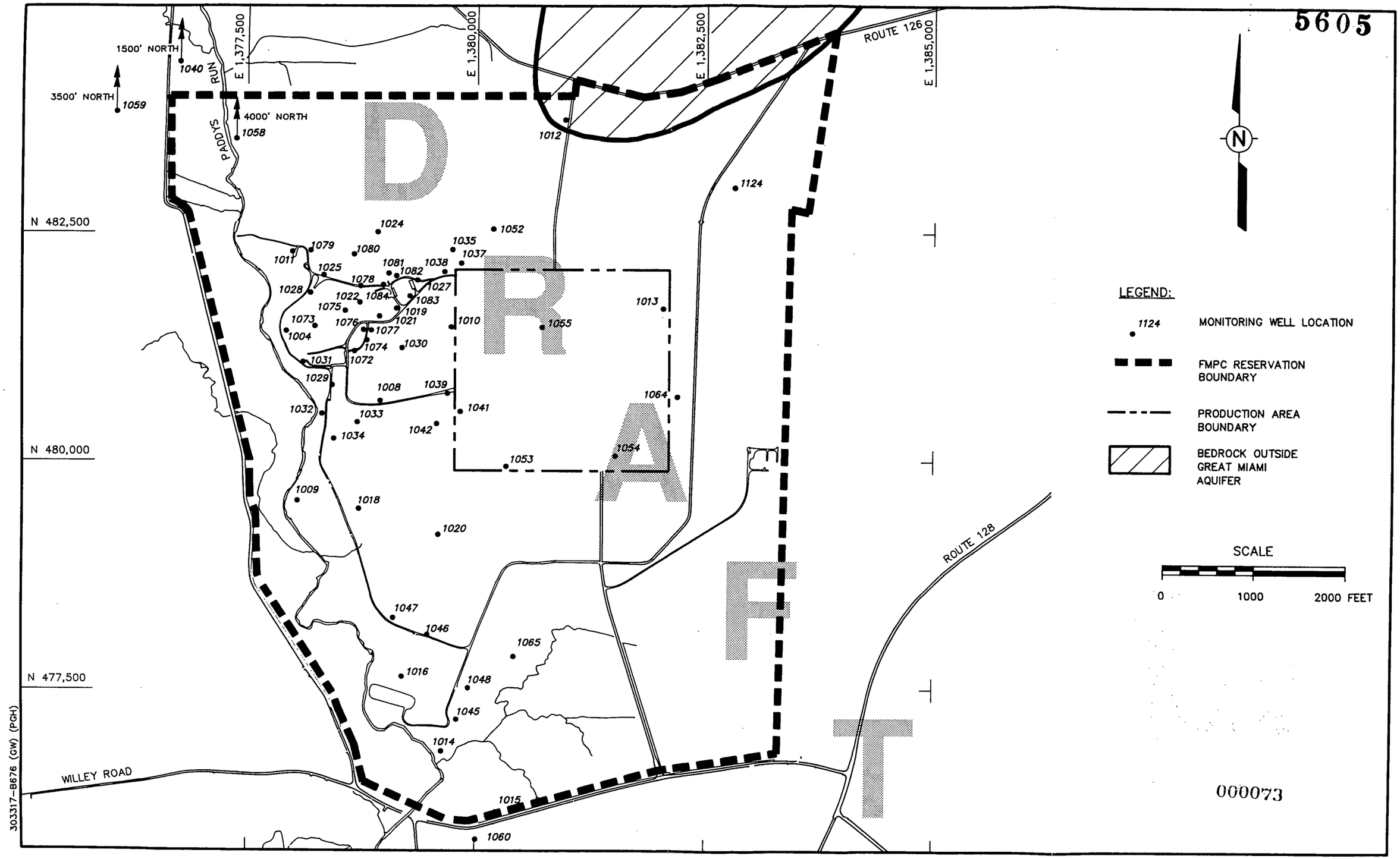

FIGURE 6-2
MONITORING WELL LOCATIONS
1000 SERIES WELLS

The 2000 Series wells were installed as part of the Phase 1 program to a depth of approximately 70 feet and screened at the water table. Fifteen feet of well screen was installed in all the 2000 Series wells so that approximately 10 feet of screen was below the water table and 5 feet of screen was above the water table to determine if nonaqueous phase contaminants were present on the water table surface. Groundwater samples collected from the 2000 Series wells were designed to sample for general groundwater quality at the top of the aquifer, which would be the first zone impacted by vertically infiltrating contaminants. Figure 6-3 shows the location of all the 2000 Series wells installed or used by the RI/FS program as of April 30, 1990.

3000 Series Wells

3000 Series wells were installed to investigate the potential downward transport of contaminants from the upper portion of the Great Miami Aquifer. Knowing the vertical component of groundwater movement is important to assess the current and future effects on contaminant transport pathways.

Previous investigations had indicated the presence of a significant clay unit in the Great Miami Aquifer beneath the FMPC (Dames and Moore 1985). This unit was labeled the "clay interbed" and was thought to be a barrier to vertical groundwater flow. Reasons for installing the 3000 Series wells were to better define the extent of this clay unit, to determine if the clay layer influenced the migration of contaminants or groundwater flow, and to provide water samples and hydrologic data at a consistent hydrogeologic elevation within the Great Miami Aquifer.

The anticipated average depth of these 3000 Series wells was 120 feet. If the clay layer was encountered, the well was constructed so that the bottom of the well screen was at the top of the clay unit. Every effort was made during boring advancement to prevent penetration of the clay unit, thereby avoiding the development of a new contaminant pathway through the clay layer. If the clay was not encountered at the target elevation, the borehole was advanced a minimum 10 feet beyond the anticipated depth of the clay to ensure that the clay unit was not present. If the clay unit was still not detected, the well was constructed so that the bottom of the well screen was at the target elevation of the clay unit. Figure 6-4 shows the location of the 3000 Series wells installed or used by the RI/FS as of April 30, 1990.

4000 Series Wells

4000 Series wells were installed just above bedrock in the lower part of the Great Miami Aquifer underlying the "clay interbed." All 4000 Series wells were advanced until bedrock was encountered. Each boring was advanced several feet into bedrock to determine that it was bedrock

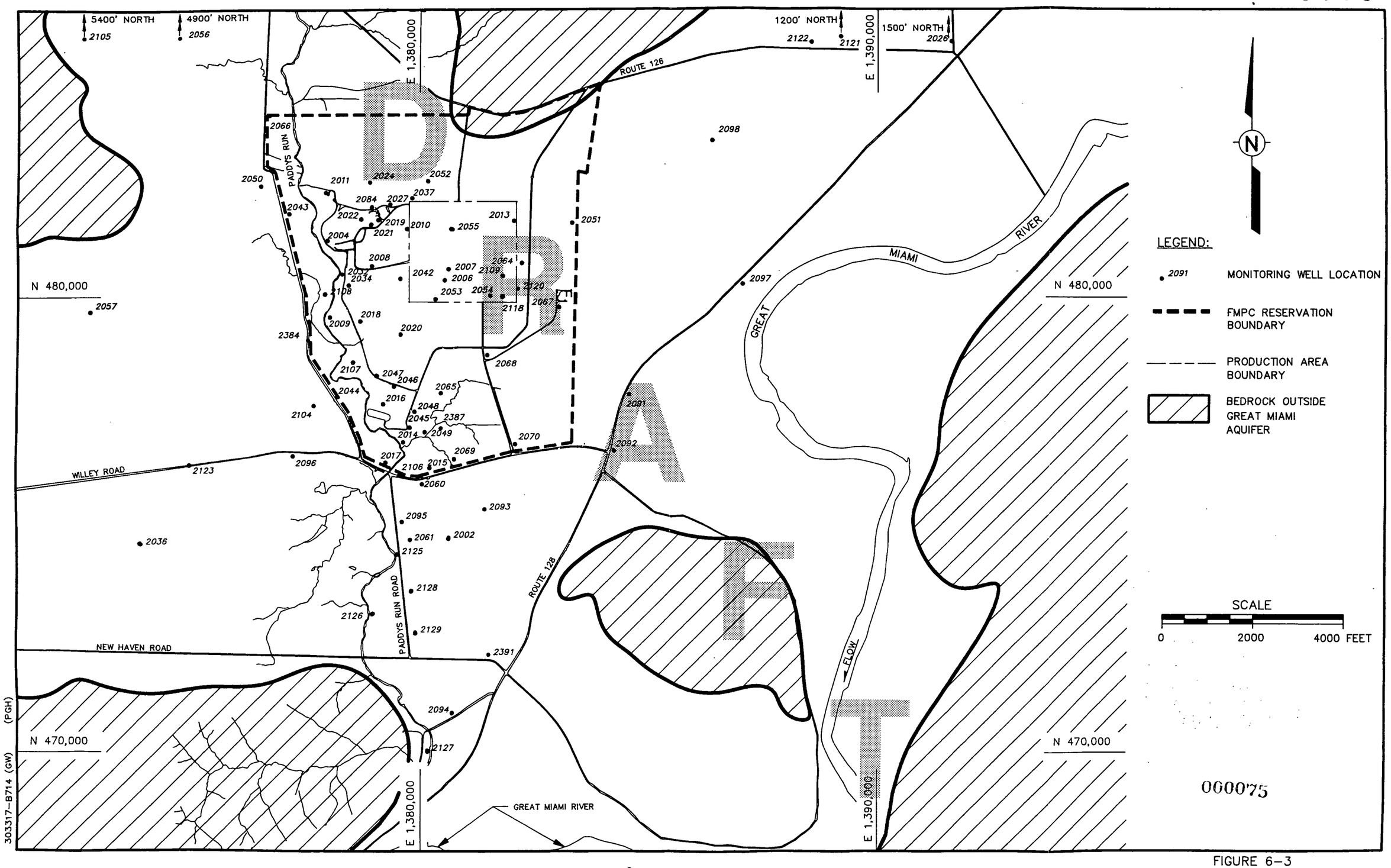

FIGURE 6-3
MONITORING WELL LOCATIONS
2000 SERIES WELLS

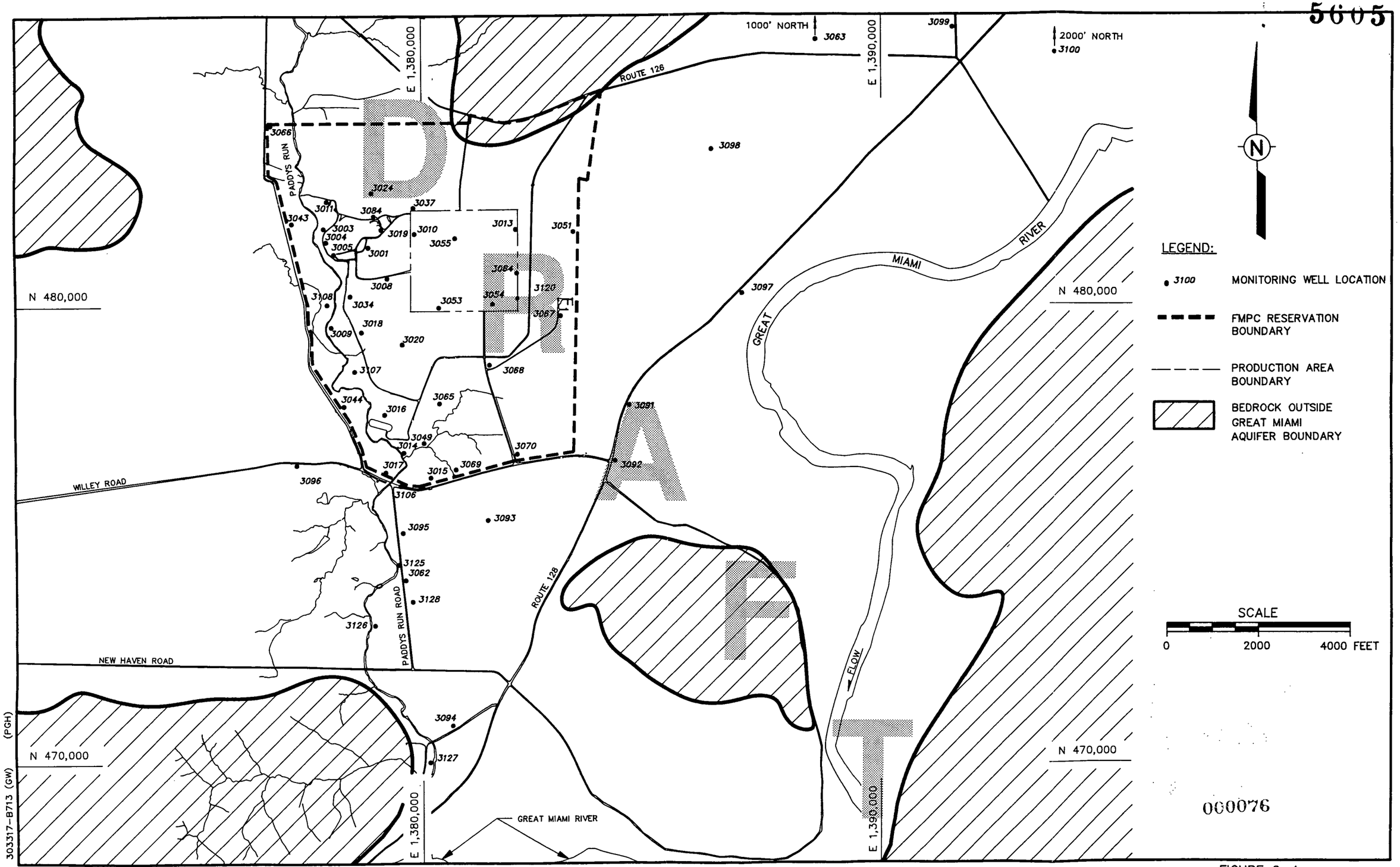

FIGURE 6-4
MONITORING WELL LOCATIONS
3000 SERIES WELLS

and not a large boulder in the outwash sands and gravels. The wells were constructed with the bottom of the screen set 10 feet above the bedrock surface.

6.1.2.2 Phase 1 (March 1988 Work Plan, Rev. 3)

The initial well locations were selected on the basis of perceived data gaps identified from previous groundwater studies and sampling results from existing wells. Well depths at each location were selected to provide the necessary vertical distribution of sampling points. The number and specific locations of the wells were formulated around 17 unresolved technical issues and related needs identified from the data quality objectives process. These technical objectives were:

- Monitor groundwater in the glacial overburden near waste areas
- Provide a ring of wells around potential sources
- Examine flow and quality in the upper Great Miami Aquifer
- Examine flow and quality in the lower Great Miami Aquifer
- Examine vertical flow components in the Great Miami Aquifer
- Characterize groundwater east of the Production Area
- Examine a potential flow divide and eastward flow component
- Provide additional data on the southern flow component
- Examine regional flow patterns
- Provide background (upgradient) control points
- Examine effects of the main effluent line
- Examine effects of the fly ash piles
- Examine effects of the Storm Sewer Outfall Ditch
- Examine groundwater quality near Paddys Run
- Examine flow patterns near Paddys Run
- Examine the Production Area as a potential source area
- Examine groundwater quality at the FMPC boundary and off the FMPC

Table 6-2 shows the relationship of each new on-FMPC well in the March 1988 Work Plan to the issue or objective that determined the specific placement of the well. Most wells addressed multiple issues, while each issue was addressed by at least one well. Table 6-2 also identifies existing wells at each location to highlight the two-, three-, and four-well clusters being formed by the new wells.

Very little was known about the quality of groundwater directly beneath the Production Area. To determine if the Production Area was a distinct source of groundwater contamination, thereby requiring investigation and potential remedial actions, wells were placed in the glacial overburden and the upper Great Miami Aquifer along upgradient and downgradient sides of the Production Area. Six existing wells located in the Production Area were also included in the quarterly deeper wells groundwater sampling program of the RI/FS. These include three 1000 Series wells and three roughly equivalent to 3000 Series wells. The logs for those wells, drilled for the baseline study by Argonne National Laboratories, were reviewed and the wells were found to be suitable for the

TABLE 6-2

PLACEMENT RATIONALE FOR PLANNED ON-FMPC MONITORING WELL LOCATIONS

EXISTING WELLS				MONITOR GROUNDWATER IN TILL NEAR WASTE AREAS	PROVIDE RING OF WELLS AROUND POTENTIAL SOURCE	EXAMINE FLOW AND QUALITY IN UPPER SAND AND GRAVEL	EXAMINE FLOW AND QUALITY IN LOWER SAND AND GRAVEL	EXAMINE VERTICAL FLOW COMPONENT IN SAND AND GRAVEL	CHARACTERIZE GROUNDWATER EAST OF THE PRODUCTION AREA	EXAMINE POTENTIAL FLOW DIVIDE AND EASTWARD FLOW COMPONENT	PROVIDE ADDITIONAL DATA ON SOUTHERN FLOW COMPONENT	EXAMINE REGIONAL FLOW PATTERNS	PROVIDE BACKGROUND (UPGRADIENT) CONTROL POINTS	EXAMINE EFFECTS OF MAIN EFFLUENT LINE	EXAMINE EFFECTS OF FLY ASH PILES	EXAMINE EFFECTS OF STORM SEWER OUTFALL DITCH	EXAMINE GROUNDWATER QUALITY NEAR PADDYS RUN	EXAMINE FLOW PATTERNS NEAR PADDYS RUN	EXAMINE PRODUCTION AREA AS POTENTIAL SOURCE	EXAMINE GROUNDWATER QUALITY AT FMPC BOUNDARY AND OFF-FMPC
1000 SERIES	2000 SERIES	3000 SERIES	4000 SERIES																		
		3001	4001																		
		3003																			
	2004			1004	1004		3004	3004													
		3005																			
		3008	4008	1008	1008	2008		2008			2008	2008									
		3009				2009		2009									1009	1009			
																	2009	2009			
		3010		1010	2010	2010		2010		2010									2010		
	2011			1011			3011	3011				3011	1011								
													3011								
1012																					
1013	2013	3013																			
	2014	3014															1014	1014			
1015	2015		4015				3015	3015			3015	3015				3015					3015
	2016	3016													1016		1016	1016			
	2018	3018		1018																	
1019	2019																				
1020	2020	3020																			
1021	2021																				
1022	2022																				
				1024	1024	2024	3024	2024			2024	2024	2024								
								3024			3024	3024	3024								
				1025	1025																
				1027	1027	2027															
				1028	1028																
				1029	1029																
				1030	1030																
				1031	1031																
				1032	1032																
				1033	1033																
				1034	1034	2034	3034	2034			2034	2034									
								3034			3034	3034									
				1035	1035																
				1037		2037	3037	2037		2037									2037		
								3037											3037		
				1038																	
				1039	1039																
				1041	1041																
				1042	1042	2042				2042									2042		
						2043	3043	2043				2043	2043				2043	2043			2043
													3043				3043	3043			
						2044	3044	2044			2044	2044					2044	2044			2044
								3044			3044	3044					3044	3044			
					1045										1045						
					1046										1046						
					1047										1047						
					1048										1048						
						2049					2049	2049			2049	2049					
						2051	3051	2051	2051	2051		2051							2051		2051
									3051	3051		3051							3051		3051
						2052							1052								
													2052						2052		
						2064	3064	2064	2064	2064		2064							2064		
									3064	3064		3064							3064		
						2065					2065					1065					
																2065					
						2066	3066	2066				2066	2066								2066
													3066								3066
	2067						3067	3067	3067	3067		3067		3067					3067		3067
	2068						3068	3068		3068	3068	3068							3068		
	2069						3069	3069			3069	3069									3069
	2070						3070	3070			3070	3070									3070
	2071						3071	3071	3071	3071											3071
				1072	1072																
				1073	1073																
				1074	1074																
				1075	1075																
				1076	1076																
				1077	1077																
				1078	1078																
				1079	1079																
				1080	1080																
				1081	1081																
				1082	1082																
				1083	1083																
				1084	1084	2084	3084														

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RI/FS. Data from the sampling of these existing wells, in addition to data from both new and existing wells upgradient and downgradient of the Production Area, were evaluated to determine if additional wells were necessary in the Production Area.

Initially, the work plan called for forty-two 1000 Series wells to examine the extent of the impact on perched water-bearing zones in the glacial overburden overlying the Great Miami Aquifer. These 1000 Series wells were placed immediately around the waste storage units and other potentially contaminated areas at the FMPC. This approach was necessary because the glacial overburden stratigraphy is highly variable and subsurface interpretations cannot be extended accurately across large areas. The 1000 Series wells included in Phase 1 of the well installation program are listed in Table 6-2 and shown in Figure 6-2.

Groundwater data collected prior to the RI/FS indicated contamination in the Great Miami Aquifer in the area immediately downgradient and east of the waste storage pits. Analysis of samples from wells south of the FMPC also exhibited elevated levels of uranium. Twenty-five 2000 Series wells were installed as part of the Phase 1 well installation program. The on-FMPC 2000 Series wells are listed in Table 6-2 and the off-FMPC wells are listed in Table 6-3.

Phase 1 of the well installation program specified twenty-five 3000 Series wells be installed. Table 6-2 lists the on-FMPC wells and rationale for their installation. Table 6-3 lists the off-FMPC 3000 Series wells installed in Phase 1.

Three 4000 Series wells were installed off the FMPC property. Two of these wells were installed to evaluate groundwater quality and vertical hydraulic gradients in the aquifer east of the site. This is where large pumping wells could influence the downward migration of contaminants into the deeper aquifer zones. The third well was installed west of the FMPC, outside the influence of the pumping wells and upgradient of the facility. Figure 6-5 shows the location of the 4000 Series wells installed or used by the RI/FS as of April 30, 1990.

6.1.2.3 Phase 2 (24-Well Program)

The data from the first and second quarterly groundwater sampling verified that the initial RI/FS wells provided valuable information regarding the extent, location, and concentration of contaminant plumes beneath the FMPC. Plumes that had been previously identified were confirmed, and the shape and distribution of these plumes were refined. The data indicated that there are two principal uranium plumes under the FMPC. One plume is centered under, and appears to originate from, the Waste Storage Area. This plume is moving east toward the Production Area. The second plume is

TABLE 6-3
OFF-FMPC WELL PROGRAM

Well No.[a]	Location
2091/3091/4091	Southwest of FMPC
2092/3092	Southeast of FMPC
2093/3093	South of FMPC
2094/3094	South of FMPC
2095/3095	South of FMPC
2096/3096/4096	East of FMPC
2097/3097/4097	Southwest of FMPC
2098/3098	East of FMPC

[a]Refer to Figures 6-3, 6-4, and 6-5 for well locations.

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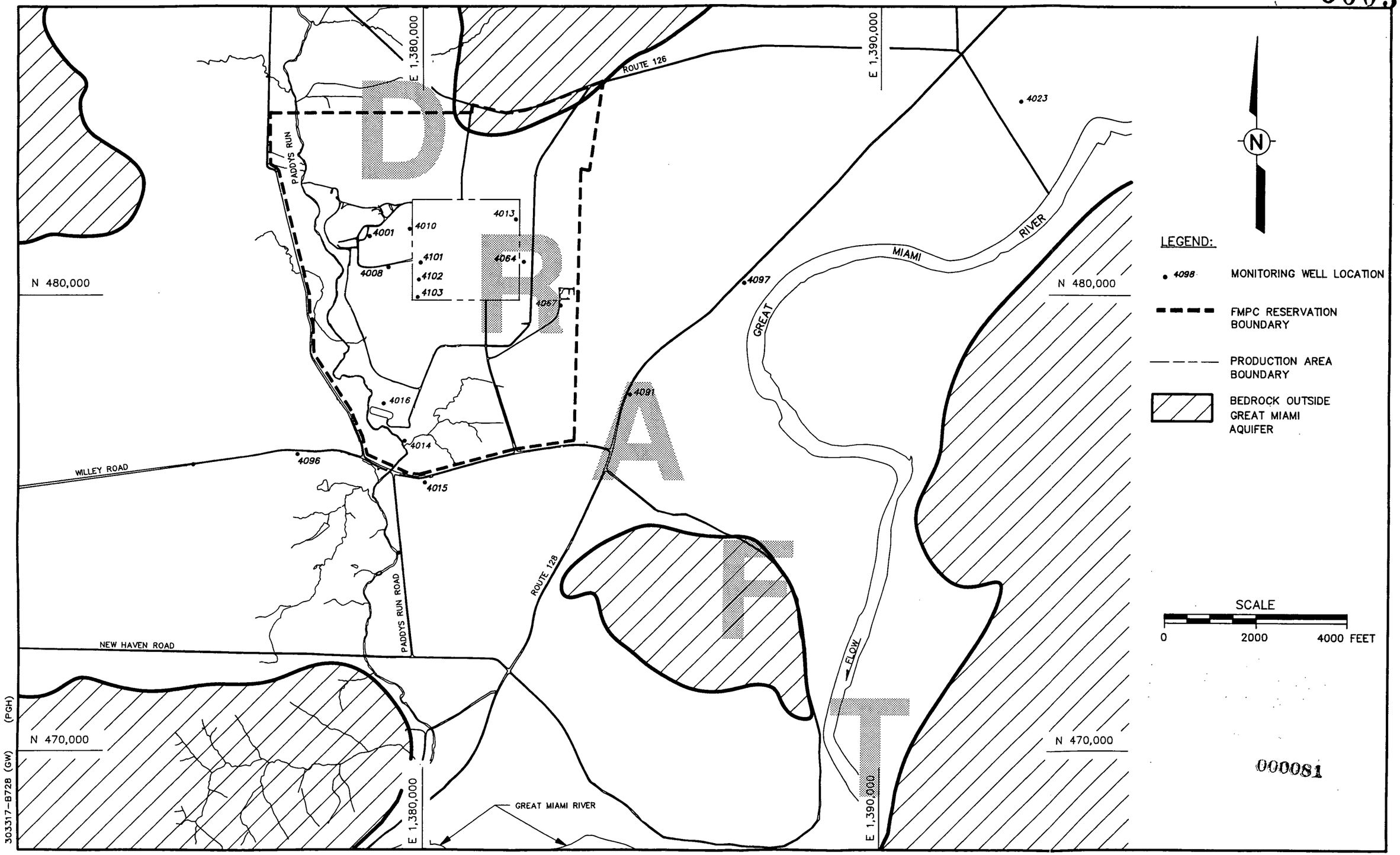

FIGURE 6-5
MONITORING WELL LOCATIONS
4000 SERIES WELLS

located under the southwestern portion of the FMPC and off-FMPC areas to the south. The source of this "South Plume" was less clearly defined by the Phase 1 Well Program.

The results of sampling indicated that there was a need for additional wells to refine the location and boundaries of the plumes, determine the extent of vertical migration, and delineate the source areas. The scope of the Phase 2 Well Program was based on discussions with the EPA and OEPA. Figure 6-6 shows the location of the 24 wells that were installed. Table 6-4 lists the wells and summary reasons for their installation. Five additional contingency wells were included in the 24-Well Program. The decision to install the contingency wells was to be based on data gathered from the groundwater samples collected from the newly installed 24 wells. Table 6-4 includes a listing of the contingency wells and the basis for the decision for their installation.

6.1.2.4 Phase 3 (10-Well Program)

The source and extent of a uranium plume in the Great Miami Aquifer, south of the FMPC, had been raised as an investigative issue in the RI/FS Work Plan. The completed Phase 1 well installation, groundwater monitoring, and initial data analysis provided insight into the width and extent of this uranium plume. The available data supported the interpretation that the principal source of the plume was centered in the vicinity of the confluence of the Storm Sewer Outfall Ditch with Paddys Run, the Inactive and Active Fly Ash piles, and Southfield. Data from the first two rounds of quarterly groundwater sampling, plus the ongoing groundwater modeling effort, were analyzed to target the Phase 3 wells and better define the South Plume. The EPA and OEPA also required that the extent of elevated levels of uranium in groundwater south of the FMPC be defined. Ten 2000 and 3000 Series wells were installed at six locations south of the FMPC (Figure 6-7) to determine the width and extent of the plume south of the FMPC boundary. Table 6-5 lists the Phase 3 wells and summary reasons for their installation.

6.1.2.5 Phase 4 (31-Well Program)

The rationale for the Phase 4 well installation program was to resolve several issues identified during groundwater data interpretation and to more fully define the limits of the South Plume. The 31-Well Program included 19 high priority wells, for which there were known issues to be resolved, and 12 low priority wells. The decision to install the low priority wells was to be based on the data obtained from the high priority wells. The high priority wells included sixteen 2000 Series and three 3000 Series wells. The low priority wells included one 2000 Series and nine 3000 Series wells.

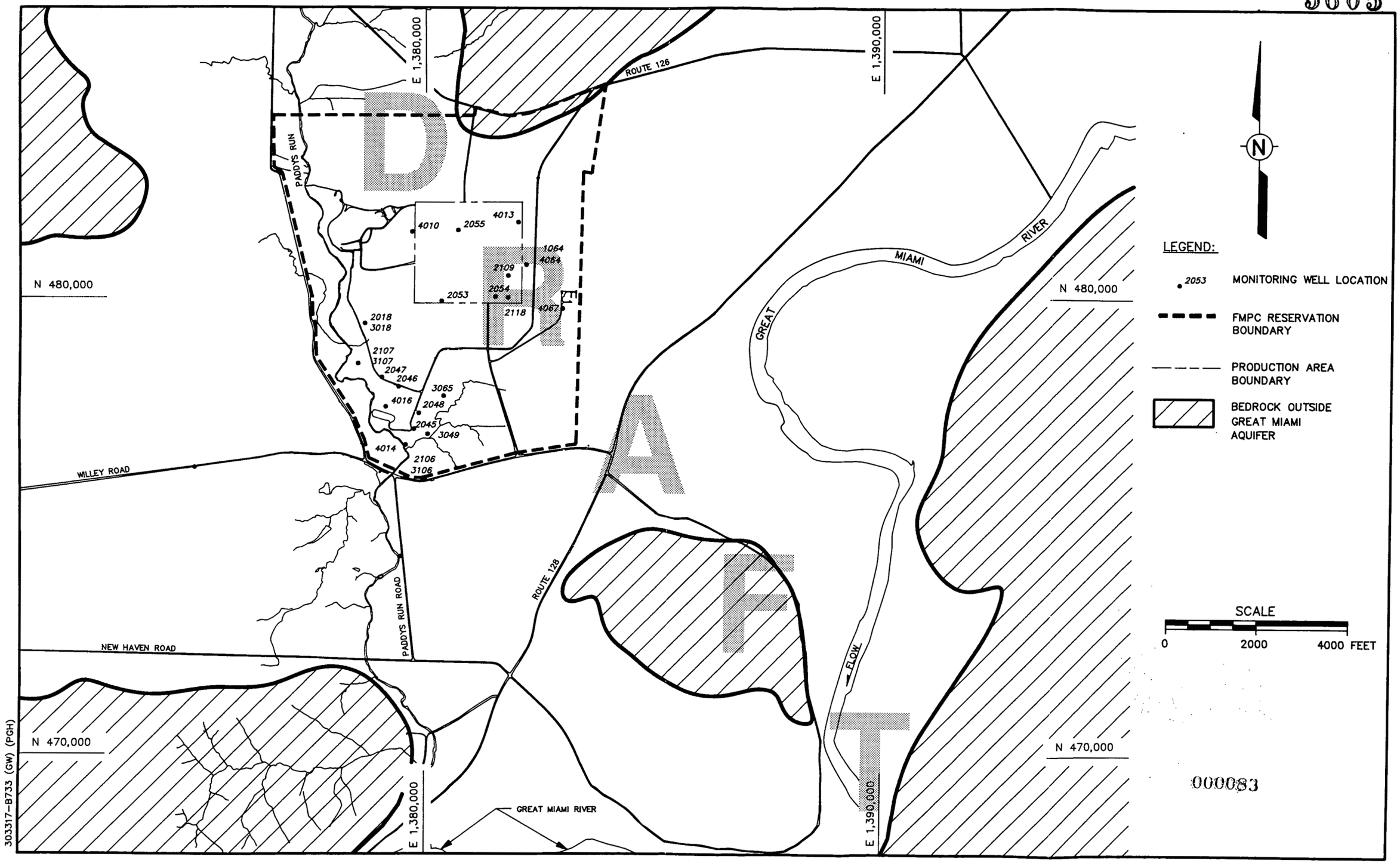

FIGURE 6-6
MONITORING WELL LOCATIONS
24-WELL PROGRAM
(PHASE 2)

TABLE 6-4
24-WELL PROGRAM (PHASE 2)

Well No./Series	Location
2053 2054 2055	Waste Pit Area
2109	Plant 6
2118	Plant 6
4013 4064 4067	Between the Production Area and SOWC pumping center
1064	Plant 6
2018 3018	Upgradient and west of the site
2107 3107	Along Paddys Run
2046 2047	Great Miami Aquifer south of the site
4016	Deep Great Miami Aquifer south of the site
2048 2045 3065 3049 4014	Evaluate the vertical extent of the south plume
2106 3106	Evaluate the area directly south of the south plume
4010	Evaluate contamination in deep Great Miami Aquifer in the Waste Storage Area

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TABLE 6-4
(continued)

Well No./Series	Location
Contingency Wells	
1000-, 2000-, 3000- Cluster East of Plant 6	Plant 6
1000 Series South of Plant 6	South of Plant 6.
4051	To determine the eastern extent of the Eastern Plume

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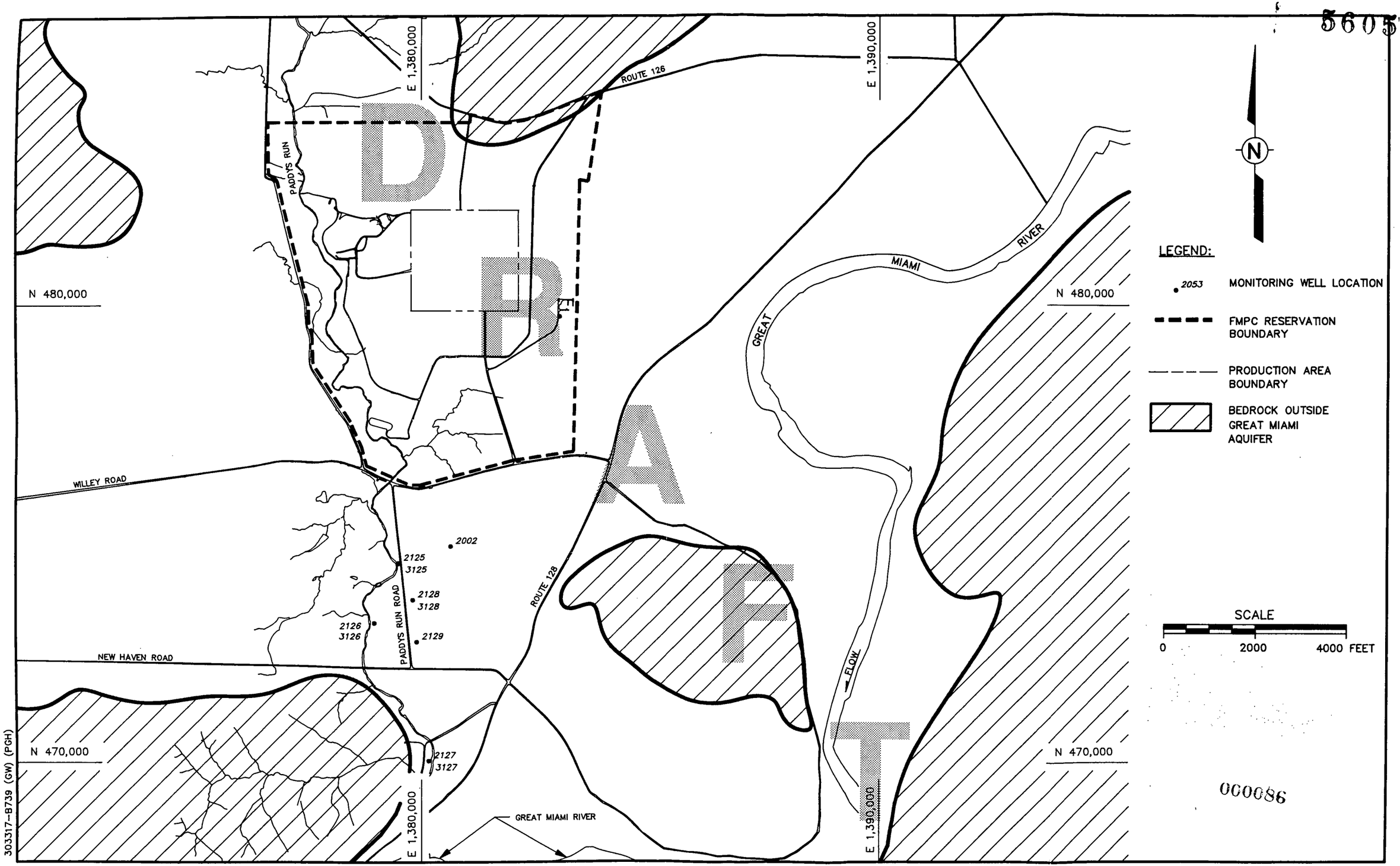

FIGURE 6-7
MONITORING WELL LOCATIONS
10-WELL PROGRAM
(PHASE 3)

TABLE 6-5
10-WELL PROGRAM (PHASE 3)

Well No.[a]	Location
2002	West of Well Locations 93 and 94
2125/3125	Northwest of Albright & Wilson Co. pumping center
2126/3126	Along Paddys Run south of previous location Well TW-2
2127/3127	Along Paddys Run north of several private wells
2128/3128	At the estimated center of the south uranium plume
2129	South of the estimated edge of the south uranium plume

[a]Refer to Figure 6-7 for the locations of wells.

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The 31-Well Program included various locations in the Production Area, Waste Storage Area, and off the FMPC. Table 6-6 lists the wells and summary reasons for their installation. Four Production Area wells were installed to investigate contamination found downgradient of Plant 6. Three wells were also installed adjacent to Paddys Run to provide groundwater quality upgradient of the Waste Storage Area and K-65 silos. The remainder of the wells were installed to evaluate the Paddys Run recharge area, Southfield, and the Storm Sewer Outfall Ditch. Figure 6-8 shows the 12 wells in the 31-Well Program that had been installed as of April 30, 1990.

6.1.2.6 Production and Additional Suspect Area Wells

The RI Work Plan Addendum, "Production and Additional Suspect Areas Work Plan," included seven 2000 Series wells. Wells 2053, 2054, 2055, 2109, and 2118 were installed under the 24-Well Program. The remaining two wells (2006 and 2007) were installed in conjunction with the piezometer installation and soil boring field activities. Well 2006 was installed downgradient of Plant 2/3 and Well 2007 downgradient of Plant 8. The locations of these wells are shown in Figure 6-3.

6.1.3 Drilling Procedures

The drilling and sampling procedures described here were used in the first four drilling phases and continue to be used in the ongoing field activities.

Cable Tool Drilling Techniques

Borehole advancement for RI/FS wells was performed using cable tool drilling techniques. The use of mud rotary or continuous flight hollow-stem augers was determined to be inadequate for RI/FS well requirements. Continuous flight soil auger drilling techniques have been used, however, to collect soil samples and to install borings and piezometers in the glacial overburden during other phases of the RI/FS. Cable tool drilling was performed in accordance with Section 5.2 of the QAPP.

The primary consideration when selecting the drilling technique to be used for RI/FS wells was the prevention of potential for cross contamination during boring advancement. The objective was to prevent the transport of contamination from the glacial overburden through the unsaturated sand and gravel outwash into the Great Miami Aquifer. The cable tool technique advances a temporary steel casing which seals the upper borehole and prevents the migration of contamination to the deeper units. This temporary casing also maintains an open borehole without the use of drilling muds, which could introduce foreign materials into the subsurface environment. The temporary steel casing was a nominal 10-inch diameter to allow for construction of the well. The temporary casing

TABLE 6-6

31-WELL PROGRAM (PHASE 4)

Well Location[a]		Location
High Priority	Low Priority	
2388		Operable Unit 3
2389		
2120		
3120		
2028	2033	Operable Units 1 & 4
2032		
2383		Operable Unit 5
2384		
3046		
3045	3047	
2385	3385	
2390	3390	
2386	3386	
2387	3387	
	Possible new well pair	
2391	3391	South Plume Area
2392	3392	
2393		
2394	3394	
2395	3395	

[a]Refer to Figure 6-8 for the locations of the wells installed as of April 30, 1990.

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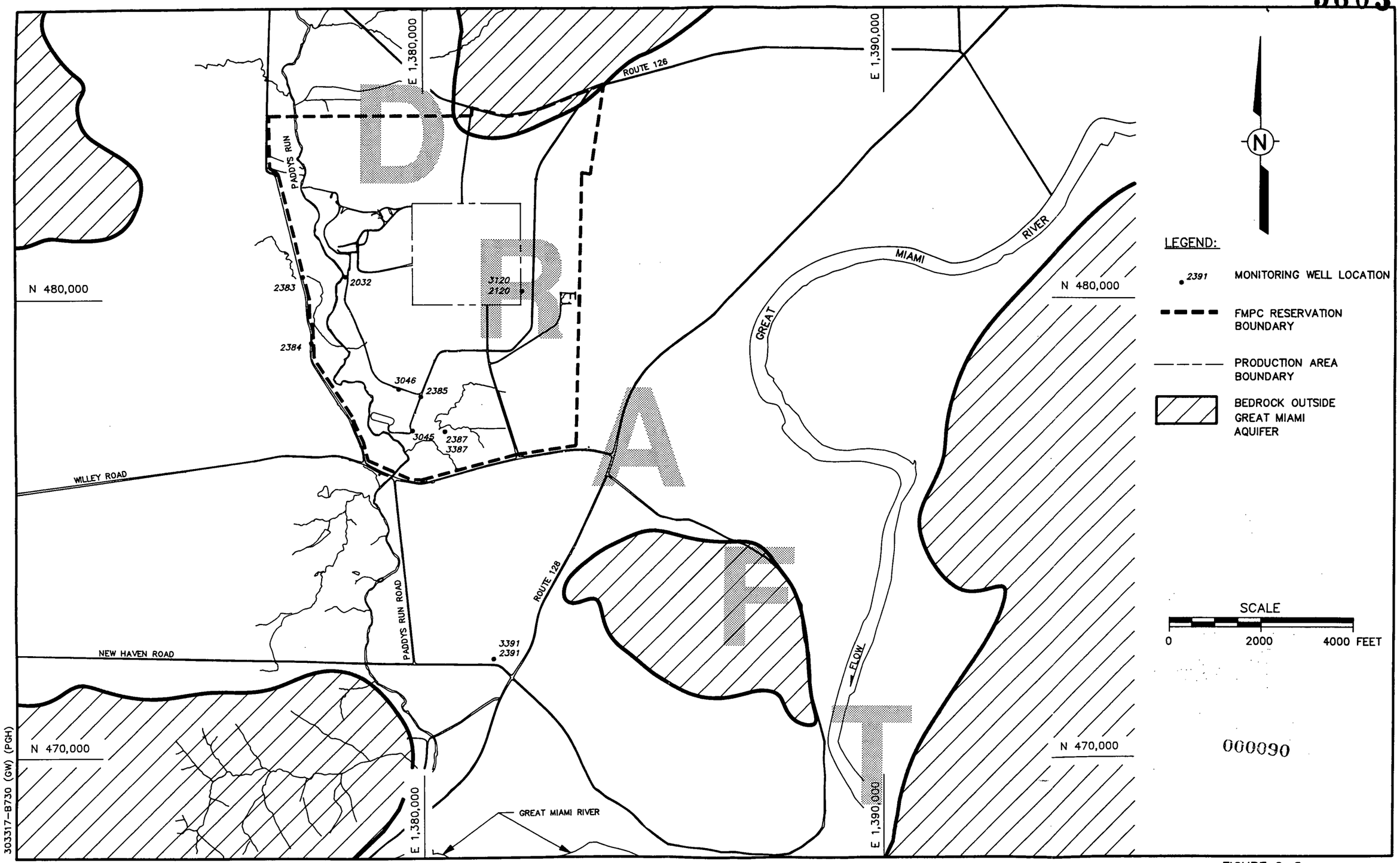


FIGURE 6-8
EXISTING MONITORING WELL LOCATIONS
OF THE 31-WELL PROGRAM
(PHASE 4)

in the 3000 and 4000 Series wells deeper than 150 feet was telescoped from a nominal 10-inch to a nominal 8-inch diameter.

A drill hammer was used to dislodge the soils inside the temporary casing. Potable water was added to the boring to facilitate cuttings removal when drilling in unsaturated material. In the glacial overburden and unsaturated sand and gravel outwash, the soil cuttings and potable water were removed from the borehole using a dart bailer. In the saturated sand and gravel material, potable water was not needed to dislodge the soil cuttings. A sand-pump bailer was used to remove soil cuttings from inside the temporary casing when drilling in the saturated sands and gravel.

On several occasions, sand and fine gravel would heave up into the temporary casing as the drill cuttings were being removed. This was caused when the drill cuttings and water were removed from the temporary casing and a lower hydraulic head was created inside the temporary casing than in the formation. To minimize this situation, additional potable water was added to the borehole to create a hydraulic head greater inside the temporary casing than in the outside formation. The result of this practice was that in some borings, significant amounts of potable water were added to the borehole during drilling. Much of this potable water was contained inside the temporary casing and removed as the boring was advanced. Any potable water that did enter the formation was removed during well development.

Auger Drilling Techniques

Borehole advancement for piezometer installation in the glacial overburden was performed using continuous flight auger drilling techniques. This drilling technique was used instead of cable tool drilling because the borings were scheduled to be drilled no deeper than 20 feet and not through the glacial overburden. Continuous flight auger drilling was performed in accordance with ASTM Designation D1452, "Soil Investigation and Sampling By Auger Borings"; the tentative test method entitled "Soil Investigation and Sampling by Hollow-Stem Auger Boring"; and Section 2.2.1.4, "Auger Boring Borehole Advancement," IT Manual of Practice, Subsurface Investigations.

Continuous flight augers were used to advance soil borings through the glacial overburden to collect subsurface soil samples. Standard 8-inch-outside-diameter (OD), 4.5-inch-inside-diameter (ID) hollow-stem augers were used. Borings were advanced by rotating the auger flights, and the soil cuttings were brought out of the boring by the auger fins. Soil sampling and piezometer construction were conducted inside the augers. If subsurface soil samples were not being continuously collected, a center plug was placed inside the augers to preclude cuttings from entering

the lower augers during boring advancement. The auger drilling operations were performed dry, without the use of water, drilling muds, or additives.

Before advancing any borings on the FMPC, penetration permits were obtained from the Facility Engineer. Before advancing any boring off FMPC property, access agreements were obtained by the DOE from the respective property owners. Area utility companies were also contacted to locate all nearby buried lines before drilling began.

Management of Drilling Cuttings

All drill cuttings and water removed from the borehole during drilling were contained in 55-gallon drums at the well site. After completion of the boring, a composite sample was collected and the drums were transported to a staging area until a determination could be made concerning final disposal. Until March 1990, drill cuttings and water from borings outside the Production and Waste Storage areas, including off-FMPC wells, were transported and staged on the Inactive Fly Ash pile. After drilling at the well location was completed, a composite liquid sample was collected for each borehole. This sample was analyzed for total uranium by the WMCO laboratory. If the composite sample analysis was below an action limit determined by WMCO, the liquid and soils were spread out on the Inactive Fly Ash pile. All the composite sample analyses from the RI/FS wells installed outside the Production and Waste Storage areas were below the WMCO action limit and the cuttings were disposed of on the Inactive Fly Ash pile.

Soil cuttings and water from borings inside the Production and Waste Storage areas were left in sealed drums at their respective boring locations. After drilling at the well location was completed, a composite liquid sample was collected for each borehole. Liquids were skimmed off the top of each drum and disposed of at the General Sump, located in the Production Area, for treatment by the FMPC treatment system. This procedure was approved by the EPA and OEPA based on the results of a comprehensive laboratory analysis for radionuclides and organics using purge water samples from existing wells considered to be the most susceptible to contamination from these areas.

Soil cutting disposal was determined by full radiological analysis for soil samples collected during boring advancement. Cuttings from inside the Production and Waste Storage areas that were below the action limit determined by WMCO were disposed of on the clean soil pile located north of Plant 1, in accordance with WMCO's operating procedures. If the analysis was above the WMCO action limit, soil samples were collected from individual drums and analyzed by WMCO for total uranium. If individual drum results were below the WMCO action limit, the soil in those drums

was disposed of on the clean soil pile north of Plant 1. Soils that could not be disposed of on the clean soil pile were collected by WMCO for proper disposal.

After March 1990, soil cuttings could no longer be disposed of on the Inactive Fly Ash pile and the clean soil pile north of Plant 1 using the above procedures. Cuttings from wells outside the Production and Waste Storage areas are currently disposed of on the Inactive Fly Ash pile only if the total uranium concentration is below 4.4 pCi/g. If total uranium is between 4.4 and 35 pCi/g, the soil is staged in the K-65 storage area. If the total uranium is between 35 and 100 pCi/g, the soil is staged by Plant 1. If the total uranium is over 100 pCi/g, the soil is packaged for disposal as low level waste by WMCO.

Cuttings from wells installed inside the Production and Waste Storage areas are currently staged at Building 64, where a composite sample is collected and analyzed for flash point, TCLP, and radiological analysis. Based on the laboratory analytical results, the soils are either staged as RCRA low level waste, or clean soil.

If volatile organics were detected in the field when installing wells outside the Production and Waste Storage areas, the cuttings would also be staged at Building 64. A composite sample would be collected and analyzed for flash point, TCLP, and radiological analysis. Based on the laboratory analysis the soils would be staged as RCRA low level waste, or clean soil.

Exceptions to Methods

All drill cuttings and water generated during boring advancement are contained in 55-gallon drums except those from Wells 2066, 3066, and 2065. These were contained in temporary plastic-lined pits. However, removing the soils from the pits and protecting the pits from direct rainfall proved to be too difficult to implement and to satisfy the requirements of the project. Therefore, drums have been used for cuttings containment for all subsequent wells and borings. A composite water sample was collected for each temporary pit and analyzed for total uranium by WMCO. If analytical results were below the limits specified by WMCO, and the soil cuttings and water were collected and disposed of on the Inactive Fly Ash pile.

6.1.4 Subsurface Soil Sampling Procedures

The sampling and logging of subsurface materials were conducted in accordance with the RI/FS Sampling Plan, Section 4.0, and QAPP, Section 5.2 (ASI/IT 1988). Continuous soil samples were collected in the glacial overburden. Outwash sand and gravel and Great Miami Aquifer material were sampled at five-foot intervals or at changes in lithology, as determined by the field geologist.

At locations where more than one well was installed, subsurface soil samples were collected only once through the geologic column, in the deepest borehole. Relatively undisturbed soil samples were collected using standard 18-inch split-spoon samplers, in accordance with ASTM Method D1586-84.

The RI/FS Work Plan called for a minimum of 20 undisturbed samples to be collected for geotechnical analysis. Conventional 30-inch Shelby tubes were used to collect two undisturbed samples from each 1000 Series well boring during cable tool drilling. One Shelby tube was collected from the oxidized portion and one Shelby tube sample from the unoxidized portions of the glacial overburden. Shelby tube samples were also to be collected from the uppermost portion of the "clay interbed" layer at Well Locations 3011, 3034 and 3037; however, the clay layer was not encountered in Wells 3011 or 3034.

All subsurface soil samples were examined and described by a project geologist. The geologist described and classified the samples based on their color (Munsell Soil Color Charts), texture (Unified Soil Classification System), estimated water content, and depth from land surface. All field observations were recorded on standard forms described in the QAPP.

6.1.5 Well Installation Procedures

After each boring reached the designated depth, a well was constructed in accordance with Section 5.3 of the QAPP. During well installation, field measurements and information such as the bottom of the boring, screen location, granular backfill interval, seals, grout, and height of riser above ground surface were recorded on the Piezometer Installation Sheet and Monitoring Well Installation Detail sketch. Quantities of grout, sand, and other materials used in the construction of the wells were recorded on the Field Activity Daily Log. After completion, the well was surveyed for horizontal and vertical control.

Well installation procedures for both cable tool drilling, which was used for the 1000, 2000, 3000, and 4000 Series wells, and auger drilling used for installing 1000 Series piezometers in the glacial overburden, were virtually identical (see Figures 6-9, 6-10, 6-11, and 6-12 for detailed sketches of these wells). In the following description of drilling procedures, the cable tool procedures are emphasized. The temporary casing used with cable tool drilling and the auger used in the auger drilling served the same function.

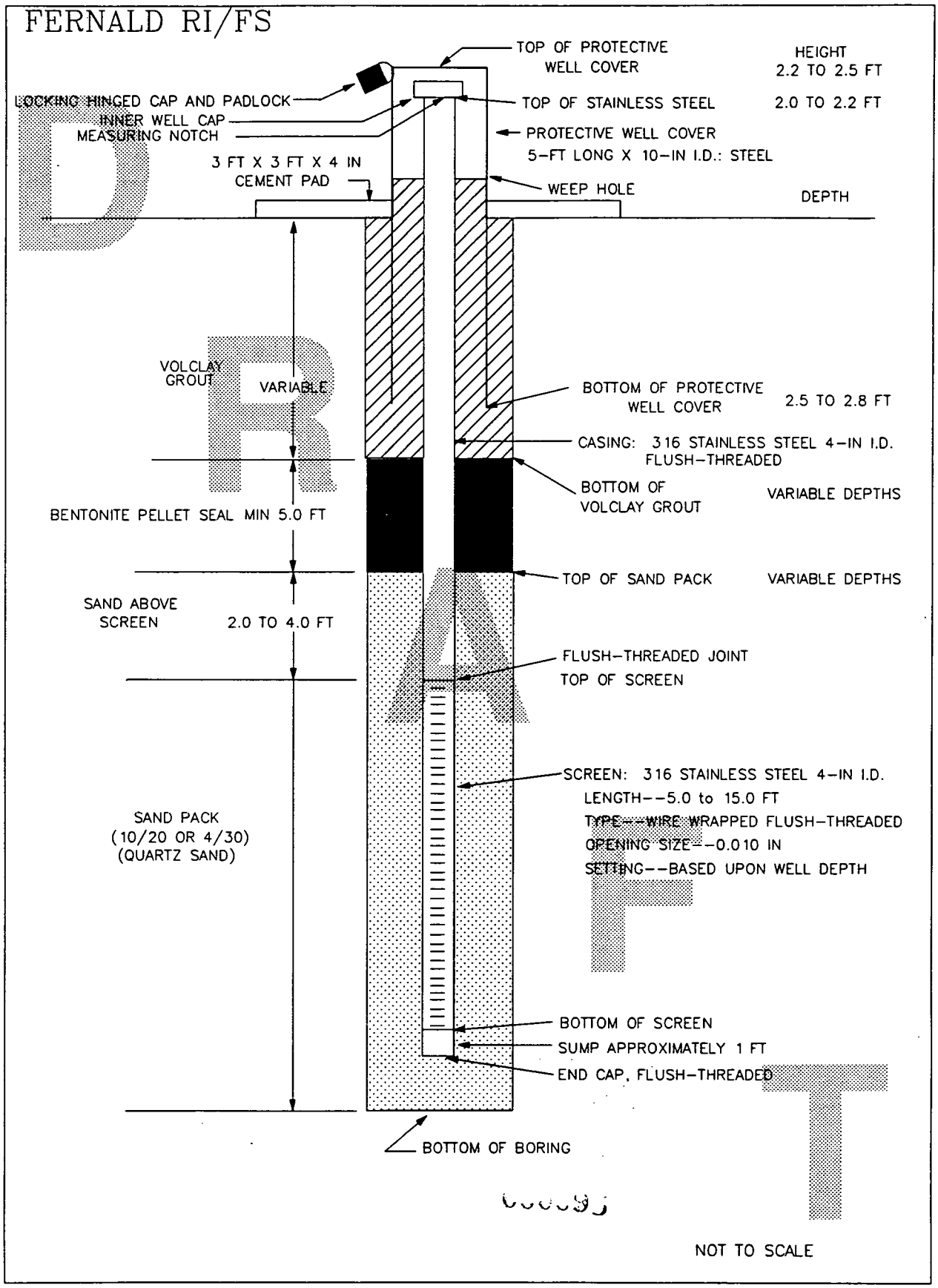


FIGURE 6-9. SPECIFICATIONS FOR WELL COMPLETION 1000 AND 2000 SERIES WELLS

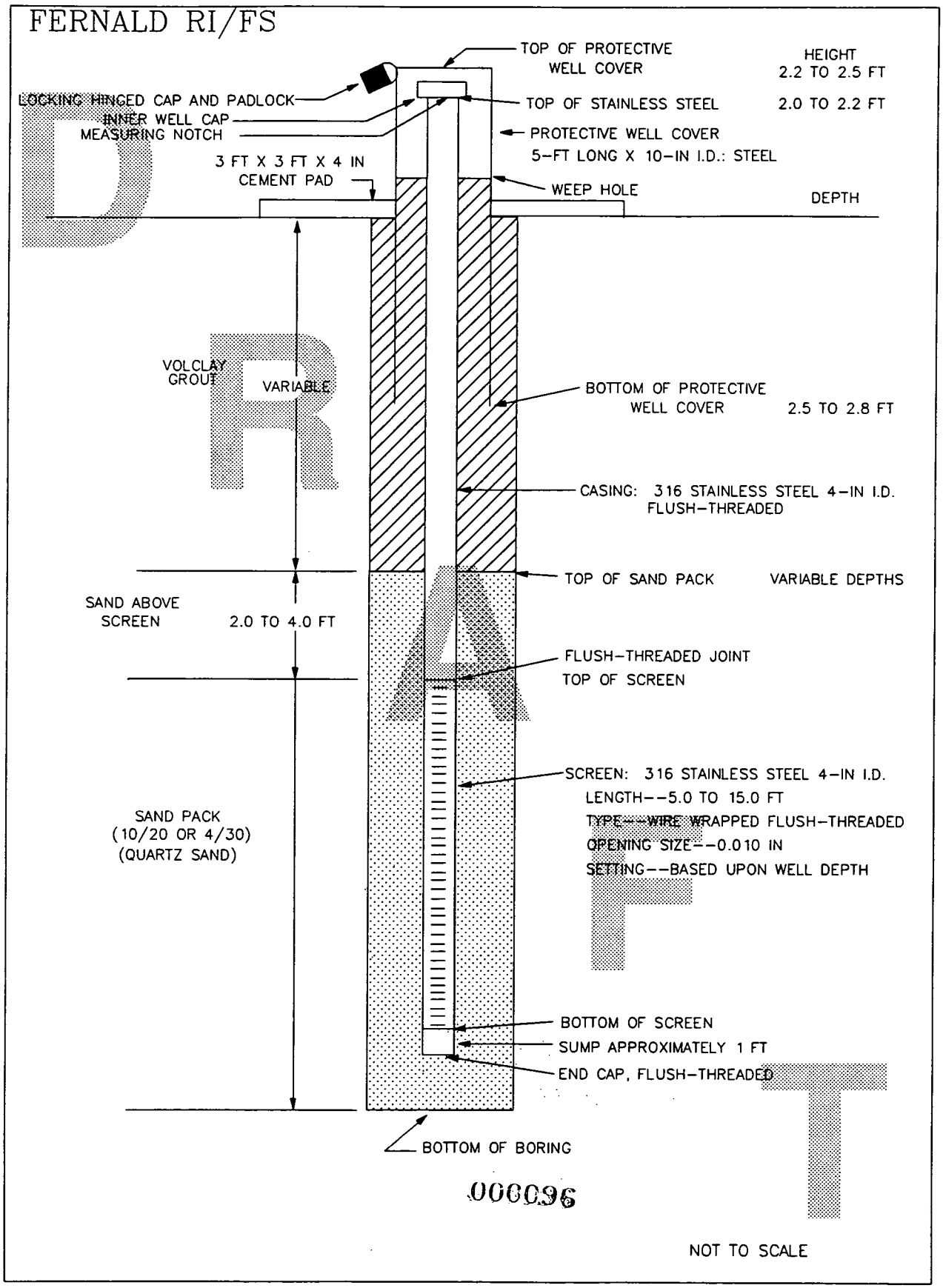


FIGURE 6-10. SPECIFICATIONS FOR WELL COMPLETION
3000 AND 4000 SERIES WELLS

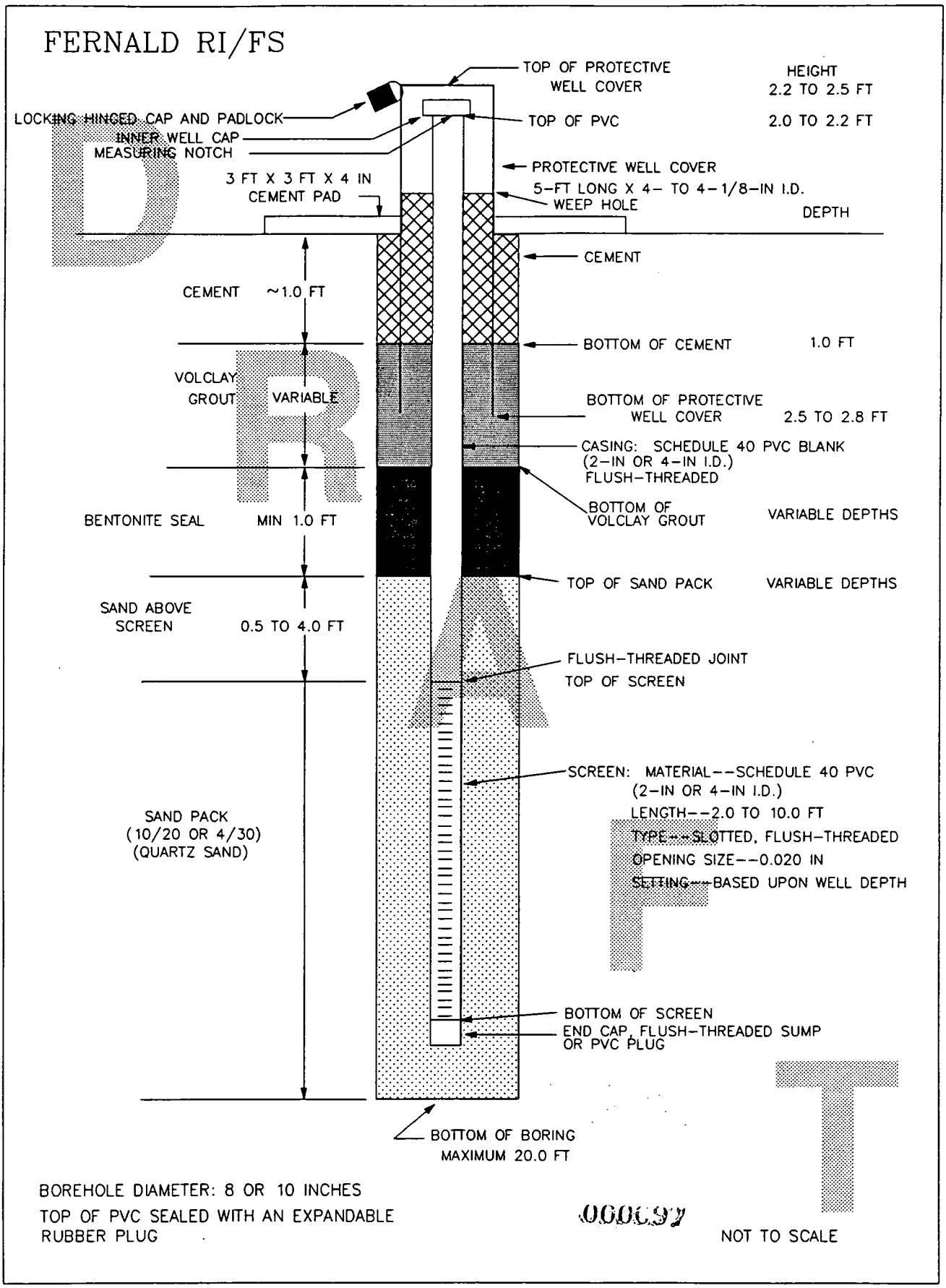
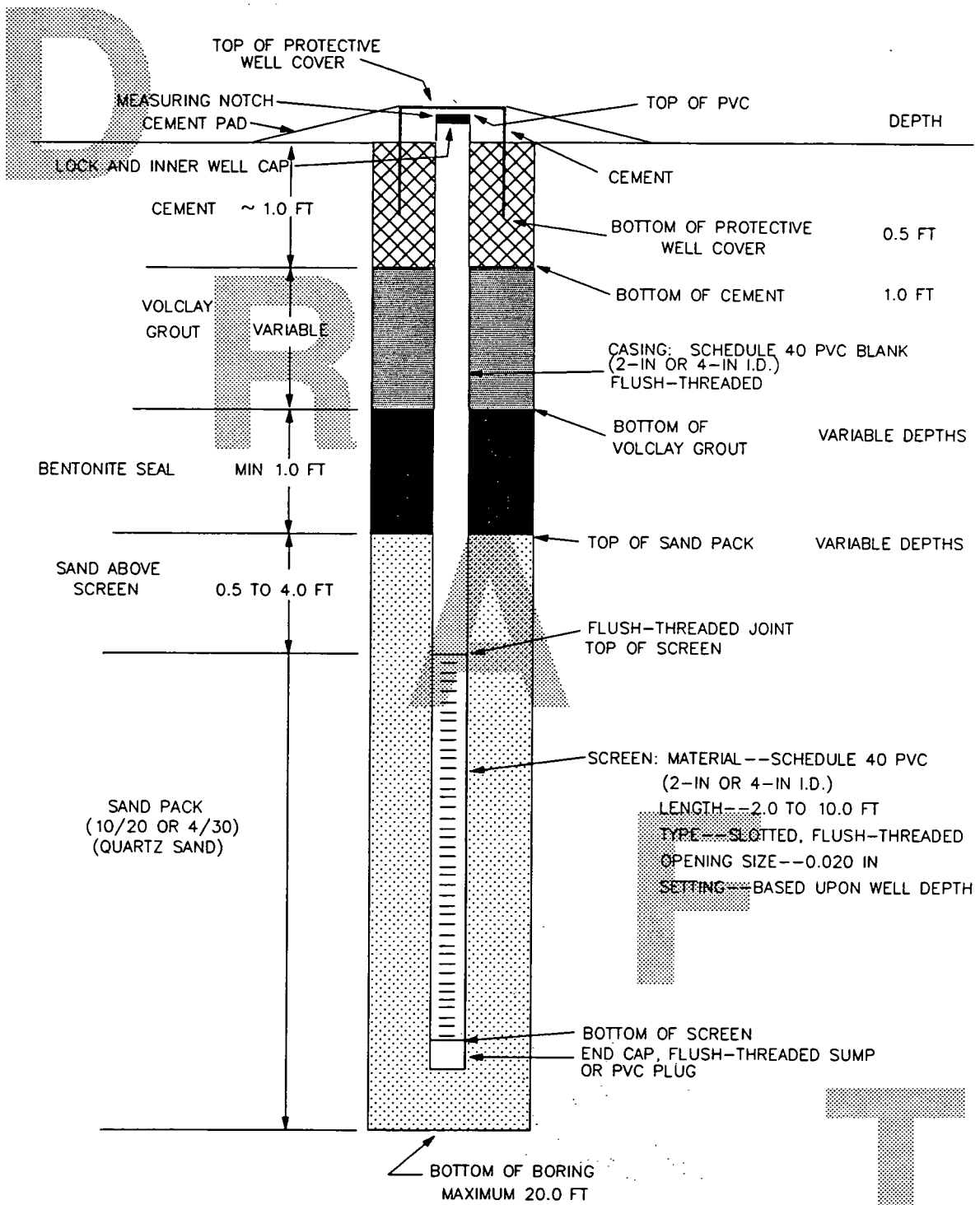


FIGURE 6-11. INSTALLATION DETAILS--1000 SERIES PIEZOMETERS

FERNALD RI/FS



BOREHOLE DIAMETER: 8 OR 10 INCHES

TOP OF PVC SEALED WITH AN EXPANDABLE RUBBER PLUG

000098

NOT TO SCALE

FIGURE 6-12. INSTALLATION DETAILS--FLUSH-MOUNT PIEZOMETERS

The following materials and procedures were used to construct the RI/FS wells:

- Casing was 4-inch-inside-diameter, 316 stainless steel with flush-thread joints for RI/FS wells, and 2-inch- or 4-inch-inside-diameter Schedule 40 PVC with flush thread joints for piezometers.

- Two-, 3-, 5-, 10-, and 15-foot sections of commercial 0.01-inch-slot stainless steel well screen with a minimum 3-square-inch open area per foot of screen were used for RI/FS wells; and 2-, 3-, 5- and 10-foot lengths of commercial 0.02-inch-slot Schedule 40 PVC were used for piezometers.

- The required length of well screen and casing, with end caps, were placed inside the temporary casing at the desired depth.

- Two-foot sumps were installed at the bottom of all stainless steel wells. In some cases, sumps were installed on PVC piezometers.

- Sand pack material was placed in the annular space between the screen and temporary casing as the temporary casing was removed from the boring. Periodic measurements were made to check the uniform placement of the sand pack. The depth to the top of the sand pack material was also measured to ensure that it was never below the bottom of the temporary casing as it was withdrawn.

- The screen packing material was a well-sorted medium or coarse quartz sand. Several grades, or types, of sand pack material were used, depending on the type of material in which the well was completed. Representative samples of each grade of packing material were retained for documentation.

- Sodium bentonite pellets and Volclay grout were used in the backfill for 1000 and 2000 Series wells. Only Volclay grout was used in 3000 and 4000 Series wells. Samples of pellet and grout materials used were retained for documentation.

- The 1000 and 2000 Series wells were backfilled with a sand pack to a height of two to four feet above the screen, then a five-foot bentonite pellet plug was placed on top of the sand pack. The remaining area above the bentonite plug was grouted to the surface. The 3000 and 4000 Series wells were backfilled with a sand pack to a height of five feet above the screen and then grouted to the surface.

- Annular space grout seals were composed of Volclay grout mixed with potable water and activator as per the manufacturer's instructions.

- The temporary casing was gradually removed as the grout was pumped into place using a tremie pipe so that the bottom of the temporary casing remained below the top of the grout.

- A 5-foot minimum length, black, 10-inch-diameter iron pipe extending approximately 2.5 feet above the ground surface was set in the Volclay grout and a concrete apron. A drain hole was drilled in the protective casing one foot above the land surface.

- A locking cover with padlock was installed to secure the top of each protective casing.

- A mixture of approximately 1:2 cement:sand and approved water or sodium bentonite pellets was placed between the well riser and the outer protective casing to a height just below the drain hole mentioned above. This design allows water which enters the annulus to drain, while protecting the integrity of the well if material is injected into the drain hole.

- The top of the inside stainless steel casing was finished with a vented cap that was not more than six inches from the top of the protective casing.

- All wells were identified with a number welded into the lid of the protective casing and painted on the inside of the cover with enamel paint. All protective casings were painted with high-visibility orange paint.

- The cover was installed such that precipitation cannot enter the protective casing. All off-FMPC wells located in agricultural areas, where pesticide/herbicide spraying may occur, are equipped with gaskets and the annular space inside the casing was filled with absorbent material. This was done as added protection to prevent any foreign material from entering the well.

- A measuring point notch was filed or cut on the inner casing of each well as a reference point for the survey coordinates and all water level measurements.

- At off-site well locations where farm equipment may be damaged by the protective casing, tall flag markers were installed. Wells 2097, 3097, and 4097 were completed with flush-mounted casing.

- All disturbed drilling areas were regraded and restored to near original conditions upon completion.

6.1.6 Well Completion Procedures

Well Development

After the wells were completed, they were developed in accordance with Section 5.4 of the QAPP to remove fines from the area around the sensing zone. Each well installed during the RI/FS was developed following the same general guidelines, in accordance with the RI/FS requirements. Well development was performed no sooner than 48 hours after grouting was completed.

Well development is conducted to restore the natural hydraulic conductivity of the formation in the vicinity of the well screen. It removes the sediment from around the well screen and sand pack material so that clear groundwater samples can be obtained. Well development was conducted with a sump and/or bottom discharge bailer, supplemented with a surge block.

The methods used to develop each well depended upon the well construction and the type of subsurface material in which the well was completed. Each well was developed until the well water was clear and sediment free, to the fullest extent practical.

The recommended acceptance/rejection value is five nephelometric turbidity units (NTU). This value is based on the need to minimize biochemical activity and possible interferences with groundwater sample quality. At a minimum, five times the water used during boring advancement plus five times the standing water in the borehole were removed. The majority of the time the wells were developed to below the 5 NTU criteria before this volume had been removed. There were several wells that could not be developed to below the 5 NTU criteria. If the well continued to yield turbid groundwater samples, the "Decision Chart for Turbid Ground-Water Samples" procedure described in EPA's Technical Enforcement Guidance Document (TEGD) was followed in an attempt to achieve turbidity-free water. As a minimum:

- In wells constructed in low permeability material, potable water was added to assist in the development of the well. No dispersing agents, acids, or disinfectants were used.
- During development of the 1000 and 2000 Series wells, water was removed from the well near the bottom of the well screen.
- During development of the 3000 and 4000 Series wells, water was removed from the upper part of the water column.

All equipment and materials used for well development were decontaminated in the same manner as the drilling equipment, before and after each use. The development equipment was also cleaned if, during well development, the equipment became visibly contaminated. In the case of visible contamination with soil, decontamination was by high-pressure hot-water wash, then a dilute-hydrochloric-acid wash, followed by two separate deionized water rinses. The internal mechanisms of the pumps were flushed using either dilute solutions of methanol and deionized water or dilute hydrochloric acid and deionized water.

The data recorded on the Monitoring Well Development form included:

- Well designation (location ID)
- Date(s) of well installation and date(s) and time of well development
- Static water level before and after development
- Quantity of water removed and time of removal
- Depth of open hole inside the well before and after development

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- Physical character of the removed water (including changes of turbidity, color, and odor) during development
- Physical character of removed sediments, to include lithology, grain size, and type
- Size/capacity of pump and/or bailer used
- Description of surge techniques, if used
- Field characteristics of water removed including pH, specific conductance, temperature, and dissolved oxygen

Management of Purge Water

All purge water collected during well development was contained in truck-mounted tanks and transported to the FMPC General Sump for disposal. Water samples were collected at the end of development and archived for future reference and/or analysis. Laboratory analysis was not required for disposal of purge water at the General Sump, based on previous testing results from purge water samples collected from "worst case" wells in the Waste Storage Area.

6.1.7 Field Screening and Laboratory Analysis of Subsurface Soil Samples

Immediately upon opening each split-spoon sample, the samples were screened for volatile organics using a photoionization detector, HNu, with 10.3 or 11.7 mev lamps. If a volatile release was detected, a soil sample of the core was transferred to two standard 40-ml VOA vials. HNu meters are sensitive to moist, cool field conditions and at times, when winds are calm, give high background readings by detecting exhaust fumes from the drilling equipment. During extreme cold and damp conditions in winter, Draeger tubes were therefore used to screen the samples for volatile organics.

Whenever volatile organics were detected and the HNu did not appear to be giving accurate measurements, a second instrument was used to confirm the first reading. Samples were also sealed in sample bottles and allowed to volatilize before a confirmation measurement was taken. If volatile organics were determined to be actually present in the soil sample, a representative portion of the sample was collected and analyzed for full Hazardous Substance List (HSL) volatile organics, semivolatile organics, inorganic metals, pesticides, and PCBs. At locations where more than one well was installed and volatile organics were present, a confirmation sample was collected from the second boring.

The samples were also screened for gross alpha, beta, and gamma. These measurements were recorded on the boring log. After the boring was completed and subsurface soil samples collected,

the samples were screened again for radionuclides utilizing a large-volume scintillation detector (SPA-3). The sample with the highest reading within each geologic horizon for each boring location was selected for full radiological analysis in the laboratory. If more than one sample from the same geologic unit had a similarly high reading, the project site field manager selected one of these samples for full radiological analysis.

Subsurface soil samples were selected for radiological analysis based on the results of the field screening. At least one sample from each of the four stratigraphic units at each well cluster location underwent radiological analysis. The sample selected for laboratory analysis was based on the highest relative reading for the given location and horizon.

All samples sent to the laboratory were tested for the set of radionuclides historically used, stored, or produced at the FMPC. These parameters were the same as those being analyzed under RCRA compliance monitoring and included:

- Gamma Spectral Analysis
- Total Uranium
- Uranium 234
- Uranium 235
- Uranium 236
- Uranium 238
- Radium 226
- Radium 228
- Technetium 99
- Thorium 228
- Thorium 230
- Thorium 232
- Cesium 137
- Strontium 90
- Ruthenium 106
- Neptunium 237
- Plutonium 238
- Plutonium 239
- Plutonium 240

6.1.8 Decontamination Procedures

Equipment and materials used for drilling, well installation, and well development were decontaminated before and between each use. The drilling equipment was normally decontaminated by high pressure hot-water washing (steam cleaning). All downhole drilling equipment and tools that came in contact with this equipment were decontaminated before and after each use. After decontamination, all downhole drilling equipment was wrapped in plastic to prevent inadvertent recontamination. The drill rigs and support vehicles were decontaminated between drilling locations.

Drilling equipment used to install wells outside the Production and Waste Storage areas, including the off-FMPC wells, was decontaminated at the decontamination pad constructed at the site field trailers, west of Waste Pit 5. Decontamination water was contained and disposed of at the General Sump, or analyzed for total uranium by WMCO and disposed of at the Inactive Fly Ash pile. Soil residue from the decontamination pad was sampled and analyzed by WMCO for total uranium. If

the analytical results were below the action limit specified by WMCO, the material was disposed on the Inactive Fly Ash pile. Decontamination water was supplied by the FMPC.

Drilling equipment used to install wells inside the Production and Waste Storage areas was decontaminated either at the Production Area decontamination area, located near Building 69, or at a location specified by WMCO near the General Sump. All downhole drilling equipment and tools were decontaminated by RI/FS personnel at the decontamination area near the General Sump, with water and steam supplied by the FMPC. All decontamination water and soil went directly into the General Sump. The drilling rigs and support vehicles were decontaminated at the Building 69 decontamination area by WMCO personnel.

Subsurface soil sampling equipment was decontaminated between each use at the drill site. The decontamination procedures consisted of first removing gross contamination with a potable water and nonphosphate detergent wash, followed by a tap water rinse. The samplers were then rinsed with methanol, followed by a final deionized water rinse. After decontamination, the samplers were either wrapped in plastic or stored in such a manner to prevent them from becoming contaminated before being used again.

Pumps and hoses used to develop wells were decontaminated between each use. The decontamination procedures consisted of first washing the outside of the equipment with high pressure hot water (steam cleaning). The inside of the pump and hoses were flushed with potable water. After decontamination, the equipment was wrapped in plastic until its next use.

6.1.9 Survey Procedures

All wells installed during the RI/FS were surveyed to establish the horizontal location of each well according to the Ohio State Planar Coordinate System. The elevation at the top of the measuring point on the well casing was also surveyed to provide vertical control for groundwater level measurements. Also surveyed were the ground surface and top of protective casing elevations at each well location. Horizontal coordinates were measured to an accuracy of less than 0.5 foot; elevations to an accuracy of less than 0.01 foot. Existing wells included in the monitoring network were also surveyed to provide elevation and location accuracy.

6.1.10 Quality Assurance and Quality Control

The field investigation was conducted in accordance with the approved Quality Assurance and Quality Control (QA/QC) program. The salient elements for QA/QC are discussed in the following sections.

6.1.10.1 Responsibilities

The Project Director is ultimately responsible for project QA/QC. To assist in this responsibility, an experienced project QA/QC Officer was assigned to the RI/FS, who reports to the Project Director and Corporate QA/QC Officer. The Project QA/QC Officer is assisted by the Project Technical Managers and various Task and Field Managers assigned to the project. These individuals are required to oversee and direct the field personnel in following the appropriate data collection procedures. Complete QA/QC is the obligation of every individual working on the project.

The QA Project Officer is responsible for guidance in the development of the QAPP and control of project QA/QC activities. The QA Project Officer provides the necessary guidance to the QA Field Representative, project and laboratory staff, and task managers on quality-related matters and performs project audits and surveillances. The QA Officer has the authority and responsibility to identify quality problems and initiate, recommend, or provide corrective actions. The QA Project Officer may take actions independent of the project group to stop the project for noncompliance with the QAPP.

A QA Field Representative reports to the Project QA Officer. This individual assists the Project QA Officer in the execution of the QAPP and control of project QA/QC activities. The QA Field Representative assists the field task managers and personnel with quality-related matters and assists the Project QA Officer in performing project audits and surveillances. The QA Field Representative is involved with the day-to-day field activities. He identifies quality problems and initiates, recommends, or provides corrective actions as they occur.

Additional QA/QC oversight is conducted by WMCO and other contractors retained by the DOE, EPA, and the OEPA. This oversight consists of field observations and document audits of the field records. Geraghty & Miller, Inc., is contracted by the DOE to conduct monthly oversight and field records auditing of all active field operations. PRC, Inc., is contracted by the EPA to observe field operations and procedures.

6.1.10.2 Field Audits

To verify compliance with QAPP requirements, the QA Project Officer and QA Field Representative and other technically qualified personnel have planned, performed, and documented audits of project field activities related to data collection. These audits consisted of, as appropriate, an evaluation of QA procedures and the effectiveness of their implementation, an evaluation of work areas and activities, and a review of project documentation. Audits have been performed in

accordance with a written checklist, as appropriate. Audit results have been formally documented and sent to the Project Director and upper management, as required.

Field audits have included, but have not been limited to, the following areas:

- Field operations work procedures and records
- Equipment calibration and records
- Identification and control of samples
- Numerical analyses
- Transmittal of information
- Record control and retention

Auditing has been performed in accordance with the QAPP and has remained consistent with the project scope. An individual audit plan has been developed to provide a basis for each task audit. The audit plan identified the audit scope, activities to be audited, audit personnel, applicable documents, and schedule. During each audit and upon completion, the auditor discussed the findings with the individuals audited and cited corrective actions to be initiated. Minor administrative findings which could be resolved to the satisfaction of the auditors during the audit were not cited as items requiring corrective action. All findings that could not be resolved during the course of the audit, and findings affecting the overall quality of the project regardless of when they are resolved, have been noted on the audit checklists.

Following completion of an audit, the auditor has prepared and submitted an audit report to the Project Director. This report has served to notify management of audit results. The report has also been sent to individuals contacted during the audit and the management of any affected subcontractor. The audit reports contain, as appropriate:

- Date of the audit
- Identification of audit participants
- Identification of activities audited
- Audit results
- Description of items requiring corrective action and, if possible, the means of correction
- Due date for completion of corrective actions and/or audit response
- Means for audit response

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If corrective action was required by the audit, it was taken as required by the QA Officer. If corrective action had not been taken in the time required, work impacted by the finding could have been stopped.

Audit responses have been prepared in writing by the various Task Managers, or appropriate personnel, and clearly state the corrective actions taken. If all corrective actions had not been completed prior to issuance of the audit response, a scheduled date for completion was provided. All requests for corrective action had to be addressed to the satisfaction of the QA Officer.

Completion of the corrective action was verified by the auditors through written communication, reaudit, or other appropriate means. After acceptance and verification of corrective actions, an audit closure report was issued to the same individual receiving the audit report. After acceptance and verification of corrective actions, an audit closure report was issued by the QA Officer.

Findings and Resolutions

Audits have been periodically conducted during the data collection field activities. All audits have been responded to, as required, and corrective actions taken. On several occasions, the audit findings led to necessary changes and revisions to the Work Plan, Sampling Plans, and QAPP. Revisions to the Sampling Plan or QAPP have been issued to holders of control copies of the Work Plan in the form of changed pages and additional pages.

6.1.10.3 Chain-of-Custody Procedures

The following procedures were used for environmental samples collected as part of the RI. Identical chain-of-custody procedures were used regardless of the source of the sample or the intended use of the results.

The following procedures were used in the chain-of-custody process for sample tracking and field activities:

- Sample identification and labeling
- Sample chain-of-custody form
- Sample collection log
- Laboratory request-for-analysis form

Examples of a sample label, chain-of-custody form, request-for-analysis form, and sample collection log are provided in the QAPP, Section 7.

Sample Identification and Labeling

Samples were marked for identification from the time of collection and packaging through shipping and storage. Sample identification markings were made on a label attached to the sample container and included:

- Project name and number
- Sample number
- Sample location (i.e., well number)
- Sampling date and time
- Initials of the individual(s) performing the sampling
- Sample preservative used

A sample number system was established for the purpose of identifying the samples according to location and type. Each sample collected during this investigation was assigned a unique sample number which was used to track the sample from collection through laboratory analysis, as described in the RI/FS Work Plan.

Chain-of-Custody Record

Documentation of the sample chain of custody was provided by the use of a chain-of-custody record that included the sample location, the type and amount of samples collected, the date and time of sample collection, the name(s) of the person(s) responsible for sample collection, the date and time of all custody transfers, the signatures of the individuals relinquishing and accepting sample custody, and other pertinent information.

Chain-of-custody procedures documented sample possession from the time of collection to disposal. A sample was considered in custody if it was:

- In one's physical possession
- In view, after being in physical possession
- Locked so that no one can tamper with it, after having been in physical custody
- In a secured area, restricted to authorized personnel

A chain-of-custody record was initiated in the field and accompanied each group of samples during shipment to the laboratory. Each time custody of the sample changed, the new sample custodian signed the record and indicated the date of transfer. If the samples were shipped to the laboratory by commercial carrier, the original chain-of-custody form was sealed in a watertight container, secured to the inside lid of the shipping container, and the shipping container custody sealed prior

to giving it to the carrier. If the samples were transported directly to the laboratory, the original chain-of-custody form was kept in the possession of the person who delivered the samples.

For samples shipped by commercial carrier, the waybill served as an extension of the chain-of-custody record between the final field custodian and receipt in the laboratory. The carrier waybill was attached to all chain-of-custody duplicates retained at the site. Upon receipt in the laboratory, the laboratory QC Coordinator, or representative, opened the shipping containers, compared the contents with the chain-of-custody record, and signed and dated the record. The QC Coordinator also recorded the carrier and waybill number on the original chain-of-custody form if not already present. The original chain-of-custody records, analytical data, and other project documentation have been maintained in a project file. Project files are stored in a central filing system pending disposition by the DOE.

A copy of the field chain-of-custody record is maintained in the Fernald RI/FS site office.

Sample Collection Log

A sample collection log was prepared for each sample to record information pertaining to the sample. The following information was required on the sample collection log, as appropriate:

- Unique sample number
- Sample location
- Collector initials
- Date and time sample collected
- Sample identification (type, media, sequence, blank, spike, duplicate, split)

Laboratory Request-for-Analysis Form

A laboratory request-for-analysis form was prepared to indicate the testing program required for the collected samples. The following information was recorded on the laboratory request-for-analysis form:

- Project name and number
- Date samples shipped
- Required report date and turnaround times for analysis
- Contact with telephone number for receipt of the analytical report and billing invoices

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- Sample identification numbers
- Sample volume collected and appropriate preservatives

Sample Tracking System

A sample tracking system is maintained in the RI/FS site office on a personal computer (PC). The sample number, type, requested analysis, and shipping date are entered into the relational data base on the PC. When analyses are received from the laboratory, they are logged into the tracking system to verify that the requested results have been received. The tracking also provides useful reports on the length of time samples have been in the laboratory.

Laboratory Sample Receipt

Upon sample receipt, the QC Coordinator or representative examined all samples and determined if proper temperature had been maintained during shipment. The receiving temperature was recorded on the chain-of-custody record. If samples had been damaged during shipment, the remaining samples were carefully examined to determine whether they had been affected. Any samples suspected of being affected were also considered damaged. It was noted on the chain-of-custody record which specific samples were damaged, and the damaged samples were removed from the sampling program. Field personnel were notified in writing as soon as possible about damaged samples, the probable cause of damage, and if they had to be resampled or the testing program changed.

The Laboratory QC Coordinator or representative performed the following:

- Compared samples received against those listed on the chain-of-custody record.
- Verified that sample holding times had not been exceeded. If the sample holding time had been exceeded, the QC Coordinator, or representative, notified the field personnel in writing that this had occurred and prepared a Nonconformance Report.
- Signed and dated the chain-of-custody record and attached the waybill to the chain-of-custody record.
- Placed the samples in appropriate laboratory storage.
- Entered the samples in the laboratory sample log-in book, which contains the following information:

  - Project identification number
  - Sample numbers
  - Types of samples
  - Date received in laboratory

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- Notified the laboratory manager or group leaders of sample arrival
- Placed the compiled chain-of-custody records in the project file

If samples arrived without chain-of-custody forms or with incorrect chain-of-custody records, the following actions were undertaken by the Laboratory QC Coordinator:

- If the chain-of-custody record was incorrect, a memorandum to the Project Director and field personnel was prepared stating the deviations. The memorandum was signed and dated by the person originating the chain of custody and by the QC Coordinator. The memorandum served as an amendment to the chain of custody. If the information on the chain-of-custody record could not be corrected by the QC Coordinator or the field personnel, the affected samples were removed from the sampling program.
- If the chain-of-custody record was not shipped with the samples, the field personnel were contacted and a memorandum prepared which listed the persons involved in collecting, shipping, and receiving the samples and the times, dates, and events. Each person involved signed and dated this memorandum. The completed memorandum was maintained in lieu of the chain-of-custody record.

Results of audit and responses are maintained in the project central files at the Fernald RI/FS field office.

Initiation of Testing Program

As stated in the QAPP Section 7, a request-for-analysis form submitted with the samples to the laboratory initiates the sample analysis. If the analytical program was not defined with the sample shipment, the QC Coordinator immediately notified the manager responsible for the work for definition of the analysis program.

The laboratory manager and group leaders have been responsible for prioritizing samples on the basis of holding time and required time needed to include the sample into the laboratory sample stream.

Sample Disposal

The chain of custody of the sample has been completed as part of sample disposal. There have been several possibilities for sample disposition:

- The sample may be completely consumed during analysis.
- Samples may be returned to the FMPC for disposal.

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- The samples may be stored after analysis. Proper environmental control and holding time had to be observed if reanalysis was anticipated. If reanalysis was not anticipated, environmental conditions for storage were not observed.

The laboratory manager has determined disposal of samples if not specified on the request-for-analysis form. The analyzing laboratory does not maintain samples or extracts longer than six months beyond completion of analysis, unless otherwise specified.

6.1.10.4 QA/QC Documentation

There are many forms of QA/QC-related reporting to various levels of management. Adequate provisions are made within the QAPP for reporting of quality-related considerations. Quality-related reports submitted to management include:

- The reporting of nonconformances by project personnel to project management.
- Reporting of the QC Coordinator to laboratory management concerning data accuracy and precision achieved through QC sample analysis and analyses of performance evaluating samples.
- Reporting of the QC Coordinator to laboratory management of nonconformances observed during internal laboratory system audits.
- Audits conducted by the QA Officer.

All field QA/QC records are maintained in central files at the Fernald RI/FS site office.

6.1.11 Results

The following sections discuss the results of the well installation program.

6.1.11.1 Boring Logs

Boring logs (Visual Classification of Soils) are presented in Appendix A. All elevations and well coordinates are based on Ohio State Planar Coordinates. Appendix A contains the Visual Classification of Soil forms completed as each boring was advanced under the RI/FS program from August 1987 through April 1990. Each form heading contains the boring number, coordinates of the boring, the ground surface elevation, the engineer or geologist who supervised the boring, the drilling method, and the dates the boring was started and completed. The body of the form records the sample depth, interval and number, sample type, hammer blows per sample interval, sample recovery, a description of the sample material, the Unified Soils Classification System (USCS) symbol, the measured consistency of the sample, and other remarks.

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6.1.11.2 Well Construction Diagrams

Piezometer installation sheets and monitoring well installation details are presented in Appendix B. All elevations and well coordinates are based on Ohio State Planar Coordinates. Appendix B contains the Monitoring Well Installation Record forms completed under the RI/FS program from August 1987 through April 1990. The forms contain the boring and well number; the engineer or geologist who supervised the installation; the person who checked the records on the form; the coordinates of the well; the date the installation was completed; the drilling method and fluid used; the bit type; the temporary casing type; the casing diameter; the well diameter, the screen size and length; and the riser pipe type, diameter, and length. The form also shows the well protection system, including the depth interval for the bentonite, sand, and well screen.

6.1.11.3 Special Observations

All special observations and noteworthy activities that occurred during drilling, well installation, or other related activities at the well site not recorded on the Visual Classification of Soils forms or well installation forms are documented in the Field Activity Daily Logs. These logs are filed by the field activity and sampling crew at the site office central files.

6.2 Groundwater Elevation Program

6.2.1 Objectives

Starting in January 1988, water level measurements were taken in developed RI/FS wells and wells installed from previous investigations. The network was expanded as additional RI/FS wells were installed. The purpose of these measurements was to map the water table and potentiometric surface in the glacial overburden and Great Miami Aquifer and evaluate the effects of seasonal variations. During the water level measurement period, the site experienced extreme dry and wet periods. Water-level measurements are still being taken monthly from all the network wells; however, for this report, only data through April 1990 are reported.

Water level measurements have only been collected from RI/FS wells that have been developed. This ensures accurate water level measurements. Data are not collected from wells that have not recovered from well development, hydraulic conductivity testing, groundwater sampling, or any other activity that may have influenced the water level of the well. Water level measurements were not collected from off-FMPC private water supply wells. Some water level data are available from these private wells and have been used in previous studies.

Initially, water level measurements for all wells in the network were completed within a two-day period. At the completion of the last well measurement on the second day, the first five wells measured the previous day were remeasured to determine if significant water level fluctuations occurred. Water level measurements were collected during this short time frame so that they would represent water level measurements at a single point in time. As more wells were completed and the well network expanded, it was difficult to complete the monthly measurement within the two-day period. The time required to collect the monthly data has gradually increased to four days.

6.2.2 Scope

The purpose of monthly water level measurements in the well network is to evaluate the groundwater flow, direction, and seasonal fluctuation within the aquifer of interest. This is done by preparing maps of the water table and potentiometric levels in the glacial overburden and Great Miami Aquifer. The approved RI/FS Work Plan indicated that the network wells were to be monitored monthly for one year to evaluate the effects of seasonal variations on the water levels. At the conclusion of the initial year, however, wells were still being installed under addenda to the RI/FS. It was decided, therefore, to continue monthly measurements and to add wells into the network as they are completed and developed. By continuing to collect water level data from the existing and additional wells within the network, the hydrogeologic conditions at the site can be further and more completely evaluated.

The monthly water level measurements were collected from the existing well network during the last week in each month. This timing varied, depending on weather and well conditions. During quarterly groundwater sampling, the water level does not return quickly to static conditions in many 1000 Series wells. Therefore, adequate time must be allowed for the low yield wells to recover before the wells are measured. Water level measurements have usually been collected after the weekend break to assure that all the wells have adequately recovered from groundwater purging or sampling.

Appendix C contains tabulated groundwater elevation data for all the monitoring wells installed under or used by the RI/FS. Included in this appendix is a listing of wells in the network and dates the measurements were taken. The tables contain the well number and well coordinates, as well as the elevations of the top of the well, top of the protective casing, ground level, and top of the concrete pad, all with respect to mean sea level. The table also provides the depth to water reading, the calculated water elevation, the reference point used for the measurement, and the date of the reading. The column titled "Type of Well" provides a single digit code to inform the reader of where the wells are located. The key to the code is provided at the bottom of the table.

6.2.3 Methods

Water level measurements were and continue to be taken to the nearest 0.01 foot with an electrical probe, referenced to the measuring point on top of the well casing. All data are recorded on the appropriate field logs.

The following procedures have been followed for collecting water level data from RI/FS and other FMPC study wells:

- The well protective casing is unlocked and inner well casing cap removed.
- In wells with known organic contamination, the head space in the well is field screened for the presence of volatile organics using a photoionization detector, HNU. If volatiles are present, the well is allowed to stand open. Only after field screening indicates the volatiles have dissipated, is the water level measurement made.
- After access to the well is made, a clean electric probe is lowered into the well until water is reached. The probe is lifted above the water level and shaken to remove any water drops that are clinging to the probe. This process is repeated until like measurements are achieved.
- The water level measurements are recorded with the time and date. The exact measurement reference point on the well is also noted.

To prevent cross contamination between wells in the network, all downhole water level measurement equipment is decontaminated between uses. Because there is only minimal contact of the water level probe in each well, the probe and measuring tape are decontaminated by rinsing with deionized water. If the well being measured is known to be grossly contaminated or if the probe and/or measuring tape becomes visibly contaminated, the equipment is either decontaminated with high pressure/hot water (steam cleaner) at the decontamination area, or scrubbed with a tap water/nonphosphate detergent mixture followed by a methanol rinse and a final deionized water rinse. When not in use, the water level equipment is stored in plastic.

6.2.3.1 Instruments

Electric water level indicators are used to measure the depth to water in the well network. These indicators operate by passing a small electric current through a wire inside the measuring tape to the probe, which is equipped with a small needle point. When the needle point contacts water, the electric circuit is completed with the probe housing and either a meter needle is deflected or a light or buzzer turns on. The measuring tapes are 150 feet in length and are graduated to 0.10 foot. Measurements are made to 0.01 foot by interpolating between the graduations.

6.2.3.2 Calibration

The water level indicators are calibrated upon arrival at the site and whenever routine maintenance is conducted. Calibration consists of comparing the tape graduations with a commercially purchased steel tape with 0.01-foot graduations. The entire length of measuring tape is examined to guarantee that there are no splices that could cause erroneous results. Periodic maintenance to the equipment involves cleaning the needle points, replacing the disposable batteries, and replacing end probes.

6.2.3.3 Precision and Accuracy

When water level measurements were collected, readings were taken several times until a minimum of three consecutive measurements were made. This technique was used to ensure that a correct measurement was made that was not influenced by outside factors, such as condensation on the inner well casing that would set off the probe. Only the final consistent measurement value was recorded on the water level elevation log.

Monthly water level measurements were made using two teams, each with similar instruments, calibrated to the same reference tape. To ensure consistency, the current water level measurement program employs one team, using the same instrument for all monthly measurements.

6.2.3.4 Reference Points on Wells

Reference points on the RI/FS wells are "V" notches that were either cut or filed into the stainless steel well casing. Reference points on the network wells from previous FMPC investigations are either "V" notches in the PVC or iron well casing, or permanent marks made on the well casing. Reference marks vary on the off-FMPC private water supply wells, but are consistently used for water level measurements. All reference points are clearly noted on the water quality collection form. All well survey elevations and coordinates are taken with respect to the well reference marks.

To investigate water level relationships between groundwater in the Great Miami Aquifer and Paddys Run, electronic transducers and data loggers were installed in March 1988 in Wells 1009, 2009, 1014, 2014, and 3014, located adjacent to Paddys Run. Stream stages were also measured at stilling wells installed in Paddys Run adjacent to the wells. These wells were not surveyed until April 1988, so the first month of data measurement was recorded using an artificial datum and later adjusted to the surveyed elevation. Subsequent data were recorded using the surveyed elevation. Water levels have been recorded continuously over intervals of wet and dry periods through April 1990.

6.2.4 Results

Water level measurement results for the 1000, 2000, 3000, and 4000 Series well networks from January 1988 through April 1990 are tabulated in Appendix C. Hydrographs of selected 1000, 2000, 3000, and 4000 Series wells are presented in Appendix D. Appendix D contains groundwater elevation hydrographs from monthly water table readings in all the monitoring wells used in the RI/FS from January 1988 through April 1990. The hydrographs present water table elevation versus time.

Hydrographs are presented for individual 1000 Series wells since they represent water levels in the perched water system. Hydrographs for the 2000, 3000, and 4000 Series wells are presented by location number, with all the wells in the cluster at a given location reported in one figure. This provides an easy assessment of the vertical gradient between these wells as well as the distribution of head over time.

6.3 GROUNDWATER QUALITY PROGRAM

6.3.1 Objectives

The hydrogeologic field program focused on determining the effect that the operations and waste disposal practices at the FMPC have had on groundwater. The overall objectives of the groundwater quality program were to:

- Determine if subsurface water-bearing zones below the FMPC have been contaminated either within or off-FMPC property
- Determine the source areas of contaminants at the FMPC and indicate migration of hazardous substances off property
- Determine the effects groundwater pumping and resulting recharge/discharge relationships have on groundwater quality
- Define areas of subsurface contaminant migration and groundwater discharge
- Determine the vertical and horizontal extent of groundwater contamination from the FMPC

To achieve the program objectives, a phased approach to field activities was planned. The first major phase of work concentrated on filling principal data requirements in the regional groundwater quality, near-specific potential sources, pathways, and receptors. Subsequent data collection and evaluation efforts have contributed to refinements in the program.

6.3.2 Scope

Initially, 89 monitoring wells were to be installed during the RI/FS. The well locations were selected based on data requirements identified from previous groundwater studies and sampling results from existing wells at the FMPC and the immediate vicinity. The existing well locations were used to the maximum extent possible in establishing a monitoring network for the investigation. Well depths at each location were selected to provide necessary information on the water-bearing zones of concern. Additional well installation programs, as discussed in Section 6.1.2, were subsequently initiated on the basis of results from the first two and later rounds of quarterly samplings.

Quarterly sampling was conducted under the RI/FS from the second calendar quarter of 1988 through the first calendar quarter of 1989. RI/FS wells that had not been completed by the start of the first quarterly sampling were sampled quarterly until four quarters of sampling had been completed. Wells installed under addenda to the RI/FS were sampled at the time of installation and the next calendar quarter. Quarterly water sampling under the RI/FS ended in July 1989. Beginning in June 1989, the revised RCRA sampling program was conducted by the RI/FS sampling crews. Samples collected in June, August, and November 1989 by the RI/FS sampling crew are included in the RI/FS data set. Other data collected by the RI/FS sampling team as a result of the continued installation of additional wells are also included as available through April 1990. Beginning in the first calendar quarter of 1990, the responsibility for routine groundwater monitoring was shifted to WMCO, under the "Long Term Groundwater Monitoring Program" at the FMPC (WMCO 1989). Data from this sampling will be made available to the RI/FS.

Appendix E contains tabulated groundwater quality data for all the groundwater samples collected under the RI/FS from the second quarter 1988 through the fourth quarter 1990. The table format presents the chemical parameter in the left column, and the quarterly analyses for that well to the right of the parameter. In wells where more than four samples have been analyzed, the remainder of the analyses are presented on the following page. Analyses from only one well appear on a page. The heading over the analytical result gives the well number, the unique sample number, and the date the sample was collected. Duplicate samples collected for QA/QC purposes are included in the tables.

A total of 152 wells were originally identified for groundwater sampling. Groundwater samples were collected from the new RI/FS wells, selected existing wells at the FMPC, and selected off-FMPC private wells. The RI/FS wells originally included forty-two 1000 Series, twenty-two 2000 Series, twenty-two 3000-Series wells, and three 4000 Series wells. Forty-five additional wells

existed on site, including three new RCRA wells and five off-FMPC wells then being sampled under the RCRA monitoring program. Additionally, approximately six glacial overburden wells, six upper Great Miami Aquifer wells, and six bottom of Great Miami Aquifer wells, were selected at upgradient locations and sampled to establish background concentrations. As wells and piezometers were added to the RI/FS through addenda to the Work Plan, they were incorporated into the groundwater sampling well network. The number of wells used for groundwater quality sampling is greater than the number of wells used for water level measurements, because it includes private wells where water levels cannot be measured. The RI/FS wells included in the RCRA monthly sampling are summarized in Table 6-7.

Since the selection of each new well was specifically justified within the context of the existing monitoring well network, it was necessary to analyze all groundwater samples for a full suite of radiological parameters and a more focused set of general water quality indicators to achieve the overall study objectives. All samples were analyzed in the field for pH, temperature, conductivity, dissolved oxygen, and iron. All groundwater samples were analyzed for a set of radiological parameters that include those radionuclides or materials handled at the FMPC. These parameters are also consistent with those being tested under the ongoing RCRA monitoring program and include:

- Total Uranium
- Isotopic Uranium
- Isotopic Plutonium
- Radium-226
- Radium-228
- Neptunium-237
- Total Thorium
- Isotopic Thorium
- Technetium-99
- Cesium-137
- Strontium-90
- Ruthenium-106

All groundwater samples were also analyzed for the following parameters used as indicators of drinking water quality under the ongoing RCRA program:

- pH
- Specific Conductance
- Chloride
- Iron
- Manganese
- Phenols (total)
- Sodium
- Sulfate
- Gross alpha
- Gross beta
- Alkalinity as $CaCO_3$
- Carbonate/Bicarbonate
- Copper
- Nickel
- Arsenic
- Barium
- Cadmium
- Chromium (Total Hexavalent)
- Fluoride
- Lead
- Mercury
- Nitrate
- Selenium
- Silver
- Ammonia
- Total Organic Nitrogen
- Molybdenum
- Calcium

TABLE 6-7
RI/FS WELLS INCLUDED IN THE WELL SAMPLING

Well No.[a]	Location
1024, 1052	Upgradient, Glacial Overburden Wells
1004, 1025, 1027, 1028, 1030 1031, 1038, 1072, 1074, 1079 1080, 1081, 1082, 1083	Downgradient, Glacial Overburden Wells
2043/3043, 2066/3066	Upgradient, Great Miami Aquifer Wells
2010/3010/4010, 2013/3013/4013, 2019/3019, 2021, 2027, 2037/3037, 2051/3051, 2055/3055, 2084/3084, 3001/4001, 3008/4008, 3024.	Downgradient, Great Miami Aquifer Wells

[a]Refer to Figures 6-2 through 6-5 for locations of the wells.

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- Potassium
- Phosphate
- Magnesium
- Sodium

The analyses of groundwater samples for organics and other toxic inorganics were performed on a limited basis. The reason for this reduced scope is twofold:

- The RCRA groundwater monitoring program that was established prior to the RI/FS included analyses for organics and metals on a quarterly basis at 44 on-FMPC and off-FMPC wells.

- The frequency and levels of detection of organic species in samples collected before the RI/FS in the RCRA program were insignificant when compared to the radiological problem that exists in the groundwater underlying the FMPC and adjacent areas.

To confirm that the organic species detected in the RCRA program are relatively insignificant, 36 selected groundwater samples were analyzed for HSL volatile and semivolatile organics, HSL inorganics (including cyanide), HSL pesticides/PCBs, primary drinking water organics, and organophosphorus pesticides. These analyses are termed the "extended HSL parameters." The wells that were sampled for the extended HSL parameters were selected to augment the quarterly RCRA monitoring program. These included the following 29 wells in or near the Waste Storage Area:

1000 Series		2000 Series	
1004	1072	2001	2001
1100	1073	2004	2002
1109	1074	2008	2027
1021	1075	2010	2034
1025	1076	2011	2037
1028	1078	2019	2042
1029	1083	2020	2052
1031			

Wells 1016, 2014, 2015, and 2016 near the fly ash piles, as well as Wells 1013, 2064, and 2065 near the Production Area, were also sampled and analyzed for the extended HSL parameters. In addition, samples from six wells in the Waste Pit Area were analyzed for dioxin, 2,3,7,8-TCDD/TCDF, and PCDD/PCDF. The specific well locations were selected following well development, with emphasis on their proximity to the Burn Pit, Pit 4, and the sanitary landfill, and on the likelihood of having received chlorinated hydrocarbons. A sample of treated water from the FMPC production well was also analyzed for the extended HSL parameters and dioxins. This water was used in the drilling operations.

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6.3.3 Groundwater Sampling Techniques

6.3.3.1 Well Purging

The primary consideration in groundwater sampling is to obtain a representative sample of the groundwater body. To safeguard against collecting nonrepresentative stagnant water from a well or piezometer, the following guidelines and techniques for well purging were followed during sample withdrawal:

- A minimum of three well volumes of water were pumped or bailed from all monitoring wells prior to collecting a sample. For wells that could not be pumped or bailed dry, at least three well volumes of water were purged before sample collection.

- For wells or piezometers that could be pumped or bailed dry, the well was evacuated and allowed to recover prior to sample withdrawal. If the recovery rate was fairly rapid and if time allowed, more than one volume of water was evacuated from the well; otherwise, sampling was conducted after sufficient recovery had occurred to allow sampling.

- After the well adequately recovered, water samples were collected in accordance with a priority list that was based on the stability and volatility of the parameter being analyzed. Samples to be used for the analysis of parameters that are unstable and volatile such as HSL volatile organic compounds, pH, specific conductance, and temperature were collected first. Samples associated with parameters that are less sensitive were sampled next.

- A stainless steel submersible pump was used to purge the 3000 and 4000 Series wells prior to sample collection. A water-level measurement was taken to determine the depth to groundwater in the casing, then the submersible pump was lowered to a depth of five to ten feet below the water level, but always above the well screen. The well was initially purged from this depth so that water from the formation passed through the screened interval and moved upward through the casing to completely flush the well. The pumping rate was maintained at less than 20 gallons per minute (gpm) and continued until field pH, temperature, and specific conductance readings stabilized.

- A stainless steel submersible pump and/or stainless steel and teflon positive displacement pump was used to purge the 2000 Series and selected 1000 Series wells prior to sample collection. A water-level measurement was initially taken to determine the depth to groundwater in the casing, then the pump was lowered to a depth of five to ten feet below the water level and a minimum of five feet above the bottom of the well, if possible. The pumping rate was maintained at less than 20 gpm and continued until field pH, temperature, and specific conductance readings stabilized.

- All purge pumps and lines were decontaminated following the sampling of each well using procedures specified in the RI/FS Work Plan (ASI/IT 1988).

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6.3.3.2 Sample Collection

Sample collection was performed using the following procedures:

- Once the well was purged and allowed to recharge, samples were collected using a stainless steel submersible pump, stainless steel and teflon positive displacement pump, or teflon bailer.
- During sampling, the pump was operated continuously, but the flow rate was reduced to approximately one liter/minute.
- Volatile organic compound samples were always collected with a bailer.
- Water samples were collected at the discharge hose if the submersible or positive displacement bladder pump was used. If the water samples were collected with a teflon bailer, the water sample was collected by pouring directly into the sample bottle from the bailer.
- When the pump and lines were removed from a well, they were placed on plastic sheeting to avoid contact with the ground.

To more efficiently collect the groundwater samples, the sampling team often sampled the well with a teflon bailer after the well purging pump was removed from the well.

6.3.3.3 Sample Filtration (As Appropriate)

When sampling for dissolved metals or radionuclides in water, the samples were filtered in the field as soon as possible after collection. The following procedures were used in this process:

- The water sample was either filtered at the well site with portable sample filtering equipment or taken to the sample collection trailer for filtration. When sampling several wells in one day, it was more efficient to transport the samples to the sample collection trailer for filtration.
- A Millipore filtration apparatus equipped with a 0.45-micron filter was used. A hand vacuum pump was used in the field and a peristaltic pump was used at the sample collection trailer to draw the sample through the filter.
- The filtering apparatus was cleaned by rinsing thoroughly with deionized water before filtering each sample.
- The first 100 to 150 ml of filtrate from each sample was discarded to rinse the filter and filtration apparatus of any residual substances.
- After the sample was filtered, it was immediately transferred to the appropriate sample bottle containing the correct preservative.
- Samples that were excessively turbid were prefiltered before final filtration with the 0.45 micron filter. The prefilter mesh size depended on the amount of suspended material in the sample.

6.3.3.4 Sample Preservation

All water samples submitted for analysis were preserved prior to final packaging and shipment to the laboratory, as required in Section 6.0 of the QAPP.

Immediately after the water samples were collected, the sample bottle was properly labeled, placed in a cooler packed with artificial icing material, and with a temperature of 4 degrees Celsius. The samples were delivered to the sample collection trailer for final packaging and shipment to the laboratory. When the samples were repacked, fresh artificial icing material was placed in the shipping cooler to maintain the sample temperature at or below 4 degrees Celsius. When sampling during hot weather, the samples were delivered to the site sample collection trailer more frequently to ensure the temperature of the sample was maintained at 4 degrees Celsius.

Samples analyzed for volatile organic compounds, acid and base-neutral extractable compounds, pesticides/PCBs, and general chemistry parameters were preserved by cooling to 4 degrees Celsius. Samples analyzed for dissolved metals were preserved first by filtration, then with concentrated nitric acid (less than pH 2) and cooled to 4 degrees Celsius. Samples analyzed for dissolved radionuclide parameters were first filtered and then preserved by cooling to 4 degrees Celsius.

6.3.3.5 Sample Numbering

Each groundwater sample was assigned a unique sample number in the field. The sample number was used to track the sample from the sampling well to the analyzing laboratory. At the laboratory, the sample was assigned a laboratory sample number that was used to track the sample through the laboratory. Laboratory certificates of analysis list both the field sample number and laboratory sample number for easy cross reference.

The field sample numbers were assigned sequentially in the order the wells were sampled for each quarter. The sample numbers assigned to the groundwater samples start with 07001 and go to 08999. All sample numbers were referenced to a master sample collection log that lists all the sample numbers, well numbers, times and dates of sampling, sampling teams, and types of samples collected.

6.3.3.6 Sample Packaging and Shipping

Samples were shipped to the analyzing laboratory by several means. The groundwater samples were shipped primarily by overnight carrier. The samples were properly packaged and labeled for shipment and dispatched to the analyzing laboratory for analysis, as specified in Section 6.0 of the

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QAPP. Separate chain-of-custody and request-for-analysis records accompanied the samples to the receiving laboratory. The following requirements for shipping containers were used:

- Field personnel shipped samples in accordance with the provisions of U.S. Department of Transportation (DOT) regulations covering the transport of hazardous materials contained in the Code of Federal Regulations (CFR) Title 49, Parts 170-179, and with IT's Manual of Practice: Sample Packaging and Shipment.

- Shipping containers were custody-sealed for shipment with filament tape wrapped around the container and a custody seal affixed at appropriate access points. Access to the container could be gained only by cutting the filament tape and breaking the seal.

- Shipping cooler containers were secured by field personnel with a proper custody seal, marked with indelible pen or ink, and addressed to the appropriate laboratory.

- Field personnel made arrangements for transportation of samples. When custody was relinquished to a shipper, field personnel telephoned the receiving laboratory custodian to report the expected time of arrival of the sample shipment and the existing time constraints (holding times) for sample analysis.

The following guidelines were used for sample packaging to avoid breakage and/or cross contamination:

- Sample container lids were never mixed. Sample lids stayed on the original container until time of sampling. Sample containers were only opened at the time of sampling. The original sample containers arrived in the field in packages with custody tape affixed at the appropriate access points. When sample container packages were received in the field, the chain-of-custody form for shipping the empty containers to the field was appropriately marked to state if the custody seal was affixed when the package arrived.

- After a sample was placed in the appropriate container and preserved, the sample container was placed in a plastic bag to minimize the potential for contamination from vermiculite or other packing material. Sample containers were placed between cardboard inserts or other appropriate packing material (i.e., bubble wrap). Care was taken not to insulate the sample from the artificial icing material, which would cause the sample temperature to rise above 4 degrees Celsius.

- Shipping coolers with containers were filled initially with approximately three inches of vermiculite or a suitable noncombustible, absorbent packing material.

- The secured sample containers were placed in the cooler in such a way that they do not touch. Other additional container protection was used as required.

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- Commercially available artificial icing material was used. If artificial ice was unavailable, ice was substituted provided that it was placed in a plastic bag.
- Remaining space in the cooler was filled with inert packing material.
- The original chain-of-custody and request-for-analysis records were placed in a plastic bag and taped to the bottom of the cooler lid.
- Upon arrival at the laboratory, the QC Coordinator, or representative, examined the contents of the shipping container and documented on the chain-of-custody record if any sample containers did not have the custody tape affixed.

6.3.3.7 Sample Chain of Custody

The following procedures were used for all groundwater samples collected under the RI regardless of the source of the sample or the intended use of the results:

- Sample identification and labeling
- Sample chain-of-custody form
- Sample collection log
- Laboratory request-for-analysis form

A detailed discussion of the sample chain of custody is presented in Section 6.1.10.3. The following is a summary of that material.

Sample Identification and Labeling

All samples were adequately marked for identification from the time of collection and packaging through shipping and storage. Marking was made on a label attached to each sample container. Sample identification included project name and number, sample number, sample location by well number, sampling date and time, the initials of the individual(s) performing the sampling, and sample preservative used.

Chain-of-Custody Record

Documentation of the sample chain of custody was provided by a chain-of-custody record that included the sample location, the type and quantity of sample collected, the date and time of sample collection, the name(s) of the person(s) responsible for sample collection, the date and time of all custody transfers, the signature of the person relinquishing and accepting sample custody, and other pertinent information. Chain-of-custody procedures documented sample possession from the time of sample collection to sample disposal.

If the samples were shipped to the laboratory by commercial carrier, the original chain of custody was sealed in a watertight container, placed in the shipping container, and the shipping container sealed with custody tape prior to giving it to the carrier. The carrier waybill served as an extension of the chain-of-custody record between the final field custodian and receipt in the laboratory. The carrier waybill was attached to all chain-of-custody duplicates retained at the site.

Upon receipt in the laboratory, the QC Coordinator, or representative, opened the shipping containers, compared the contents with the chain-of-custody record, and signed and dated the record. The QC Coordinator also recorded the carrier and waybill numbers on the original chain-of-custody form. All original chain-of-custody records, analytical data, and other project documentation are maintained in the site project files.

Laboratory Request-for-Analysis Form

The laboratory request-for-analysis form was prepared to indicate the testing program required for the collected samples. The information recorded on the laboratory request-for-analysis form included project name and number, date samples shipped, required report date and turnaround times for analysis, contact with telephone number for receipt of the analytical report and billing invoices, sample identification numbers and sample volume collected, and appropriate preservatives.

Initiation of Testing Program

A request-for-analysis form was submitted with each group of samples sent to the laboratory. If the analytical program was not clearly defined with the sample shipment, the laboratory immediately notified the field personnel for definition of the analysis program.

Sample Disposal

The chain of custody for the sample was completed when the sample was disposed of. The possibilities for sample disposition included:

- The sample was consumed during analysis.
- Sample was returned to the FMPC for disposal.
- The sample was stored after analysis. Proper environmental control and holding time were observed if reanalysis was anticipated. If reanalysis was not anticipated, environmental conditions for storage were not observed.

6.3.3.8 Decontamination Procedures

The groundwater sampling equipment was decontaminated prior to each use. The purge and sampling pumps and lines were drained and the outside surfaces decontaminated with a high

pressure hot-water wash and rinsed with deionized water. The internal surfaces were decontaminated by pumping deionized water through the pump system.

The sampling equipment decontamination procedures varied, depending on the type of contamination anticipated at the sampling location. In the case of inorganic contaminants, the equipment was first washed with a nonphosphate detergent, then rinsed with dilute 0.1 normal hydrochloric acid followed by two separate deionized water rinses. In the case of organic contaminants, the equipment was first washed with a nonphosphate detergent, then rinsed with tap water, methanol, and two separate deionized water rinses. Sampling equipment was never placed directly on the ground or on other potentially contaminated surfaces. The equipment was wrapped in or placed on a clean plastic sheet between wells.

As part of the RI/FS QC requirements, one sample of the final deionized water rinse was collected. This rinsate sample was analyzed at a frequency of one per every set of twenty samples, to check for potential cross contamination between monitoring wells.

Decontamination of the submersible sampling pump(s) and other sampling equipment was performed at a designated central staging area at the FMPC. If it was not practical to transport the equipment to the decontamination areas, the sampling equipment was decontaminated in the field.

6.3.4 Purge Water Management

Prior to groundwater sampling, three to five times the volume of water standing in the well was required to be purged from each well. The purge water from on- and off-FMPC wells was contained at the well site and transported to the FMPC General Sump for treatment prior to release.

To determine if the FMPC General Sump was adequate to treat and dispose of purge water from RI/FS wells, selected wells were purged and the resultant water was analyzed, as specified in the RI/FS Work Plan Section 4.2.1.3. Well development was initiated at Well 1084, and a sample of the development water was analyzed for the extended HSL parameters, dioxins, 2,3,7,8-TCDD/TCDF and PCDD/PCDF.

The analytical results for the sample for Well 1084 are summarized in Table 6-8. After review of the purge water analytical results by the EPA, authorization was given to dispose of all purge water at the FMPC General Sump. All development and purge water from the wells or piezometers, both on- and off-FMPC, was transferred to the General Sump for treatment at the FMPC wastewater treatment system, prior to discharge to the Great Miami River.

TABLE 6-8

WELL 1084 WATER ANALYTICAL RESULTS
MARCH 7, 1988

Metals	Concentration (ug/L)
Aluminum	90.0 B
Antimony	60.0 U
Arsenic	10.0 U
Barium	96.0 B
Baryllium	0.2 U
Cadmium	4.7
Calcium	139,000
Chromium	5.2 U
Cobalt	5.8 U
Copper	167
Iron	34.0 B
Lead	5.0 U
Magnesium	61,100
Manganese	57.0
Mercury	0.2 U
Nickel	12.1 U
Potassium	5,000 U
Selenium	5.0 U
Silver	10.0 U
Sodium	32,900
Thallium	10.0 U
Vanadium	19.0 B
Zinc	134
Cyanide	10.0 U

See footnotes at end of table.

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TABLE 6-8
(continued)

Volatile Organics	Concentration (ug/L)
Chloromethane	10 U
Bromomethane	10 U
Vinyl Chloride	10 U
Chloroethane	10 U
Methylene Chloride	4 J
Acetone	4 J
Carbon Disulfide	5 U
1,1-Dichloroethene	5 U
1,1-Dichloroethane	5 U
1,2-Dichloroethene (total)	5 U
Chloroform	5 U
1,2-Dichloroethane	5 U
2-Butanone	10 U
1,1,1-Trichloroethane	5 U
Carbon Tetrachloride	5 U
Vinyl Acetate	10 U
Bromodichloromethane	5 U
1,2-Dichloropropane	5 U
cis-1,3-Dichloropropene	5 U
Trichloroethene	5 U
Dibromochloromethane	5 U
1,1,2-Trichloroethane	5 U
Benzene	5 U
trans-1,3-Dichloropropene	5 U
Bromoform	5 U
4-Methyl-2-Pentanone	10 U

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TABLE 6-8
(continued)

Volatile Organics	Concentration (ug/L)
2-Hexanone	10 U
Tetrachloroethene	5 U
1,1,2,2-Tetrachloroethane	5 U
Toluene	5 U

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TABLE 6-8
(continued)

Semivolatile Organics	Concentration (ug/L)
Chlorobenzene	5 U
Ethylbenzene	5 U
Styrene	5 U
Xylene (total)	5 U
Phenol	10 U
bis (2-Chloroethyl) ether	10 U
2-Chlorophenol	10 U
1,3-Dichlorobenzene	10 U
1,4-Dichlorobenzene	10 U
Benzyl alcohol	10 U
1,2-Dichlorobenzene	10 U
2-Methylphenol	10 U
bis (2-Chlorisopropyl) ether	10 U
4-Methylphenol	10 U
N-Nitroso-di-n-propylamine	10 U
Hexachloroethane	10 U
Nitrobenzene	10 U
Isophorone	10 U
2-Nitropheno	10 U
2,4-Dimethylphenol	10 U
Benzoic acid	50 U
bis (2-Chloroethoxy) methane	10 U
2,4-Dichlorophenol	10 U

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TABLE 6-8
(continued)

Semivolatile Organics	Concentration (ug/L)
1,2,4-Trichlorobezene	10 U
Naphthalene	10 U
4-Chloroaniline	10 U
Hexachlorobutadiene	10 U
4-Chloro-3-methylphenol	10 U
2-Methylnaphthalene	10 U
Hexachlorocyclopentadiene	10 U
2,4,6-Trichlorophenol	10 U
2,4,5-Trichlorophenol	50 U
2-Chloronaphthalene	10 U
2-Nitroaniline	50 U
Dimethylphthalate	10 U
Acenaphthylene	10 U
2,6-Dinitrotoluene	10 U
3-Nitroaniline	50 U
Acenaphthene	10 U
2,4-Dinitrophenol	50 U
4-Nitrophenol	50 U
Dibenzofuran	10 U
2,4-Dinitrotoluene	10 U
Diethylphthalate	10 U
4-Chlorophenyl-phenylether	10 U
Fluorene	10 U
4-Nitroaniline	50 U

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TABLE 6-8
(continued)

Semivolatile Organics	Concentration (ug/L)
4,6-Dinitro-2-methylphenol	50 U
N-Nitrosodiphenylamine (1)	15 U
4-Bromophenyl-phenylether	10 U
Hexachlorobenzene	10 U
Pentachlorophenol	50 U
Phenanthrene	10 U
Anthracene	10 U
Di-n-butylphthalate	10 U
Fluoranthene	10 U
Pyrene	10 U
Butylbenzylphthalate	10 U
3,3-Dichlorobenzidine	20 U
Benzo(a)anthracene	10 U
Chrysene	10 U
bis(2-Ethylhexyl)phthalate	4 BJ
Di-n-octyl phthalate	10 U
Benzo(b)fluoranthene	10 U
Benzo(k)fluoranthene	10 U
Benzo(a)pyrene	10 U
Indeno(1,2,3-cd)pyrene	10 U
Dibenz(a,h)anthracene	10 U
Benzo(g,h,i)perylene	10 U
1-Hexadecyne	54 BJ

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TABLE 6-8
(continued)

Pesticides Organics	Concentration (ug/L)
alpha-BHC	0.25 U
beta-BHC	0.25 U
delta-BHC	0.25 U
gamma-BHC (Lindane)	0.25 U
Heptachlor	0.25 U
Aldrin	0.25 U
Heptachlor epoxide	0.25 U
Endosulfan I	0.25 U
Dieldrin	0.50 U
4,4'-DDE	0.50 U
Endrin	0.50 U
Endosulfan II	0.50 U
4,4'-DDD	0.50 U
Endosulfan sulfate	0.50 U
4,4'-DDT	0.50 U
Methoxychlor	2.5 U
Endrin ketone	0.50 U
alpha-Chlordane	2.5 U
gamma-Chlordane	2.5 U
Toxaphene	5.0 U
Aroclor-1016	2.5 U
Aroclor-1221	2.5 U
Aroclor-1232	2.5 U
Aroclor-1242	2.5 U

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TABLE 6-8
(continued)

Pesticides Organics	Concentration (ug/L)
Aroclor-1248	2.5 U
Aroclor-1254	5.0 U
Aroclor-1260	5.0 U

B - Compound was found in the method blank.

J - Compound detected, but below the contract required quantitation limit. The value given was an estimate.

U - Compound analyzed for, but not detected at the detection limits shown.

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6.3.5 Laboratory Screening

Groundwater samples from the RI/FS wells undergo radiological screening at the IT Oak Ridge Laboratory to classify the samples into one of three categories. All samples are counted for gross alpha and gross beta activity. Samples that contain, or are suspected to contain, low energy beta emitters are analyzed by liquid scintillation counting.

6.3.5.1 Purpose

The purpose of the screening is threefold:

- To determine if the samples can be shipped to other IT laboratories
- To verify that the radioactivity content is below the IT Oak Ridge Laboratory license limit
- To evaluate the radioactivity hazard associated with the sample preparation and analysis procedure

6.3.5.2 Methods and Instruments

When collecting each set of groundwater samples from the sampling well, a screening sample was also collected. The screening samples were shipped with the other sample bottles and included on the chain-of-custody and request-for-analysis records. After the sample shipment was received at the laboratory, the screening sample was removed and analyzed for gross alpha and gross beta activities using a scintillation counter. Samples that contain, or were suspected to contain, low energy beta emitters were analyzed by liquid scintillation counting.

6.3.5.3 Results

Results of the laboratory screens are used by the laboratory health and safety officer to determine the classification of the sample for laboratory management. The three categories are:

- Category I: There are no radiological hazards associated with these samples. Category I samples may be shipped to other laboratories.
- Category II: Category II samples must be analyzed at the IT Oak Ridge Laboratory. Standard laboratory procedures are sufficient to protect the health of laboratory personnel.
- Category III: Category III samples must be analyzed at IT Oak Ridge Laboratory. Screening results are reviewed on a case-by-case basis to specify handling and monitoring requirements and to verify that the radionuclide content of the sample does not exceed the license limit.

The results of the screening are not included in the RI/FS data base.

6.3.6 Quality Assurance/Quality Control

6.3.6.1 QA/QC Samples

During groundwater sampling, various QA/QC samples were collected on a routine basis to verify and determine accuracy and precision. These QA/QC samples included duplicate and rinsate samples, as well as trip (travel) blanks.

Duplicate Samples

Duplicate samples were collected to evaluate the precision of the analysis. Results of the duplicate analyses were used to determine the relative percent difference between replicate samples. A duplicate analysis was performed whenever a group of samples was analyzed at one time. Results of duplicate analyses are maintained with the corresponding sample analytical data in the project file.

Trip (Travel) Blank

Volatile organic samples are susceptible to contamination by diffusion of organic contaminants through the teflon-faced silicone rubber septum of the sample vial. Therefore, trip blanks were analyzed to monitor for possible sample contamination during sample collection and shipment. Trip blanks were started, or generated, by the laboratory by filling two 40-ml VOA vials with organic-free water and shipping the blanks with the empty sample bottles. Trip blanks accompanied the sample bottles through collection and return shipment to the laboratory and were stored with the samples. Following the analyses, if the trip blanks indicated possible contamination, the actual samples were corrected for the trip blank concentration or the sources were resampled. Results of trip blank analyses are maintained with the corresponding sample analytical data in the project file.

Rinsate Samples

The decontamination process ends with a final water rinse of the equipment. Samples of the rinse water after it passes through the sampling equipment are rinsate samples. They are analyzed to verify that the cleaning and decontamination procedures have been effective. Results of the rinsate samples are maintained in the central file at the project office.

Frequency of QA/QC Sample Collection

A trip blank sample set accompanied all samples during sample collection and shipment to the laboratory. Trip blanks were shipped at a rate of one per day when samples were sent to the laboratory. The trip blanks were analyzed for the same set of parameters as the most-extensive analysis in the shipment.

Rinsate samples were taken from sample collection equipment following decontamination. Rinsate samples were analyzed at a frequency of one per every set of 20 samples, or portion thereof, in a sampling program. Thus, if there were 33 samples to collect, two rinsate samples were collected and analyzed.

Duplicate samples were collected at selected wells and assigned a unique sample number. Duplicate samples were analyzed at a frequency of one per every set of 10 samples, or portion thereof, in a sampling program.

6.3.6.2 Field Audits

To verify compliance with QAPP requirements, the QA Project Officer and other technically qualified personnel planned, performed, and documented audits of groundwater sampling activities. These audits consisted of an evaluation of QA procedures and the effectiveness of their implementation. They also included an evaluation of work area activities and a review of project documentation. Audits were performed by a technical specialist in accordance with written checklists. Audits were formally documented and sent to the Project Director and other appropriate personnel.

Findings

Following completion of the audit, audit reports were prepared and submitted to the Project Director and other appropriate personnel. During the audit, and upon completion, the findings were discussed with the individual sampling team members and task leaders. Corrective actions were immediately initiated, if required. Minor findings which were resolved to the satisfaction of the auditor during the audit were not presented as items requiring corrective action. Findings that could not be resolved during the course of the audit and that affect the overall quality of the project were reported.

Resolution

All audit report findings were corrected and/or appropriate measures taken to comply with the QAPP requirements. Findings that could not be corrected were reported as a variance or nonconformance, depending on the situation. Authorization was then sought to change the procedures and/or to revise the QAPP, so that the procedures would be appropriate to the site-specific conditions which required the change.

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6.3.6.3 Chain-of-Custody Procedures

The following procedures were used for all groundwater samples collected as part of the RI/FS regardless of the source of the sample or the intended use of the results:

- Sample identification and labeling
- Sample chain-of-custody form
- Sample collection log
- Laboratory request-for-analysis form

Sample identification, labeling, and chain-of-custody procedures were previously described in Section 6.3.3.7.

6.3.6.4 QA/QC Documentation

Field QA/QC documentation of groundwater sampling activities was conducted in accordance with QAPP Section 6.2. Field forms and checklists were used to ensure that all required data were collected and proper procedures followed. The forms were filled out in the field as the tasks were accomplished. Calculations made in the field were verified by other sampling team members. Instruments calibrated in the field and all measurements were observed by other sampling team members and the QA Field Representative, as appropriate.

Water Quality Field Collection Report

The project name and number, sampling location, date and time of sampling, sampling team members, and weather conditions were recorded on the Water Quality Field Collection Report. In addition, field instrument calibration data for the temperature, pH, specific conductance and dissolved oxygen were recorded on this field form. Field measurements and calculations, if appropriate, were also recorded on this form.

Sample Collection Log

The sample collection log was used to record the sample number, sample location, sampling team members, and type of sample collected. The sample collection log is a master list to cross reference all groundwater samples collected to a unique sample number. The sample number is used to track the sample from the sampling well to the laboratory and to cross reference the analytical results to the appropriate well location.

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Field Activity Daily Log

The field activity daily log was used to document a chronology of the sampling team's activities. Included on this log were the times when well purging and sampling were conducted, well static water levels before well purging, volume of water removed from each well, and any noteworthy events that occurred during the daily sampling effort. The Field Activity Daily Log was also used by the sampling team to record any noteworthy data not specified on the sample collection form.

Laboratory Log

The laboratory log documented the wet chemistry analyses conducted in the sample collection trailer. The laboratory collection log documented the alkalinity titration, iron (total and ferrous iron) determination, water sample filtration (if required), and noteworthy laboratory events that occurred. The titration data recorded in the laboratory log were transferred to a computerized data base for analysis. Any calculations made in the log were checked and signed by another sampling team member. The computerized data base inputs and outputs were also checked per QAPP requirements.

6.3.7 Field Analytical Program

6.3.7.1 Parameters

Immediately following sample collection, the temperature, pH, specific conductance, Eh (when measured), and dissolved oxygen of the groundwater were measured in the field. These parameters were documented on the Water Quality Field Collection Report. The field procedures that pertain to these tests were followed in accordance with Section 6.2 of the QAPP. All field analyses, except iron, were performed on unpreserved samples. During adverse weather conditions, field analysis was performed at the site sample collection trailer, in an area maintained at 20 to 25 degrees Celsius. Whenever possible, groundwater field measurements were taken either in situ (downhole) to avoid changes which might occur if the sample was removed from the well, or in a flow box to avoid sample reaction with the atmosphere. Test conditioning and methods employed were clearly noted on the Water Quality Field Collection Report form.

Other types of wet chemistry analyses were performed in the site sample collection trailer due to the need for special equipment and controlled conditions. These analyses measured alkalinity and total and ferrous iron.

6.3.7.2 Methods

Temperature

The temperature of groundwater is required to normalize data from other field analytical measurements such as pH, Eh, specific conductance, alkalinity, and dissolved oxygen. Temperature is also an indicator used to determine if a representative groundwater sample had been collected from the well.

Temperature readings were obtained periodically during well pumping by partially immersing a thermometer in a water sample collected from the purged groundwater or flow box and allowing it to equilibrate for about two minutes. Temperature was measured using a standard glass, mercury-filled thermometer. A minimum of two consecutive readings were obtained at each well during sampling.

pH

pH is defined as the negative logarithm of hydrogen-ion activity in a sample and is a measure of the effective hydrogen-ion concentration. The pH values are very useful for assessing the acidic or basic nature of groundwater and the subsequent analysis of complex chemical reactions that are pH dependent.

The apparatus used to measure pH consisted of a standard pH meter (battery operated) with an expanded scale capable of measuring pH to the nearest 0.01 unit. The pH meter was equipped with a combination electrode that measured the hydrogen-ion potential and temperature. Three standard buffer solutions (pH 4.0, pH 7.0 and pH 10.0) were used to calibrate the meter to the range of pH to be measured. Calibration of the pH meter was done twice daily, prior to collecting of the first sample of the day and after the lunch break. The pH meter was recalibrated as necessary. To determine if the pH meter required recalibration, the pH of the 7.0 buffer solution was measured before each sample collection. All calibration procedures followed the manufacturer's instructions for calibration.

pH measurements were taken by first rinsing the electrodes with distilled water and either inserting the pH electrode in the sample flow box or immersing the electrode in a portion of the sample that had been transferred into a 100-ml beaker. The electrode was then allowed to equilibrate for a few minutes. If the pH was measured from a beaker, the water sample was stirred during measurement. After the electrode had equilibrated, the pH values were read to the nearest 0.01 unit. The pH meters used during this investigation had automatic temperature control (ATC) which automatically compensated the pH value displayed on the meter to the sample temperature.

Specific Conductance

The ability of a water solution to conduct an electric current is approximately proportional to the concentration of dissolved solids in the water. Since specific conductance of a sample can change with time and temperature, this measurement was taken in the field immediately after sample collection. The field specific conductance measurement aided in assessing whether the sample was a representative sample.

Specific conductance measurements were taken at the well site with a conductivity cell or probe. A thermometer was used to determine the sample temperature, which was then dialed into the meter. The measurement was taken by immersing the conductivity probe in the water sample and reading the conductance in micromhos per centimeter (mhos/cm) directly from the meter. The instrument readings were automatically corrected for temperature and were displayed in mhos/cm at 25 degrees Celsius.

Dissolved Oxygen

The concentration of dissolved oxygen in groundwater is an important indicator of the degree a groundwater system is being locally recharged. Groundwater samples with relatively high dissolved oxygen indicate that recharge is occurring, while low or zero dissolved oxygen readings indicate that the groundwater is far from the recharge point for the aquifer. Dissolved oxygen values also provide an indirect indicator that the groundwater environment is either chemically oxidized or reduced and sometimes indication of the mode and degree of biologic activities.

Dissolved oxygen is measured in the field by using a membrane electrode. Oxygen gas molecules diffuse through a membrane into a measuring cell at a rate proportional to the concentration of molecular oxygen in the water. Inside the sensor, the oxygen reacts with an electrolyte and is reduced spontaneously or by an applied voltage, depending on the instrument. The current that is generated is directly proportional to the concentration of molecular oxygen in the water outside the sensor. The instrument reading is converted to the concentration of molecular oxygen present, by calculation or proper calibration of the instrument.

Dissolved oxygen was measured at the well site with an oxygen-sensitive membrane electrode. The dissolved oxygen electrode was first calibrated with oxygen saturated air. During calibration, the existing temperature (ambient and water sample), elevation (feet above mean sea level), and atmospheric pressure were measured and recorded. The electrode was calibrated with water of a known dissolved oxygen concentration.

After the instrument was calibrated, the probe was immersed into the water sample flow box. The electrode was inserted into the flow box without head space, such that sufficient sample would flow across the membrane surface to obtain an accurate measurement and to overcome erratic instrument responses. The dissolved oxygen concentration was read from the meter and recorded on the Water Quality Field Collection Report form. The instrument was then decontaminated with deionized or distilled water and properly stored until needed. The operation and calibration of the instrument followed the manufacturer's procedures and calibration instructions.

Alkalinity Titration

The alkalinity of a water is a measure of its capacity to neutralize acids. Bicarbonates represent the major form of alkalinity, and are formed from the action of carbon dioxide on carbonate minerals in the soils and aquifer materials. Alkalinity is measured volumetrically by titration with sulfuric acid (H_2SO_4) and is reported in terms of equivalent calcium carbonate ($CaCO_3$).

Water samples were titrated to phenolphthalein end points of pH 8.3 and 4.5. The 8.3 end point is the equivalent point where the conversion of carbonate ion to bicarbonate ion occurs. The 4.5 end point is the equivalent point where the conversion of bicarbonate ion to carbonic acid occurs. Calculation of the total alkalinity of the water sample was accomplished by plotting the titration values of pH versus (H_2SO_4) acid added. This plot is an S-shaped curve, with the inflection point on the curve representing the equivalent point where the conversion of carbonate to bicarbonate occurs. The amount of acid required to reach this end point is the total acid neutralizing capacity of the sample, or total alkalinity.

Titration data were recorded in a laboratory notebook and later transferred to a computer spreadsheet data base. The data were then plotted and the inflection points were determined from the computer algorithms. Algorithms were also formulated to determine the sample total alkalinity and to perform the appropriate calculation to convert this inflection point value to total alkalinity in equivalent $CaCO_3$. All algorithms were checked using established QA/QC procedures.

Eh

During the first quarter of 1989 groundwater sampling, Eh was measured in the field to validate and determine if the calculated Eh values were representative of the aquifer systems. Eh is difficult to accurately measure in the field, so strict procedures were followed to obtain the most accurate and precise values possible. The Eh measurement is based on the potential difference between a constant voltage reference electrode and a variable voltage platinum electrode. The voltage of the platinum electrode is dependent of the concentration of electrons in solution.

The apparatus used to measure Eh consisted of a standard pH/Eh meter (battery operated) with an expanded scale capable of measuring Eh to the nearest 0.01 electron volts. The Eh meter was equipped with a combination electrode that measured the Eh, and the pH and temperature were measured with separate electrodes attached to the same meter. The Eh of water was measured at the well site by immersing the combination electrode in a flow box, without head space, and measuring the potential difference with an Eh meter. The combination electrode consisted of a platinum redox electrode and a silver/silver chloride reference electrode.

Two standard Zobel solutions were used to calibrate the meter. The Eh meter was calibrated by measuring the potential of each of the two Zobel calibration solutions and recording the values on the Water Quality Field Collection Report. Calibration of the Eh meter was done twice daily, prior to collection of the first sample of the day and after the lunch break. The Eh meter was recalibrated more often when conditions required. All Eh field procedures followed the manufacturer's instructions for operation and calibration.

6.3.7.3 Instrumentation

Temperature	BCR mercury sealed glass thermometer with 1.0°C increments from 35°C to 55°C that were calibrated against a certified master thermometer using National Institute of Standard Measures (NISM) procedures.
pH	Fisher Scientific pH meter, Model 956; Orion pH meter, Model SA250.
Specific Conductance	YSI conductivity meter, Model 33.
Dissolved Oxygen	YSI dissolved oxygen meter, Model S1-B.
Eh	Orion pH meter, Model SA 250 with a platinum Eh electrode.

The precision of the instruments is typically much greater than the uncertainties involved in sample collection and handling. This is the primary reason why all the field measurements were made at the well site immediately after the sample was removed from the well.

6.3.7.4 Results

Results for the parameters measured in the field are summarized in Appendix E.

6.3.7.5 U^{+4}/U^{+6} Analysis

To assist in determining the redox (Eh) of groundwater, 16 wells were sampled and analyzed for U^{+4} and total U to investigate the U^{+4}/U^{+6} redox couple. U^{+4} and U^{+6} (U^{+6} = total U - U^{+4}) are defined as the sum of all uranium species for each oxidation state. The U^{+4} and total U analyses were done by United Nuclear Corporation Geotech Laboratories (UNC Geotech), Grand Junction, Colorado. Detailed procedures for the U^{+4} and total U field sampling and analytical methods are given in the Appendix of the Field Sampling and Laboratory Procedure Plan for the Geochemical Program (IT 1989).

Groundwater samples were collected for total U and U^{+4} analysis to estimate the Eh of the groundwater. This analysis was independent of Eh measurements obtained on the groundwater using standard platinum-electrode techniques. The U^{+4} in solution is complexed with cerium and precipitated with hydrofluoric acid. U^{+6} is determined by the difference of total U and U^{+4}. The field procedure was as follows:

- Approximately 250 ml of sample was collected after filtering the groundwater through a 0.45 micron filter
- The sample was split and half was acidified with HNO_3 (pH less than 2) and shipped to the laboratory for total U analysis.
- 25 ml of the remaining split was placed into a 125-ml plastic bottle, and 0.125 ml of cerium solution was added to the sample and mixed well.
- 1.25 ml of reagent grade HF was added to the solution to precipitate the U^{+4}, and the solution was mixed thoroughly and cooled for 15 minutes in a cooler.
- The sample was removed from the cooler, shaken, and filtered through a 0.1 micron filter.
- The sample bottle was rinsed three times with distilled water and the rinse solution was passed through the 0.1 micron filter.
- The filter funnel and filter paper were rinsed with distilled water prior to placing the filter paper in a container for shipment to the laboratory, where it was analyzed for U^{+4}.

6.4 HYDRAULIC CONDUCTIVITY TESTING

As part of the FMPC site characterization program, short-term hydraulic conductivity tests (slug tests) were conducted on selected 1000 Series wells. These hydraulic conductivity tests were conducted to measure the hydraulic conductivity of the glacial overburden in and around the Waste Storage Area and fly ash pile areas.

Hydraulic conductivity testing could not be performed on preselected Wells 1004, 1009, 1014 and 1045 because these wells have been dry since they were installed. A hydraulic conductivity test was not performed on Well 1022 because this well was constructed prior to the RI/FS in a test pit that was backfilled with gravel. The results from hydraulic conductivity tests performed on these preselected wells would yield meaningless values. Alternative wells were, therefore, selected (Table 6-9).

Falling head slug tests were conducted by injecting a known volume of water into the well and recording the water level decline with time. The procedures used to conduct these tests followed Sampling Plan Section 3.4.2, QAPP Section 5.6. A duplicate rising head hydraulic conductivity test was conducted on Well 1018 to validate the falling head slug test results.

Slug test data were analyzed following the procedures outlined in NAVFAC DM7, Design Manual, Soil Mechanics, Foundations and Earth Structures, 2nd Edition, Department of the Navy, 1971 (Hvorslev Method). The data were analyzed manually using the Hvorslev Method. The hydraulic conductivity results are summarized in Table 6-9. The variability in the values reflects the local variations in subsurface soil properties in the till.

6.5 GEOPHYSICAL PROGRAM

6.5.1 Objectives

Surface geophysical methods were used on a limited basis primarily to locate buried pipelines, debris, and previous construction excavations. The methods were used as a screening tool to assist in drilling activities. Surface geophysics were used more systematically during the Production and Additional Suspect areas investigations to locate buried objects and to define the limits of previous excavations.

The geophysical techniques used were magnetometer, gravity, and ground penetrating radar surveys. Magnetometer surveys were used to locate buried metal objects such as drums, piping, underground storage tanks, and other miscellaneous metal debris. Gravity and ground penetrating radar geophysical techniques were used to locate and define areas of previous excavations and buried nonmetallic materials.

TABLE 6-9
HYDRAULIC CONDUCTIVITY TEST RESULTS

Well No.	(ft/day)	(cm/s)
1008	0.37	1.3×10^{-4}
1012	4.53	1.6×10^{-3}
1018	1.61	5.7×10^{-4}
1025	0.01	2.5×10^{-6}
1034	0.07	2.5×10^{-5}
1035	0.07	2.5×10^{-5}
1041	0.31	1.1×10^{-4}
1046	0.19	6.8×10^{-5}
1048	0.45	1.6×10^{-4}
1065	0.06	2.2×10^{-5}
1079	0.05	1.8×10^{-5}

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6.5.2 Methods

Magnetometer Surveys

A magnetometer measures minute changes or deflections in the earth's magnetic field caused by metallic objects. The accuracy of the magnetometer in locating buried objects depends on the size and depth of the object. It also depends on any natural or man-made interferences in the area being surveyed. These interferences include electric power lines and large metallic objects such as metal buildings that mask out the smaller objects being investigated. Magnetometer surveys were conducted at each RI/FS well location to determine and confirm that buried objects such as utility and plant process lines were not present at the drill site. This geophysical technique also was used to locate buried metal objects during the Production and Suspect areas investigations. The magnetometer surveys were conducted with a flux-gate magnetometer, Fisher M-Scope FX-3 Ferro Probe.

To support the drilling operation, magnetometer geophysical surveys were conducted by systematically scanning or sweeping a region and finding an area where magnetic anomalies were not present. A minimum area of approximately 10 feet in diameter was cleared for each drill site and marked with pin flags. There were locations in the Waste Storage Area where this minimum area had to be reduced because a region this large could not be located. In this case, an area as large as possible was cleared and marked with pin flags for the drilling crew.

Ground Penetrating Radar Surveys

Ground penetrating radar (GPR) is used to locate nonmetallic buried objects, such as concrete storm sewers and previous excavations and fill areas. GPR was used to locate the disposal trench during the investigation of the former drum bailing area and in the Waste Storage Area to locate buried objects and waste pit boundaries. Because of the composition of the glacial overburden and high water table present at the FMPC, it was determined that GPR could only penetrate approximately two to three feet in undisturbed soils. Therefore, only very-near subsurface objects and excavations could be accurately located using this geophysical technique. GPR surveys in the Waste Storage Area were not successful because of the high water content of the clay-rich soils present in this area.

Gravity Surveys

The intent of the gravity geophysical surveys was to detect underground structures by means of the disturbance they produce in the earth's gravitational field. Small differences in the strength of gravity can be quickly and accurately measured with a portable gravimeter. In essence, what is

being measured are the relative changes in density of the subsurface materials at each station. These changes in density may represent fill material or large buried objects.

When conducting the gravity survey, a reference point of known elevation had to be periodically revisited to account for the continuous changes that occur in the earth's gravitational field. Compensations had to be made for changes in elevation and topographic conditions at each gravity station. Gravity values were presented as Bouguer anomalies, which are defined as the discrepancy between the observed gravity field and that expected after correcting for all known effects.

6.6 SURFACE WATER AND SEDIMENT PROGRAM

6.6.1 Objectives

The surface water and sediment sampling programs have been combined due to a similarity of objectives. These objectives are to:

- Characterize the radiological and hazardous substances and their spatial distributions in surface water at one point in time along drainage pathways from the FMPC toward Paddys Run, discharge points into Paddys Run, as well as in Paddys Run.
- Identify the distribution and extent of radiological constituents in sediments from Paddys Run and site drainage systems leading into Paddys Run.
- Determine the presence of radiological constituents and their concentrations at a given point in time at several locations in the Great Miami River both upstream and downstream of the FMPC outfall and the confluence of Paddys Run with the Great Miami River.
- Identify radiological constituents in the sediments of the Great Miami River at locations upstream and downstream of the FMPC NPDES outfall, at the confluence of Paddys Run with the Great Miami River, and at two depositional locations in the Great Miami River.
- Determine if the FMPC is a source of organics and selected inorganics to the Great Miami River and Paddys Run.

A key component of this portion of the investigation was to examine the effects of the main effluent line on river water quality and, in turn, the interactions between the water column, sediments, and underlying Great Miami Aquifer.

The two primary components of the surface water and sediment sampling were: the principal surface water courses, Great Miami River, Paddys Run, the Storm Sewer Outfall Ditch, and the

main effluent line, involving multielement sampling designed to make use of ongoing WMCO monitoring programs and previous study results; and a variety of surface water drainage paths in the Waste Storage Area and Production Area. This limited effort was conducted to pinpoint any significant contaminant sources or problems that would otherwise continue undetected. The results of either of these components of the sampling plan would indicate that additional sampling was required to fully evaluate the respective source or pathway of concern.

6.6.2 Surface Water Sampling Locations

6.6.2.1 Great Miami River

Surface water sampling locations on the Great Miami River coincided with the sampling stations established by WMCO plus four additional sampling locations (Figure 6-13). At the time the RI/FS Work Plan was developed, WMCO was collecting daily grab samples from Sampling Points W1 and W3. Weekly grab samples were collected at Point W4, downstream from the confluence of Paddys Run with the Great Miami River. The daily and weekly samples are composited monthly for a determination of uranium, Ra-226 and Ra-228, and gross alpha and beta concentrations. The additional locations are immediately opposite the collector wells on the west bank, just downstream from the point of discharge of the main effluent line, within the depositional area at the bend in the river downstream from the previous point, and immediately downstream from the confluence with Paddys Run.

6.6.2.2 Paddys Run

Surface water in Paddys Run was monitored at WMCO Stations W5, W9, W10, W11, W7, and W8 (Figure 6-13). Station W5 provides an upstream control, Stations W9 and W10 represent upstream and downstream locations with respect to the Waste Storage Area, Stations W11 and W7 provide a similar upstream/downstream pair for the confluence of the Storm Sewer Outfall Ditch with Paddys Run, and Station W8 is a downstream off-FMPC location. Weekly samples were analyzed by WMCO for uranium content and gross alpha and beta activities. Bimonthly composites of weekly samples were analyzed for Ra-226 and Ra-228.

The spatial distribution provided by these six stations was considered adequate for monitoring surface water effects in Paddys Run. The ongoing program was supported in the RI/FS by quarterly sampling at Stations W10, W11, and W7. Sample analysis was for the full radiological program, TOC, TOX, and the general water quality parameters.

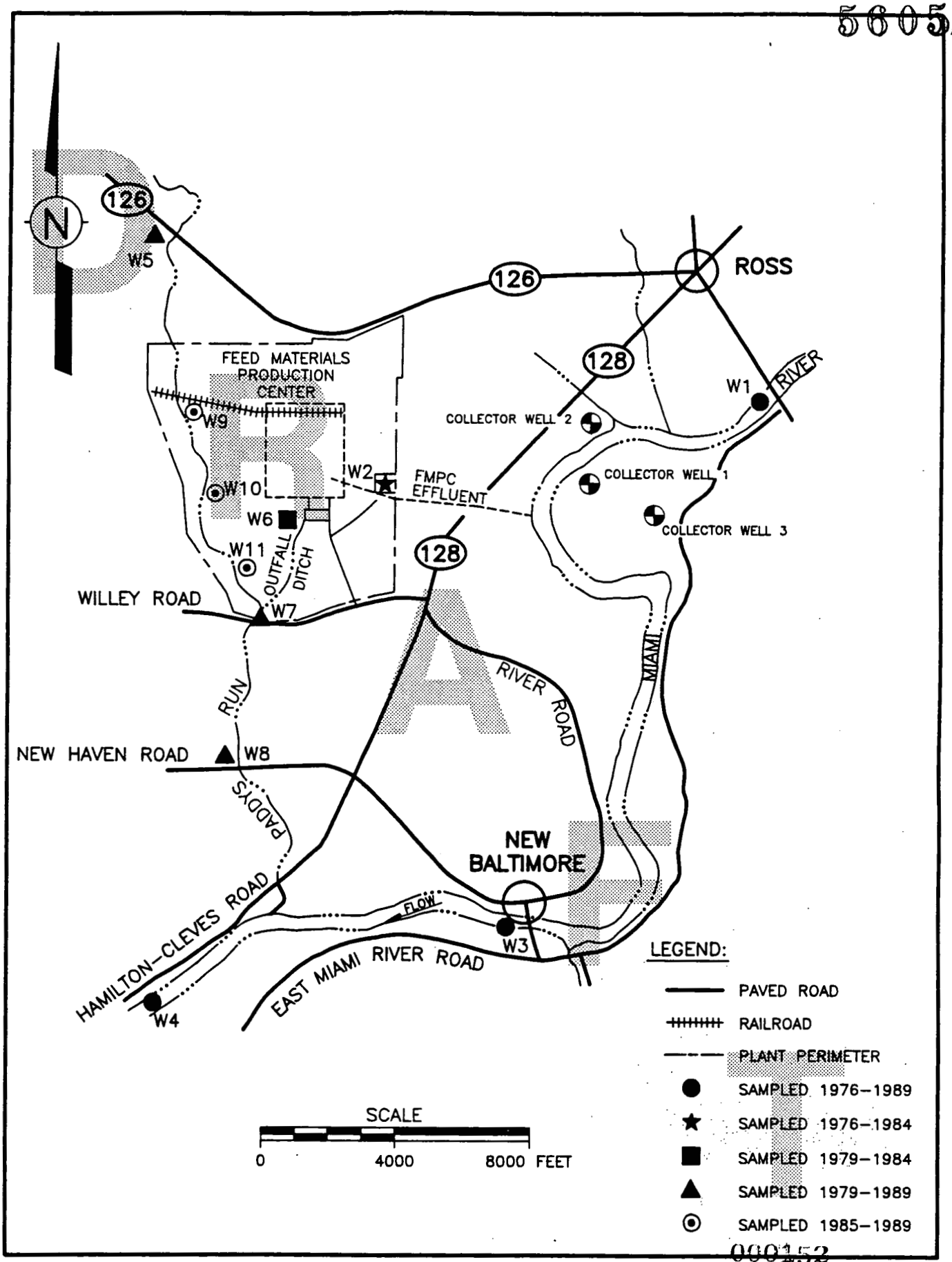

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FIGURE 6–13
SURFACE WATER AND SEDIMENT
SAMPLING LOCATIONS

6.6.2.3 Storm Sewer Outfall Ditch

Station W6 was used by WMCO to monitor effluent associated with the storm water drainage ditch. Weekly samples were collected for uranium and gross alpha and beta analyses, while a bimonthly composite was analyzed for Ra-226 and Ra-228. The RI/FS program involved a single sampling episode during a storm event at five locations along the ditch. Four samples were analyzed only for the base set of radiological parameters, while the sample collected furthest downstream was analyzed for the full radiological parameter list, TOC, TOX, and the general water quality parameters.

6.6.2.4 Manhole 175

Wastewater discharges are monitored by WMCO at Station W2. Station W2 is the sampling point at Manhole 175 that is used to monitor effluent from the Production Area and is the specified compliance point for the NPDES permit. Continuous samples are collected in proportion to the total flow. Samples are collected daily (24-hour composites) and analyzed for uranium content and alpha/beta radioactivity. Monthly composites of the daily samples are analyzed for Ra-226, Ra-228, Ru-106, and Th-232. Two semiannual composites are analyzed for other radionuclides.

In support of the data base being generated by WMCO, quarterly surface water samples were to be obtained from Station W2 for one year and analyzed for the full set of radionuclides, TOX, TOC, and general water quality parameters. The initial sample was analyzed for the extended HSL parameters. This program provided confirmatory data as to whether organics and selected inorganics are being discharged to the Great Miami River via the main effluent line.

6.6.2.5 Waste Storage Area

Numerous drainageways exist within or near the Waste Storage Area. These drainageways were potential receptors of contaminants from spills, leaks, or other releases associated with the waste storage units or plant operations. Single surface water and sediment samples were collected along the drainageways and analyzed for the base set of radiological parameters.

6.6.2.6 Production Area

Several drainageways and storm water run-off conveyances exist within the Production Area. Single samples from eight locations were analyzed for total uranium, Ra-226, Ra-228, and gross alpha and beta counts.

6.6.3 Surface Water Sampling

The procedures and practices are to collect, grab, and composite water samples from streams, rivers, springs, and seeps.

Whether the technique of sampling was grab or composite sampling, the sampling practice included:

- Sample containers with preservative were not used to collect the sample water. Initially, the samples were collected by a separate container (grab bottle) to obtain samples from a body of water. Subsequent to sampling, the sample was transferred into the container with a preservative.
- The sample containers were clean and uncontaminated. Sample containers with pre-added preservatives were filled to the top without overflowing to prevent loss of the preservatives.
- The point of sampling was chosen with care so that a representative sample of the water to be tested was obtained.
- Sampling was not conducted when there was visible surface debris or when artificial turbulence was present in the stream.
- The sampling crew member stood downstream from the collection point to prevent any possible contamination during sample collection.
- Sampling consisted of placing the bottle mouth down into the water, avoiding surface scum. The bottle opening was positioned toward the current flow and away from the hand of the collector, the shore, the side of sampling platform, or boat. The sampling depth was 6 inches below the water surface.
- VOA vials were filled by placing an inverted glass bottle without preservative about 12 inches below the surface of the water and then turning the bottle over to allow it to fill below the surface water. The glass container was then removed from the water, and the VOA vials immediately filled from the container.
- When more than one grab bottle volume of sample was required to fill all the necessary sample containers, the portions were composited in a holding container prior to filling the individual sample containers. This provided for homogeneity of the collected sample.
- Field measurements were performed in accordance with Section 6.2 of the sampling plan.
- Stored collected samples in the field in an ice chest filled with ice and maintained at approximately 4 degrees Celsius.
- Samples were properly labeled and chain-of-custody records, sample collection logs, Water Quality Field Collection reports, and laboratory request-for-analysis forms were properly filled out.

6.6.4 Sediment Sampling Locations

6.6.4.1 Great Miami River

Sediment samples were collected on a quarterly basis from the same locations on the Great Miami River. Samples were collected at the quarter points in the channel and from depositional and flood plain areas at each location. One sample from the most prominent depositional area at each location was used for full radiological analysis to determine if the potential for a long-term release of contaminants exists, and grain-size testing was performed at one location to assist in determining if sorption was an important process. All other sediment samples from the Great Miami River were archived within their original containers in an environmentally controlled area. If the single sample analyzed from each location exhibited a concentration of any parameter exceeding twice background, all archived samples from that location and sampling event were to be subjected to a full radiological analysis. An exception to this strategy was that all sediment samples from the background location (W1) were analyzed during the first round of sampling to better establish background conditions.

6.6.4.2 Paddys Run

Sediment samples were collected from Paddys Run at Stations W10, W11, and W7 on a quarterly basis. Station W5 was included in the sediment sampling program to provide a background comparison. Samples from Stations W5, W11, and W10 were analyzed only for the base set of parameters (uranium, Ra-226, Ra-228, gross alpha and beta); whereas, a full complement of radiological parameters were tested along with grain size for sediment samples from Station W7. Sediment samples from the same four locations were analyzed on one occasion for the extended HSL parameters.

6.6.4.3 Storm Sewer Outfall Ditch

Three sediment samples were collected along the length of the ditch. A full set of radiological parameters and grain-size analyses were run to document these conditions and to establish any correlation with grain size. In addition, sediment samples were collected for the extended HSL analysis at two locations. These included a point just upstream from the confluence with Paddys Run (downstream from the fly ash piles), and a point of depression in the channel pathway near the midpoint of the ditch length (upstream from the fly ash piles).

6.6.4.4 Manhole 175

Sediment samples were collected from Manhole 175 concurrently with the quarterly surface water samples. The samples were analyzed for the full set of radiological parameters and grain size.

One sediment sample was analyzed for the extended HSL parameters during the initial round of sampling.

6.6.4.5 Waste Storage Area

Sediment samples were collected for radiological analysis at numerous locations along drainageways in the Waste Storage Area. The object was to collect a single sediment sample from drainages to Paddys Run at points downstream from potential releases from the Waste Storage Area. These samples underwent extended HSL analysis.

6.6.4.6 Production Area

Several drainageways and storm water run-off conveyances exist within the Production Area. Single samples from eight locations were analyzed for total uranium, Ra-226, Ra-228, and gross alpha and beta counts.

6.6.5 Sediment Sampling

The following practices were used for sediment sampling:

- When traverse sampling of rivers and large streams was conducted, a clamshell or dredge was used for bottom sample collection.
- Prior to sampling sediments in a stream, the clam shell sampling device, was rinsed with stream water downstream from the sampling location.
- Sediment samples were collected to a depth of approximately six inches below the sediment/water interface.
- The dredge was decontaminated between each sample collection by cleaning with river water and a brush.

6.6.6 Field Screening

Surface water and sediment samples are field screened following the procedures discussed in Section 6.3.5.

6.6.7 QA/QC

QA/QC procedures are followed as discussed in Section 6.3.6. Sufficient QA/QC duplicate, rinse, and trip blank samples are collected and field audits conducted as required. QA/QC documentation is conducted as discussed in Section 6.3.6.4.

6.6.8 Field Analytical Program

During sample collection, temperature, pH, specific conductance, and dissolved oxygen are measured in the field. The field procedures that pertain to these tests are followed in accordance with Section 6.2 of the QAPP and as previously discussed in Section 6.3.7.1.

6.6.9 Laboratory Analytical Program

Since the identification and preliminary characterization of potential sources and pathways is the principal goal of the surface water and sediment sampling, the supporting analytical programs will have a common comparative basis in a specific set of radiological parameters. These parameters have been selected to achieve consistency with WMCO's ongoing monitoring program and include total uranium, Ra-226, Ra-228, and gross alpha and beta contents. Some surface water samples will undergo the same extended analyses, as the RI/FS groundwater sampling program.

TOC and TOX have been chosen as indicator parameters of potential organic contamination in waters from selected drainages, Paddys Run, and the Great Miami River. Based on the detection of various organics in the Waste Storage Area, selected surface water and sediment samples will be analyzed for the extended HSL parameters.

6.6.10 Results

Analytical results of the surface water and sediment sampling are presented in Appendices F and G. Decontamination of the surface water and sediment sampling equipment was performed at a designated central staging area at the FMPC.

6.7 SURFACE WATER ELEVATION DATA

To assess the potential impacts of Paddys Run on groundwater quality at the FMPC, continuous water level recorders were installed to record hourly water level readings at Well Clusters 9 and 14. Well Cluster 9 is located along Paddys Run, midway between the Waste Storage Area and the southern FMPC boundary. Well Cluster 14 is also located along Paddys Run, near the confluence of the Storm Sewer Outfall Ditch. Continuous water levels measurements were collected in Wells 2009, 3009, 2014, and 3014. Stream stage was also recorded in stilling wells installed at these well cluster locations. The locations of these wells are shown in Figures 6-2 through 6-5. Water level measurements were recorded hourly starting in March 1988 and continued for approximately three years. Water level elevations were measured with pressure transducers to within 0.01 foot.

Data from these recorders were used to detect patterns in water level changes between Paddys Run and the Great Miami Aquifer during dry and wet seasons. Hydrographs were generated from the collected data and stream stage/groundwater elevations were compared. Data from Well Clusters 9

and 14, from approximately February 21, 1989 to June 21, 1989, are presented in Appendix H. These data were chosen because they represent typical stream water/groundwater interactions and responses for several significant precipitation events.

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7.0 FIELD INVESTIGATION: PRODUCTION AREA

The Federal Facility Compliance Agreement (FFCA) signed by the DOE and EPA on July 18, 1986 pertained to assessing the environmental impacts associated with the FMPC. A site-wide RI/FS was initiated to investigate the impacts, so that the remedial response actions could be formulated, assessed, and implemented. One requirement of the FFCA was the development and execution of a sampling and analysis program to characterize all materials emitted, discharged, released, or potentially released into the environment in the Production Area. To address this requirement, an addendum to the RI/FS Work Plan entitled "Production and Additional Suspect Areas Work Plan" was presented to the EPA in November 1988, and was finalized in October 1989.

7.1 OBJECTIVES

The overall objectives of the Production and Additional Suspect areas investigation were to determine if releases of hazardous and/or radioactive materials have occurred, or have a reasonable potential for occurring. For purposes of this testing program, the term "Suspect Area" was used to represent any localized area of the FMPC that could potentially contribute to environmental contamination due to a known use of the area or a previous activity performed within the area. Specific objectives of this investigation included the following:

- To define the nature and extent of current groundwater contamination associated with production facilities and identified suspect areas
- To evaluate the potential for groundwater contamination by defining the lateral and vertical extent of radionuclide and hazardous substance contamination of surface and subsurface soils within these areas
- To determine if problems exist in the Production Area not associated with production facilities and suspect areas, and to adequately define any problems in terms of current or potential future environmental releases
- To gain a refined understanding of the hydrogeologic system and groundwater flow patterns throughout the glacial overburden underlying the Production Area

7.2 SCOPE

The sample locations and analytical parameters were established based on the historic use of the areas and the materials handled in each area. The selection and prioritization of the areas to be investigated were based on the findings of a WMCO task force that was chartered to identify those areas where there is a high probability of historic, current, or potential releases. The subsurface data and analytical results generated by this investigation have been incorporated into the RI/FS.

The investigation in the Production Area included:

- Raw product and waste container storage and transfer facilities
- Oil burner area
- Graphite burner area
- Area southwest of the laboratory
- Metal scrap pile area
- Polychlorinated biphenyl (PCB) transformer/hydraulic oil area
- Former waste solvent drum storage area behind the laboratory
- Abandoned drum areas
- Plant 1 shot blaster area
- South interior end of Plant 6
- Drum bailing area and burial trench
- Aboveground and underground storage tanks
- Below-grade piping
- Main effluent line from the Clearwell to Manhole 175

The suspect areas outside the Production Area included the fire training area; an area north and east of the fire training area; an area south of the laboratory, where laboratory hoods are buried; Southfield, several rubble mounds and abandoned drum locations; and an area in the vicinity of the flagpole, near the entrance to the administration building.

The Production and Additional Suspect areas investigation included three boring programs. The first program was to advance soil borings in a systematic 250-foot grid throughout the Production Area. The second program was to advance soil borings at the known or suspected locations of environmental releases. The third program was to install 2000 Series wells in the Great Miami Aquifer at selected locations. Piezometer boring and well locations are presented in Figures 7-1 and 7-2 for the southern half of the Production Area and the northern half of the Production Area, respectively.

7.2.1 Systematic Boring Program

A 250-by-250-foot grid was established in the Production Area. Except for several special locations, borings were advanced at all points of intersection on the grid. Ninety-three borings were originally proposed. Where grid locations fell inside buildings, the borings were relocated outside, adjacent to the nearest wall of the building. Similarly, if a grid location fell inside diked containment areas, the boring was moved outside the diked area. If grid borings were along paved roadways, the boring location was shifted to the shoulder of the roadway.

7.2.2 Focused Boring Program

The focused boring program involved the advancement and sampling of borings specifically sited at locations where the potential for environmental contamination is high. The number and location of

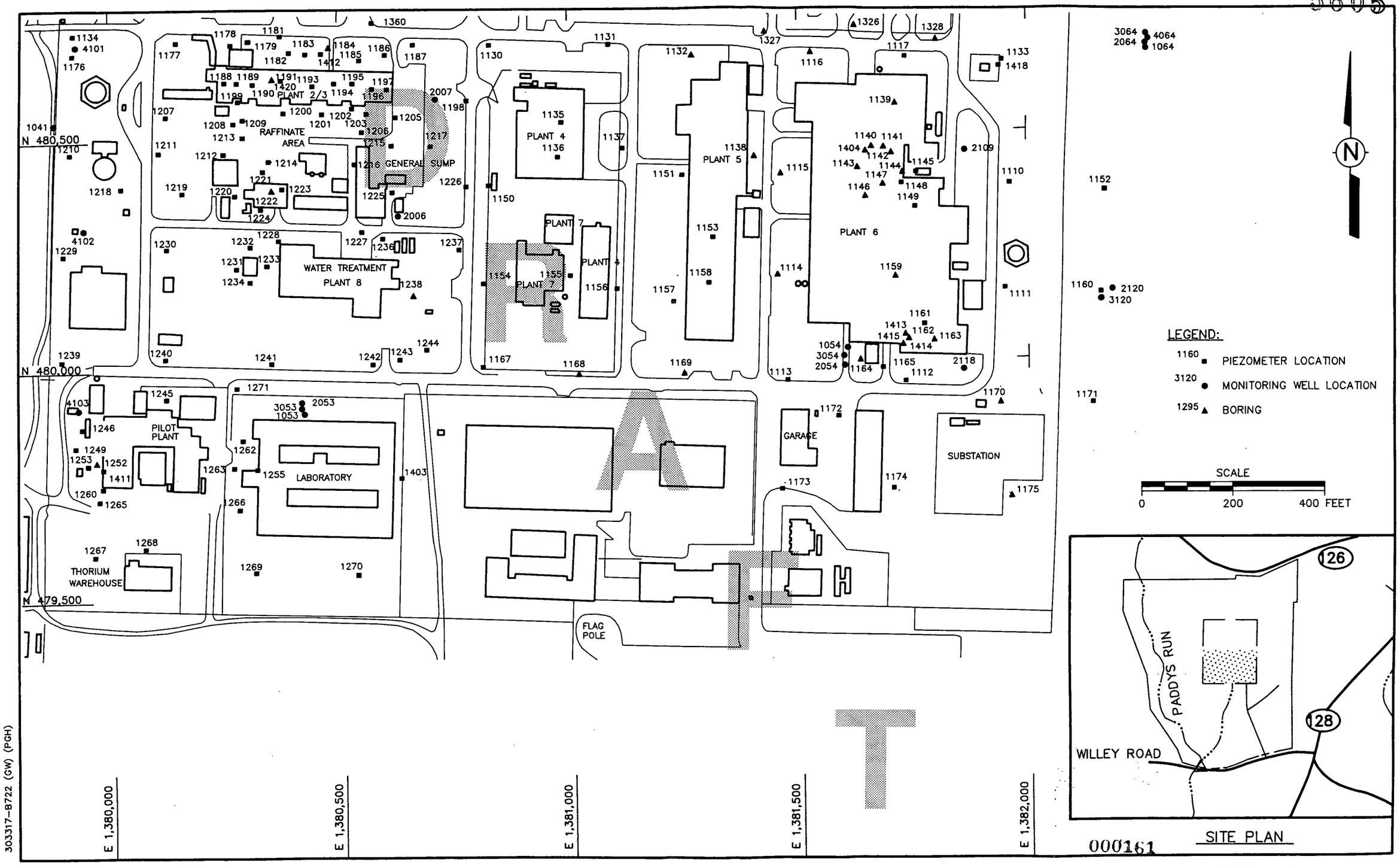

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FIGURE 7-1
FMPC PRODUCTION AREA
SOUTHERN HALF
PIEZOMETER, MONITORING WELL
AND BORING LOCATIONS

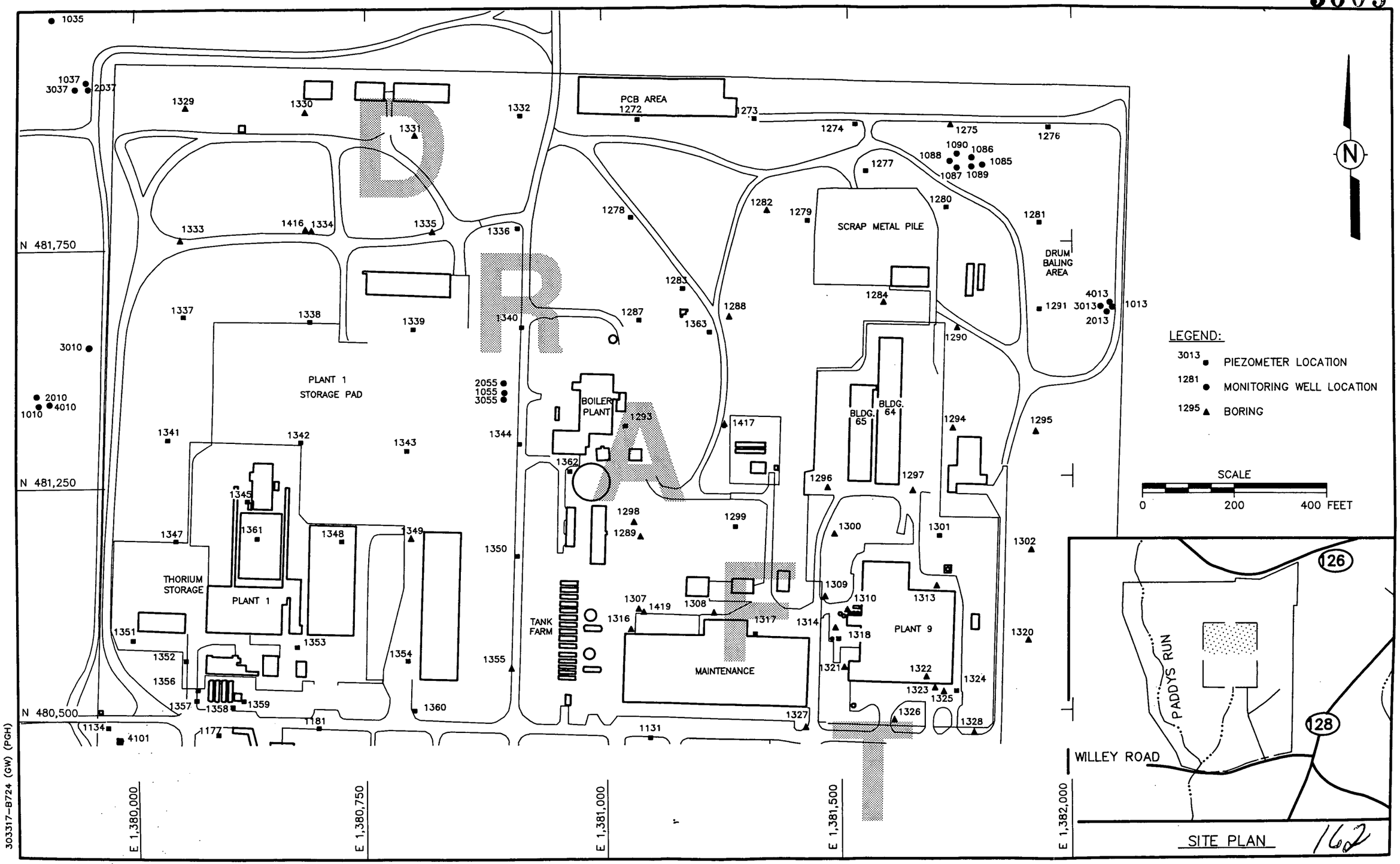

FIGURE 7-2
FMPC PRODUCTION AREA
NORTHERN HALF
PIEZOMETER, MONITORING WELL
AND BORING LOCATIONS

borings at each area of concern were in accordance with the "Production and Additional Suspect Areas Work Plan." The focused program included borings inside of buildings in those cases when there is a high probability that an environmental problem exists under the building.

7.2.3 Piezometers

All borings were advanced using 8-inch hollow-stem augers following the procedures described in Section 6.1.3 and as outlined in the "Production and Additional Suspect Areas Work Plan." If groundwater was encountered within the glacial overburden, piezometers were installed. If groundwater was not encountered, the borings were backfilled with grout and capped with cement.

7.2.4 Monitoring Wells

Six monitoring wells existed in the Production Area prior to the RI/FS. "The Production and Additional Suspect Area Work Plan" called for the installation of seven additional 2000 Series monitoring wells and provided for several contingency wells. Five of the seven wells were installed under the 24-Well Program described in Section 6.1.2.3. Wells 2006 and 2007 were installed as part of the Production Area investigation to complete the seven wells specified in the Work Plan. Each well was installed using the same procedures as for wells in the RI, as described in Section 6.1.5.

7.3 METHODS

7.3.1 Drilling

Hollow-stem auger drilling methods were used to drill borings for piezometer installation. Cable tool techniques were employed for well installation. Borings were advanced following the drilling procedures described in Section 6.1.3 of this report and Section 5.2 of the QAPP.

7.3.2 Subsurface Soil Sampling

Continuous split-spoon samples were collected throughout the full depth of each boring using an 18-inch split-spoon sampler. The sampler was driven at 18-inch intervals. The selected depth increments were 0.0 to 0.5 foot, 2.0 to 2.5 feet, 5.0 to 5.5 feet, and at each successive 5.0-foot increment until perched water or the projected depth of the boring was reached. Soil samples were not collected for laboratory analysis below the water table.

Each sample underwent full radiological and volatile organic screening and was characterized by a geologist in accordance with the procedures in the RI/FS Work Plan. If any soil samples exceeded the field screening criteria of a sustained reading greater than 5 ppm on the HNu for at least 10

seconds, the sample that exhibited the highest reading from each boring was transferred to the appropriate sample bottle and submitted to IT's Oak Ridge Laboratory for full HSL testing. Other soil samples submitted for full HSL analysis were from borings in areas where organics are known to have been stored and handled. From March to September 1989, samples from preselected depths were sent to the WMCO FMPC laboratory for total uranium and total thorium analysis. After October 1, 1989, these analyses were done at the IT Oak Ridge Laboratory.

7.3.3 Piezometer Installation

Borings that encountered water were completed as two-inch- or four-inch-diameter piezometers constructed of PVC. Screen length varied from two to ten feet and depended on the thickness of the water-bearing unit encountered. The screen length determination was made in the field by the site geologist with the assistance of the on-FMPC technical manager. Screens are 2-inch diameter, 0.020-inch slot size, Schedule 40 PVC. In some locations, where future pumping is expected, 4-inch diameter screens and casing were used. In those cases where the piezometers were finished in high traffic areas, flush-mounted protective well enclosures were used to secure the well head. The piezometers were installed following the procedures discussed in Section 6.1.6

7.3.4 Field Screening

Field screening procedures for radiological and organics were the same as for RI/FS well installation, as discussed in Section 6.1.4.

7.3.5 Water Level Survey

Water level measurements were taken following the procedures described in Section 6.2. Water levels measurements were collected at the time the piezometer was installed and monthly thereafter. These measurements were incorporated into the overall water level measurement program being conducted under the RI/FS. Water level measurements are summarized in Appendix C.

7.3.6 Groundwater Sampling

Groundwater samples were collected from each well after installation and at a minimum of one more occasion under different seasonal conditions. Initial water samples collected from the 2000 Series wells were analyzed for full HSL and full radiological parameters. Subsequent analyses were for general groundwater quality parameters and full radiological parameters, as specified in the RI/FS Work Plan.

Samples from piezometers were analyzed for total uranium, total thorium, and nitrates at the time of completion and again approximately two months later.

7.3.6.1. Purging

The primary consideration in groundwater sampling is to obtain a representative sample of the groundwater body. To safeguard against collecting nonrepresentative stagnant water from a piezometer, the guidelines and techniques for well purging discussed in Section 6.3.3.1 were followed. A minimum of three well volumes of water was bailed from all piezometers prior to collecting a sample. For piezometers that could be bailed dry, the piezometers were evacuated and allowed to recover prior to sample withdrawal. If the recovery rate was fairly rapid, and if time allowed, more than one volume of water was evacuated from the piezometer. After the piezometer had adequately recovered, water samples were collected in accordance with a priority list based on the stability and volatility of the parameter for which the sample was to be analyzed. All purging equipment was decontaminated between wells using procedures previously specified for well development equipment.

Water generated while purging the piezometers was contained at the well and transported to the General Sump for disposal. Water from the equipment decontamination pad, located at the site trailers, was also contained and transported to the General Sump. Decontamination water from the equipment decontamination pad located east of the General Sump flows directly into the General Sump. Water generated as a result of equipment documentation at the FMPC equipment decontamination area (Building 69) was disposed of by WMCO personnel.

7.3.6.2 Sample Collection

Water samples were collected from the wells and piezometers following the procedures discussed in Section 6.3.3.2. Prior to sample collection, a water-level measurement was taken to determine the depth to groundwater. The well or piezometer was then purged by bailing. While purging, field pH, temperature, and specific conductance measurements were taken and recorded. Water samples were collected with a teflon bailer and poured directly from the bailer into the sample bottle.

7.3.6.3 Sample Filtration

When sampling for dissolved metals or radionuclides in water, the sample was filtered in the field following the procedures discussed in Section 6.3.3.3. The water sample was either filtered at the well or piezometer site with portable sample filtering equipment, or was taken to the sample collection trailer for filtration. A Millipore filtration apparatus equipped with a 0.45-micron filter was used. The filtering apparatus was properly decontaminated between samples. After the sample was filtered, it was immediately transferred to the appropriate sample bottle containing the necessary preservative. Samples that were excessively turbid were prefiltered before final filtration with the

0.45-micron filter. The prefilter mesh size depended on the amount of suspended material in the sample.

7.3.6.4 Sample Preservation

All water samples submitted for laboratory analysis were preserved prior to final packaging and shipment to the laboratory, as required in Section 6.0 of the QAPP and as discussed in Section 6.3.3.4 of this report.

Immediately after the water samples were collected, the sample bottles were properly labeled, placed in a cooler packed with artificial icing material, and cooled to 4 degrees Celsius. The samples were delivered to the sample collection trailer for final packaging and shipment to the laboratory. When the samples were repacked, fresh artificial icing material was placed in the shipping cooler to maintain the sample temperature at 4 degrees Celsius. When samples were collected during hot weather, the samples were delivered to the site sample collection trailer more frequently to ensure the temperature of the sample was maintained below 4 degrees Celsius.

Samples analyzed for volatile organic compounds, acid and base-neutral extractable compounds, pesticides/PCBs, and general chemistry parameters were preserved by cooling to 4 degrees Celsius. Samples analyzed for dissolved metals were preserved with concentrated nitric acid to reduce the pH to less than 2 and cooled to 4 degrees Celsius. Samples analyzed for dissolved radionuclide parameters were filtered and then cooled to 4 degrees Celsius.

7.3.6.5 Sample Numbering

Each groundwater sample was assigned a unique sample number that was used to track the sample from the sampling well to the analyzing laboratory. At the laboratory, the sample was assigned a laboratory sample number that was used to track the sample through the laboratory. Laboratory certificates of analyses list both the field sample number and laboratory sample number for easy cross reference.

The field sample numbers were assigned sequentially in the order the wells in the network were sampled for each sampling event. The block of sample numbers assigned to the groundwater samples from the Production Area wells and piezometers start with 45120 and go to 47120. All sample numbers were referenced to a master sample collection log that lists all the sample numbers, well numbers, time and date of sampling, sampling team, and type of sample collected.

7.3.6.6 Sample Packaging and Shipping

Samples were hand carried to the WMCO FMPC laboratory and/or shipped to an analyzing laboratory by overnight carrier. The samples were properly packaged and dispatched to the analyzing laboratory for analysis, as specified in Section 6.0 of the QAPP and as discussed in Section 6.3.3.6 of this report. Separate chain-of-custody and request-for-analysis records were prepared and accompanied the samples to the receiving laboratory.

7.3.6.7 Chain of Custody

The chain-of-custody procedures discussed in Section 6.1.10.3 were used for all groundwater samples shipped to either the WMCO laboratory or the IT laboratory. All samples were adequately marked for identification from the time of collection and packaging through shipping and storage. Markings were made on a label attached to each sample container. Sample identification included project name and number, sample number, sample location by well number, sampling date and time, the initials of the individual(s) performing the sampling, and the sample preservative used.

Documentation of the sample chain of custody was provided by a chain-of-custody form that included the sample location, the types and amounts of sample collected, the date and time of sample collection, the name of the person responsible for sample collection, the dates and times of all custody transfers, the signature of the person relinquishing and accepting sample custody, and other pertinent information. Chain-of-custody procedures documented sample possession from the time of sample collection to sample disposal.

A chain-of-custody record was initiated in the field and accompanied each group of samples during shipment to the laboratory. Each time custody of the sample changed, the new custodian signed the record and indicated the date of transfer.

If the samples were directly transported to the laboratory by project personnel, the original chain-of-custody form was kept in possession of the person delivering the samples. If the samples were shipped to the laboratory by commercial carrier, the original chain-of-custody form was sealed in a watertight container and placed in the shipping container, which was sealed with custody tape prior to giving it to the carrier. The carrier waybill served as an extension of the chain-of-custody record between the final field custodian and receipt in the laboratory. The carrier waybill was attached to all chain-of-custody duplicates, which were retained in the site central files. The chain of custody for the sample was completed when the sample was disposed of.

The laboratory request-for-analysis form was prepared to indicate the testing program required for the collected samples. The information recorded on the laboratory request-for-analysis form included project name and number, date samples were shipped, required report date and turnaround times for analysis, contact with telephone number for receipt of the analytical report and billing information, sample identification numbers, and sample volume and preservatives. A request-for-analysis form was submitted with each group of samples sent to the laboratory.

A sample tracking system was maintained in the RI/FS site office on a personal computer (PC). The sample number, type, requested analysis, and shipping date were entered into the relational data base on the PC. When analytical results were received from the laboratory, they were logged into the tracking system to verify that the requested results had been received. The tracking system also provided useful reports on the length of time that samples had been in the laboratory.

7.3.6.8 Decontamination

The groundwater purging and sampling equipment was decontaminated after each use. The sampling equipment decontamination procedures varied depending on the type of contamination anticipated at the sampling location. In the case of inorganic contaminants, the equipment was first washed with a nonphosphate detergent and then rinsed with dilute (0.1 N) hydrochloric acid, followed by two separate deionized water rinses. In the case of organic contaminants, the equipment was first washed with a nonphosphate detergent and then rinsed with tap water, methanol, and two separate deionized water rinses. Sampling equipment was never placed directly on the ground or on other potentially contaminated surfaces.

As part of the RI/FS QC requirements, one sample of the final deionized water rinse was collected. The rinsate samples were analyzed at a frequency of one per every set of 20 samples, or fraction thereof, within a sampling program, to check for cross contamination between wells or piezometers.

7.4 FIELD ANALYTICAL PROGRAM

The field analytical procedures required under the "Production and Additional Suspect Area Work Plan" are the same as those specified in the March 1988 RI/FS Work Plan, as discussed in Section 6.3.7 of this report.

7.4.1 Parameters

Immediately following sample collection, the temperature, pH, and specific conductance were measured in the field and documented on the Water Quality Field Collection Report. Dissolved oxygen was measured only for the well samples. No dissolved oxygen or Eh measurements were made for piezometer samples. The field procedures pertaining to these tests were followed in

accordance with Section 6.2 of the QAPP and as discussed in Section 6.3.7 of this report. Field analyses were performed on unpreserved samples. During adverse weather conditions, field analysis was performed at the site sample collection trailer, in an area maintained at 20 to 25 degrees Celsius.

7.4.2 Methods

Field analytical procedures used in sampling piezometers were the same as those described for wells in Section 6.3.7.2.

7.4.3 Instrumentation

Instrumentation and procedures used for the field measurements were the same as discussed in Section 6.3.7.3. Each instrument was calibrated as per the manufacturers' guidelines and as determined to be required in the field, as discussed in Section 6.3.7.2. The calibration documents were maintained in the FMPC project files.

7.5 QUALITY ASSURANCE/QUALITY CONTROL

7.5.1 QA/QC Samples

During groundwater sampling, various QA/QC samples were collected on a routine basis to verify and determine accuracy and precision. These QA/QC samples included duplicate and rinsate samples, as well as trip blanks. The QA/QC samples were collected using the same procedures as discussed in Section 6.3.6.1, as summarized below.

Duplicate samples were collected at the well location and were assigned unique sample numbers. Duplicate samples were analyzed at a frequency of one per every set of 10 samples, or fraction thereof, in a sampling program. Trip blanks were collected at a rate of one per day when samples were sent to the laboratory. Trip blanks were analyzed for the same set of parameters as the sample with the most extensive analysis. Rinsate samples were collected from the equipment following each well sampling. Rinsate samples were analyzed at a frequency of one per every set of 20 samples, or fraction thereof, in a sampling program.

7.5.2 Field Audits

To verify compliance with the QAPP requirements, the QA Project Officer and other technically qualified personnel planned, performed, and documented audits of groundwater sampling activities. These audits consisted of an evaluation of QA procedures and the effectiveness of their

implementation, an evaluation of work area activities, and a review of project documentation. Audits were performed in accordance with written checklists and were formally documented.

Following the completion of the audits, a report was prepared and submitted to the Project Director and other appropriate personnel. During the audit, and upon completion, the findings were discussed with the individual sampling team members and task leaders. Corrective actions were immediately initiated, if required. All audit report findings were corrected and appropriate measures were taken to comply with the QAPP requirements.

7.5.3 QA/QC Documentation

Field QA/QC documentation of the groundwater sampling activities was conducted in accordance with QAPP Section 6.2. Numerous field forms and checklists were used to ensure all required data were collected and proper procedures were followed. These forms were filled out in the field as the tasks were accomplished. Calculations made in the field were verified by other sampling team members. Instrument calibration and measurements were observed by other sampling team members, as appropriate.

Water Quality Field Collection Report

The project name and number, sampling location, date and time of sampling, sampling team members, and weather conditions were recorded on the Water Quality Field Collection Report. Field instrument calibrations were also recorded on this field form, as were the field measurements.

Sample Collection Log

The sample collection log was used to record the sample number, sample location, sampling team members, and type of sample collected. The sample collection log provided a master list to cross reference all groundwater and soil samples collected to a unique sample number. The sample number was used to track the sample from the well site to the laboratory and to cross reference the analytical results to the appropriate well location.

Field Activity Daily Log

The Field Activity Daily Log was used to document the chronology of the sampling team's activities. Included on this log are the times when well purging and sampling were conducted, well static water levels before well purging, volume of water removed from each well, and any other noteworthy events that occurred during the sampling effort. The Field Activity Daily Log was used by the sampling team to record any noteworthy data not specified in any of the sample collection forms.

7.6 RESULTS

All field QA/QC records described in Section 7.5.3 are maintained in the site office central files. Boring logs (Visual Classification of Soils) are presented in Appendix A. Piezometer installation sheets and monitoring well installation details are presented in Appendix B. All elevations and horizontal coordinates are based on Ohio State Planar Coordinates.

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8.0 LABORATORY ANALYTICAL PROGRAM

Groundwater, surface water, soil, and sediment samples have been collected to evaluate current environmental conditions at the FMPC and surrounding areas. Additionally, the data were used to predict future conditions resulting from the implementation of various remedial alternatives. Samples have been analyzed for parameters historically used, stored, or produced at the FMPC. Regulatory agencies have required that additional organic and inorganic parameters also be analyzed to more completely characterize the impact of operations on the environment.

The laboratory testing program conducted on groundwater and subsurface soil samples can be divided into three elements that include:

- Radiological analysis
- Geochemical analysis
- Organic/inorganic analysis

8.1 RADIOLOGICAL PARAMETER ANALYSIS

Samples designated for radiological analysis were tested for a set of radionuclides historically used, stored, or produced at the FMPC. These parameters were the same as those being analyzed under RCRA compliance monitoring, and include:

- Gamma Spectral Analysis
- Total Uranium
- Uranium 234
- Uranium 235
- Uranium 236
- Uranium 238
- Radium 226
- Radium 228
- Technetium 99
- Thorium 228
- Thorium 230
- Thorium 232
- Cesium 137
- Strontium 90
- Ruthenium 106
- Neptunium 237
- Plutonium 238
- Plutonium 239
- Plutonium 240

8.1.1 Analytical Methods

Radiological analyses were performed in accordance with the IT/RSL Radioanalytical Methodology and Procedures Manual. This manual includes the following procedures that were applied to radiological analyses:

- RSL-001 Acquisition and Use of Standard Reference Material
- RSL-002 Standardization of Carrier Solutions
- RSL-102 Operation of Alpha Spectrometer Systems
- RSL-103 Calibration of Liquid Scintillation Counting Systems
- RSL-104 Operation of Low Background Alpha/Beta Counting Instruments
- RSL-105 Calibration of Alpha Spectrometer Systems
- RSL-106 Calibration of Alpha/Beta Counting Instruments

- RSL-107 Operation of Liquid Scintillation Counting Instruments
- RSL-108 Operation of Alpha Scintillation Counting Instruments
- RSL-109 Background Determination of a Germanium Detector Spectroscopic System
- RSL-110 Determination of Germanium Detector Counts Reproducibility
- RSL-111 Linearity Check of Germanium Gamma-Ray Spectroscopic Systems
- RSL-112 Operation of Germanium Gamma Spectroscopic System (ND 66/680)
- RSL-113 Determination of Germanium Detector Counts Reproducibility
- RSL-201 Samples Preparation
- RSL-202 Extraction of Iron from Soil or Metallic Samples
- RSL-304 Determination of Selected Alpha Emitting Isotopes
- RSL-305 Determination of Strontium 89,90 in Water Samples
- RSL-306 Determination of Strontium 89,90 in Milk Samples
- RSL-308 Determination of Gross Alpha and/or Beta Activity
- RSL-309 Determination of Radium-226, 228 in Aqueous Samples
- RSL-310 Determination of Technetium-99
- RSL-501 Data Verification
- RSL-601 Performing Interlaboratory Quality Control Analyses
- RSL-602 Performing Interlaboratory Quality Control
- RSL-603 Internal Surveillances and Audits
- RSL-703 Storage and Maintenance of Records
- RSL-801 Instructions for Glassware Cleaning and Laboratory Housekeeping
- RSL-802 Checking Laboratory Measuring and Test Equipment
- RSL-901 Training and Qualification of Laboratory Technicians
- RSL-902 QA Orientation of New Employees
- RSL-903 Materials and Equipment Procurement, Receipt, Storage and Control
- RSL-904 Reporting of Defects and Noncompliances per 10CFR21
- RSL-1001 Sample Receiving
- RSL-1002 Radiological Screening and Classification of Mixed Waste Samples
- RSL-1004 Sample and Data Flow

8.1.2 Detection Limits

Typical detection limits for the radionuclides analyzed were summarized in Table 8-1. As with any analytical method, it was not always possible to obtain these levels of detection because of analytical difficulties related to sample composition matrix and volume.

8.1.3 Differential Leaching Test

Samples of subsurface materials from the Great Miami Aquifer were subjected to a differential leaching test to estimate the amount and type of adsorbed uranium on the solids. A leachate was a liquid that results from the mixing of a solvent such as water or an organic mixture with a solid material. Various compounds of interest were transferred from the solid to the liquid, where after removal of the solids, they can undergo chemical analysis. Leachates recovered from this test were analyzed for uranium by standard laser-fluorimetry procedures. Detailed laboratory procedures for the leaching test can be found in the Work Plan for the Geochemical Program and the Field Sampling and Laboratory Procedure Plan for the Geochemical Program.

TABLE 8-1

TYPICAL DETECTION LIMITS OF THE ANALYZED RADIONUCLIDES

Parameter	Detection Limit
Total U	1 mg/L
U-234	1 pCi/L
U-235, 236	1 pCi/L
U-238	1 pCi/L
TH-228	1 pCi/L
TH-230	1 pCi/L
TH-232	1 pCi/L
PU-238	1 pCi/L
PU-239, 240	1 pCi/L
SR-90	50 pCi/L
TC-99	30 pCi/L
NP-237	1 pCi/L
RA-226	1 pCi/L
RA-228	3 pCi/L
Total TH	1 ug/L

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The differential leaching test was designed to distinguish between easily mobilized and available uranium in sorbed or amorphous uranium phases from insoluble uranium in mineral lattices, such as zircon, that is not available to the groundwater environment. The differential leaching test was designed to provide the following information:

- Uranium present in fine-grained carbonate minerals (i.e., pore cement)
- Uranium present as sorbed species on clay minerals and amorphous iron and aluminum oxyhydroxides
- Uranium present as sorbed species or within organics in the soils or wastes
- Uranium present in amorphous solids or oxide phases such as UO_2 or U_3O_8.

The four-step extraction technique can be summarized as follows:

- Sodium acetate was used to digest the fine-grained carbonate minerals
- Disodium ethylenediaminetetraacetic acid (EDTA) was used to strip sorbed uranium from clay minerals and amorphous iron and aluminum oxyhydroxides
- Hydrogen peroxide was used to digest organic material
- Nitric acid (1:1 with distilled H_2O) was used to dissolve amorphous solids and oxides of uranium.

At each step, the reagent was agitated with the sample, and the resulting leachate was recovered by centrifuging and analyzed for total uranium by laser fluorimetry.

Aquifer solids were also subjected to a leach test to determine the amount of leachable iron and manganese. This test was conducted to assist in the evaluation of uranium adsorption on iron and manganese oxyhydroxide films that coat grains or fractures in the aquifer. Detailed laboratory procedures for the iron and manganese leaching test are in the Work Plan for the Geochemical Program and the Field Sampling and Laboratory Procedure Plan for the Geochemical Program.

The leaching technique was designed to recover iron and manganese from amorphous-oxyhydroxide coatings on grains or fractures and crystalline oxide minerals using a solution of acetic acid and hydroxylamine hydrochloride. Aquifer solids were mixed with the leaching solution, agitated, and the leachate recovered by centrifuging. Unlike the differential leaching procedure which recovered recently bound uranium, this procedure would also recover ancient uranium locked in the mineral lattices of detrital grains or fracture coatings. Therefore, uranium sorbed to iron- and manganese-oxyhydroxide coatings on grain surfaces or fractures would be removed and mixed with uranium

recovered from the lattice sites in iron- and manganese-oxide minerals, detrital grains, or fracture coatings of hematite or pyrolusite. The two uranium components cannot be distinguished in the analysis, and the background component uranium in mineral lattices must be estimated from aquifer solids which are known to be uncontaminated.

8.2 INORGANIC CHEMICALS

Designated samples were analyzed for the following parameters used as indicators of drinking water quality under the ongoing RCRA program:

- pH
- Specific conductance
- Chloride
- Iron
- Manganese
- Phenols (total)
- Sodium
- Sulfate
- Gross alpha
- Gross beta
- Alkalinity as $CaCO_3$
- Carbonate/bicarbonate
- Copper
- Nickel
- Potassium
- Phosphate
- Arsenic
- Barium
- Cadmium
- Chromium (hexavalent; total)
- Fluoride
- Lead
- Mercury
- Nitrate
- Selenium
- Silver
- Ammonia
- Total organic nitrogen
- Molybdenum
- Calcium
- Magnesium

8.2.1 Analytical Methods

The inorganic analytical procedures were:

- Inductively Coupled Argon Plasma Spectrometry (ICP) (U.S. EPA Method 200.7 CLP-M) for the analysis of Al, As, Ba, Be, B, Cd, Ca, Cr, Co, Fe, Pb, Mg, Mn, Mo, Ni, Si, Na, Th, V and Zn)

- Graphite Furnace Atomic Absorption Spectrophotometry for Arsenic (U.S. EPA Method 206.2 CLP-M) and Selenium (U.S. EPA Method 270.2 CLP-M)

- Cold Vapor Atomic Absorption Spectrophotometry for Mercury (U.S. EPA Methods 245.1 CLP-M and 245.2 CLP-M)

- Alkaline Extraction and Colorimetric Determination of Hexavalent Chromium (U.S. EPA Methods 3060 and 7196)

- Digestion/Distillation and Titrametric/Colorimetric Determination of Cyanide (U.S. EPA Method 335.2 CLP-M)

- Bellack Distillation and Specific Ion Electrode Determination of Fluoride (U.S. EPA Method 340.2)

- Colorimetric Determination of Nitrate Nitrogen (U.S. EPA Method 352.1)

8.2.2 Detection Limits

Detection limits for the inorganic parameters analyzed are summarized in Table 8-2.

8.3 ORGANIC CHEMICALS

Samples designated for organic chemical analysis were analyzed for the following extended HSL parameters:

- HSL inorganics
- HSL volatiles
- HSL semivolatiles
- HSL pesticides/PCBs
- Primary drinking water organics
- Organophosphorus pesticides
- Dioxin and furans

8.3.1 Analytical Methods

The analytical program for the HSL volatile organics, semivolatile organics, and pesticides/PCBs followed the methodologies outlined under U.S. EPA, 1985 "Chemical Analytical Services for Multi-media Multi-Concentration Organics, GC/MS Techniques." A library search was also executed for non-HSL sample compounds for the purpose of tentative identification.

8.3.2 Detection Limits

Detection limits for the organic parameters analyzed were summarized in Tables 8-3, 8-4, and 8-5 for volatile organics, semivolatile organics, and pesticides and PCBs, respectively.

8.3.3 Sample Request for Analysis

Table 8-6 lists the analytical parameters included in the HSL, full HSL, HSL plus, and full radiological analytical groups. These terms were used to identify the specific groups of analyses throughout the RI/FS program.

8.4 RESULTS

Results of the laboratory analysis are presented in Appendix E for groundwater samples and Appendix I for subsurface soils.

8.5 QUALITY ASSURANCE/QUALITY CONTROL

Laboratory QA/QC procedures were followed as provided in the IT Analytical Services QA Manual, the IT Oak Ridge Laboratory QA Manual, and the Laboratory-Specific Attachments for IT Oak Ridge Laboratory, Mixed Waste and Middlebrook Pike laboratories. The laboratory results and QC

TABLE 8-2

TYPICAL DETECTION LIMITS OF ANALYZED INORGANIC CONSTITUENTS (mg/L)

Parameter	Detection Limit
Chloride	0.5
Iron	0.05
Manganese	0.001
Phenols (total)	0.01
Sodium	0.002
Sulfate	1
Copper	0.01
pH	± 0.01[a]
Nickel	0.02
Potassium	0.1
Phosphate (as P)	0.02
Arsenic	0.002
Barium	0.002
Cadmium	0.002
Chromium (hexavalent; total)	0.02
Fluoride	0.1
Lead	0.02
Mercury	0.0002
Nitrate (as N)	5
Selenium	0.002
Silver	0.05
Ammonia (as N)	0.1
Total Organic Nitrogen	0.1
Molybdenum	0.02
Calcium	0.01
Magnesium	0.05
Sodium	0.05

[a]Standard units.

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TABLE 8-3

TYPICAL ORGANIC DETECTION LIMITS OF ANALYZED VOLATILE ORGANICS (ug/L)

Parameter	Detection Limit
Chloromethane	10
Bromomethane	10
Vinyl chloride	10
Chloroethane	10
Methylene chloride	5
Acetone	10
Carbon disulfide	5
1,1-Dichloroethene	5
1,1-Dichloroethane	5
1,2-Dichloroethene (total)	5
Chloroform	5
1,2-Dichloroethane	5
2-Butanone	10
1,1,1-Tetrichloroethane	5
Carbon tetrachloride	5
Vinyl acetate	10
Bromodichloromethane	5
1,2-Dichloropropane	5
cis-1,3-Dichloropropene	5
Trichloroethene	5
Dibromochloromethane	5
1,1,2-Trichloroethane	5
Benzene	5
trans-1,3-Dichloropropene	5
Bromoform	5
4-Methyl-2-pentanone	10
2-Hexanone	10
Tetrachloroethene	5

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TABLE 8-4
TYPICAL DETECTION LIMITS OF ANALYZED SEMIVOLATILE ORGANICS (ug/L)

Parameter	Detection Limit
1,1,2,2-Tetrachloroethane	5
Toluene	5
Chlorobenzene	5
Ethylbenzene	5
Styrene	5
Xylene (total)	5
Phenol	10
bis(2-Chloroethyl)ether	10
2-Chlorophenol	10
1,3-Dichlorobenzene	10
1,4-Dichlorobenzene	10
Benzyl alcohol	10
1,2-Dichlorobenzene	10
2-Methylphenol	10
bis(2-Chloroisopropyl)ether	10
4-Methylphenol	10
N-Nitroso-di-n-propylamine	10
Hexachloroethane	10
Nitrobenzene	10
Isophorone	10
2-Nitrophenol	10
2,4-Dimethylphenol	10
Benzoic acid	50
bis(2-Chloroethoxy)methane	10
2,4-Dichlorophenol	10
1,2,4-Trichlorobenzene	10
Naphthalene	10
4-Chloroaniline	10

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TABLE 8-4
(continued)

Parameter	Detection Limit
Hexachlorobutadiene	10
4-Chloro-3-methylphenol	10
2-Methylnaphthalene	10
Hexachlorocyclopentadiene	10
2,4,6-Trichlorophenol	10
2,4,5-Trichlorophenol	50
2-Chloronaphthalene	10
2-Nitroaniline	50
Dimethylphthalate	10
Acenaphthylene	10
2,6-Dinitrotoluene	10
3-Nitroaniline	50
Acenaphthene	10
2,4-Dinitrophenol	10
4-Nitrophenol	50
Dibenzofuran	10
2,4-Dinitrotoluene	50
Diethylphthalate	10
4-Chlorophenyl-phenylether	10
Fluorene	50
4-Nitroaniline	50
4,6-Dinitro-2-methylphenol	10
N-Nitrosodiphenylamine (1)	10
4-Bromophenyl-phenylether	10
Hexachlorobenzene	10
Pentachlorophenol	50
Phenanthrene	10

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TABLE 8-4
(continued)

Parameter	Detection Limit
Anthracene	10
Di-n-butylphthalate	10
Fluoranthene	10
Pyrene	10
Butylbenzylphthalate	10
3,3-Dichlorobenzidine	20
Benzo(a)anthracene	10
Chrysene	10
bis(2-Ethylhexyl)phthalate	10
Di-n-octylphthalate	10
Benzo(b)fluoranthene	10
Benzo(k)fluoranthene	10
Benzo(a)pyrene	10
Indeno(1,2,3-cd)pyrene	10
Dibenz(a,h)anthracene	10
Benzo(g,h,i)perylene	10

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TABLE 8-5
DETECTION LIMITS OF ANALYZED PESTICIDES AND PCBs (ug/L)

Parameter	Detection Limit
alpha-BHC	0.050
beta-BHC	0.050
delta-BHC	0.050
gamma-BHC (Lindane)	0.050
Heptachlor	0.050
Aldrin	0.050
Heptachlor epoxide	0.050
Endosulfan I	0.050
Dieldrin	0.10
4,4'-DDE	0.10
Endrin	0.10
Endosulfan II	0.10
4,4'-DDD	0.10
Endosulfan sulfate	0.10
4,4'-DDT	0.10
Methoxychlor	0.50
Endrin ketone	0.10
alpha-Chlordane	0.50
gamma-Chlordane	0.50
Toxaphene	1.0
Aroclor-1016	0.50
Aroclor-1221	0.50
Aroclor-1232	0.50
Aroclor-1242	0.50
Aroclor-1248	0.50
Aroclor-1254	1.0
Aroclor-1260	1.0

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TABLE 8-5
(continued)

Parameter	Detection Limit
Azinphos-methyl	5.0
Demeton	1.0
Diazinon	0.5
Disulfoton	0.5
Ethion	0.5
Malathion	1.0
Parathion-ethyl	0.5
Parathion-methyl	1.0

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TABLE 8-6
ANALYTICAL PARAMETER GROUPS

Full Radiological

- Total Uranium
- Isotopic Uranium
- Isotopic Plutonium
- Radium-226
- Radium-228
- Neptunium-137
- Total Thorium
- Isotopic Thorium
- Technetium-99
- Cesium-137
- Strontium-90
- Ruthenium-106

(HSL) Hazardous Substance List[a]

Volatile and Semivolatile Organic Compounds
Metals Plus Molybdenum
Mercury
Cyanide

Full HSL

All of the above plus HSL Pesticides/PCBs

HSL +

All of the above plus Organophosphorus Pesticides, Dioxins, Furans

[a]HSL as defined in 40 CFR Part 130.

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data were reviewed by the appropriate laboratory manager and QC Coordinator. The QC data were reported with the analytical results.

Designated samples were also analyzed following the criteria established by the U.S. EPA Contract Laboratory Program (CLP). Other EPA-approved alternate analytical methods followed prescribedanalytical procedures considered acceptable. Data generated by EPA-approved alternate analytical methods were verified and validated in accordance with the quality control specifications documented for the alternate method or its originating reference document.

Internal QC checks were performed to verify the resulting quality of the measurements of the field and laboratory investigation.

8.5.1 Data Verification

At the time this report was prepared, data verification was still in progress.

8.5.2 Data Validation

At the time this report was prepared, data validation was still in progress.

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9.0 DATA FROM OTHER STUDIES

Several environmental investigations and studies have been conducted in and around the FMPC. The studies were focused primarily on potential health and environmental problems associated with releases from the FMPC. Major past studies undertaken by the DOE, NLO, WMCO, and others pertinent to the groundwater investigation are summarized below.

9.1. ENVIRONMENTAL SURVEYS

For more than 10 years, the environment in and around the FMPC has been closely monitored by DOE (1977, 1985, 1987), Oak Ridge Associated Universities (ORAU 1985), various FMPC-related committees (WMCO 1986, 1987; Fleming and Ross 1984), and various contracted agencies (IT 1986; Weston 1986; Battelle 1981). The DOE and ORAU documents include environmental impact assessments, EIS studies, and environmental surveys. Internal reports of studies by NLO and WMCO include the annual Environmental Monitoring Reports and the Aquifer Contamination Control Reports (various authors, 1965 to present). These documents are available through WMCO.

The contracted studies represent more comprehensive environmental sampling and analysis programs. The material contained in these reports document the analytical results from a large number of groundwater, surface water, sediments, soils, and air samples. The analytical constituents included radionuclides, organic compounds, metals, and general water quality parameters. A sampling and analysis program to comply with RCRA provisions is also ongoing at the FMPC.

IT Corporation, 1986, Air, Soil, Water and Health Risk Assessment in the Vicinity of the FMPC. This study was conducted to determine the geographic extent of off-FMPC radionuclide impacts and to assess the associated risks on the local communities with respect to the FMPC operations. The study area encompassed the region within a five-mile radius of the FMPC. The data collected during the 1986 investigation were used in the formulation of the initial RI/FS Phase 1 well program, and continues to be used in the present study when evaluating releases to the subsurface environment from the FMPC. A stringent QA/QC controls program was implemented during this study and the quality of the data was considered to be acceptable for use as part of the RI/FS data base.

IT, 1988, Hydrogeologic Study of FMPC Discharge to the Great Miami River. In 1988, IT conducted a hydrogeologic study to determine the relationship between the FMPC effluent discharge and the water quality of the collector wells and other pumping centers. This study was highly dependent on the results of a two-dimensional groundwater flow model that represents an

intermediate point in the development of the model described in Part IV of this report. The conclusions from this model study were:

- The discharge from the FMPC effluent pipeline likely occurs within a portion of the Great Miami River that contributes flow, via inducted infiltration, to the collector wells.

- The incremental impact of the effluent on the quality of water pumped from the collector wells lies within the range of variability of previous observations of collector wells water quality; therefore, it may not be detected under average conditions.

- The radius of influence of the Albright & Wilson Co. and FMPC pumping centers is not large enough to capture water infiltrating through the Great Miami River bed near the FMPC discharge point due to their relatively low pumping rates and large distance from the effluent discharge point.

- A mass balance of the source of uranium observed in the collector wells was not performed. The model results indicate a potential eastward component of groundwater flow from the FMPC Production and Waste Storage areas to the collector wells. Water infiltrating from the Production and Waste Storage areas is within the zone of model uncertainty in relation to the capture zone of the collector wells. The low levels of uranium in groundwater remain an unresolved issue that may be significant when quantifying a mass balance at the collector wells due to the low uranium concentrations observed in the collector wells.

Weston, 1987, Characterization Investigation Study. Roy F. Weston conducted a Characterization Investigation Study (CIS) of the FMPC during 1986-1987. The CIS was primarily a data collection investigative study to characterize the materials in the Waste Storage Area. Results of this study are contained in several volumes. As part of this study, soil and waste (sludge) samples were collected from the Waste Storage Area for chemical and geotechnical analyses. Samples were collected from Pits 1 through 6, the burn pit, the two lime sludge ponds, and the sanitary landfill. A walk-over survey was also conducted and samples were collected from Southfield and the Active and Inactive Fly Ash piles. Conclusions from the testing program indicated that more sampling would be required to fully define the physical and chemical characteristics of the stored waste materials.

The data collected during the CIS investigation have been extensively used in the RI/FS to evaluate the potential contribution of the Waste Storage Area and the Southfield/Fly Ash Area to the contaminant plume(s) in the Great Miami Aquifer beneath and south of the FMPC.

Geotrans, 1985, Preliminary Characterization of the Groundwater Flow System Near the Feed Materials Production Center, Great Miami River Valley Fill Aquifer, Fernald, Ohio. The Geotrans groundwater study evaluated a groundwater divide presented by the USGS (Sedan 1985) using a groundwater simulation model. Geotrans indicated that more wells were needed along the eastern site boundary to better define the groundwater divide and groundwater flow in that area. The Geotrans groundwater modeling study concluded that:

- There exists a groundwater divide which trends from the southeast to northwest across the south-central portion of the FMPC
- Water in the Great Miami Aquifer near the Waste Storage Area will travel east toward the Great Miami River
- Water south of the Waste Storage Area will travel south and southeasterly toward the Great Miami River

NLO, 1985, History of FMPC Radionuclide Discharge and WMCO, 1986 (Revision). This report and revision presented information on the discharge of radionuclides from the FMPC during the years of plant operation (1954 to 1984). Discharges to both air and water had occurred, but airborne releases were emphasized in the report. Estimates were made when historic evidence was not available concerning the time and amount of releases from the FMPC. A summary of the data contained in the report follows:

- Air Emissions: Most of the calculated potential dose from FMPC operations is due to uranium; however, daughter products, fission products, and transuranic nuclides have been emitted. Over the years the FMPC was in operation, uranium was discharged from 110 stacks, with the emissions totaling approximately 123,000 kilograms (kg).
- Wastewater Discharge: Over the years the FMPC was in operation, uranium was discharged to the Great Miami River, with an estimated discharge totaling 74,308 kg. Thorium discharge data have been collected since 1969. The estimated thorium discharged to the Great Miami River is 367 kg. Eight- to 24-year records were available concerning curies discharged for Sr-90, Tc-99, Ru-106, Cs-137, Ra-226, Ra-228, Np-237, Pu-238, and Pu-239/240.
- Groundwater Discharge: Twenty-two off-FMPC wells were routinely sampled. Three of these wells have above-background uranium concentrations. These wells were no longer used as drinking water sources.
- Radon-222 Source Term: The estimated source term for Radon-222 flux, for both K-65 silos under present storage conditions, is 60 curies per year. Dispersion code calculations predict that this flux will add an average of 0.006 pCi/L to the Radon-222 concentrations, or 2.5 percent of the natural background Rn-222 concentrations in the Cincinnati area. The amount of Ra-222 in the silos was assumed to be 1,760 curies, instead of the previously used estimate of 1,652 curies.

9.2 GEOLOGIC INVESTIGATIONS

Geologic investigations of the area that surrounds and includes the FMPC have contributed substantial information to the RI/FS investigation. Fenneman (1916) performed an extensive survey of the geology in the Cincinnati area. This report is among the first that describes in detail the interbedded limestone and shale bedrock and its mantle of glaciofluvial and alluvial sediments. Later, workers such as Durrell (1961) supported the earlier observations of Fenneman. The shape of the buried channel aquifer was further refined by Watkins and Spieker (1971) via geophysical surveys of the area around Fernald. More recent information includes various maps of the geology of Hamilton and Butler counties, Ohio, as well as individual quadrangle maps of areas located in those counties (Leow 1985; Vormelker 1985; Ford 1974; Swinford, in preparation). Maps showing the extent and age of glacial till in the study area have also been produced (Brockman 1986). Lerch et al. (1980 and 1982), performed soil surveys of Butler and Hamilton counties, Ohio.

9.3 SURFACE WATER INVESTIGATION

The Miami Conservancy District has kept precipitation and runoff records for the Miami River Valley since the early 1900 (Houck 1921). Precipitation records have also been kept at the Cincinnati Airport. Flood information for the Great Miami River and Paddys Run is available from the Federal Emergency Management Agency (FEMA 1982). Additional information on most Ohio streams, including the Great Miami River and Paddys Run, has been well documented with respect to flow duration and water quality (Cross and Hedges 1959; OEPA 1982).

Flow in the drainage basin is monitored by the USGS using a gaging station on the Great Miami River at Hamilton, Ohio. Flow regulation on the Great Miami River has been studied by Spieker (1968a). Paddys Run data have been compiled by Dames and Moore (1985a). Realignments and other modifications of Paddys Run and its tributaries on the FMPC have been documented by Dove (1961) and WMCO (1987). Surface water quality data for the FMPC area are available from NLO for the period 1979 through 1985 and the OEPA for the period 1977 through 1983. WMCO has maintained surface water quality data since 1986.

9.4 HYDROGEOLOGIC INVESTIGATIONS

Dove (1961) and Spieker (1968a) extensively described the hydrology and hydrogeology of the Great Miami Aquifer in the lower Great Miami River Valley. These studies documented recharge rates, permeabilities of various lithologies, and other aquifer characteristics. Both also discussed groundwater/surface water interactions, specifically for the Great Miami River and Paddys Run. Other studies of the regional valley-fill aquifer in the vicinity of the FMPC include a study by the Miami Conservancy District (1985), several studies by the Ohio Department of Natural Resources

(Walker 1986; Walton and Schaefer 1956), and various contracted studies (Geotrans 1985; Dames and Moore 1985a; ATEC Associates, Inc. 1982). Two other studies by Spieker (1968b,c) deal with the potential effects of increased pumping of the groundwater and future development of the groundwater resources, respectively.

9.5 CONTAMINATION RELEASES AT THE FMPC

Dove and Norris (1951) were the first to describe the possible fate of chemical and radionuclide wastes that infiltrate the groundwater in the Great Miami Aquifer. Publications released in the last five years document radionuclide releases from the FMPC into the environment. These studies are from either DOE (1985a) or are internal WMCO documents (Boback et al. 1985, 1986; WMCO 1987, 1989; Clark et al. 1989). Spieker and Norris (1962) investigated radionuclide contamination of the groundwater and the transport of the contaminated water through the Fernald, Ohio area. Additionally, the Ohio Department of Health (ODH) has documented radionuclide contamination in private wells in the FMPC area (ODH 1988). Sedam (1984) investigated the occurrence of uranium in the groundwater in the vicinity of the FMPC for DOE. Starkey et al. (1962), and the NLO (Spenceley 1983) performed internal investigations to distinguish between FMPC contamination and non-FMPC contamination.

DRAFT

PART III. DATA ANALYSIS

Part III of the FMPC groundwater report provides an in-depth discussion on the regional and site-wide hydrogeologic setting and geochemical and groundwater quality. Figure III-1 presents a schematic of the overall structure of the FMPC groundwater studies being documented in this report. The figure not only provides a retrospective summary of the planning and data collection phases reported in Parts I and II of this report, but also gives an indication of the types of applications to be discussed in forthcoming Parts IV and V. The necessary transition step from data collection to project application and data analysis is the subject of Part III of this report.

Part III has been divided into eight chapters. The rationale and sequences of the data analysis are discussed in Chapter 10.0. The regional geology and hydrogeology are presented in Chapters 11.0 and 12.0. The method for hydrologic parameter estimation is given in Chapter 13.0.

Surface and groundwater quality are discussed in Chapters 14.0 and 15.0. Estimation of the geochemical parameters as input data to models is made in Chapter 16.0. Finally, Chapter 17.0 is devoted to the discussion of the operable unit area hydrogeology.

DRAFT

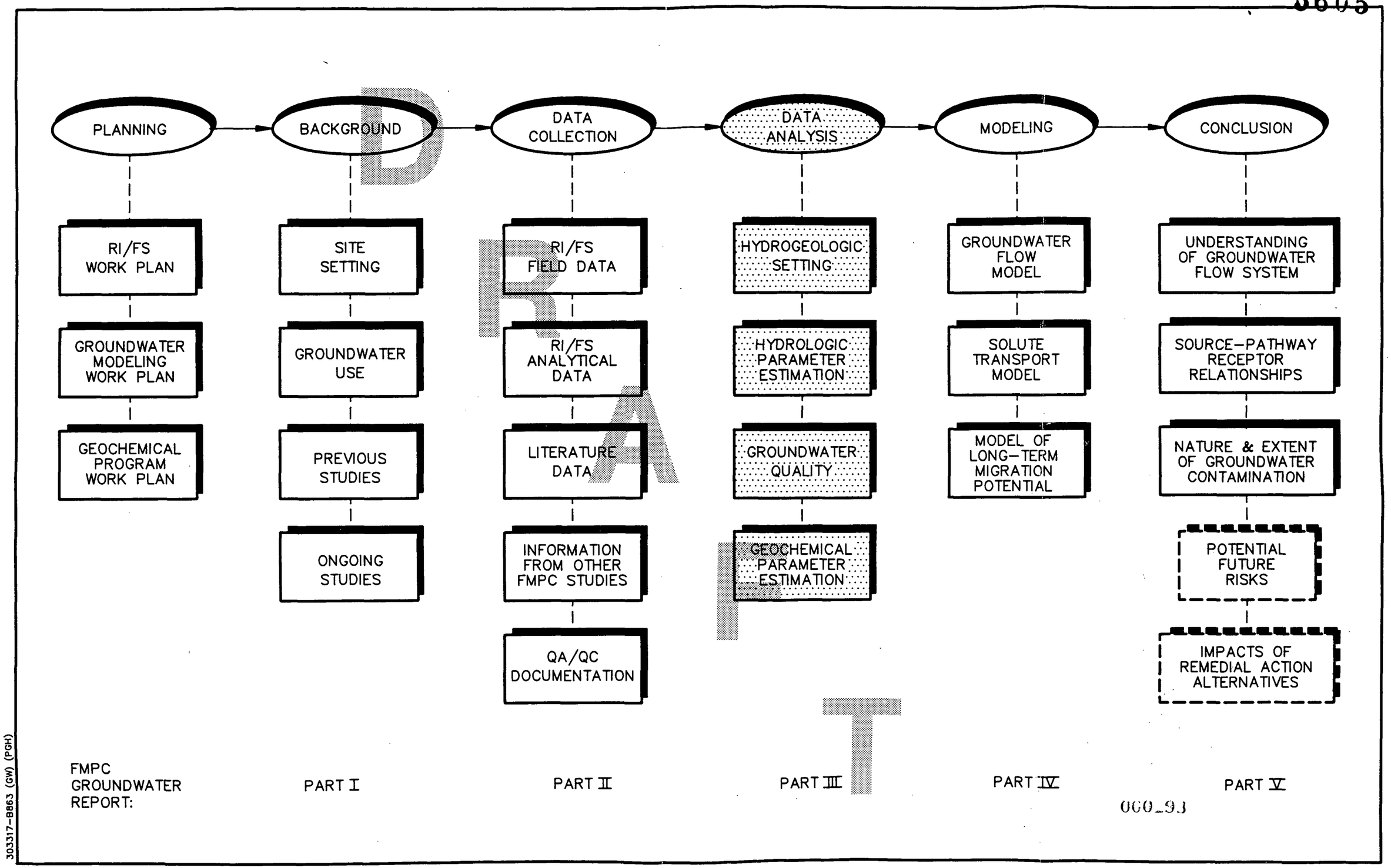

FIGURE III-1
OVERVIEW OF DATA ANALYSIS COMPONENT

10.0 INTRODUCTION

The development of an effective and economical remedial solution for a contaminated site such as the FMPC requires a comprehensive understanding of the source-pathway-receptor relationships. This understanding requires knowledge of the rate and quantity of the contaminants reaching the groundwater. It must also determine the rate of migration of the contaminants and their concentrations at different locations and times. This information will show the spatial and temporal concentrations of the various chemical constituents within regions of concern in and around the FMPC site.

However, during any field investigation program, regardless of its magnitude, the data are obtained at discrete locations and times. These data should be interpreted and furthermore extrapolated to define the spatial and temporal variations of the hydrologic setting and chemical constituent concentrations. The purpose of the data analysis is to provide the link between the field data and the extrapolation techniques (e.g., modeling). Because of the importance of the hydrogeology, geochemistry, and water quality to the source-pathway-receptor relationship, a great emphasis has been placed on interpretation of the above subjects. This interpretation has helped to determine the key input parameters to the model, identify the data gaps prior to groundwater modeling, and to develop a conceptual three-dimensional model of the site.

For purposes of this report, the data analysis effort has been separated into five distinct subject areas. Both the regional and local hydrogeologic settings are addressed in Chapters 11.0 and 12.0, with an emphasis on observed groundwater elevations in each aquifer and the interpretation thereof to establish the seasonal groundwater flow directions and velocities. This information provides a critical input for the calibration of the groundwater flow model and the overall evaluation of contaminant migration pathways.

A combination of published information and RI/FS field studies is used in Chapter 13.0 to establish representative, site-specific values for the hydrologic parameters of primary concern. These parameters include vertical and horizontal permeabilities, transmissivities, infiltration and recharge rates, stream leakage rates, and pumping rates. They find their

principal use in this report as input values to the groundwater models, and were modified within a limited range as a consequence of model calibration.

A similar analysis is performed in Chapter 16.0 to establish representative values for the geochemical parameters of interest. The retardation factors for each radionuclide and chemical of concern for the various operable units are the principal parameters addressed in this chapter. Separate values are derived for different subsurface environments, such as the Great Miami Aquifer and the glacial overburden underlying much of the site. Geochemical laboratory studies and geochemical models used in support of parameter determination are also discussed in this chapter. The resultant parameters are principally used as input to both the solute transport model and the model of long-term migration, with the latter highly dependent on the geochemistry of both the release from and depletion of the waste units and the saturated and unsaturated glacial overburden.

The reporting and interpretation of surface water and groundwater quality data for the FMPC are the emphasis of Chapters 14.0 and 15.0. These data provide direct evidence to establish the current nature and extent of surface water and groundwater contamination, as well as important baseline conditions for recognition of source terms and calibration of the solute transport model for use in predicting future conditions. Incremental contributions of environmental contaminants attributable to the FMPC can only be distinguished once background conditions are established. The background concentration of each principal parameter of concern is estimated in Chapters 14.0 and 15.0 based on published information and RI/FS analytical data.

The specific application of the groundwater data to operable units is the subject of Chapter 17.0. In this chapter, the hydrogeology in the immediate vicinity of each operable unit is developed with an emphasis on the locally viable overburden conditions. This analysis was performed in support of the concurrent RI efforts for each operable unit to ensure that the individual RI interpretations are consistent with the understanding of site-wide conditions.

The eventual applications of the results of the data analysis effort, as reported in Chapters 11.0 through 15.0, are subsequently described in Parts IV and V. Part IV is dedicated to the various groundwater modeling studies, whereas Part V addresses various issues important to the RI/FSs being prepared for individual operable units. The specific applications of the results to operable units are summarized in Part V. Details of these applications are presented in the RI and FS reports for the respective operable units.

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11.0 REGIONAL GEOLOGY

11.1 GEOLOGIC HISTORY

The geology of the FMPC study area has been previously described by Fenneman (1916), Darrell (1961), and Spieker (1968). Previous reports by the above-mentioned authors and Watkins and Spieker (1971) and Brockman (1986) provide detailed geologic descriptions. Based on these studies, with modifications and extensions resulting from data collected during the RI studies, a comprehensive geologic history has been developed for the study area. This geologic history was described in detail in Section 2.2.1 and is summarized below in relation to those aspects of principal importance to the RI/FS.

In Late Ordovician time (approximately 450 million years ago), sediments which would become predominantly flat-lying shale with thin interbedded limestone were deposited in a shallow sea. This shale forms the relatively impermeable bedrock which now underlies the FMPC site area and forms the highlands to the north.

During the Kansan-Illinoian interglacial period (300,000 to 450,000 years ago), a large watercourse (larger than the present-day Great Miami River) cut a valley into this shale bedrock to a level of more than 200 feet below the present-day Great Miami River, forming the Deep Stage Drainage System. During continental glacial events, sea levels drop because of the large amount of water stored as ice on the continents. This drop in sea level allowed the rivers in the Deep Stage Drainage System to carve valleys roughly 200 feet deeper into the bedrock in the Cincinnati area than could happen under current sea level conditions.

As the Illinoian glacier advanced further into the Cincinnati area, the ancestral Ohio River (Figure 2-3) flowing in the Deep Stage Valley was dammed by the glacier. The lake that formed behind the dam overflowed at the low divide in the vicinity of the present day Anderson's Ferry. As the divide eroded, the present course of the Ohio River was established (Figure 2-3b). A further ice advance faced the ancestral Great Miami River was forced out of the Deep Stage Valley and carved a new narrow deep stage valley from just north of New Baltimore to a location about one mile west of Cleves, where it returned to the original Deep Stage Valley. Because only water from the Great Miami River and

its tributaries carved this valley, it is much smaller than the ancestral Ohio River Valley. This two-mile-wide valley was termed the New Haven Trough by Fenneman (1916).

During the Illinoian glacial retreat, about 250,000 years ago, the Deep Stage Valley including the New Haven Trough was filled with about 200 feet of glaciofluvial sediments. These sediments were deposited by water running from the margins of the glaciers and consisted mainly of well-sorted sand and gravel. This formed the Great Miami Aquifer. A blanket of poorly-sorted, clay-rich glacial overburden was deposited on top of these sediments during the Wisconsin ice advance, about 100,000 years ago.

When the Wisconsin ice sheet advanced to its southern limit, it deposited a terminal moraine, the Shelbyville End Moraine, south of the present-day FMPC reservation. The ice and terminal moraine again blocked the course of the ancestral Great Miami River and forced it to abandon its channel under the valley of present day Paddys Run and cut a new valley to the south, where the modern Great Miami River Valley is presently located. The terminal moraine also blocked the ancestral Dry Fork of the Whitewater River, creating a lake as the ice sheet retreated. The drainage disruption caused the Dry Fork of the Whitewater River to abandon its ancestral valley and cut its present valley to the west. When the end moraine was breached, the lake drained and created Paddys Run, which now occupies the ancestral Dry Fork Valley.

Postglacial erosion by the Great Miami River and its tributaries removed significant portions of the glacial overburden and left terrace remnants which stand topographically higher than surrounding bottom lands. Today, in the area of the FMPC, the Great Miami River flows south from Middleton to just north of New Baltimore in the former Deep Stage Valley. There is no surface stream occupying the Deep Stage Valley between the Great Miami River east of the FMPC and the Whitewater River west of the FMPC.

The FMPC site lies on glacial overburden above the terrace remnants left after the establishment of the present day Great Miami River channel. This geologic history of bedrock erosion and subsequent filling in of the valley with glacial outwash and till gave rise to the present day deposits within the FMPC area.

11.2 BEDROCK VALLEY

The eroded bedrock beneath the Great Miami Aquifer consists of predominantly flat-lying Ordovician shales with thin, interbedded layers of limestone. This bedrock unit reaches a total thickness of approximately 800 feet. During Pleistocene interglacial periods prior to the Illinoian and Wisconsin glacial advances, the ancestral Ohio River eroded a valley in the bedrock. This bedrock valley has a broad, relatively flat bottom and steep valley walls (Figure 11-1).

During the retreat of the Illinoian ice sheets, the valley was filled with 200 feet of glaciofluvial sand and gravel, which today is the Great Miami Aquifer.

Watkins and Spieker (1971) performed extensive seismic refraction surveys to determine the thickness and extent of the sand and gravel deposits filling the bedrock valley. Test drilling was used in conjunction with the refraction surveys to verify the accuracy of the seismic determinations of the depth of the valley floor. The map of the top of bedrock (Figure 11-2) was derived from the bedrock map produced by Watkins and Spieker (1971), with additional information provided by Leow (1985) and Vormelker (1985), and wells constructed for the RI.

11.3 GREAT MIAMI AQUIFER

The portion of the Great Miami Aquifer that underlies the FMPC study area consists primarily of glaciofluvial sand and gravel outwash deposited during the latest two Pleistocene glaciations. These deposits lie unconformably on the Ordovician shales, filling the bedrock valley to a depth of 200 feet in places. In the study area, the thickness of the Great Miami Aquifer varies from 120 to 200 feet in the valley and tributary valley centers to only a few feet along the valley walls. Although the glaciofluvial deposits are heterogeneous, they are typically well-sorted sands and gravels with only minor amounts of silt and clay. Within the coarse-grained sediments of the Great Miami Aquifer lies an interbedded clay layer that underlies most of the FMPC and parts of the surrounding areas (Figure 11-3). The clay interbed lies about 100 to 125 feet below the surface and generally about 60 to 80 feet below the water table (Figure 11-4). It ranges from 5 to 15 feet in thickness and consists of a low permeability homogeneous clay which acts as an

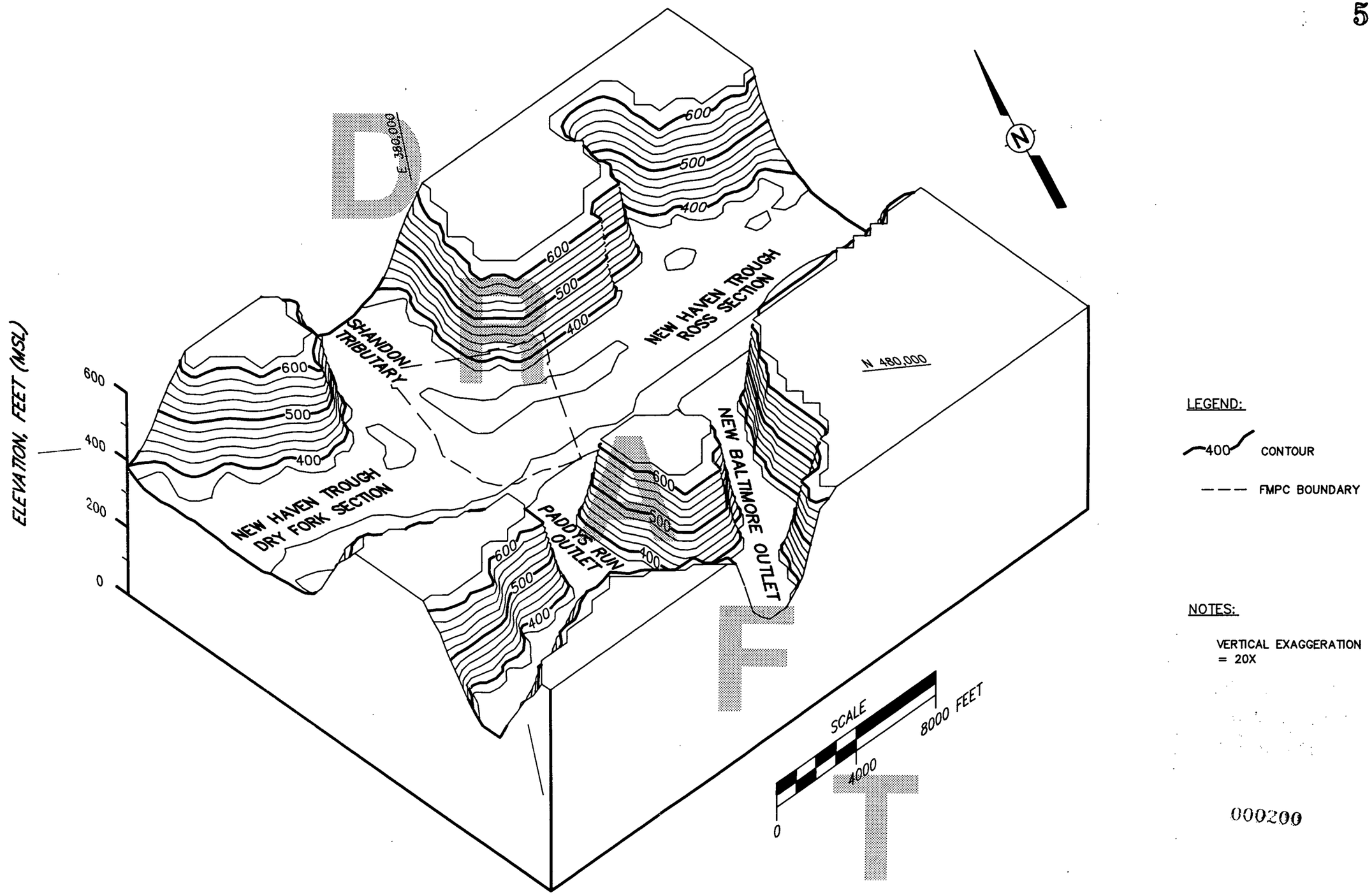

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FIGURE 11-1
3-DIMENSIONAL BEDROCK CONFIGURATION

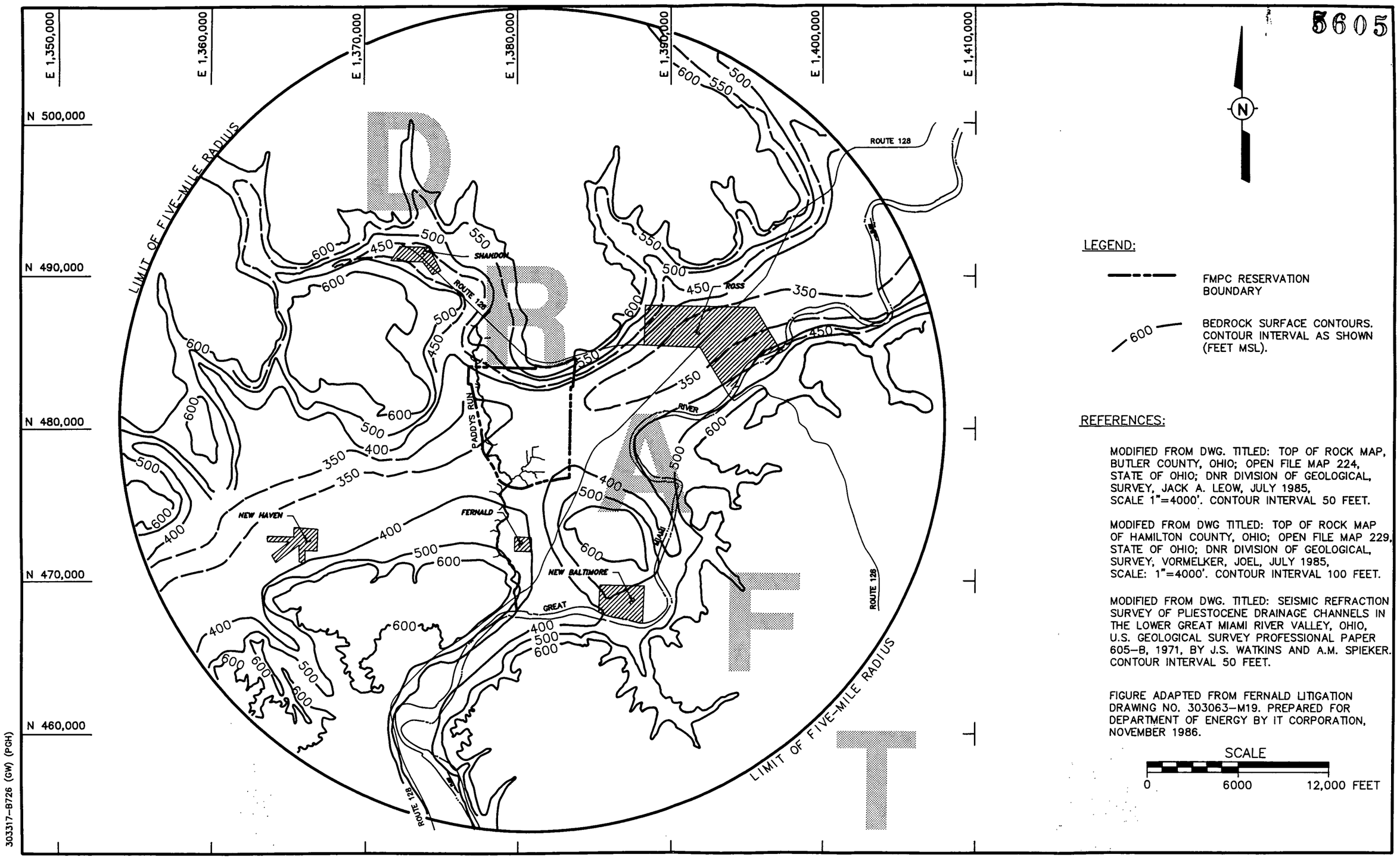

FIGURE 11-2
BEDROCK TOPOGRAPHY

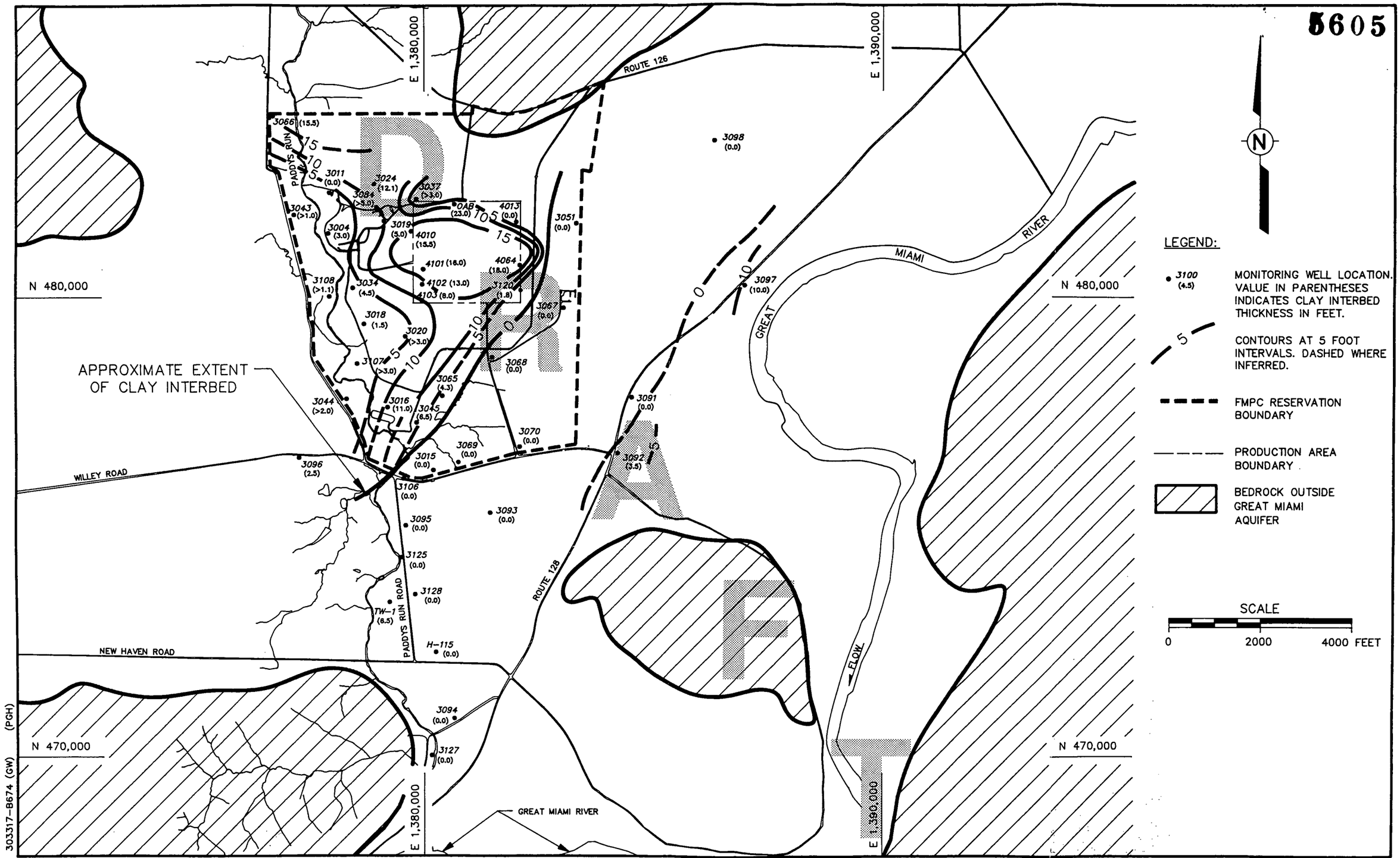

FIGURE 11-3
CLAY INTERBED THICKNESS

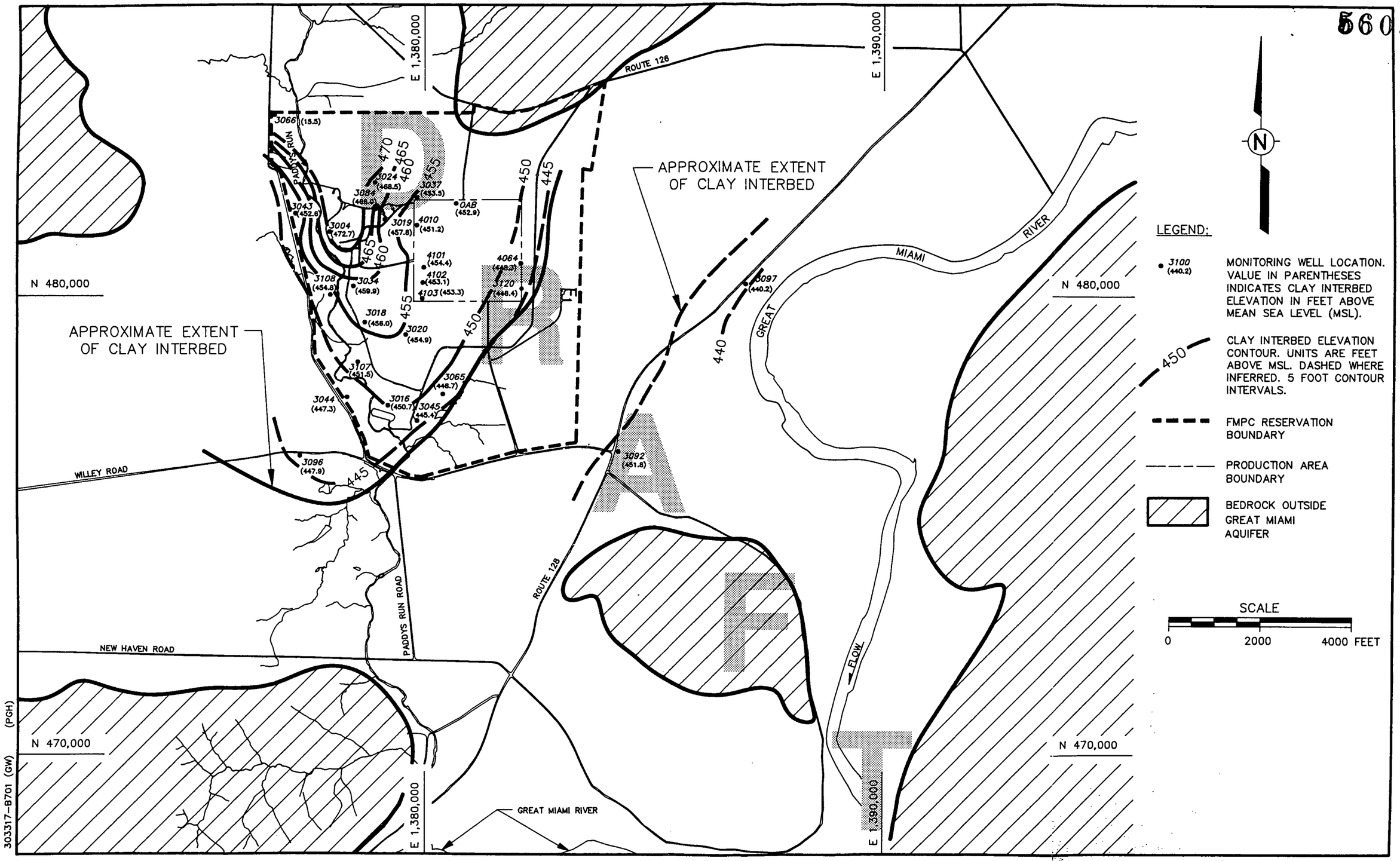

FIGURE 11-4
CLAY INTERBED
TOPOGRAPHIC SURFACE

aquitard within the Great Miami Aquifer. Because of this interbed, the aquifer is divided into upper and lower halves.

The clay of the interbedded layer is uniform in texture and contains only a small amount of silt and sand. It was deposited in a lacustrine or low-energy fluvial environment and displays varving in some samples (Appendix A, Boring 4096). The interbed pinches out to the south and east, extends an unknown distance to the west, and grades into other lacustrine, glaciofluvial, and glacial till deposits to the north in the Shandon Tributary.

11.4 GLACIAL OVERBURDEN

Glacial overburden covers the Great Miami Aquifer throughout most of the study area. It is of varying composition, including loess, lacustrine deposits, till, and glaciofluvial sediments. The overburden itself cannot be classified on a regional basis, as it is composed of varying amounts of the four materials, differing in structure and extent from location to location. For this reason, these materials are grouped into one unit for the purposes of both this discussion and future explanations of how the glacial overburden materials are modeled.

Within the FMPC study area, the glacial overburden ranges up to 5 and 50 feet in thickness, but most commonly averages between 20 and 30 feet (Figure 11-5). It extends to the north and west outside of the study area, but ends within the study area to the south and east where the Great Miami River has stripped off the glacial overburden as it carved its present channel. The types of materials included as glacial overburden are described below:

- Loess: Loess is an aeolian deposit consisting of homogenous, silt-sized particles. It blankets large areas within the study area and is derived from wind erosion of unconsolidated glacial and glaciofluvial sediments. The loess is typically a buff to light yellow or yellow-brown silt bed between 1-1/2 to 3 feet thick.

- Lacustrine Deposits: The lacustrine deposits present in the study area consist of well-sorted, stratified fine sands, silts, and clays, often with varving present. The clays may be interbedded with wave-sorted beach deposits along the margins of a former lake basin. Lacustrine deposits are found primarily along Paddys Run and are generally several feet in thickness.

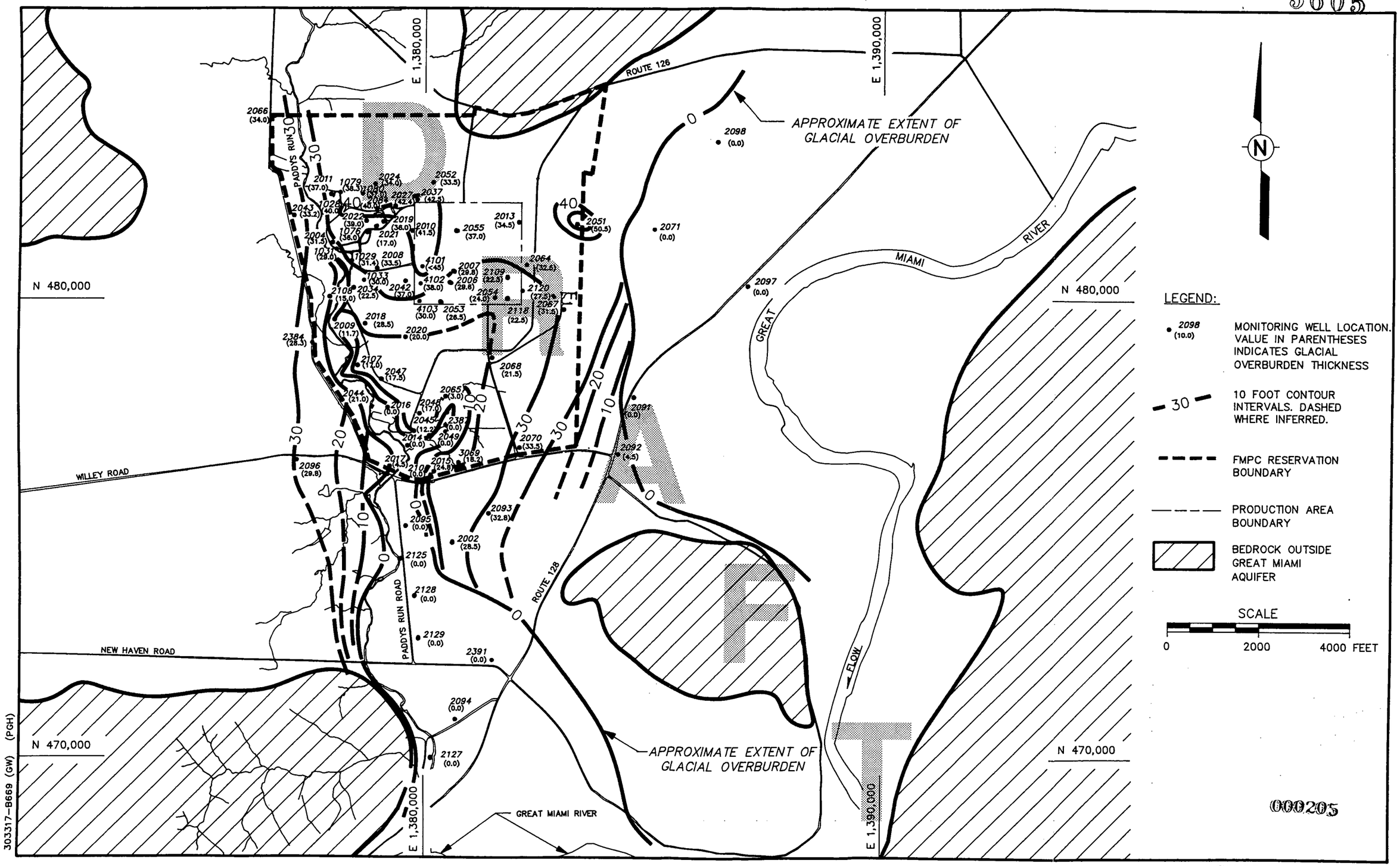

FIGURE 11–5
GLACIAL OVERBURDEN THICKNESS

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- Till: Undifferentiated till makes up the bulk of the glacial overburden materials in the study area. The tills were deposited either subglacially or at the melting margins of the glaciers and consist of a heterogeneous mixture of clays, silts, and pebbles. Tills may be of several types, including moraine deposits, ablation tills, and subglacial till sheets. The tills in the FMPC study area range in color from tan to brown to gray and are between 10 and 40 feet in thickness. They occur throughout most of the study area, but are not present in areas close to the Great Miami River, where they have been removed by erosion or were not deposited.

- Glaciofluvial Deposits: Glaciofluvial beds deposited by marginal or subglacial meltwater streams are interbedded within the till deposits. These beds consist of well-sorted sands and fine gravels. They are regionally discontinuous within the till and occur throughout the study area. They range in thickness from between a few inches to over 10 feet. Locally, interconnection of these beds may allow migration of groundwater within the glacial overburden.

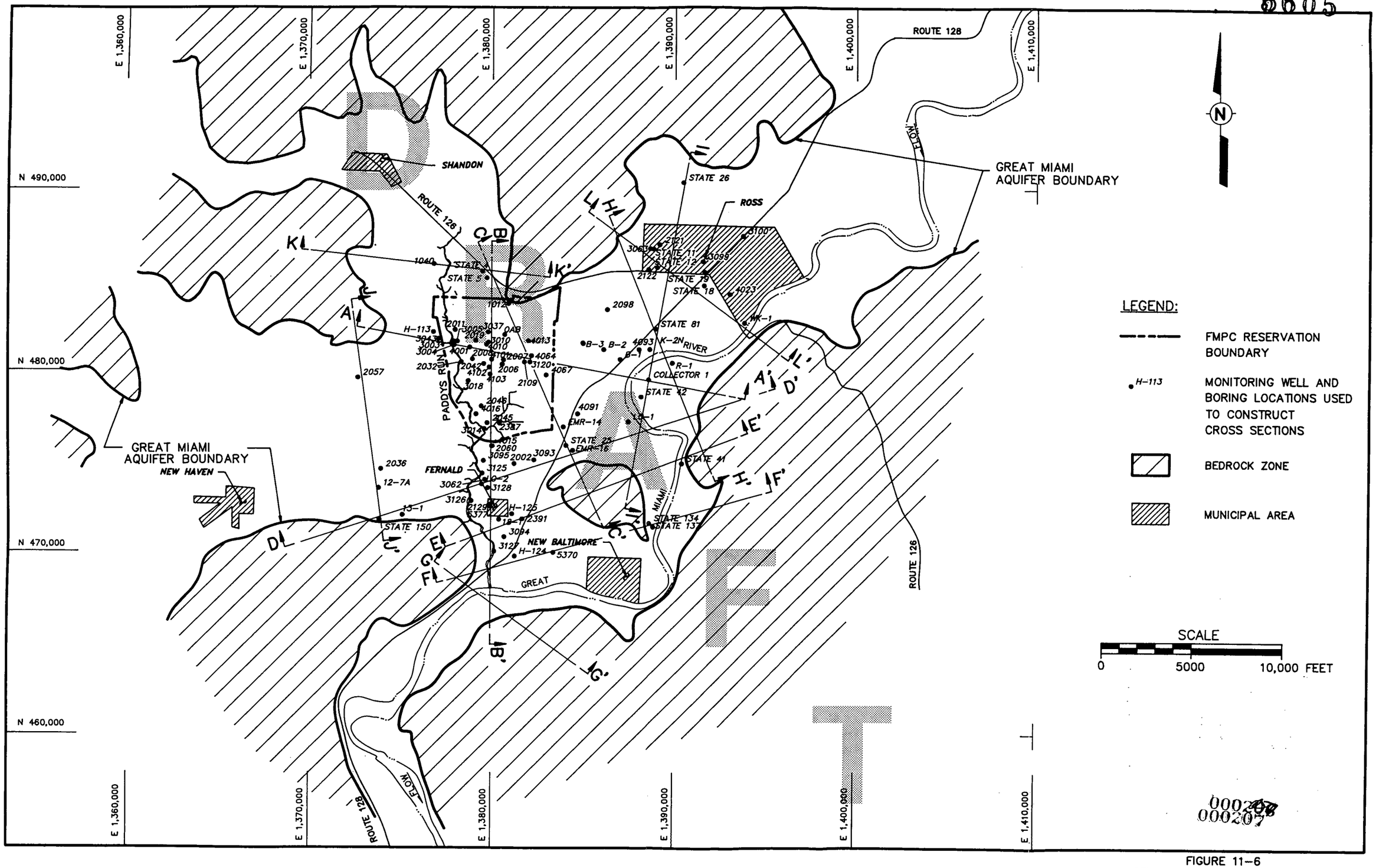
11.5 REGIONAL GEOLOGIC TRENDS

Due to the large number of borings available from the RI, extensive correlation of the geologic units is possible within the study area. Figure 11-6 shows the cross section locations, and Figures 11-7 through 11-18 are the regional cross sections derived from bedrock maps, topographic maps, RI borings, and pre-RI wells. These cross sections exhibit the following trends and correlations:

- Cross Section A-A' (Figure 11-7) is a typical cross section obliquely cutting the bedrock valley. Glacial overburden is seen on the western half of the section; on the eastern half it has been eroded away by the Great Miami River. The Great Miami Aquifer is fairly constant in thickness throughout the section, averaging about 150 to 200 feet thick, with the clay interbed occurring in the western area beneath the FMPC. Bedrock erosional topography is shown in this cross section.

- Cross Section C-C' (Figure 11-9) shows a typical cross section perpendicular to the valley trend. The glacial overburden again thins in the direction of the Great Miami River where erosion has stripped much of it away. The Great Miami Aquifer remains fairly constant in thickness. The clay interbed is present beneath the FMPC.

- Cross Sections A-A', B-B', and C-C' (Figures 11-7, 11-8, and 11-9) all illustrate the geology underlying the FMPC. Thick deposits of glacial overburden overlie the Great Miami Aquifer. The Great Miami Aquifer is thickest in the area which lies



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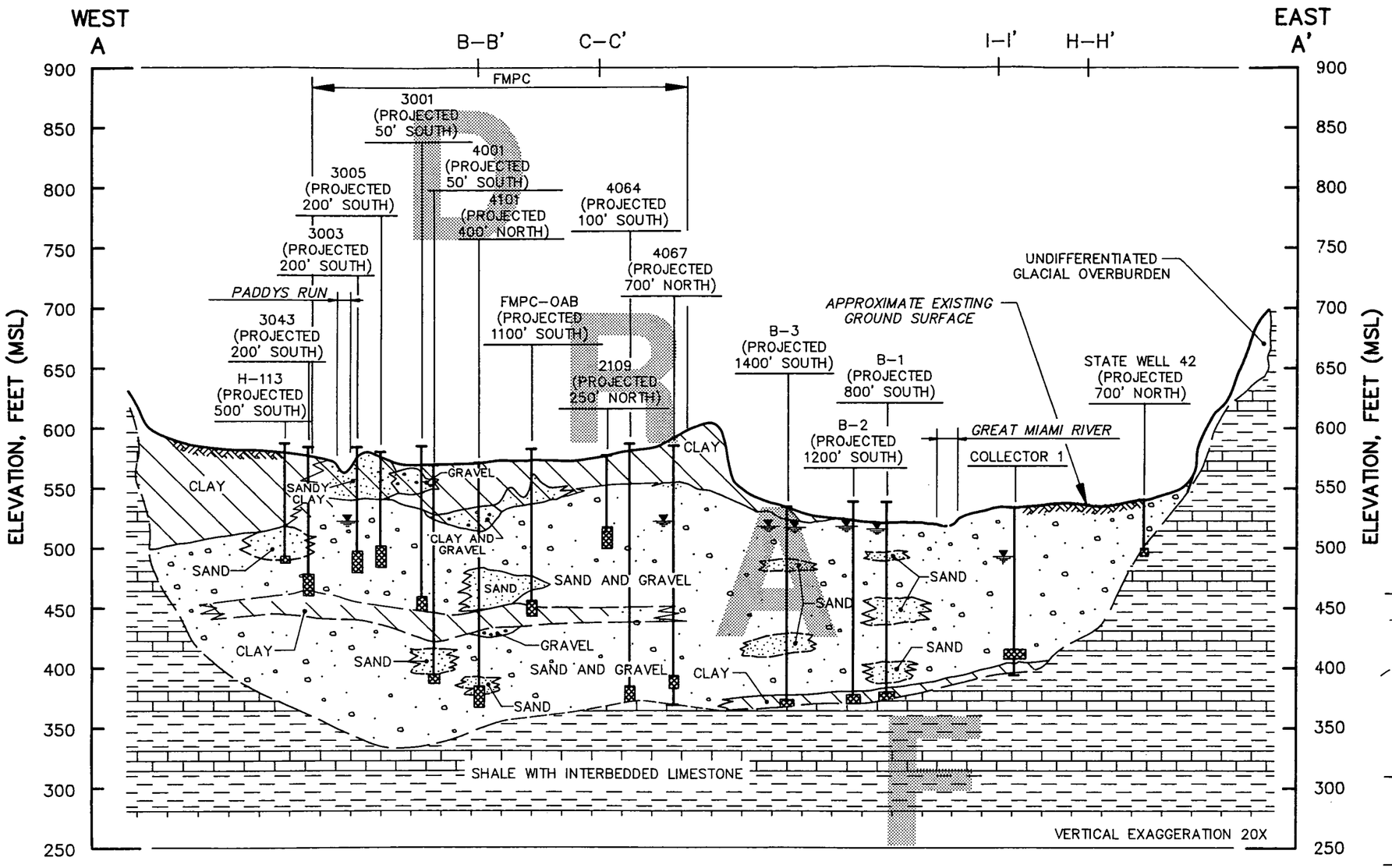
000207

FIGURE 11-6
STUDY AREA GEOLOGIC CROSS SECTION LOCATIONS



THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION A–A', SEE FIGURE 11–6

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B16. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

CROSS SECTION A–A'

(LOOKING NORTH)

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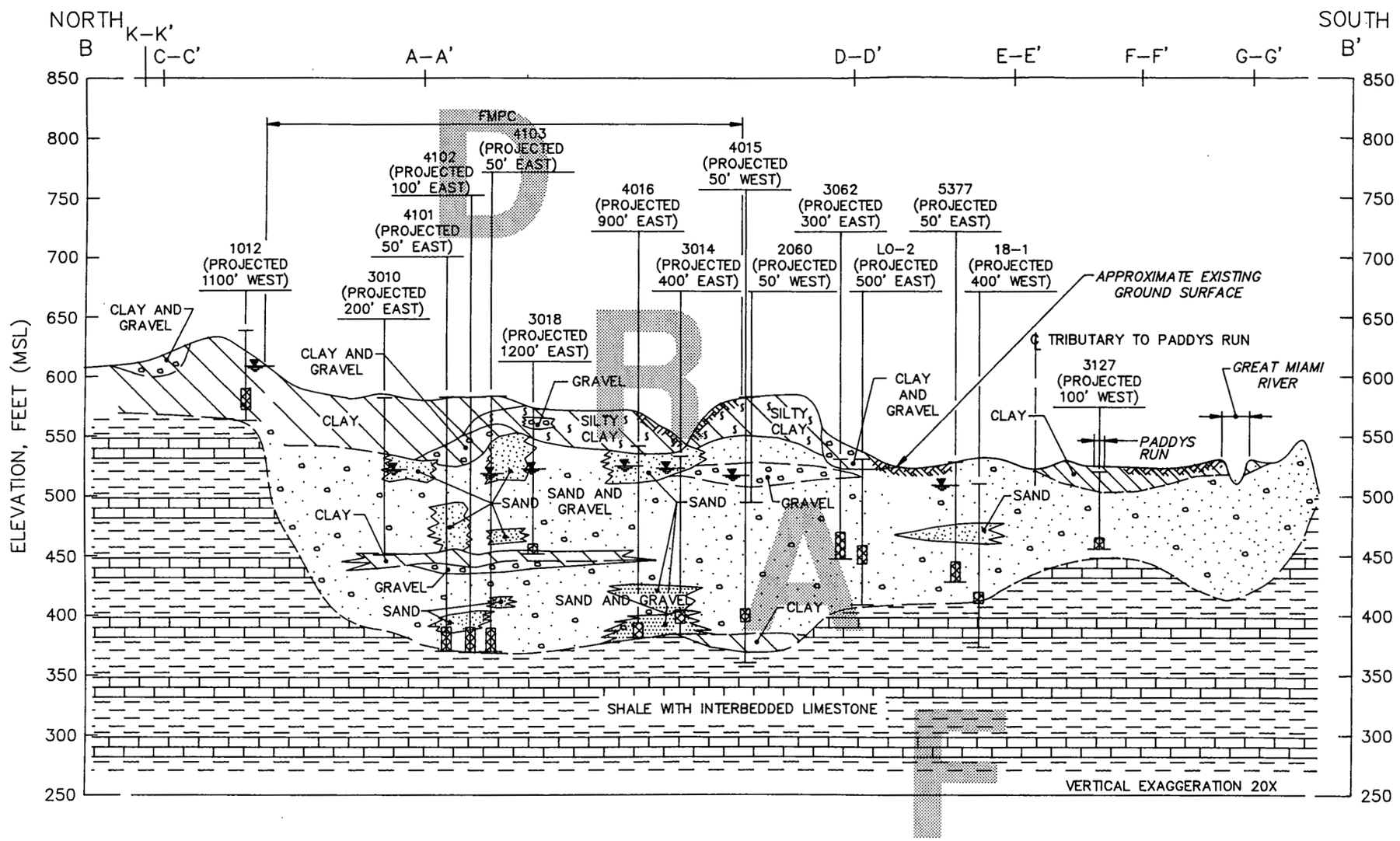
FIGURE 11–7
GEOLOGIC CROSS SECTION A–A'
STUDY AREA



CROSS SECTION B–B'

(LOOKING EAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

- WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)
- INFERRED CONTACT
- OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION B–B', SEE FIGURE 11–6

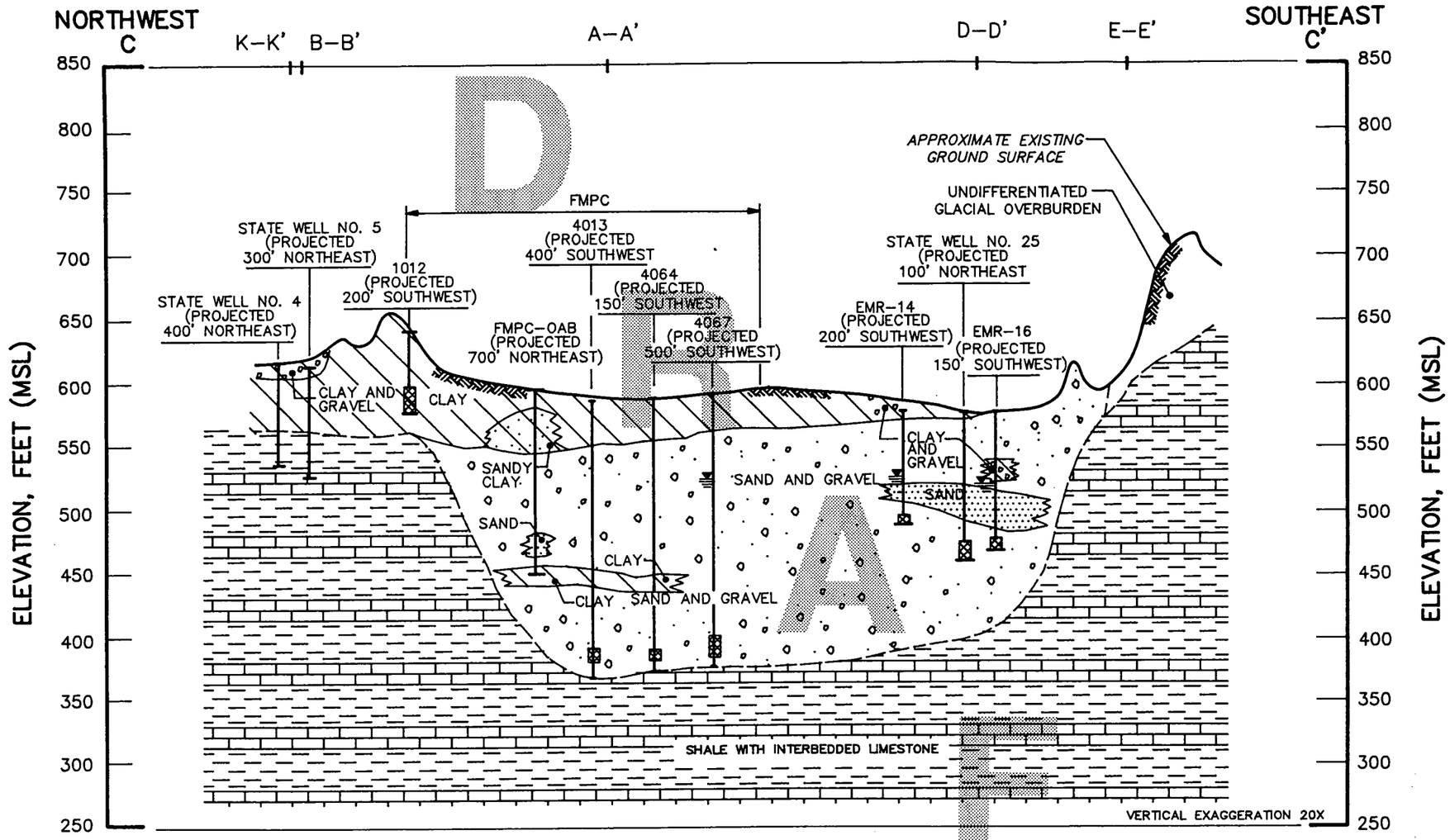
REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B17. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

303317–B538 (GW) (PGH)

FIGURE 11–8
GEOLOGIC CROSS SECTION B–B'
STUDY AREA



CROSS SECTION C–C'

(LOOKING NORTHEAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION C–C", SEE FIGURE 11–6

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B18. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

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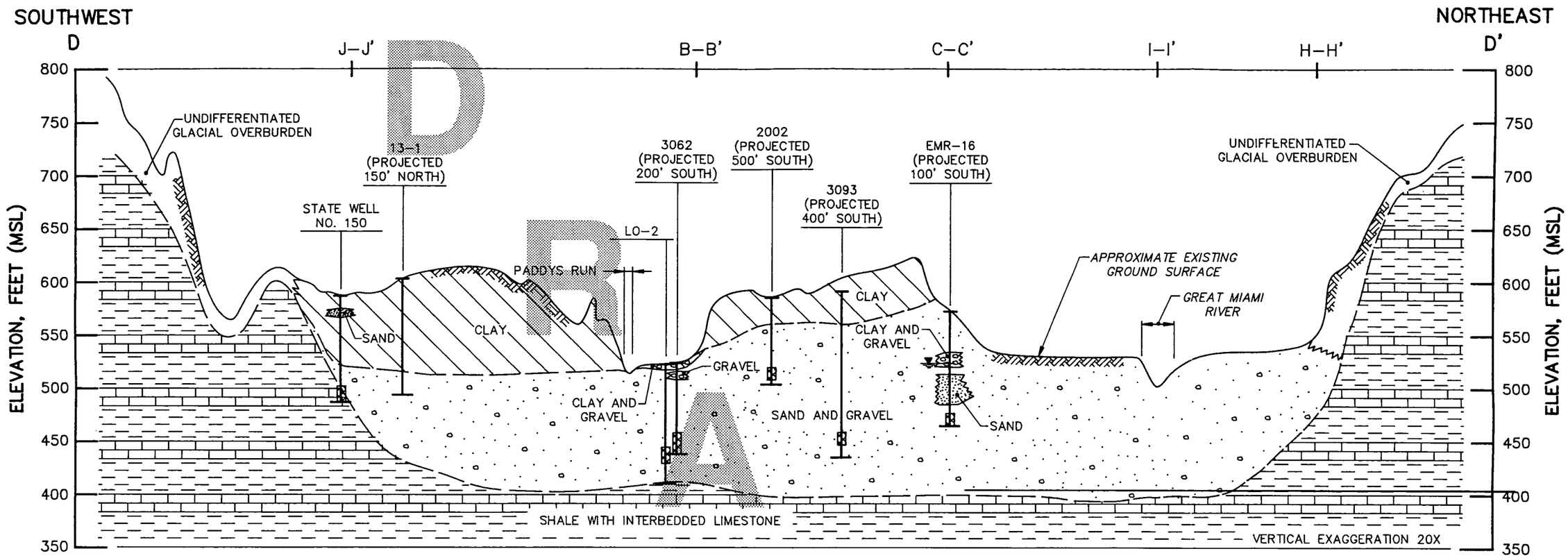
FIGURE 11–9
GEOLOGIC CROSS SECTION C–C'
STUDY AREA



CROSS SECTION D–D'

(LOOKING NORTHWEST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION D–D', SEE FIGURE 11–6

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK A REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B19. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

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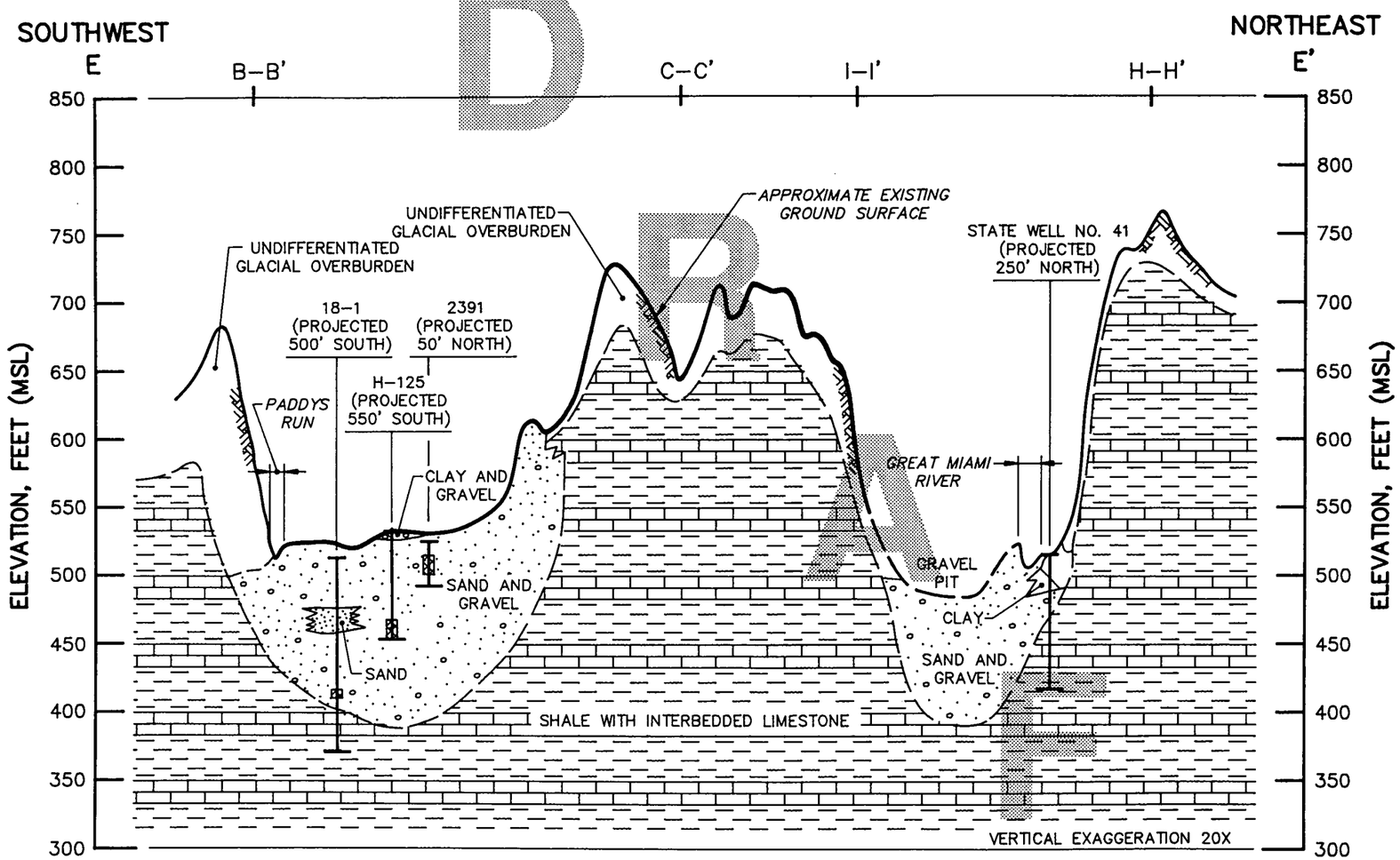
FIGURE 11–10
GEOLOGIC CROSS SECTION D–D'
STUDY AREA



CROSS SECTION E–E'

(LOOKING NORTHWEST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

- WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)
- INFERRED CONTACT
- OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION E–E', SEE FIGURE 11–6

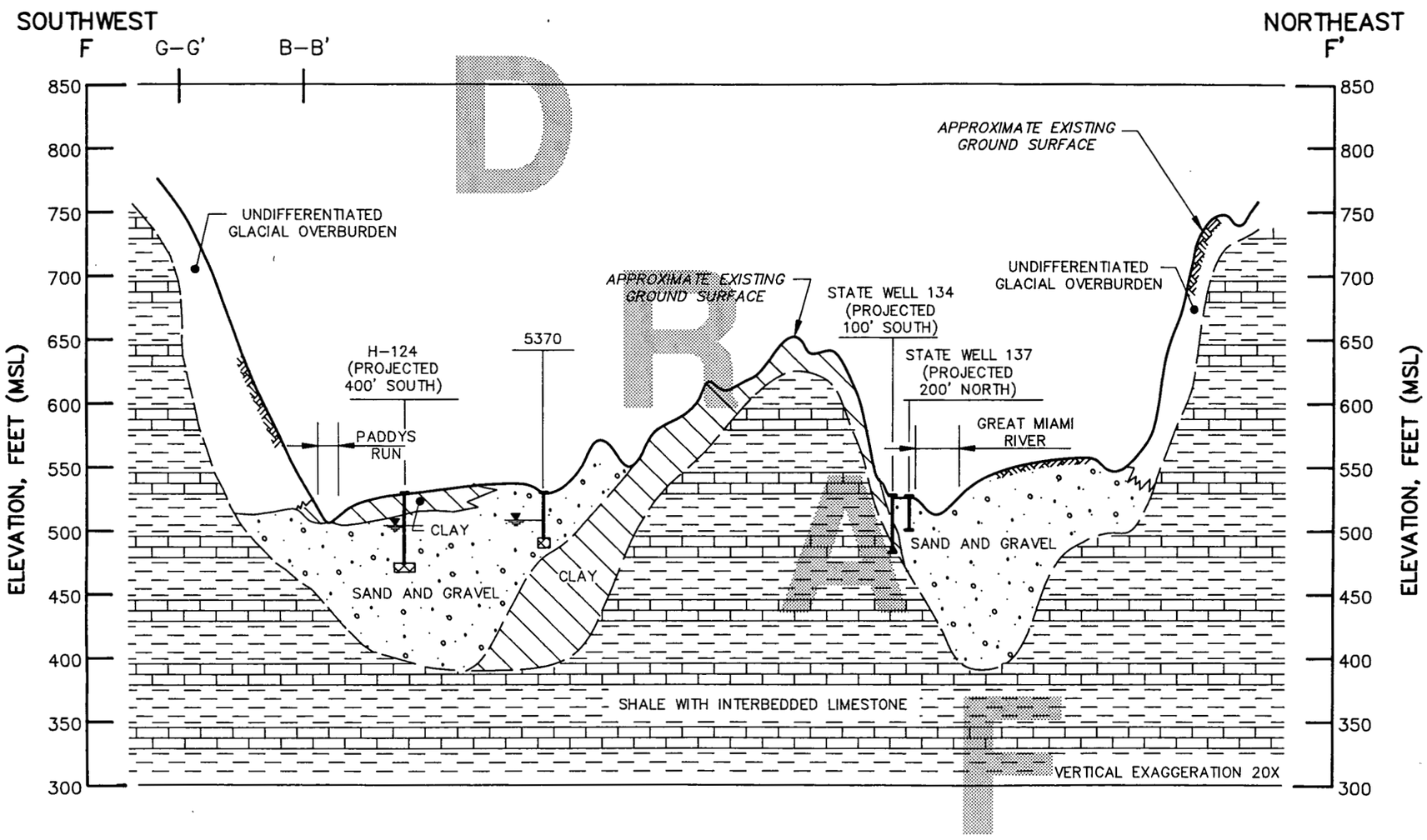
REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B20. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

303317–B536 (GW) (PGH)

FIGURE 11–11
GEOLOGIC CROSS SECTION E–E'
STUDY AREA



CROSS SECTION F–F'

(LOOKING NORTHWEST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

- WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)
- INFERRED CONTACT
- OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION F–F', SEE FIGURE 11–6

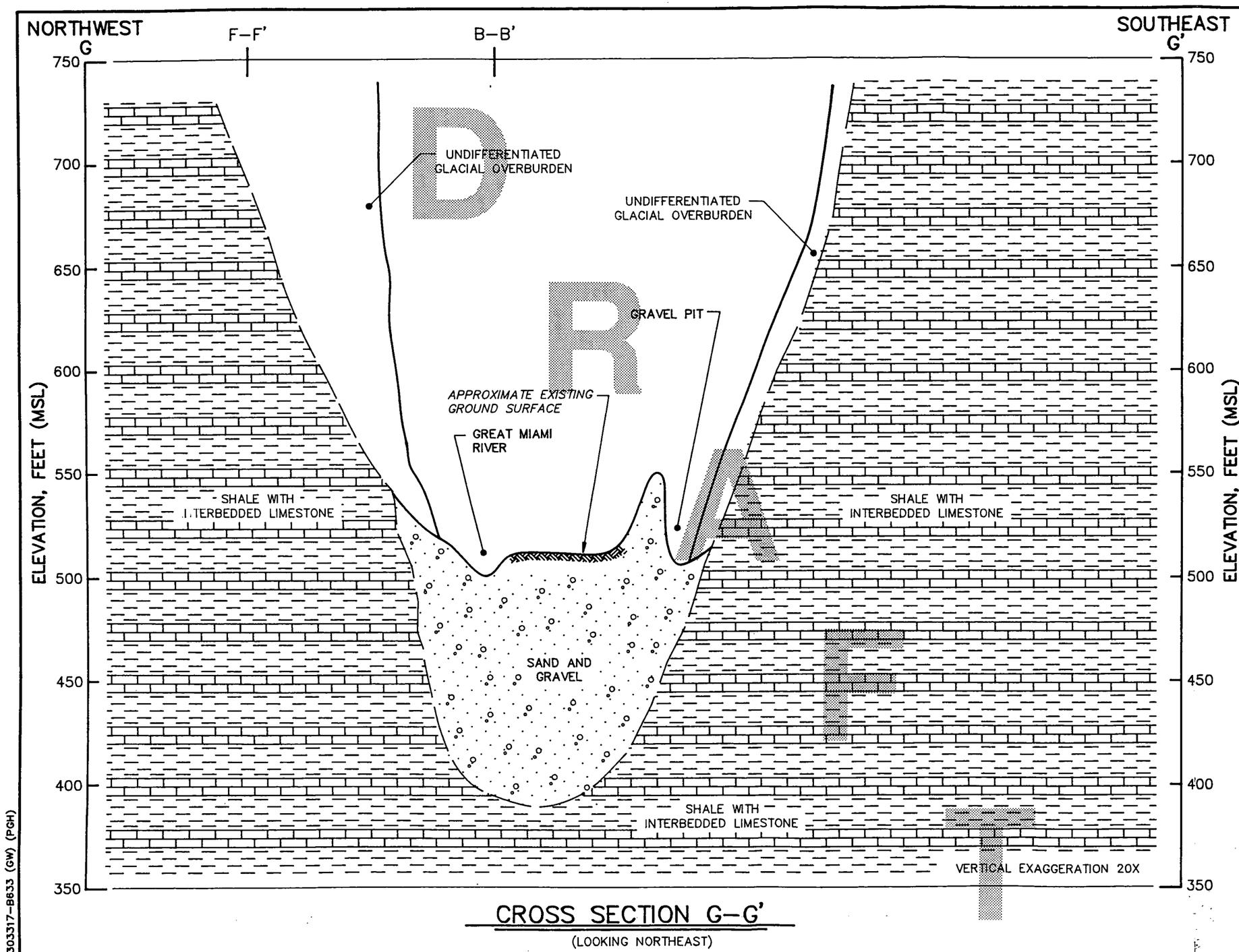
REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063–B21. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER 1986.

303317–B533 (GW) (PGH)

FIGURE 11–12
GEOLOGIC CROSS SECTION F–F'
STUDY AREA



CROSS SECTION G–G'

(LOOKING NORTHEAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 50 100 FEET

HORIZONTAL SCALE

0 1000 2000 FEET

LEGEND:

INFERRED CONTACT

NOTE:

FOR LOCATION OF CROSS SECTION G–G' SEE FIGURE 11–6

THE SUBSURFACE CONDITIONS DEPICTED ARE BASED ON THE REFERENCES. THE DEPTH AND THICKNESS OF SUBSURFACE STRATA INDICATED ON THE SECTION ARE BASED ON THESE REFERENCES AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS MAY VARY SINCE TEST BORINGS HAVE NOT BEEN CONDUCTED AT THESE LOCATIONS.

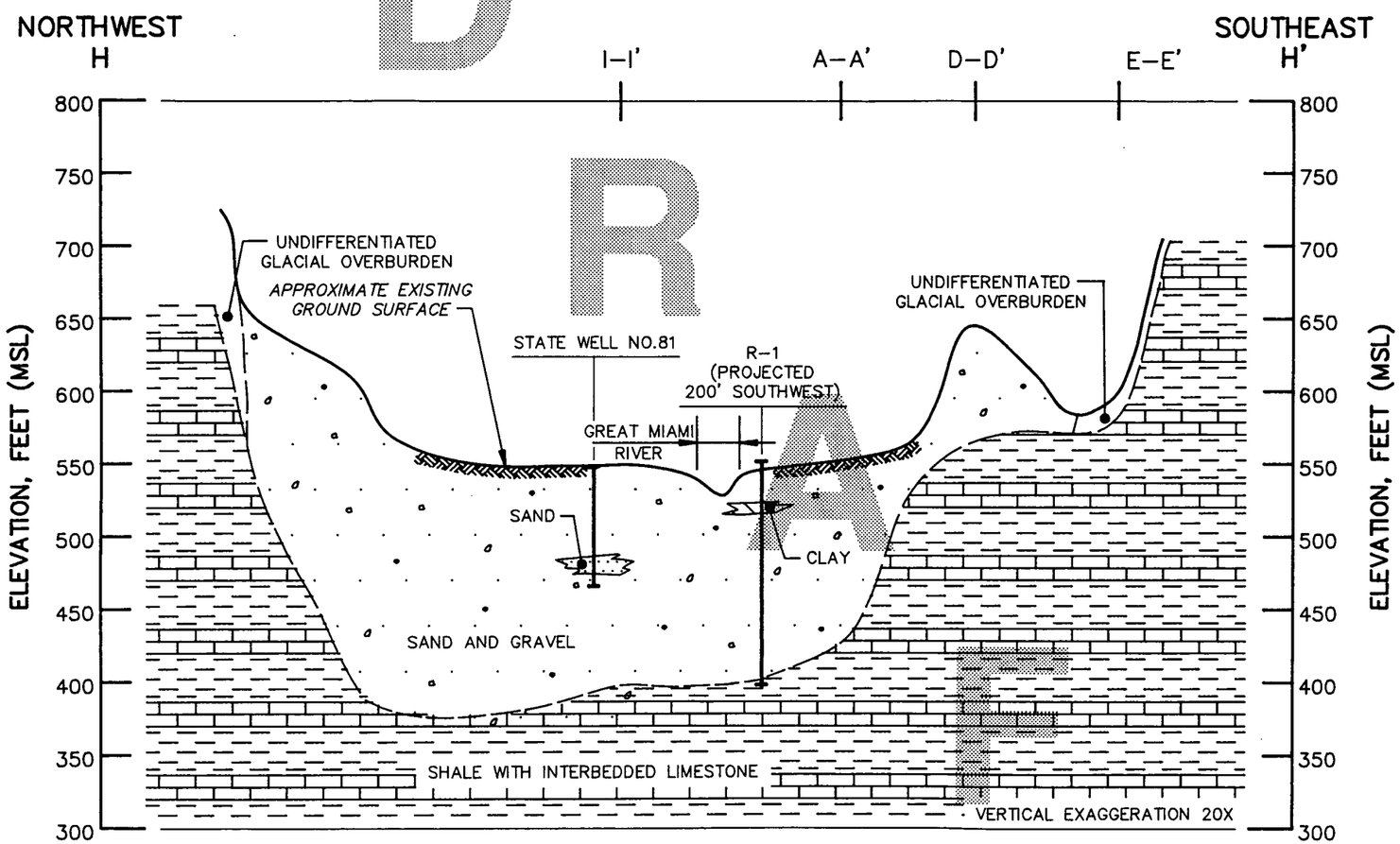
REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

FIGURE ADAPTED FROM DRAWING NO. 303317–A104, FROM "HYDROGEOLOGIC STUDY OF THE GREAT MIAMI RIVER" PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, AUGUST 1988.

303317–B633 (GW) (PGH)

FIGURE 11–13
GEOLOGIC CROSS SECTION G–G'
STUDY AREA



CROSS SECTION H–H'

(LOOKING NORTHEAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

INFERRED CONTACT

NOTE:

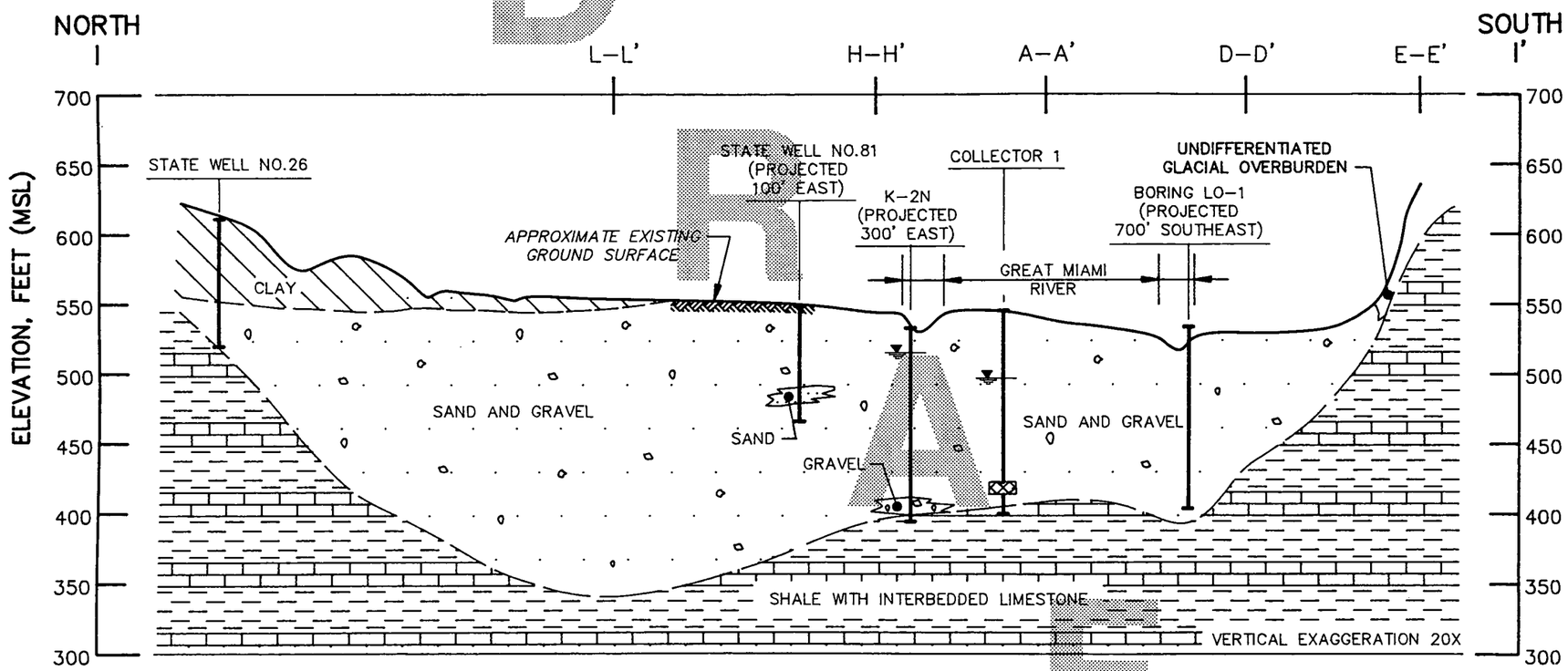
FOR LOCATION OF CROSS SECTION H–H' SEE FIGURE 11–6

REFERENCE:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS.

303317–B535 (GW) (PGH)

FIGURE 11–14
GEOLOGIC CROSS SECTION H–H'
STUDY AREA



CROSS SECTION I–I'

(LOOKING EAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

- WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)
- INFERRED CONTACT
- OPEN OR SCREENED INTERVAL

NOTE:

FOR LOCATION OF CROSS SECTION I–I', SEE FIGURE 11–6

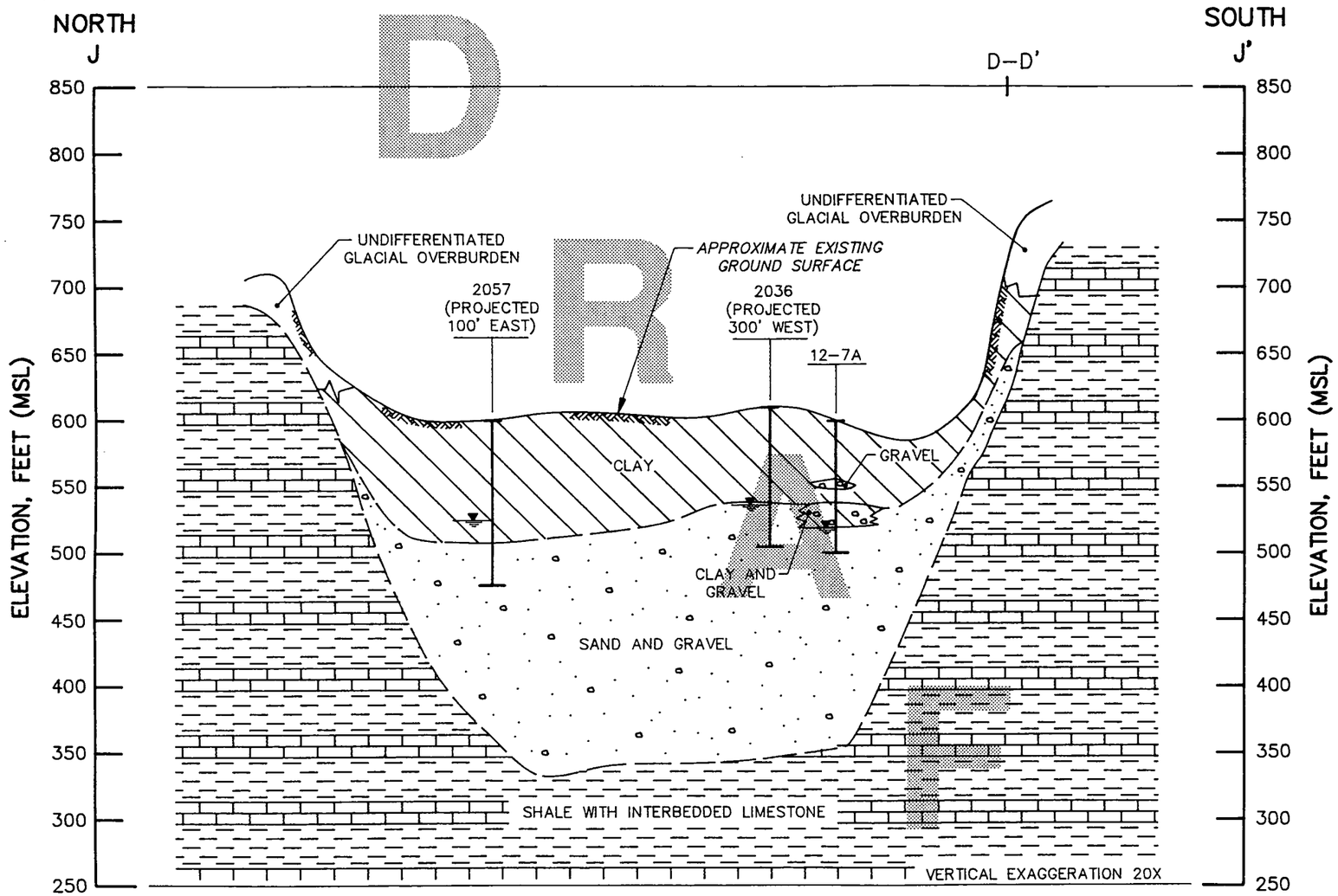
REFERENCES:

OHIO STATE WATER WELL RECORDS, STATE OF OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF WATER TECHNICAL REPORT NO. 4, AND REPORT PREPARED FOR OHIO ENVIRONMENTAL PROTECTION AGENCY BY GEOTRANS, INC.

000216

303317–B534 (GW) (PGH)

FIGURE 11–15
GEOLOGIC CROSS SECTION I–I'
STUDY AREA



CROSS SECTION J–J'

(LOOKING EAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

NOTE:

FOR LOCATION OF CROSS SECTION J–J', SEE FIGURE 11–6

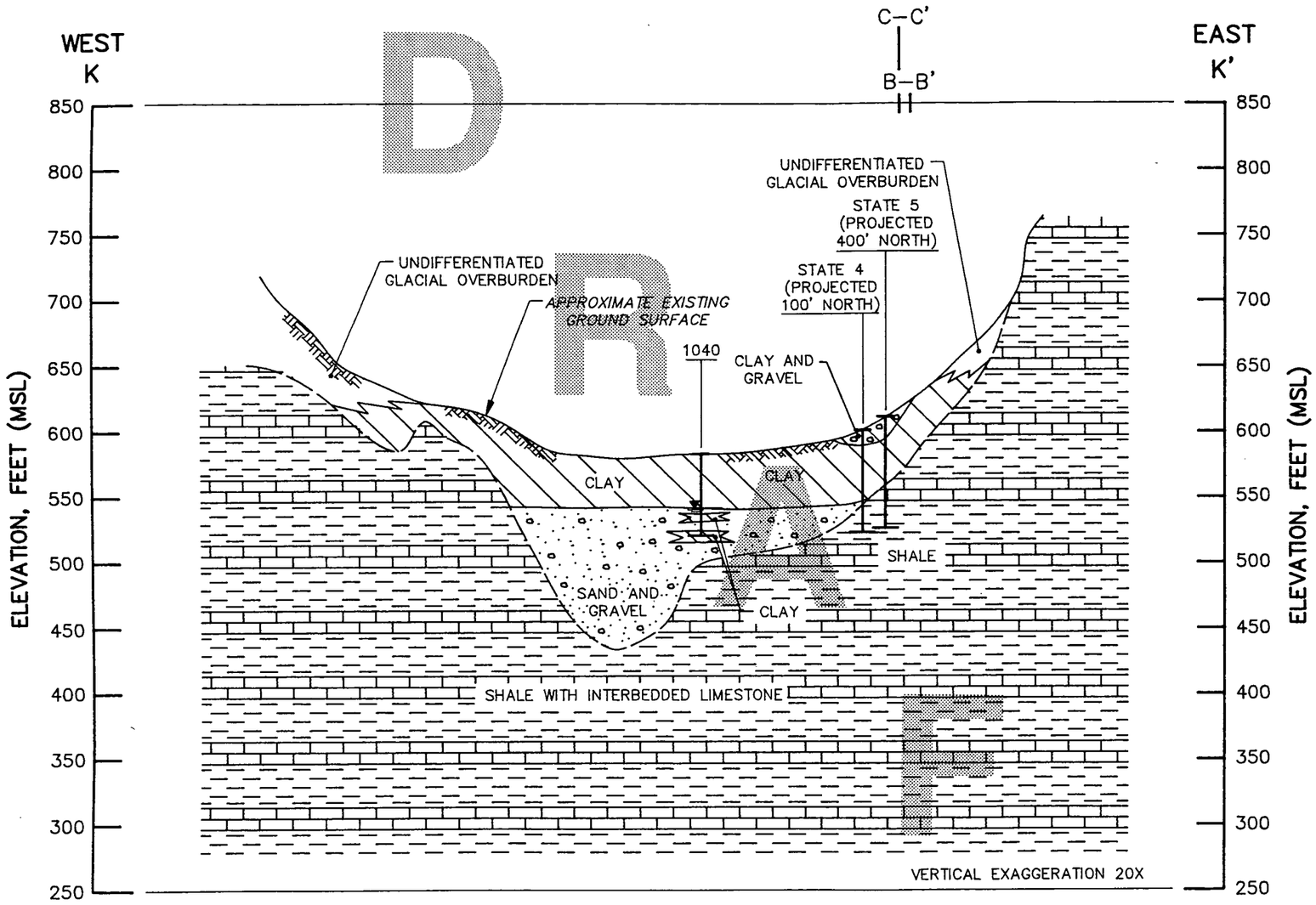
REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

303317–B529 (GW) (PGH)

000217

FIGURE 11–16
GEOLOGIC CROSS SECTION J–J'
STUDY AREA



CROSS SECTION K–K'

(LOOKING NORTH)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

NOTES:

FOR LOCATION OF CROSS SECTION K–K', SEE FIGURE 11–6

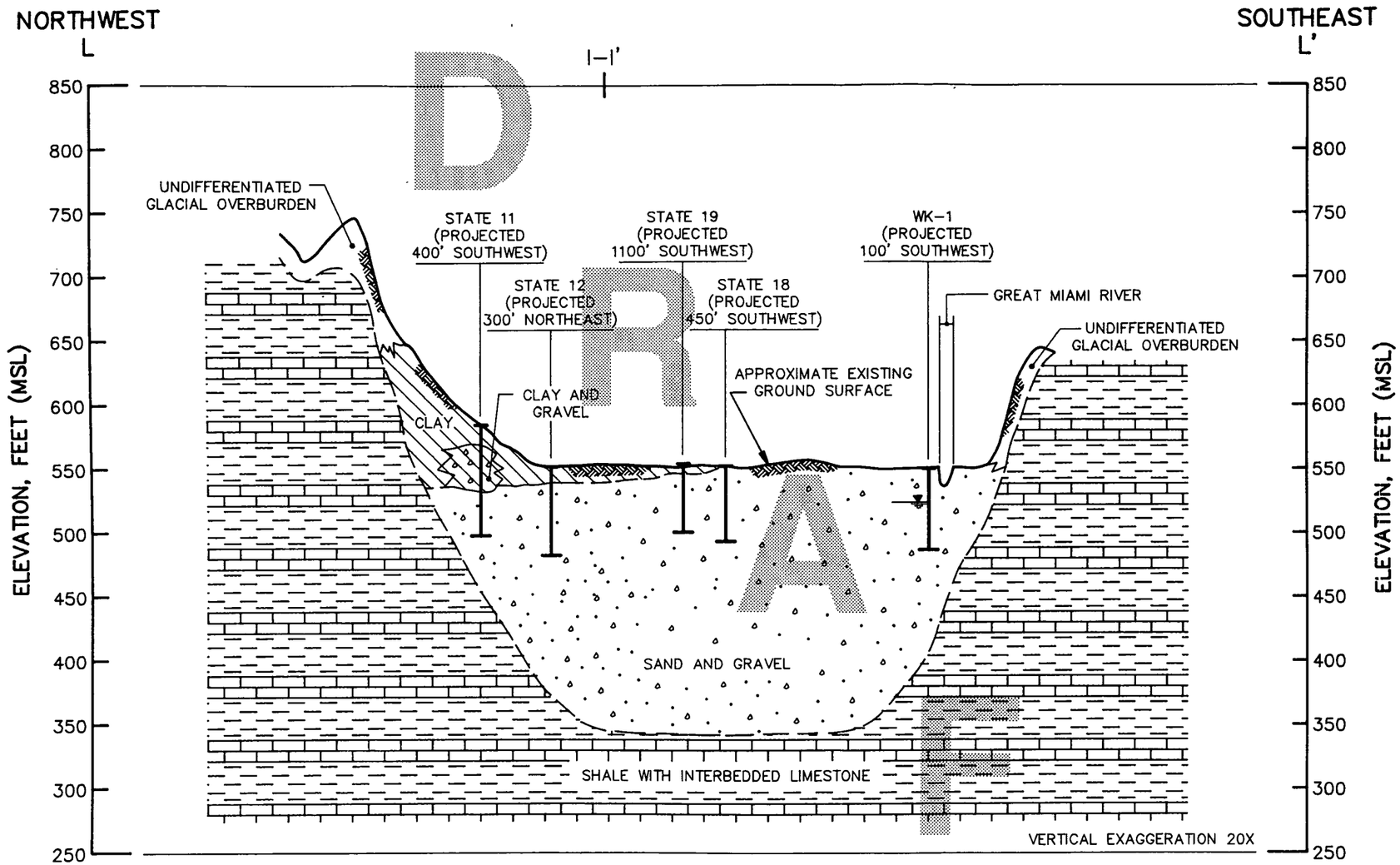
DUE TO INSUFFICIENT BORING LOG DATA IN THE CROSS SECTION AREA, FURTHER DEFINITION WAS ADDED BY USING BORING LOG 3066 TO EXPAND THE INTERBEDS OF CLAY IN THE BURIED CHANNEL.

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

303317–B530 (GW) (PGH)

FIGURE 11–17
GEOLOGIC CROSS SECTION K–K'
STUDY AREA



CROSS SECTION L–L'

(LOOKING NORTHEAST)

THE BORING LOGS AND RELATED INFORMATION DEPICT SUBSURFACE CONDITIONS ONLY AT THE SPECIFIC LOCATIONS AND DATES INDICATED. SOIL CONDITIONS AND WATER LEVELS AT OTHER LOCATIONS MAY DIFFER FROM CONDITIONS OCCURRING AT THESE BORING LOCATIONS. ALSO THE PASSAGE OF TIME MAY RESULT IN A CHANGE IN THE CONDITIONS AT THESE BORING LOCATIONS.

THE DEPTH AND THICKNESS OF THE SUBSURFACE STRATA INDICATED ON THE SECTIONS WERE GENERALIZED FROM AND INTERPOLATED BETWEEN THE TEST BORINGS. INFORMATION ON ACTUAL SUBSURFACE CONDITIONS EXISTS ONLY AT THE LOCATION OF THE TEST BORINGS AND IT IS POSSIBLE THAT SUBSURFACE CONDITIONS BETWEEN THE TEST BORINGS MAY VARY FROM THOSE INDICATED.

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

LEGEND:

WATER LEVELS (MEASURED 3/27/86 THROUGH 4/11/86)

INFERRED CONTACT

NOTE:

FOR LOCATION OF CROSS SECTION L–L', SEE FIGURE 11–6

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER NO. 605–A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES & MOORE'S "FEED MATERIALS PRODUCTION CENTER GROUNDWATER STUDY, TASK C REPORT" FOR THE DOE (1985), AND IT (1986) RI/FS BORING LOGS.

303317–B528 (GW) (PGH)

000219

FIGURE 11–18
GEOLOGIC CROSS SECTION L–L'
STUDY AREA

underneath the FMPC where it approaches 200 feet. The clay interbed underlies the northwestern half of the FMPC, dividing the aquifer almost equally into upper and lower halves. The FMPC Production Well P3, shown in Cross Section B-B', pumps an average of 292 gpm from the lower half of the aquifer. Cross Section D-D' (Figure 11-10) shows a longitudinal view of the southern portion of the New Haven Trough. A topographic expression of the moraine which dammed a glacial lake in Paddys Run Valley appears on either side of Paddys Run. It should also be noted that the clay interbed is not present this far to the south of the FMPC.

- Cross Section E-E' (Figure 11-11) is a section across the Paddys Run Outlet in the west and the current channel of the Great Miami River in the east. The Paddys Run Outlet here has had its glacial overburden eroded away by the Great Miami River. Only small remnants of clay interbeds (probably fluvial in origin) are still present in this area. This region of the Great Miami River Valley also exhibits erosion and terracing and has levees along the river channel.

- Cross Section F-F' (Figure 11-12) exhibits nearly the same features as Cross Section E-E', but contains an additional clay lens present in the Fernald Outlet adjacent to the bedrock knob which separates the two valleys. This clay pocket may be a remnant of the glacial overburden which was protected from erosion by the bedrock knob. The surface topographic map (Figure 2-2) shows an elevated terrace which lies above the present stream valley and on which the town of New Baltimore is located.

- Cross Section G-G' (Figure 11-13) shows the bedrock valley further downstream from the Paddys Run Outlet.

- Cross Section H-H' (Figure 11-14) is almost perpendicular to the New Haven Trough and is upstream of the FMPC. The bedrock valley is relatively narrow here, and the surface topography is dominated by fluvial terraces and the flood plain of the Great Miami River. A small interbed of clay is found in this area; otherwise, the aquifer is fairly homogeneous.

- Cross Section I-I' (Figure 11-15) is a north-south section located to the east of the FMPC, and cuts longitudinally through the Big Bend area of the Great Miami River where the SOWC's large collector wells are located. Collector Well No. 1 is included on the cross section, and pumps an average of 6,026 gpm of water from the aquifer. Collector Well No. 2 (not shown) is located west of the section and has the same average pumping rate and design as Collector Well No. 1. The aquifer in this area ranges in thickness from 150 to 200 feet, and is composed almost exclusively

of sand and gravel with no silt or clay lenses. As it is hydraulically connected with the riverbed, the aquifer receives induced infiltration from the Great Miami River which is available for use by the collector wells.

- Cross Section J-J' (Figure 11-16) shows the area west of the FMPC site in the buried valley. As at the FMPC, the valley is basically U-shaped with the Great Miami Aquifer filling it. The presence or absence of the clay interbed is uncertain due to lack of borings in the area. The glacial overburden is much thicker in this region, approaching 100 feet through part of the section, and is not breached by stream erosion.

- Cross Section K-K' (Figure 11-17) shows a section through a typical region of the Shandon Tributary, which lies north of the FMPC. This is a tributary valley to the New Haven Trough; thus, the cross-sectional area of the aquifer is smaller than in other regions, primarily because of the decreasing bedrock valley depth. The Great Miami Aquifer has more interbedded clays present within its upper portions. Thick deposits of undisected glacial overburden also reduce recharge rates, and further reduce groundwater flow in this area.

- Cross Section L-L' (Figure 11-18) is perpendicular to the New Haven Trough at Ross, east of the FMPC, and upstream of the SOWC collector wells. A thin layer of glacial overburden overlies the northwestern half of this area. The Great Miami Aquifer is well sorted and homogeneous, with high transmissivity.

DRAFT

12.0 REGIONAL HYDROGEOLOGY

Within a hydrogeological context, two major types of geologic material underlie the FMPC site:

- The Ordovician shale and limestone bedrock in which the New Haven Trough has been excavated.
- The unconsolidated glacial and fluvial deposits which overlie the Ordovician bedrock and fill the New Haven Trough.

Saturated zones occur in the glacial overburden and the valley fill deposits. These saturated zones were monitored for water level and water quality using a series of monitoring wells (Figures 6-1 through 6-5). The 1000 Series wells were used to monitor the perched groundwater system located in the glacial overburden, while the 2000 through 4000 Series wells were used to monitor successively deeper levels within the Great Miami Aquifer.

Both the classic and regulatory definitions of an aquifer were considered when evaluating the hydrogeology of the study area. The classic definition of an aquifer is "a water-saturated unit that will yield water to wells or springs at a sufficient rate so that the wells or springs can serve as practical sources of water supply" (Driscoll 1986). Saturated zones occur that cannot sustain withdrawals sufficient for water supplies, but meet the regulatory definition of an aquifer; that is, "the uppermost formation nearest to the ground surface that is capable of yielding a significant amount of groundwater to wells or springs" (U.S. EPA 1986). Saturated zones that do not yield significant water may still be important as contaminant pathways.

In the FMPC study area, the sand and gravel deposits of the Great Miami Aquifer represent a classic aquifer. The perched groundwater system within the glacial overburden, while not representing a practical water supply, satisfies the regulatory definition of an aquifer in some locations and is important as a potential contaminant pathway to the regional aquifer, streams, and springs.

The principal sources of recharge to these aquifer units are:

- Recharge from bedrock
- Recharge from direct precipitation
- Recharge from induced stream infiltration

Recharge due to groundwater occurring in the shale and limestone bedrock is limited. The shale itself is nearly impermeable, with water movement limited to fractures within thin limestone lenses.

Recharge from the bedrock to the valley fill is approximately 200,000 gallons per day (140 gpm) per linear mile along the valley (Dove 1961).

Precipitation falling within the basin is the dominant source of groundwater recharge. Infiltration of rainfall provides approximately 570,000 gallons per day per square mile (12 in/yr) of recharge to the unconsolidated aquifer systems (Dove 1961). This includes recharge through the glacial overburden, river terraces, and flood plain deposits.

Induced stream infiltration resulting from pumping water supply wells near the Great Miami River causes a portion of the surface water to infiltrate through the bed of the river into the groundwater system. The rate of recharge by stream infiltration varies based upon fluctuating river levels, hydraulic gradients, stream bed conditions, and water temperature (Section 12.5.1). Natural recharge from Paddys Run along the west side of the FMPC and the Dry Fork of the White Water River west of the site also provides significant amounts of recharge on a seasonal basis.

12.1 GREAT MIAMI AQUIFER

The Great Miami Aquifer can be divided into areas with similar hydrologic and geologic properties that are distinct from other adjacent areas of the aquifer. These subdivisions have been designated as hydrogeologic environments (Spieker 1968). A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of the aquifer in adjacent areas. During these investigations, five major hydrogeologic environments were identified and mapped in the Great Miami River Valley (Figure 2-6). These environments include:

- Type I (Subtypes I-A-I and I-A-2): Sand and gravel aquifer; recharge by induced stream infiltration potentially available.
- Type II: Sand and gravel aquifer without the possibility of stream recharge.
- Type III: Sand and gravel aquifer overlain by clay; stream recharge generally not available.
- Type IV: Buried valleys filled with clay; large water supplies generally not available.
- Type V: Shale and limestone bedrock overlain by till; large water supplies generally not available.

Two characteristics of unconfined aquifers are used. These characteristics are transmissivity and specific yield, which describe the ability of water to move through the aquifer material and the ability of the aquifer to produce water, respectively. The higher the transmissivity the greater the

ability to transmit water. The specific yield is a measure of the quantity of water an aquifer will yield from storage when the hydraulic head declines, and is related to the porosity and the grain size. The smaller the grain size, the more water that will be retained in the aquifer and not available to a pumping well. Conversely, coarser sediment will retain less water and have a larger specific yield.

The Type I hydrogeologic environment describes the Great Miami Aquifer along the flood plain of the Great Miami River to the south and east of the FMPC facility, and also in the valley of Paddys Run west and south of the FMPC Production Area. The Type I-A-1 aquifer is 150 to 200 feet thick, and the Type I-A-2 aquifer is less than 150 feet thick; both are underlain by bedrock. The aquifer sediments crop out at the surface; thus, stream infiltration is possible in areas proximal to local streams. The lithology of the aquifer consists primarily of well-sorted sand with gravel, although scattered lenses of clay or fine-grained material are also present. In the main valley, these lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to significantly affect groundwater movement. Aquifer transmissivity generally ranges from 40,000 to 67,000 square feet per day (ft^2/day), with a specific yield of about 0.2. Individual wells can yield as much as 3,000 gpm.

The Type II hydrogeologic environment is characterized by having less than 150 feet of sand and gravel, with no areally extensive interstratified clay layers present. Recharge by stream infiltration is not available. The specific yield for the aquifer is about 0.2. Large groundwater supplies are not generally available from the Type II aquifer. Those portions of the Great Miami Aquifer that exhibit characteristics of a Type II environment are of limited areal extent, within the study area. They are generally located in close proximity to bedrock valley walls.

The Type III hydrogeologic environment is characterized by clayey glacial overburden overlying the Great Miami Aquifer. In the region directly beneath the FMPC, the aquifer is divided into upper and lower parts by a clay interbed approximately 10 to 20 feet thick occurring approximately 140 feet below land surface. Hence, the lower aquifer is classified as a semiconfined or leaky confined aquifer. Spieker and Norris (1962) have estimated a coefficient of storage of 0.001 for the lower sand and gravel aquifer. Spieker (1968a) estimated a transmissivity range of 4,700 to 40,000 ft^2/day.

The Type IV hydrogeologic environment is typified by valleys filled largely with clay. No examples of this environment are found within the study area.

The Type V hydrogeologic environment includes all of the areas outside of the buried valley of the Great Miami Aquifer. These areas are bedrock uplands consisting of shale with interbedded limestone overlain by 50 feet or less of clay-rich glacial overburden. Large quantities of groundwater are not generally transported through this material. Well yields vary widely, generally ranging from 0 to 10 gpm. However, sand and gravel lenses are erratically distributed throughout this glacial overburden and, in some cases, wells completed in these units may yield up to 50 gpm.

12.2 GLACIAL OVERBURDEN GROUNDWATER SYSTEM

In addition to the regional hydrogeologic environments in the Great Miami Aquifer, localized perched groundwater occurs in the glacial overburden. The perched groundwater system is not described by the USGS as a separate environment type, but is described as the uppermost, recharge-restricting layer of the Type III hydrogeologic environment.

Dense, fine-grained glacial till and glaciolacustrine deposits of silt and clay classify the overburden as an aquitard in most locations. However, small-scale fluvial and beach deposits interbedded within the till form layers of relatively high hydraulic conductivity. Hydraulic conductivities in the perched zones at the site range from 8×10^{-3} ft/day to 0.85 (2.8×10^{-6} cm/s to 3.0×10^{-4}), based on falling head tests in 1000 Series wells (Table 12-1). The hydrogeologic characteristics of the overburden vary with the season and specific locations. At the FMPC, depth to perched groundwater in the glacial overburden ranged from 1 to 15 feet. A perched water table can seasonally fluctuate by up to 10 feet at a single location, with the highest water levels occurring during the early spring and the lowest during the late fall.

The four glacial overburden materials present in the regional geologic setting have the following hydrogeologic characteristics:

- Loess: Blanket deposits of loess deposited during Pleistocene and post-Pleistocene time generally consist of silt with small amounts of clay. These deposits are moderately cohesive with a porosity of 40 to 50 percent. Hydraulic conductivity for loess is reported as 0.028 ft/day to 2.8 (1.0×10^{-5} cm/s to 1.0×10^{-3}) without secondary permeability. Near-surface deposits of loess have an enhanced secondary permeability due to fracturing, animal burrows, and root tubes, as indicated by site borings. These features can impart a secondary permeability that greatly exceeds the unenhanced permeability (Freeze and Cherry 1979).

DRAFT

TABLE 12-1

SUMMARY
HYDRAULIC CONDUCTIVITY TESTING

Monitoring Well No.	Subsurface Soil Type	Hydraulic Conductivity (cm/s)
1008	Clay, Trace Gravel	1.3×10^{-4}
1012	Clay w/Gravel, Shale Bedrock	1.6×10^{-3}
1018	Sand, Silt, Clay	5.7×10^{-4}
1025	Clay, Trace Gravel	2.5×10^{-6}
1034	Clay, Fine Sand, Some Silt and Gravel	2.5×10^{-5}
1035	Clay, Some Silt	2.5×10^{-5}
1041	Clay, Some Silt	1.1×10^{-4}
1046	Clay, Silt, Sand	6.8×10^{-5}
1048	Clay, Silt, Sand, Gravel	1.6×10^{-4}
1065	Silt, Some Clay, Some Sand	2.2×10^{-5}
1079	Clay, Some Sand, Some Gravel	1.8×10^{-5}

- Lacustrine Deposits: Offshore silt and clay with interbedded near-shore beach sands were deposited in meltwater lakes that existed during Pleistocene time. Unfractured, fine-grained lacustrine deposits can form large aquitards as evidenced by the clay interbed within the Great Miami Aquifer, while near-surface deposits are generally fractured. The interbedded sand and gravel beach deposits can form aquifers, but these are limited in extent and yield.

- Till: Till consists of sediments that are deposited directly under, from within, or from the top of a glacier without the sorting action of water. At the site, no attempt has been made to differentiate the till types or to determine if individual till sheets exist. Till is a heterogenous mixture of silt, clay, sand, gravel, and boulder-sized materials. Although the coarser materials are present, the till in the study area is too fine grained to be a permeable hydrogeologic unit.

  At the Fernald site where shale and limestone comprise the regional bedrock, glacial erosion has produced till comprised mainly of silt and clay which, therefore, has low permeability. Water supply investigations which included the FMPC site (Spieker, 1968a, 1968b) considered the glacial overburden as an aquitard which restricted surface recharge to the Great Miami Aquifer. Investigations in similar geologic settings (Hendry 1988; Cravens and Ruesduli 1987; Barari and Hedges 1985; Grisak et al. 1976; Hendry 1982) indicate that till deposits can be divided from a hydrogeologic standpoint into an oxidized near-surface weathered zone and a deeper, reduced unweathered zone. These studies indicate that infiltration occurs only in the weathered till, in which much of the infiltrating water is lost to evapotranspiration. In addition to this loss, some water discharges to seeps or drainages. This latter type of loss is evident in the FMPC study area along Paddys Run, where small seeps occur during periods of high rainfall.

- Glaciofluvial Deposits: Most of the large productive aquifers found in areas covered by continental glaciation are found in the glaciofluvial outwash deposits left by the meltwater of receding glaciers. These deposits, which consist of well-sorted sand and gravel, occur as extensive blanket valley fill deposits. At the FMPC, these deposits are confined by surface layers of till or glaciolacustrine silts and clays and may also have interbedded tills which act as aquitards.

The perched groundwaters in the glacial overburden at the FMPC occur under both confined and unconfined conditions. General groundwater movement in the perched system in the vicinity of the FMPC is toward Paddys Run and the Storm Sewer Outfall Ditch. However, because the shallow perched zones are not interconnected across the facility, the movement of fluids is likely to be discontinuous with different areas affected by different influences. The flow patterns within these zones vary seasonally due to variations in recharge. Shallow groundwater flow may also be

influenced by the widespread presence of drain tiles installed by the previous owners of the property in support of agricultural activities of the (WMCO various memos, 1987).

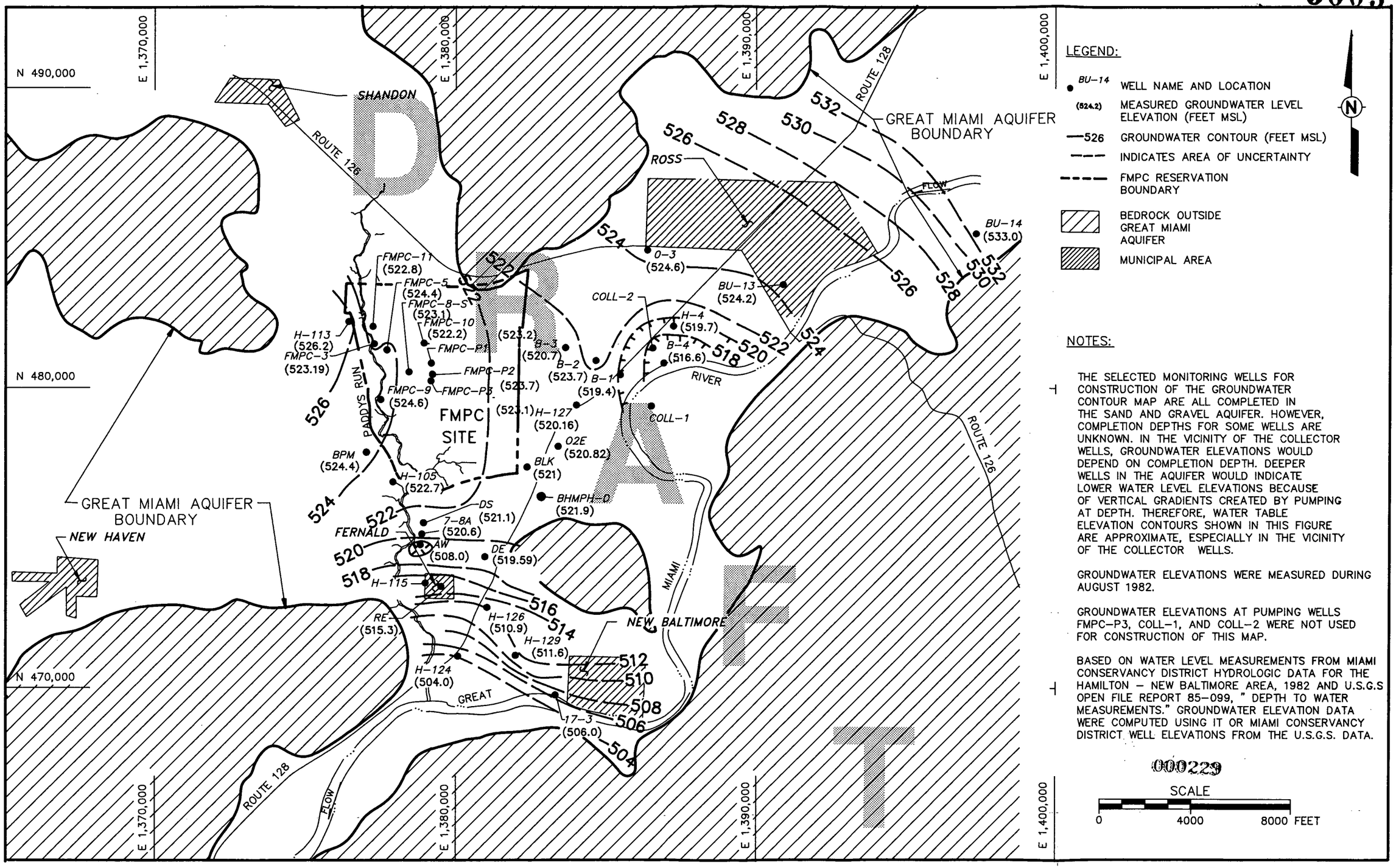
12.3 GROUNDWATER ELEVATIONS AND FLOW

The generalized groundwater flow pattern in the Great Miami Aquifer is shown in Figure 2-7. Groundwater enters the study area from three directions. In the northeast, groundwater moves southwest from the Ross area into the portion of the New Haven Trough now occupied by the Great Miami River. For simplicity, this report will refer to flow from the northeast as flow from the Ross Section of the New Haven Trough. The second source of groundwater is the Shandon Tributary to the north of the FMPC, which contains a tributary of the New Haven Trough under the town of Shandon. The majority of the groundwater from the Shandon Tributary flows under the Waste Storage Area and the Production Area and leaves along the eastern boundary of the FMPC to discharge into the Great Miami River. This flow is strongly influenced by the pumping of the collector wells. The groundwater and surface water exit this area via the Great Miami River Valley at what will be referred to in this report as the New Baltimore Outlet. The third source of groundwater is from the west. The recharge from the Dry Fork of the Whitewater River, located about two miles west of the FMPC, causes groundwater to move to the east toward the FMPC. This flow turns southward under the southern part of the FMPC and flows to the Great Miami River in the glaciofluvial deposits under the southern part of Paddys Run, termed the Paddys Run Outlet. A portion of the groundwater from the Shandon Tributary also reaches the Great Miami River via Paddys Run Outlet.

Although these general flow patterns dominate the regional flow system, local and short-term variations do occur within it. Groundwater elevation contour maps, developed from the 2000 and 3000 Series wells in the FMPC Study Area, are presented in Appendix K. The maps represent groundwater flow patterns for the period of January 1988 through April 1990 for the FMPC Study Area. In addition, regional groundwater maps constructed from more comprehensive water elevation surveys in August 1982, April 1986, and May 1988 are presented in Figures 12-1, 12-2, and 12-3.

Within the context of these flow patterns, the following conclusions can be reached:

- Groundwater enters the FMPC from the north, west, and northwest and exits toward the Great Miami River Valley to the south and toward the Great Miami River and SOWC production wells to the east (Figure 2-7).
- The large SOWC pumping wells, located in the "Big Bend" meander on the Great Miami River east of the FMPC, produce a pronounced and persistent cone of depression. This cone of depression creates an induced eastward flow of groundwater in the northern and central portions of the



NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER, COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS WERE MEASURED DURING AUGUST 1982.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

BASED ON WATER LEVEL MEASUREMENTS FROM MIAMI CONSERVANCY DISTRICT HYDROLOGIC DATA FOR THE HAMILTON - NEW BALTIMORE AREA, 1982 AND U.S.G.S OPEN FILE REPORT 85-099, " DEPTH TO WATER MEASUREMENTS." GROUNDWATER ELEVATION DATA WERE COMPUTED USING IT OR MIAMI CONSERVANCY DISTRICT WELL ELEVATIONS FROM THE U.S.G.S. DATA.

000229

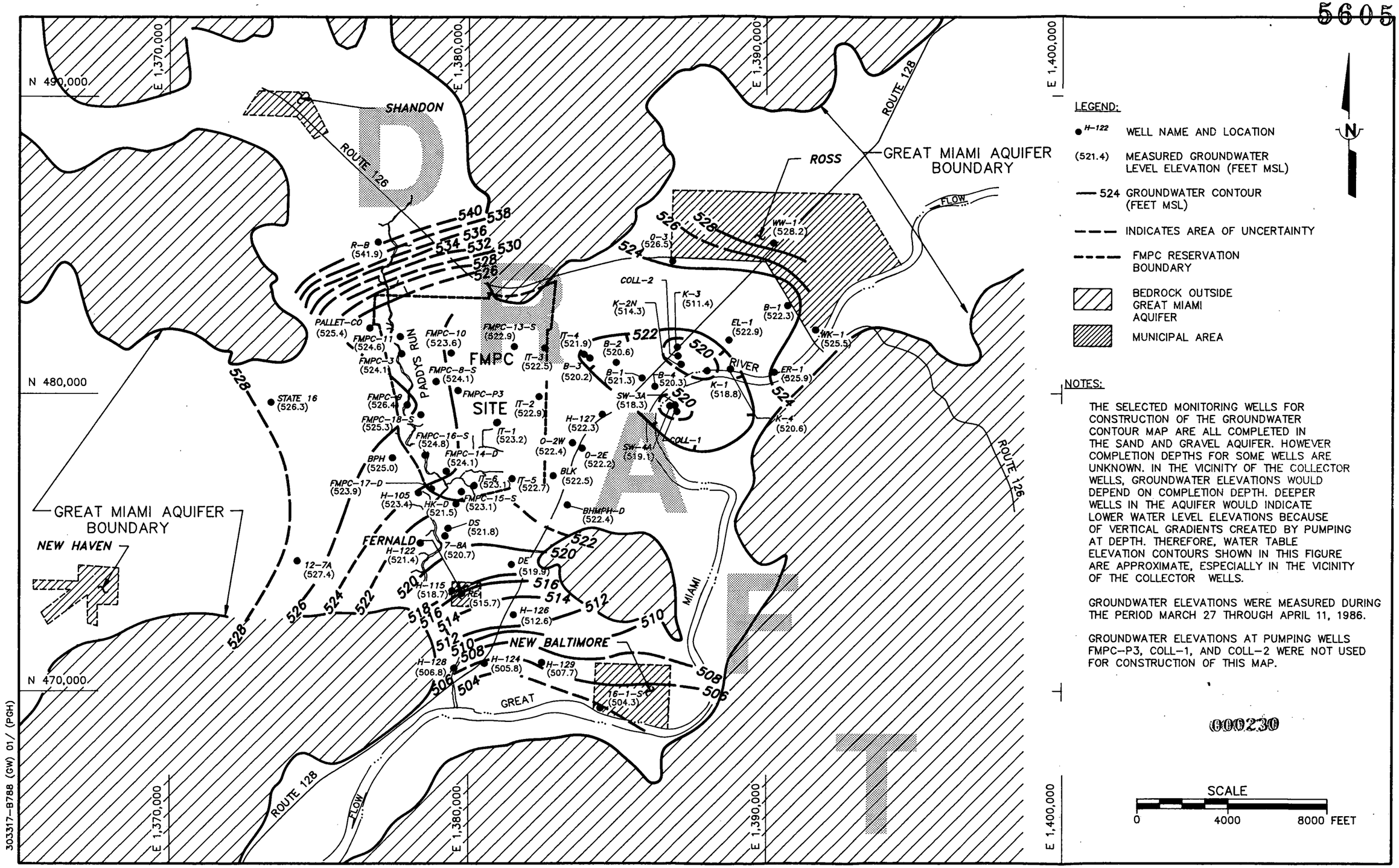
FIGURE 12-1

REGIONAL GROUNDWATER ELEVATIONS
AUGUST 1982

303317-B787 (GW) /01 100% BLUE

303317-B787 (GW) /01 (PGH)

303317-B788 (GW) 01/ 100% BLUE



NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS WERE MEASURED DURING THE PERIOD MARCH 27 THROUGH APRIL 11, 1986.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

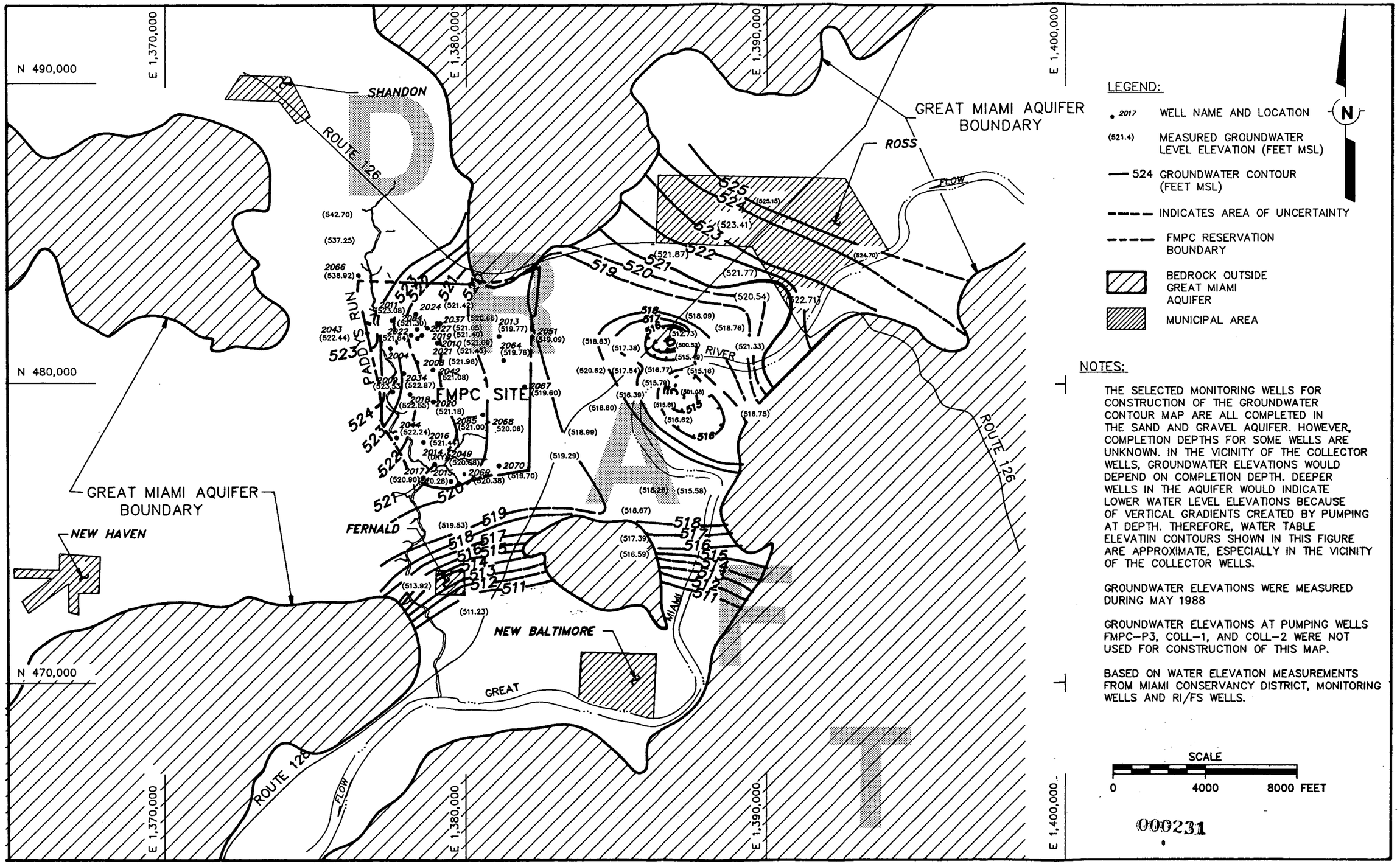
000230

FIGURE 12-2

REGIONAL GROUNDWATER ELEVATIONS
APRIL 1986

303317-B788 (GW) 01/ (PGH)

303317-789 (GW) /01, 100% BLUE



303317-789 (GW) 01/ (PGH)

000231

FIGURE 12-3

REGIONAL GROUNDWATER ELEVATIONS
MAY 1988

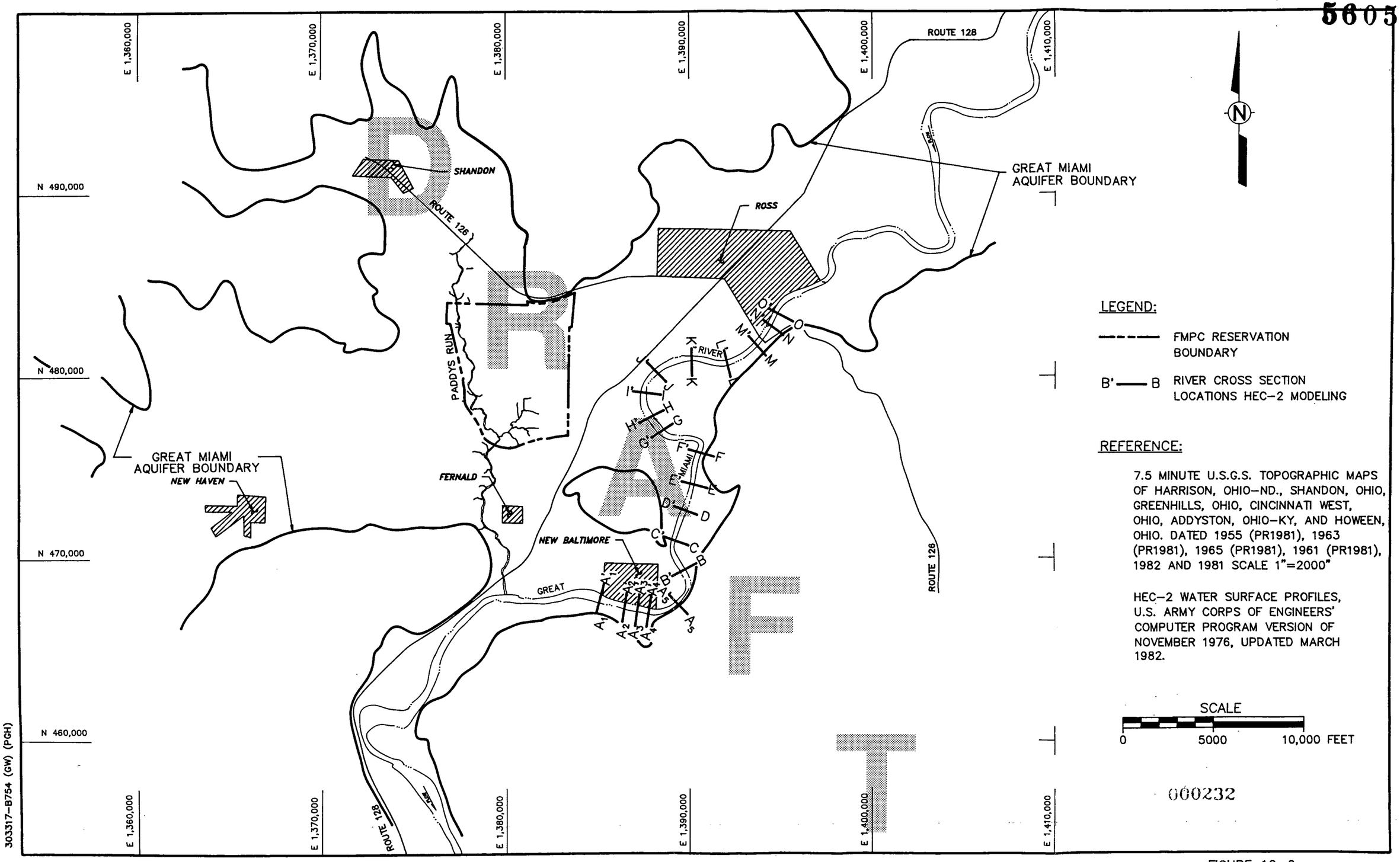


FIGURE 12-6
LOCATION OF RIVER
CROSS SECTIONS USED TO OBTAIN
HYDRAULIC CHARACTERISTICS

FMPC (Figures 12-2 and 2-7), resulting in a groundwater divide trending northwest to southeast across the south-central portion of the FMPC.

- Paddys Run affects local groundwater flow along the western boundary and in the area south of the FMPC. During dry seasons when there is little recharge to the regional aquifer, groundwater flows southeastward. During periods of high flow in Paddys Run, stream water infiltrates the Great Miami Aquifer and creates a groundwater mound and strong southward gradients. In the northern portion of the study area, the mound creates a local reversal causing a northward component of flow. Both of these flows are transient conditions which only last for the duration of seasonal high flow in Paddys Run.

- Bedrock highs south of the FMPC on the east and west also control groundwater flow direction. The combination of the eastern and western bedrock highs forces groundwater to flow due south toward the Great Miami River. The groundwater gradient steepens in the narrow bedrock channel.

- Monthly groundwater elevations show seasonal fluctuation, as shown in hydrographs of selected monitoring wells (Appendix D). The short-term fluctuations are due to surface water/groundwater interaction, which is discussed in Section 12.5.

Examination of the groundwater data from January 1988 through April 1990 shows some of the transient effects resulting from both drought and flood conditions. These features are prevalent throughout the 2000 Series groundwater elevation maps (Appendix K), although they can be seen in the 3000 and 4000 Series maps as well. Using these maps, the following trends and conditions can be identified:

- Flow conditions across much of the FMPC generally trend almost due east. These flow patterns are relatively stable, although they tend to shift slightly northward during periods of extended recharge (April-May 1989).

- Peak groundwater levels generally occur during the spring and early summer months, which are also the major groundwater recharge months. For the period of record, the highest groundwater contours occurred during the month of June 1989, when unusually large amounts of rainfall caused much recharge to occur. This caused groundwater elevations to rise to approximately 4 to 5 feet above their mean levels. Wells proximal to Paddys Run exhibited elevations as much as 10 feet over their normal levels due to the large amount of groundwater recharge entering from Paddys Run (Appendix D--cluster hydrographs).

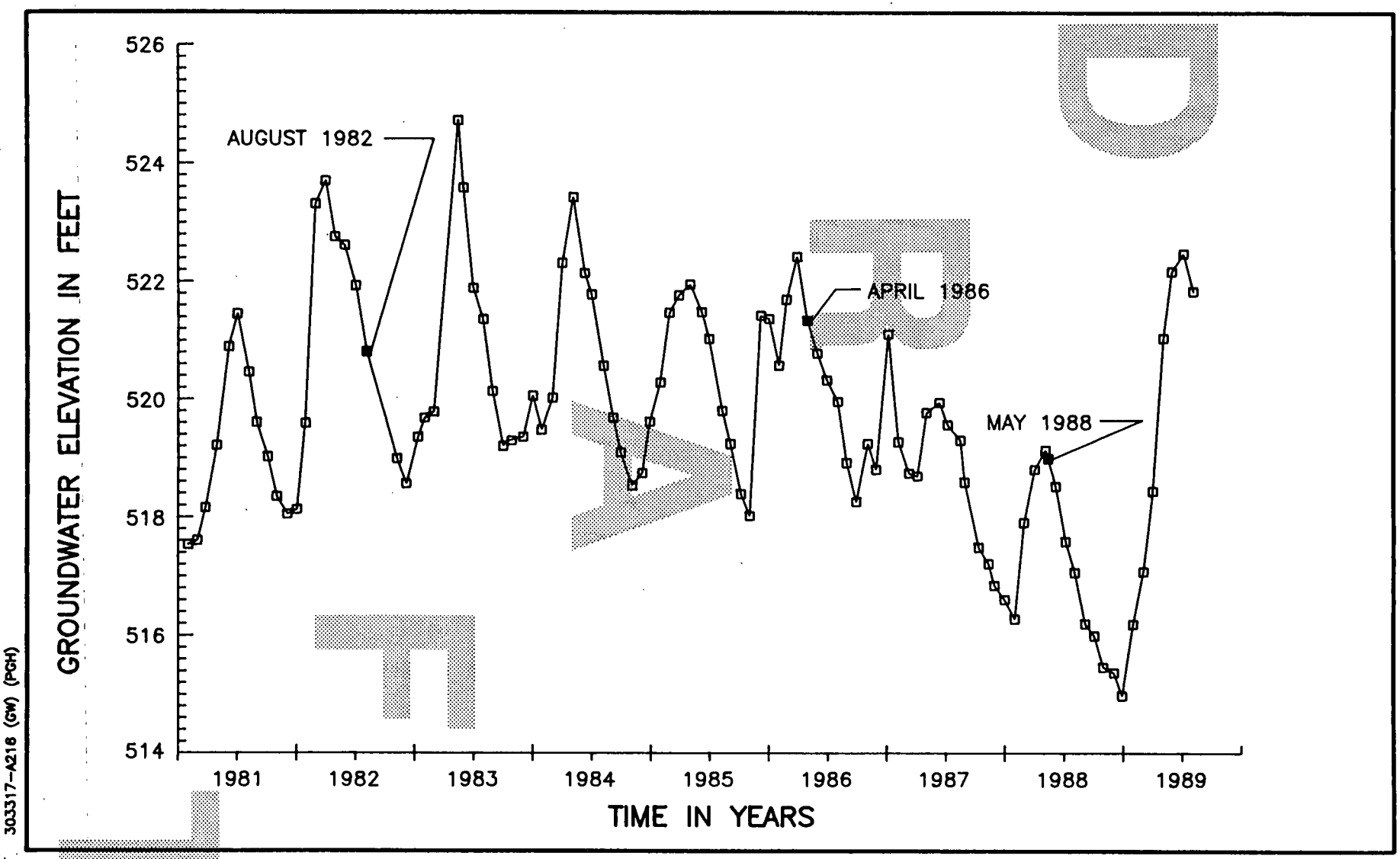
- Minimum groundwater levels generally occur during the late fall and early winter months of the year. This corresponds with the dry season for southern Ohio, which generally starts in late summer or early fall and runs to late fall. For the January 1988 through April

1990 time period, minimum groundwater levels occurred during the months of November 1988 through January 1989. Levels during this time were unusually low due to drought conditions that occurred from spring through fall of 1988. This caused groundwater levels to fall to approximately 2 to 3 feet below their normal seasonal lows.

Recharge events occurring in Paddys Run can be seen in May-June 1989 and March-April 1990. Leakage from Paddys Run can be seen to cause a "mound" in the groundwater as it infiltrates through the stream bed and enters the groundwater system. This effect is transient, although it appears to occur on an annual basis as part of the recharge during the spring and early summer months (Section 12.5.2).

The hydrograph of a representative water well located in the flood plain of the Great Miami River is shown in Figure 12-4. As previously discussed, the water level readings show a broad cyclic trend on a yearly basis. High water levels generally occur in the spring or early summer, and low water levels generally occur in the late fall or early winter. Well O2E to the east of the site exhibits this characteristic behavior, with seasonal fluctuations visible as cyclic patterns in the well's hydrograph. For most years, the groundwater experiences a fluctuation on the order of 4 to 6 feet, with increases occurring faster than decreases. The average recharge period is 4 to 5 months, while the average discharge period lasts 7 to 8 months. This is a typical water cycle for southern Ohio.

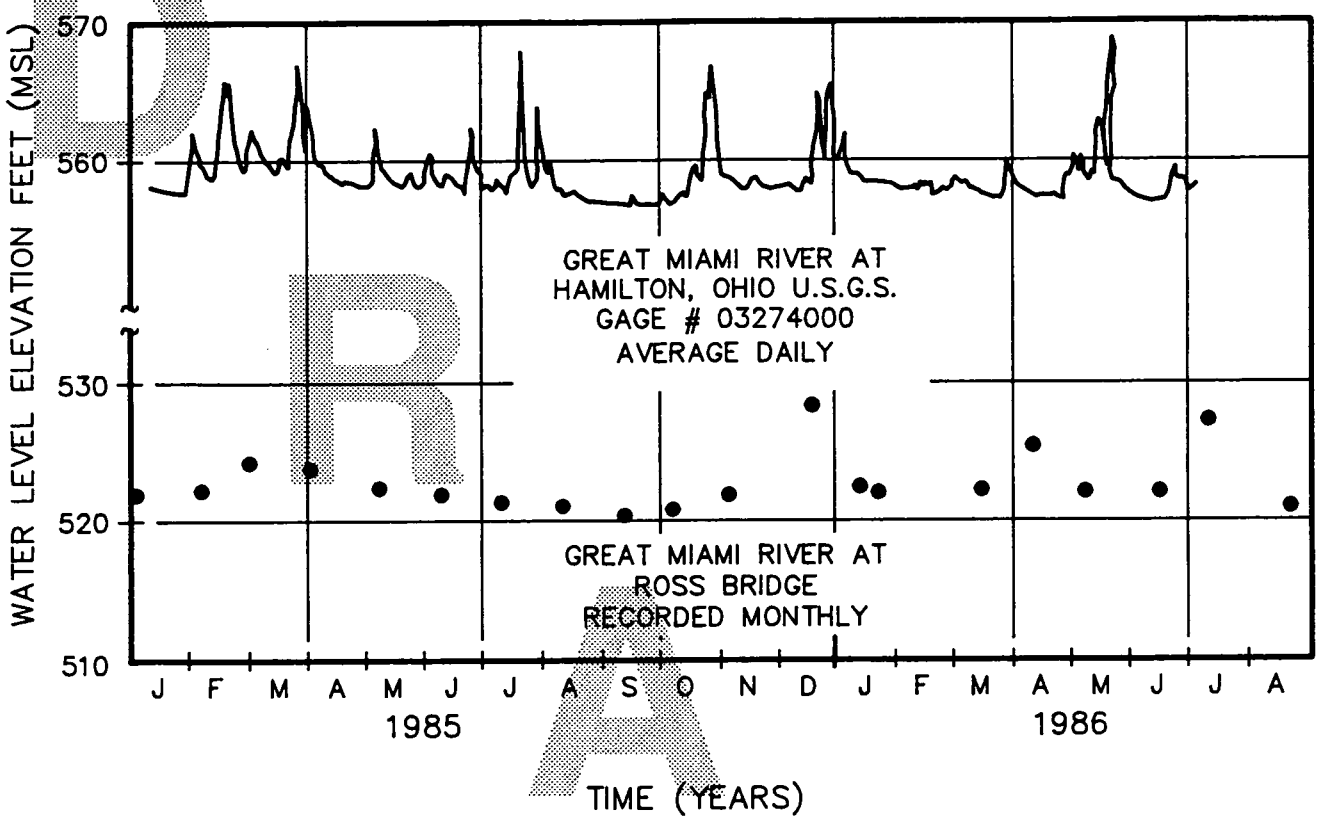
The drought experienced by the Cincinnati area in 1987-1988 is visible on the hydrograph as the two lowest points on its curve. Although recharge did occur during the spring of 1988, it was not enough to counteract the water lost by the groundwater system during 1987. Thus, the peak groundwater level in 1988 was approximately the same as the minimum groundwater levels from previous years. The regional groundwater map for May 1988 (Figure 12-3) was developed from data taken during this drought period. Two other maps, one in August 1982 (Figure 12-4) and the other in April 1986 (Figure 12-5), show similar water level conditions. The August 1982 levels were taken approximately midway through the dry season, while the April 1986 values were taken just after peak groundwater season. These two data sets represent very similar types of flow regime. Primary influences on hydraulic head in the Great Miami Aquifer during these periods were the pumping rates of the collector wells, precipitation recharge, recharge from Paddys Run, and the stage of the Great Miami River.



303317-A218 (GW) (PGH)

FIGURE 12-4

HYDROGRAPH OF WELL O2E
JANUARY 1981 – DECEMBER 1989



DRAFT

303317-A192 (GW) (PGH)

FIGURE 12-5
RIVER STAGE AT HAMILTON
AND ROSS, OHIO
1985 AND 1986

12.4 SURFACE WATER HYDROLOGY

The surface water system in the FMPC area is dominated by the Great Miami River to the east and south of the site and Paddys Run which flows along the western edge of the FMPC. Both of these water systems are described below.

12.4.1 The Great Miami River

The FMPC is located within the Great Miami River drainage basin. The river is the main surface water feature in the vicinity of the FMPC (Figure 1-1), and receives treated effluent from the facility. It flows to the southwest and has a drainage area of approximately 3,360 square miles at the Hamilton Gage, which is located about 10 miles upstream from the FMPC discharge pipe. The meander patterns of the river result in sharp directional changes over distances of less than 3,000 feet. Directly east of the FMPC, within the RI/FS study area, the river passes through a 180-degree curve known as the "Big Bend" (Figure 1-1). A 90-degree bend in the river also occurs near New Baltimore, approximately two miles downstream from the FMPC's point of discharge. As reported by IT (1988), the average discharge of the Great Miami River at Hamilton, based on 55 years of records, is 3,305 cfs. Using drainage area scaling, the corresponding average flow at the FMPC point of discharge has been estimated to be 3,460 cfs.

Figure 12-5 presents the continuous record of river stage at the Hamilton Gage for 1985 and 1986. The stage is shown to fluctuate by only a few feet over most of the year, with periodic increases up to approximately 12 feet above normal flow conditions. The average depth of water in the Great Miami River under mean flow conditions in the vicinity of the FMPC discharge is 5.4 feet, based on model results from the U.S. Army Corps of Engineers' HEC-2 computer program for calculating water surface profiles. Input data for HEC-2 were obtained from the U.S. Corps of Engineers, Louisville District, and included cross-sectional geometry and reach lengths along the river between Ross and New Baltimore (Figure 12-6). The HEC-2 modeling is described in IT (1986b).

12.4.2 Paddys Run

Paddys Run is an ungaged intermittent tributary of the Great Miami River that flows southward along the western edge of the FMPC. Paddys Run is critical in the evaluation of the FMPC Study Area, as it is the discharge point for the majority of natural drainage from the FMPC, including the Storm Sewer Outfall Ditch.

Paddys Run has a 10-square-mile drainage basin and an estimated average discharge of 0.2 to 4.0 cfs (Dames and Moore 1985). High water marks suggest a water stage of up to 4 feet during peak flows (SCRWC 1986).

The banks of Paddys Run are steep to near vertical and display glacial overburden deposits. The stream bed of Paddys Run rests on the underlying sand and gravel alluvium of the Great Miami Aquifer along the section between the silo area and the Great Miami River (Figure 11-5). The contact with the buried valley deposits results in the infiltration of surface flow in both of these stream valleys. Similarly, the bed of the Storm Sewer Outfall Ditch rests on the aquifer from a point at the storm water retention basins to Paddys Run. Periods of recharge typically occur from January through May and following heavy precipitation events. Various locations on the cut banks show evidence of groundwater seepage from the perched aquifer zones that occur in the overburden material.

The course of Paddys Run has been artificially modified by FMPC activities at least twice. Part of Paddys Run previously flowed close to the Waste Storage Area, but in 1961 it was diverted to the west, away from the waste pits. The now swampy, abandoned stretch of Paddys Run near the waste pit berms catches and retains surface runoff (WMCO 1987). A second modification occurred in 1970, downstream of the K-65 silos. In this case, Paddys Run was straightened to prevent erosion of Paddys Run Road. Approximately 700 cubic yards of sand and gravel were removed from the bed of Paddys Run, near the K-65 silos, between 1952 and 1985 (WMCO 1987) for FMPC construction activities.

There are several tributaries which contribute significantly to the flow in Paddys Run. The most significant tributary is the Storm Sewer Outfall Ditch, which receives all the surface water from east of the Production Area, the southeast quarter of the FMPC reservation, and a considerable area southeast of the FMPC. The second largest tributary to Paddys Run drains the area north of the Production Area and flows west into Paddys Run on the north side of the railroad tracks northwest of the waste pits. Surface water runoff from the Waste Storage Area enters Paddys Run via three tributaries. The larger of the three enters Paddys Run just north of the silos and south of the Clearwell. The two smaller tributaries drain the area north of Pit 5, including the northwest corner of the Production Area and the area between Pit 5 and Pit 3. These two drainages enter Paddys Run immediately south of the railroad tracks and about 100 yards south of the tracks, respectively. There is also a tributary that drains the area west of the Production Area and south of the Waste Storage Area. This tributary enters Paddys Run a little south of the K-65 silos.

The Storm Sewer Outfall Ditch historically conveyed surface water runoff from the Production Area when the capacity of the storm water collection system was exceeded and provided local drainage for the area east and southeast of the Production Area. Two storm water retention basins designed to retain the runoff from a 10-year, 24-hour rainfall event were constructed at the head of the Storm Sewer Outfall Ditch in October 1986 and December 1988. These basins essentially eliminated the contribution of storm water from the Production Area to the outfall ditch. Storm water runoff from the Production Area is currently conveyed to these retention basins. After at least a 24-hour retention period to allow for settling of suspended solids, the water is pumped out to the Great Miami River via the FMPC's main effluent line.

12.5 SURFACE WATER/GROUNDWATER INTERACTION

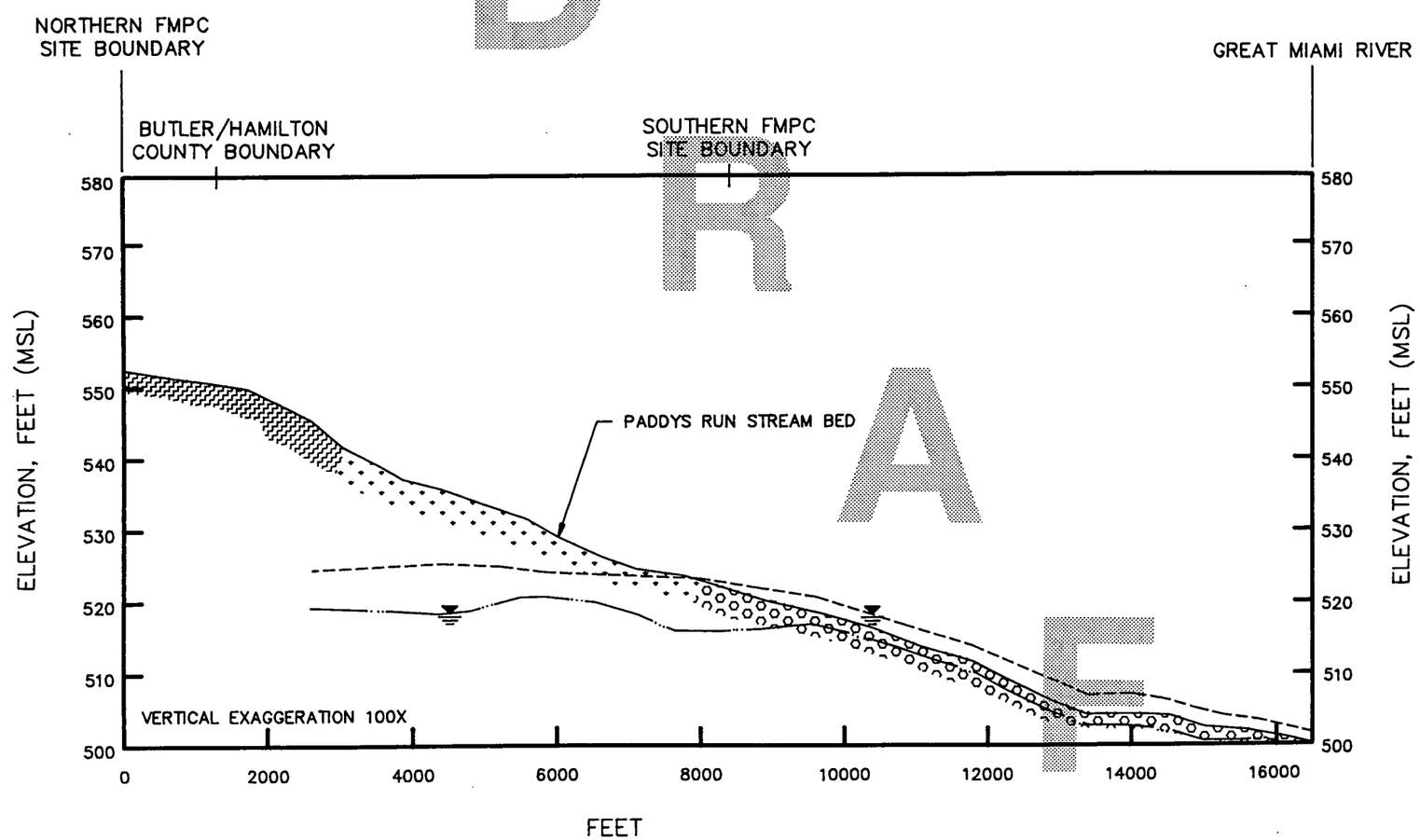
The geomorphic setting of the Great Miami River and Paddys Run provides for interaction between the surface water and groundwater. Both surface water systems have eroded through the low permeability glacial overburden material to the Great Miami Aquifer. This contact allows for the direct exchange of water between the surface water and groundwater, which is important in relation to increased usage of the aquifer for water supplies and contaminant transport in the FMPC Study Area.

12.5.1 Great Miami River/Groundwater Interaction

The Great Miami River bed is in contact with the sand and gravel deposits of the Great Miami Aquifer. Because the Great Miami River partially penetrates the water table, a portion of its flow originates from surface water while a portion also comes from the aquifer beneath the river. The natural groundwater flow is generally from the aquifer to the river; that is, groundwater discharges into the river. However, pumping of the collector wells, which are located close to the river, induces recharge to the aquifer by stream infiltration. This occurs by creating a local hydraulic gradient, which causes flow from the river to the aquifer. This induced infiltration allows the collector wells to maintain a higher yield from the aquifer than could be achieved if the river was not present.

The rate of induced infiltration varies with respect to the season and the location on the stream. Factors which influence the infiltration rate include:

- River stage
- Hydraulic gradient
- Stream bed characteristics
- Water temperature



LEGEND:

- HIGH WATER TABLE (FEBRUARY TO JUNE, 1989 TO 1990)
- LOW WATER TABLE (SEPTEMBER TO DECEMBER, 1988 TO 1989)
- GLACIAL OVERBURDEN PRESENT; MINIMUM STREAM WATER INFILTRATION EXPECTED
- SURFACE WATER INFILTRATION OCCURS REGARDLESS OF WATER TABLE ELEVATION
- POSSIBLE SURFACE WATER INFILTRATION DEPENDING ON WATER TABLE ELEVATION

NOTE:

WATER TABLES SHOWN ARE BASED ON READINGS COLLECTED FROM WELLS 2004, 2009, 2014, 2107, 2125, 2126 AND 2127 FROM JANUARY 1988 TO APRIL 1990. PADDYS RUN STREAM BED AND GROUNDWATER TABLE ELEVATIONS ARE PROJECTED ONTO A VERTICAL PROFILE BETWEEN THE NORTHERN FMPC BOUNDARY AND THE GREAT MIAMI RIVER WHERE PADDYS RUN INTERSECTS.

VERTICAL SCALE

0 20 40 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

DRAFT

303317-B751 (GW) (PGH)

FIGURE 12-7
AREAS OF SURFACE WATER INFILTRATION TO THE GREAT MIAMI AQUIFER ALONG PADDYS RUN

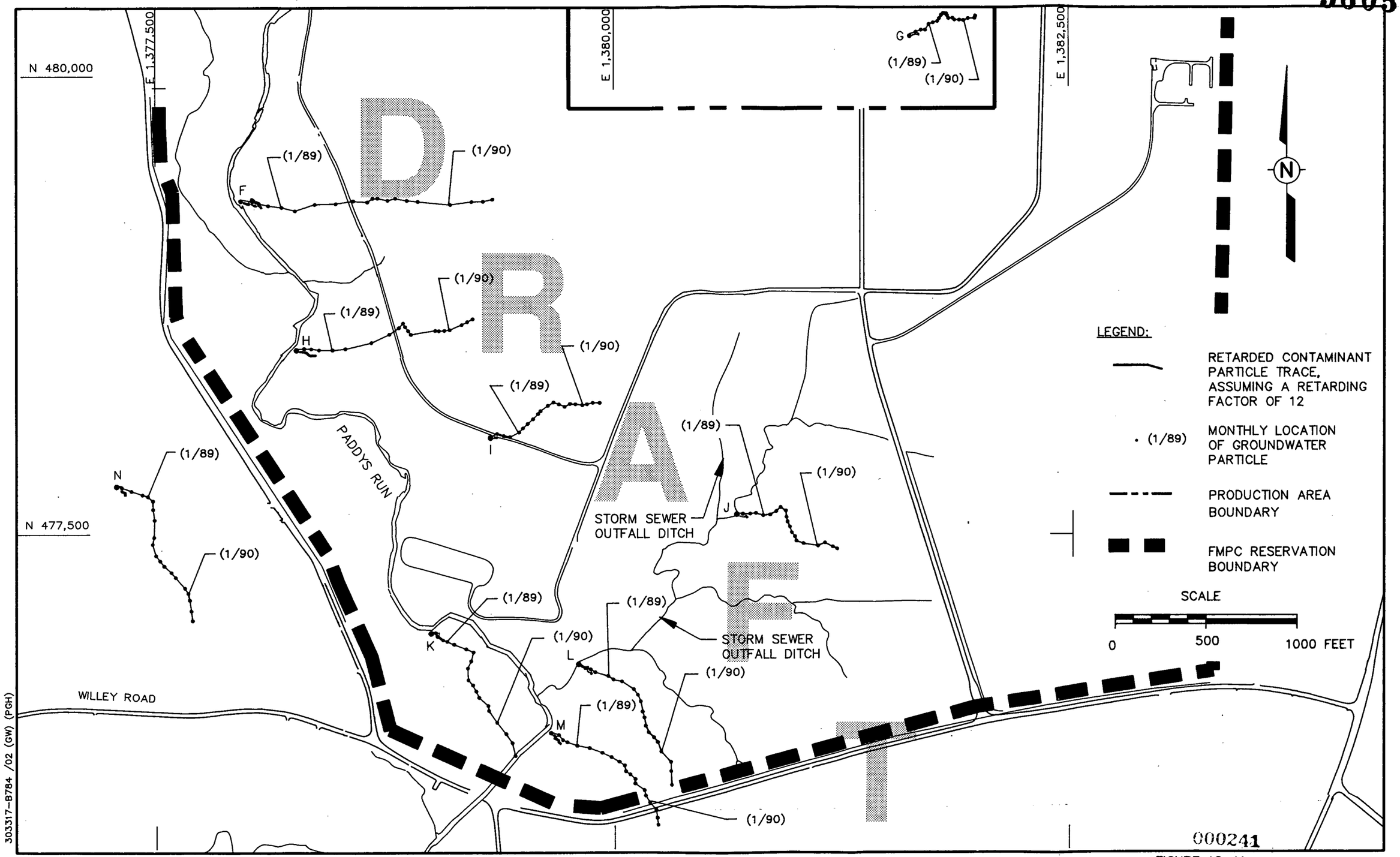
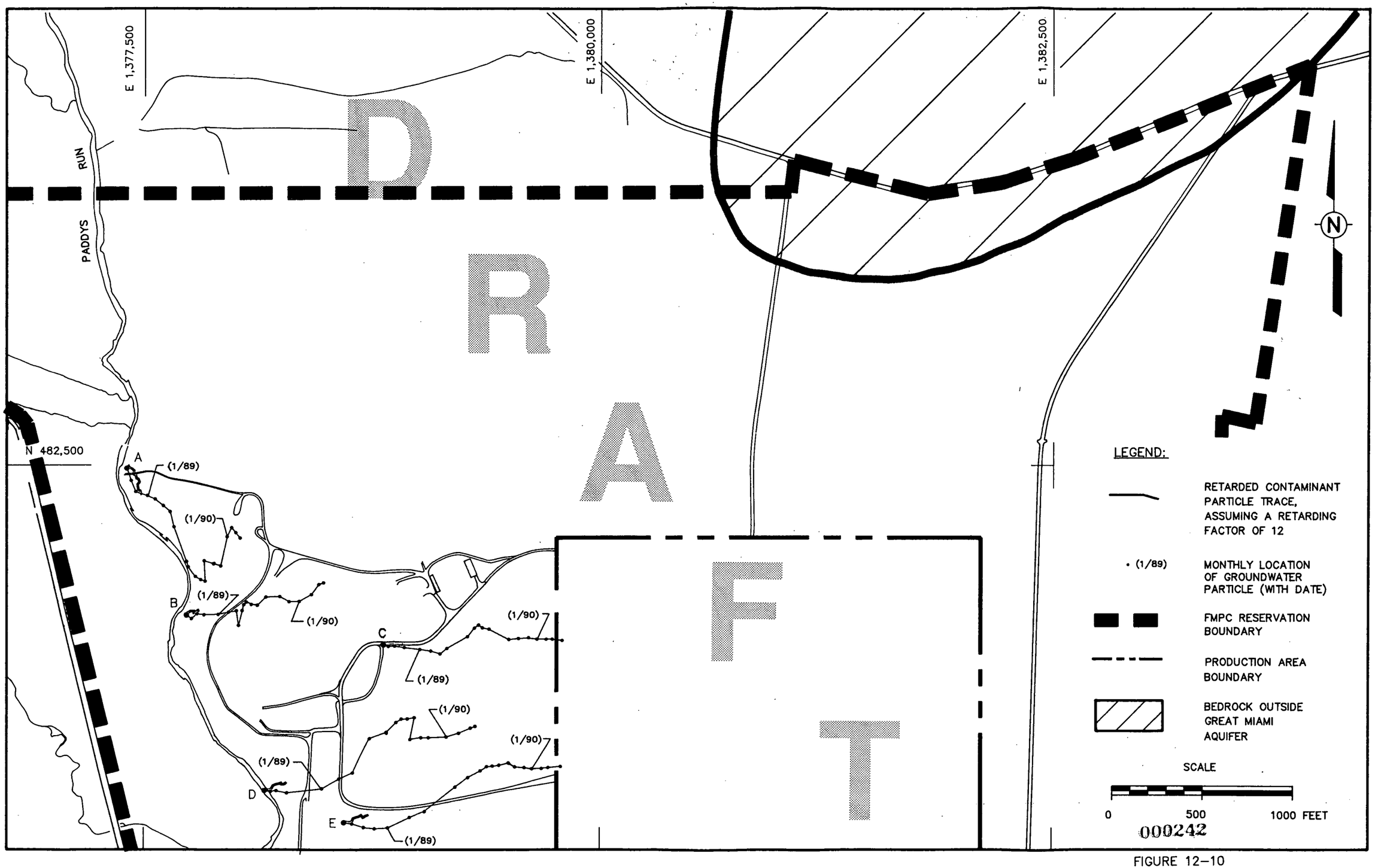


FIGURE 12–11
MONTHLY GROUNDWATER AND CONTAINMENT PARTICLE MOVEMENT IN UPPER GREAT MIAMI AQUIFER AT SELECTED LOCATIONS OF SOUTHERN PORTION OF FMPC FROM SEPTEMBER 1988 TO APRIL 1990

303317–B784 /02 (GW) 100% ORG.
303317–B784 /02 (GW) 100% BLUE
303317–B784 /02 (GW) (PGH)

303317-B785 /02 (GW) 100% ORG.
303317-B785 /02 (GW) 100%



303317-B785 /02 (GW) (PGH)

FIGURE 12-10
MONTHLY GROUNDWATER AND CONTAINMENT PARTICLE MOVEMENT IN UPPER GREAT MIAMI AQUIFER AT SELECTED LOCATIONS OF NORTHERN PORTION OF FMPC FROM SEPTEMBER 1988 TO APRIL 1990

The river bed infiltration rate had been investigated during the summer of 1956 near Ross (Dove 1961), and in Fairfield Township in the summer of 1962 (Spieker 1968a). Infiltration rates were calculated to be 240,000 and 492,000 gpd per acre (3,200 and 6,600 in/yr) of stream bed, respectively. Both tests were performed in similar terrains, under low stream flow conditions, at water temperatures of approximately 80 degrees Fahrenheit.

The effects of the FMPC effluent discharge on groundwater quality due to the induced infiltration of Great Miami River water has been evaluated in a separate report (IT 1988). This study concluded that the FMPC discharge did not have a quantifiable effect on the groundwater system due to the high degree of induced infiltration that occurred upstream from the discharge point.

12.5.2 Paddys Run/Groundwater Interaction

Paddys Run interacts with the Great Miami Aquifer in several different ways that affect groundwater flow and discharge. The stream has eroded through the glacial overburden and into the top of the Great Miami Aquifer from its confluence with the Great Miami River to about the position of the silos (Figure 11-5). It is, therefore, directly connected with the Great Miami Aquifer in that reach. South of the FMPC, the elevation of the water table is close to or above the elevation of the stream bottom (Figure 12-7); consequently, during most of the year, the stream receives groundwater in this reach. In the vicinity of the FMPC, however, the stream is above the water table and loses water to the regional aquifer. It is generally dry, except during runoff periods following rainfall and snow-melt events. Sustained flow has been reported in Paddys Run during the winter and spring by Dames and Moore (1985) and by stream gaging stations monitored during the RI. Relatively little recharge of the Great Miami Aquifer occurs where Paddys Run is on clayey till north of the silos.

Groundwater elevation contour maps derived from the 2000 and 3000 Series wells (Appendix K, Figures K-1 through K-56) show that the regional water table fluctuated, based on monthly readings, as much as 8 feet during the period of January 1988 to June 1989. This water table fluctuation may be considered extreme, since the FMPC experienced drought conditions from spring 1988 to early winter 1989, followed by an extended period of higher than average precipitation from late winter to early summer 1989. The cycle repeats in the winter of 1989/1990.

As shown in Figures 12-8 and 12-9, there is a high degree of correlation between the Paddys Run hydrograph and the regional aquifer hydrographs. These figures are based on continuous 60-minute readings using pressure transducers and a data logger. As the Paddys Run hydrograph peaks, the

groundwater hydrograph shows a peak a very short time later, which indicates the hydrologic connection between the stream and the regional aquifer.

Increases in runoff in Paddys Run leads to the formation of a groundwater mound typically centered on Wells 2108 or 2009, but under extremely wet conditions extending from Well 2004 to Well 2107. A slight influence is seen in the dry months of a normal (nondrought) year, but the mound is most pronounced during periods of high precipitation, such as from March to June 1989. This increased recharge forms a large transient groundwater mound in the regional water table, which affects the direction of flow in the vicinity of the mound (Figure K-18 in Appendix K). As the flow in Paddys Run decreases, and therefore the infiltration to the aquifer is reduced, the mound decreases in size until the flow patterns show only slight influence.

The effect of the recharge mound on groundwater and contaminant movement is analyses by calculating the position of a particle of groundwater on a monthly basis. The position is determined by starting at an arbitrary point and calculating the movement for monthly intervals of a particle from that point using the slope and direction of the groundwater gradient at that point. The new gradient and slope for each particle each month is taken from the monthly water table maps in Appendix K .

Particle tracks for contaminants if they were present are also shown on Figures 12-10 and 12-11 for all 14 locations. There is no relation between these tracks and any actual contamination in the aquifer other than a prediction of movement if contamination was present. The contaminant tracks are based on contaminants moving at one twelfth of the velocity of groundwater because a contaminant retardation factor of 12 is currently being used in the groundwater modeling.

Figures 12-10 and 12-11 show the particle tracks for 14 locations for the period beginning September 1989 through April 1990. This period represents both the time when the well network was sufficiently dense to provide good water table data and the period of transition from unusually dry to unusually wet conditions. The points for January 1989 and 1990 are labeled on each track so the movement over a one year time period is easily comparable from location to location.

The hydrographs in Appendix D show that from September through December 1988 the water table was generally at its lowest level as a result of a dry year in 1987 being followed by a drought in 1988. The particle tracks for the September through December time frame therefore indicate the groundwater flow direction if there is no recharge from Paddys Run. Recharge from Paddys Run began in January 1989 and peaked in June and July of 1989. Water levels fell until December 1989

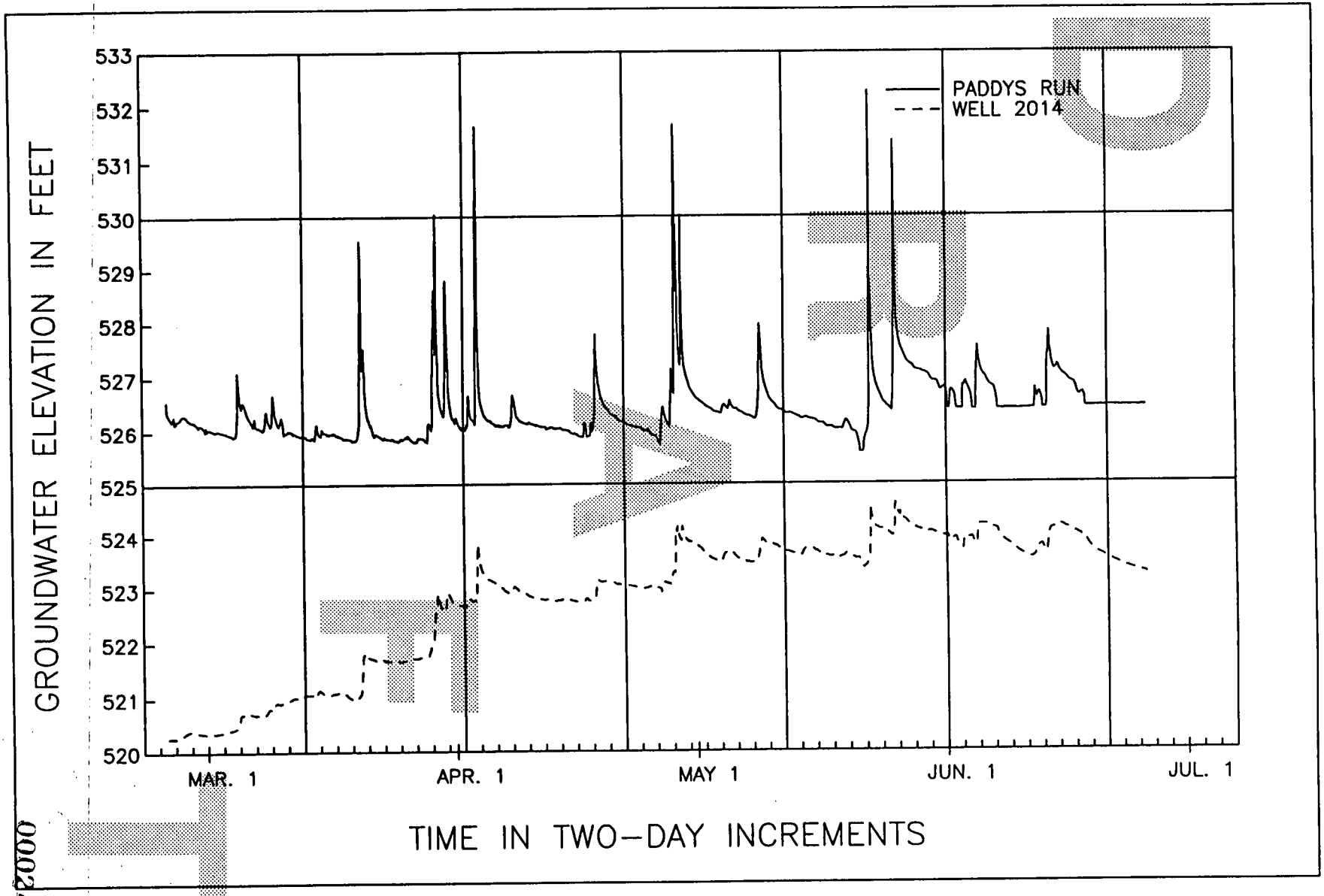


FIGURE 12-8. HYDROGRAPH OF PADDYS RUN AND GREAT MIAMI AQUIFER AT WELL LOCATION 14, FEBRUARY 24, 1989 – JUNE 26, 1989

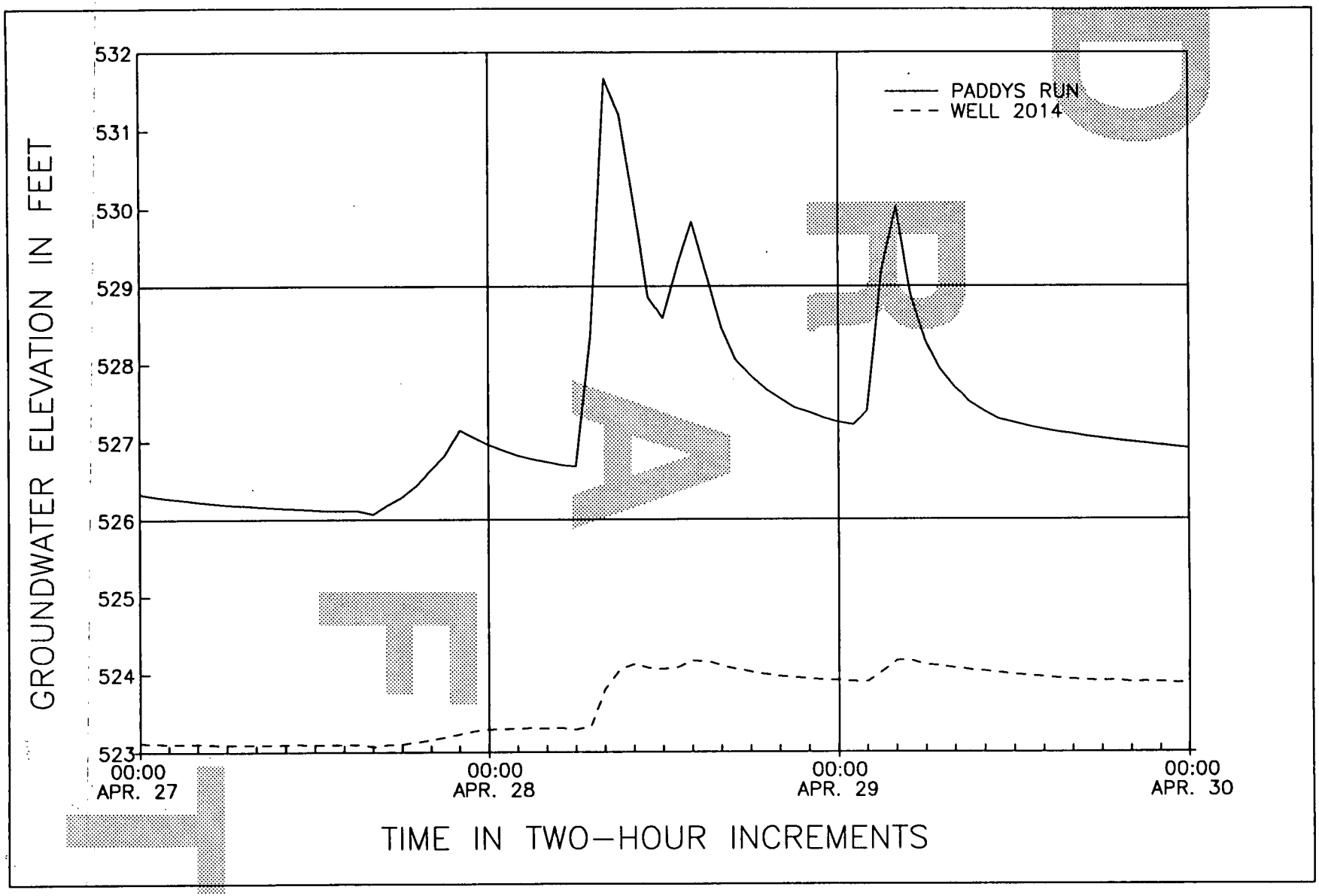


FIGURE 12-9. HYDROGRAPH OF PADDYS RUN AND GREAT MIAMI AQUIFER AT WELL LOCATION 14, APRIL 27, 1989 - APRIL 30, 1989

but not to the low levels of 1988. Water levels rose again from January through April 1990 to levels equal to the highest levels in 1989.

Figure 12-10 shows the particle tracks for locations A through E in the northwest corner of the FMPC Reservation. Locations A, B, and D lie along Paddys Run. Both locations A and B are started in locations where Paddys Run is flowing on glacial overburden north of the point where recharge from Paddys Run to the aquifer occurs. The northern most point where recharge begins appears to be about 300 to 500 feet north of location D in Figure 12-10. The particle tracks from all five locations in Figure 12-10 were influenced by the recharge. The degree of the influence is in part a function of the distance of the starting location from Paddys Run.

For the particle at location A the normal gradient is to the south southeast parallel to Paddys Run as shown by the September through December 1988 points. The track is deflected to the east slightly during the January to April 1989 period indicating that perhaps there is some leakage form Paddys Run through the glacial overburden. The track takes an abrupt turn to the north east in October of 1989 and continues on an erratic path to the northeast through April 1990. This erratic movement appears to be in response to a reversal of gradient that results from the effect of recharge from the south moving to the north. The net movement from January 1989 to January 1990 is a path to the southeast rather than to the south southeast. The particle track for a contaminant starting at Location A would still have been to the south during the year because it stayed well north of the main influence of recharge from Paddys Run.

For particles at locations B and C in Figure 12-10, the normal gradient is to the east. Both particle tracks show a slight shift to the north but the net movement from January 1989 to January 1990 is to the east northeast. The contaminant track for both of these points is short and to the east indicating that contamination in the aquifer from the waste pits will likely be migrating directly to the east.

Particles at Location D, 300 to 500 feet downgradient the area where recharge appears to take place, and Location E just east of the K-65 silos show a different pattern. The September through December 1988 period indicates that flow without recharge from Paddys Run is to the east or slightly southeast. The net movement form January 1989 to January 1990 is to the northeast. The net distance traveled is also greater than for the particles from Locations A, B, or C in the same time period. This appears to be because of the steep gradients developed by the mound during the time when Paddys Run recharge was at its greatest, from January through May 1989. The contaminant particle tracks also have a distinctly different path than the water particles from

locations D and E. Due to retardation the contaminants stay under the influence of the steep recharge gradients for a longer period of time and the net movement is to the east northeast.

Figure 12-11 shows the particle tracks for Locations F through N. The groundwater track for Location F shows that the highest groundwater velocities under the FMPC reservation occur where recharge from Paddys Run simply reenforces the normal gradient. As the track shows normal flow is slightly south of east. Paddys Run is almost perpendicular to the groundwater flow lines so the recharge increases the gradient without changing the gradient direction. The result is the longest flow path for the January 1989 to January 1990 period. The net flow direction is also essentially east as is the contaminant track.

For particles at locations H and I the normal groundwater flow direction is to the east. The impact of recharge from Paddys Run has resulted in a net flow from January 1989 to January 1990 to be to the northeast. This is where groundwater flow without recharge would turn to the southeast. Particle tracks for contaminants are essentially to the east in these two locations.

Particles at locations K and N have a slightly different path because these locations are on the upgradient side of Paddys Run. The normal gradient from September through December 1988 is to the southeast. Flow is diverted to the southwest at both locations although at slightly different times. Location N is further north so it is impacted earlier than location K. The recharge front is moving south along the length of Paddys Run as the saturated portion of the aquifer forces water in the stream to move farther and farther south before infiltrating.

At location N the regional gradient caused movement to the east southeast from September 1988 through January 1989 and from July through December in 1989. Recharge from Paddys Run diverts this flow to almost directly south from February through June 1989 and again from January through April 1990. The net movement for the January 1989 through January 1990 period is only slightly east of south rather then to the east southeast. The short contaminant path is also considerably more to the south than the normal groundwater gradient indicates it should be.

At Location K the flow is diverted to the south west in May of 1989 an approximately 90 degree change in direction. The flow returns to a southeasterly direction July 1989. The net movement from January 1989 to January 1990 is to the south east rather than the east southeast. The contaminant track is also diverted from an easterly path to a southerly path.

Locations L and M show particle tracks that are strongly influenced by the steep groundwater gradient to the south out the Fernald Outlet. The normal flow line approximated by the September through December 1988 period indicates that flow should be to the southeast. Only a slight increase in the spacing between the points in early 1989 indicate an increase in velocity due to recharge. The track for location L turns almost south in May 1989 after the main recharge period. The net direction of flow for the L track is more to the south than the M track. Both tracks appear to be converging on the location of well 2060 where off- FMPC contamination was first discovered. These two tracks appear to show how the contamination transported by Paddys Run could have traveled south off the reservation.

The particle track for Location J is different from the others because this is an area where the regional gradient is not very steep and it is influenced by recharge from the Storm Sewer Outfall Ditch and its tributaries. The close spacing of the points indicates that the gradient is relatively flat therefore, even though there are a number of abrupt changes in direction the net distance is relatively short. It appears that the normal gradient is to the east and recharge causes a displacement to the south. The net movement from January 1989 through January 1990 is to the southeast.

Location G is in the vicinity of Plant 6 in the southeast corner of the Production Area. The particle path is very short again due to the very flat groundwater gradient under the production area. Although there is a slight deflection of the particle track to the north in the middle of the track, the net movement from January 1989 through 1990 is to the east northeast. This location is within the area of influence of the collector wells located along the Great Miami River to the east northeast. The distance traveled by this particle is the shortest of all the tracks calculated because of the low gradient. Contaminant transport is also in a north northeast direction for this area.

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13.0 HYDROLOGIC PARAMETER ESTIMATION

This chapter presents the informational and analytical basis for the selection of initial values for those hydrologic parameters required as input to the groundwater flow model. Final values for these parameters were established based on the results of model calibration, as discussed in Part IV of this report.

13.1 REGIONAL AQUIFER

This section discusses the hydrologic parameters of the regional aquifer, including transmissivity, porosity, and infiltration. In addition, the interaction of the Great Miami River and Paddys Run with the regional aquifer is discussed.

13.1.1 Transmissivities and Hydraulic Conductivities

Spieker (1968a) mapped 11 units in the Great Miami Aquifer with distinctive physical and hydraulic properties. He reported that transmissivity values generally ranged from 300,000 to 500,000 gpd/ft (40,000 to 67,000 ft^2 day), and that individual wells can yield as much as 3,000 gallons per minute (gpm).

Geotrans (1985) summarized hydraulic properties for the Great Miami Aquifer near Hamilton, Ohio, approximately 10 miles north of the FMPC. Transmissivities ranging from 30,000 to 700,000 gpd/ft (4,000 to 94,000 ft^2/day)) were reported for a site in the northern part of the city of Hamilton. Most values are reported in the range of 100,000 to 300,000 gpd/ft (approximately 13,000 to 40,000 ft^2/day). The aquifer at the site is 180 feet thick (Ward et al. 1987). Consequently, hydraulic conductivities range from 20 to 520 ft/day (7.05×10^{-3} to 0.18 cm/s), with most values being in the range of 75 to 225 ft/day (0.026 to 0.079 cm/s). The highest hydraulic conductivity reported for the aquifer near Hamilton was 774 ft/day (0.27 cm/s). Ward et al (1987) stated that slug tests showed hydraulic conductivity increases with depth in the Great Miami Aquifer at Hamilton.

Hydraulic conductivities derived from pumping tests of the collector wells have ranged from 318 to 391 ft/day (0.11 to 0.14 cm/s) (Geotrans 1985).

The pumping tests of the Great Miami Aquifer at the FMPC are described by Spieker and Norris (1962). They performed tests that utilized the FMPC water supply wells, which were screened below the clay interbed. They used the leaky aquifer method of analysis and obtained a hydraulic

conductivity of 270 ft/day (0.095 cm/s). Two separate pumping tests were performed and estimates of the vertical hydraulic conductivity of the clay interbed, 0.43 ft/day (1.5 x 10^{-4} cm/s) and 0.33 ft/day (1.16 x 10^{-4} cm/s) were obtained. These values are far outside of the typical range of values for clay which is usually about 10^{-4} to 10^{-3} ft/day (3.5 x 10^{-7} cm/s) (Freeze and Cherry 1979, p. 29).

It is unlikely that the various analyses of the pumping tests reported for the Great Miami Aquifer adequately allowed for the combined effects of partial penetration and vertical anisotropy of the aquifer. Consequently, the transmissivities and hydraulic conductivities reported are probably lower than the true values for these parameters.

The calibrated three-dimensional flow model values reported in Section 20.2.3 are 450 ft/day (0.16 cm/s) for the upper part of the aquifer and 600 ft/day (0.21 cm/s) for the lower part. These values fall within the range of reported values. They are slightly higher than most of the values reported; however, the model-calibrated values are consistent with the observation that the reported values probably tend to be lower than true values. The hydraulic conductivities in the various model layers increase downward, which is a condition that has been observed near Hamilton.

13.1.2 Porosity

No estimates of porosity in the Great Miami Aquifer were found in the literature. However, some estimates of specific yield have been made, and porosity of such deposits tends to be only slightly greater than specific yield. Spieker (1968a) stated that the aquifer may be classified with a specific yield of about 0.2. A three-day pumping test reported by Geotrans (1965) provided a specific yield of 0.23. The average specific yield for aquifers composed of gravelly sand was reported to be 0.25 by Johnson (1967). A value of 0.25 was used for porosity in the present aquifer modeling. It is slightly higher than the single measurement of specific yield (0.23) and falls within the range of reported values in the literature.

13.1.3 Infiltration/Recharge Rates

Spieker (1968a) estimated recharge to the Great Miami Aquifer throughout the study area at 6 to 21 inches per year (in/yr), and used a recharge value of 15.2 in/yr in his electric analog model calibration (Spieker 1968b). Walton and Schaefer (1956) estimated that recharge in the area of the SOWC wells was 8.5 in/yr at the time of their study, which was a year of near-average precipitation. Smith (1962) estimated a recharge maximum of 21 in/yr in the Fairfield area northeast of Ross. Geotrans (1985) produced a preliminary three-dimensional finite-difference flow model with a recharge of 15 in/yr where the Great Miami Aquifer is exposed at the ground surface,

and 6 in/yr where glacial overburden covers the aquifer. The modeling described in Part IV of this report uses initial values of 14 in/yr where the aquifer is exposed at the surface and 6 in/yr where the overburden is present. These recharge values are consistent with the earlier estimates for recharge in the area. A recharge value of 6 in/yr implies a vertical hydraulic conductivity of 1.4×10^{-3} ft/day (4.9×10^{-7} cm/s), under unit hydraulic gradient, which is in the middle of the range for hydraulic conductivities given for glacial till (Freeze and Cherry, Table 2.2).

13.1.4 Great Miami River Leakage

The Great Miami River loses water by induced infiltration as it flows past the SOWC wells. Walton and Schaefer (1956) investigated this stream leakage using a flow net approach. They estimated induced infiltration at 10,550,000 gpd, 62 percent of the water pumped from the SOWC wells. Based on an electric analog model, Spieker (1968) estimated that 75 percent of the pumping was from induced infiltration.

The flow model discussed in the present report uses a leakage coefficient to quantify the degree of interconnection between the river and the aquifer. No information is available for values for the coefficient and it was established during model calibration. Upon calibration, the three-dimensional flow model indicated 75 percent of the water pumped from the SOWC wells was from the induced infiltration, which is in good agreement with previously reported estimates.

13.1.5 Paddys Run Leakage

The main surface water drainage for the FMPC is Paddys Run, which flows along the western edge of the site. This is an intermittent stream which gains and loses flow along its course to the Great Miami River. A major tributary of Paddys Run is the Storm Sewer Outfall Ditch, which is a natural gully that has eroded through the glacial overburden in the southern portion of the FMPC. Surface water infiltrates through the sandy and gravelly beds of Paddys Run and the Storm Sewer Outfall Ditch, providing recharge to the Great Miami Aquifer.

Leakage from Paddys Run to the Great Miami Aquifer was assumed to occur along the reach of the stream bed south of the Clearwell to a point about 2000 feet to the south of the FMPC. Leakage from the Storm Sewer Outfall Ditch to the Great Miami Aquifer was assumed to occur along the stream channel south of the storm water retention basins to its confluence with Paddys Run. The actual amount of leakage is variable, depending on the magnitude and duration of flows in each of these channels.

As will be discussed in Chapters 20.0 and 21.0, infiltration rates were established for the losing reaches of these stream channels based on the most appropriate interpretation of available data. For the groundwater flow model, infiltration leakage was set at 14 in/yr, which is the same value used for areas not covered with glacial overburden. This should be a reasonable approximation of infiltration from the losing stream reaches due to the relatively large cell sizes and steady-state conditions in the flow model. Leakage rates were set at 32 in/yr in the solute transport model, because the surface areas of the cells had to be substantially reduced for numerical stability and were not reflective of actual stream widths.

13.1.6 Pumping Rates

The only wells determined to have a significant effect on the groundwater flow system are the collector wells. The discharge rate of 6026 gpm used for each of these wells in the three-dimensional flow model is the average collector well pumping rate for March and April 1986, divided equally between the wells (Miami Conservancy District, unpublished data). The water level data used for calibration of the model were collected in these months. SOWC well pumping records for the period from 1952 through 1989 indicate that an equal allocation of the discharge rates between the wells would be realistic for average long-term conditions. Pumping rates for the Albright & Wilson Co. wells are not accurately known; the value used in the final calibration of the three-dimensional flow model was 225 gpm, considered to be the upper limit of Albright & Wilson Co.'s pumping. This value was obtained from WMCO (1988).

13.2 GLACIAL OVERBURDEN

The term glacial overburden has been selected to describe the hydrostratigraphic unit located above the glaciofluvial material of the Great Miami Aquifer. The glacial overburden is found over the majority of the site. The exceptions include areas which have been subjected to erosion along Paddys Run and areas outside of the advance of the Wisconsin glaciers. The glacial overburden includes loess, lacustrine, till, and glaciofluvial material.

While these deposits are related, each has a unique depositional environment. These depositional environments impart on the material hydrogeologic characteristics that are based primarily on the energy available for sorting at the time of deposition. For water lain deposits, where higher sorting energy was available at the time of deposition, the more able the deposit was to transmit water as an aquifer. In the Paddys Run glacial lake, there was higher sorting energy along the beaches than in the deeper lake areas; thus, the beach sands and gravels are potential aquifers and the clays that settled in the still part of the lake are not. Secondary processes that occur after

formation of the deposit, such as fracturing and the development of root and worm tubes, will also affect the potential rates of flow.

During the RI/FS field investigations at the site, the material encountered during drilling was described by the physical characteristics rather than the depositional character of the site. Although the descriptions in the boring logs (Appendix A) are based upon color and gradation, a depositional correlation can be made using the descriptions found in other publications (Brockman 1988; Hendry 1988; Cravens 1987; Barari 1986; Leggett 1976) and outcrop studies at the site. For example, it can be generally it is assumed that the gray and brown clays and silts represent the Wisconsin age glacial tills. The coloration of the till is a weathering phenomenon and is not due to depositional differences.

Based upon the location of the glacial lake spillway (Brockman 1988) and descriptions found in the U.S. Army Corps of Engineers' boring program conducted during FMPC construction, it is believed that near-surface brown silts found in the western portions of the FMPC area may represent lacustrine deposits. As described in this boring program, these near-surface materials often exhibited varving. Varved clays are a type of layering that is unique to glacial lake deposits. It is also likely that a portion of these near-surface brown silts and clay are loess deposits.

Sand and gravel beds which are common within glaciolacustrine and till deposits can result from processes such as small meltwater streams or beach deposits. These glaciofluvial interbeds are important in the hydrogeology of glacial material as they form the majority of the small perched aquifer systems within glacial deposits. These intertill aquifers are generally under confined conditions, very limited in extent, and can produce only small quantities of water. Within the FMPC study area, these small interbedded deposits within the glacial overburden are classified as glaciofluvial materials without regard to the type of origin. These beds can range in thickness from a few inches to 10 feet or more with highly variable lateral extent. The interconnection between these beds is highly variable across the site.

Each of the overburden layers have distinct hydrogeologic characteristics that affect the vertical and lateral movement of fluids. The hydrologic characteristics of the different units are outlined below.

13.2.1 Glaciofluvial Deposits

Within the glacial overburden deposits there are numerous perched water bearing zones that have limited interconnection. The majority of these perched zones are of glaciofluvial origin and consist of small beds of highly sorted sands and gravels. These beds are probably the result of small

meltwater streams that occurred along the ice margin and within the glacier itself. These intertill aquifers have the following general characteristics:

- High variability in areal extent, thickness, and volume.
- Based upon hydrograph analysis, limited interconnection between the intertill aquifers.
- The majority are confined by layers of relatively impermeable till. This results in conditions where water will rise in a well to a level higher than where the water was first encountered (confined or artesian conditions).
- Hydraulic conductivities are highly variable with an expected range of 2.8×10^{-2} to 280 ft/day (10^{-5} to 0.1 cm/s) (Freeze and Cherry 1979). At the FMPC, series of slug tests of water-bearing zones in the till found hydraulic conductivities ranging from 1.6 ft/day (5.6×10^{-4} cm/s) in Well 1048 to 7.1×10^{-3} ft/day (2.5×10^{-6} cm/s) in Well 1079.
- Porosities range from 22.1 percent to 36.7 percent, with a mean of 31 percent (Morris and Johnson 1967)

Generally these glaciofluvial interbeds are considered to be the major water-bearing units within the glacial overburden. However, movement of water and contaminants within these units will be constrained because of the limited extent and interconnection of these units.

13.2.2 Glaciolacustrine Deposits

In the meltwater lakes that existed during Pleistocene time, deposits of glaciolacustrine silt and clay were laid down offshore. These deposits form some of the most extensive shallow aquitards in North America. However, at the FMPC, the lacustrine deposits are near surface, are both jointed and weathered, and are expected to have a substantial secondary permeability. For the purposes of evaluating the groundwater systems at the FMPC, the glaciolacustrine deposits are considered to have an insignificant effect on infiltration and contaminant migration.

13.2.3 Till Deposits

Within the glacial overburden at the FMPC, the till deposits represent the dominant control on water and contaminant movement. Dense, fine-grained glacial tills are the most common aquitards in most of the northern part of the United States. These deposits have intergranular hydraulic conductivities that are very low, with values ranging from 10^{-9} to 10^{-5} ft/day (3.5×10^{-13} to 3.5×10^{-9} cm/s) (Heath 1983; Cravens 1987). Extensive deposits of clayey till can cause isolation from zones of near-surface groundwater flow. A comparison of the hydraulic conductivities of the

till with those measured in the water-bearing zones at the FMPC (Section 13.2.1) indicates the relative impermeability of the till unit.

In the Great Plains region and in parts of the Midwest, near-surface deposits of clayey or silty till and glaciolacustrine clay have networks of predominantly vertical joints or fractures. This jointing pattern in the Wisconsin tills has also been noted in the area surrounding the FMPC (Brockman 1988). In the FMPC area, joints were observed to be near vertical and to have a polygonal expression with a typical maximum axial dimension of 18 to 25 inches. The joints are generally oxidized for approximately a depth of two inches on either side of the joint surface. Within the FMPC, fractures have also been noted in the till during the RI/FS drilling program and field reconnaissance. As a result of the increased lateral stresses caused by overburden loading and increased water content, the hydraulic conductivity of fractured till and clay decreases with depth.

Recent investigations in similar geologic settings indicate that till deposits can be divided from a hydrogeologic standpoint into a brown weathered zone and a gray unweathered zone (Barari and Hedges 1985; Hendry 1988; Cravens 1987; Bayrock and Jones 1963; Williams and Farvolden 1969; Karrow 1975; Grisak et. al. 1976; Hendry 1982). These investigations have found that while precipitation enters the upper zone, it does not act as a significant source of recharge to deeper aquifer zones and that the majority of the water lost from till deposits is from evapotranspiration. In addition to the losses due to evapotranspiration, water discharge to small seeps or drainages may occur.

Although the degree of fracturing within the upper tills at the FMPC has not been quantified, sufficient observations have been made at the site and in the literature to indicate their presence is a characteristic physical property of these tills. Since fractures have been noted as a dominant feature in most brown tills, it is necessary to consider the effect that these fractures have on water and contaminant transport within the tills. Fractures have reportedly enhanced the bulk hydraulic conductivity of till by as much as 1000 times (Hendry 1988), but with an expected typical increase of only 1 to 3 times. At the FMPC, the appreciable silt and clay content of the till was regarded as providing the Great Miami Aquifer with protection from the activities at the site (Dove and Norris 1951). This line of reasoning has justification because the low hydraulic conductivity produces very low velocities even if the hydraulic gradients are large. In addition most contaminants being transported by seepage through the till matrix undergo attenuation and retardation.

If the till is fractured these generalizations are not applicable because the velocities of water in the fractures are relatively large compared to the intergranular pore velocities in the unfractured matrix. It should be noted that although the velocities are relatively large, the contaminant flux may be relatively small because the Darcy flux is small.

Fractures not only control velocity but they also impart a much lower capability for attenuation and retardation by adsorption of non-conservative contaminants. The adsorption processes are capable of removing more contaminant mass from solution if the water is in contact with larger surface areas in the matrix. Contaminants transported by seepage along fractures have only an opportunity to react with the mineral constituents present in a veneer layer on the exterior of the fracture. Therefore in the fractured system there is less surface area available for chemical reactions that reduce the concentration of a contaminant or slow the movement of that contaminant.

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14.0 SURFACE WATER QUALITY

The Great Miami River receives treated effluent from the FMPC through a discharge pipeline. Groundwater discharging to the river can potentially contribute radiological and chemical constituents to the surface water course (IT 1988). Flow from Paddys Run may also carry FMPC contaminants into the Great Miami River, since runoff from a large portion of the FMPC reservation enters Paddys Run. A direct connection between the Paddys Run stream bed and the Great Miami Aquifer is and was most likely a pathway for contaminants entering the aquifer (Chapter 12.0).

Because of the interaction between groundwater and surface water in the vicinity of the FMPC, it is necessary to include an analysis of surface water chemistry in this report. This section discusses the water quality of Paddys Run and associated tributaries, the Storm Sewer Outfall Ditch, and the Great Miami River.

14.1 PADDYS RUN

Figure 14-1 shows the locations for the surface water and sediment sampling locations used by the FMPC and the RI/FS. RI/FS surface water samples from Paddys Run Stations W-7, W-10, and W-11 were analyzed for radionuclides, metals, HSL organic compounds, and general chemical parameters. Station W-10 is the furthest upstream station used by the RI/FS and is located near Monitoring Well Cluster 009; Station W-11 is located downstream of Station W-10 and is approximately 300 feet upstream of the Storm Sewer Outfall Ditch confluence; Station W-7 is located furthest downstream and is immediately north of the Willey Road bridge.

14.1.1 General Chemistry, Metals, and Organic Compounds

Table 14-1 shows the average concentration of metals and general chemical parameters in Paddys Run surface water samples collected during RI/FS sampling. Paddys Run stream water is well-oxygenated and total dissolved solids (TDS) range between 400 and 500 mg/L. The stream water is similar in composition to groundwater; calcium is the dominant cation, followed by magnesium and sodium. Bicarbonate is the dominant anion, followed by sulfate, chloride, and nitrate (Table 14-1). The major chemical composition of Paddys Run water does not change as the stream flows through the FMPC.

Heavy metals were either not detected or concentrations were very low in samples of surface water collected from Paddys Run. Samples collected in January 1989 indicate that HSL organic compounds were not present in Paddys Run water at that time. N-nitrosodiphenylamine at

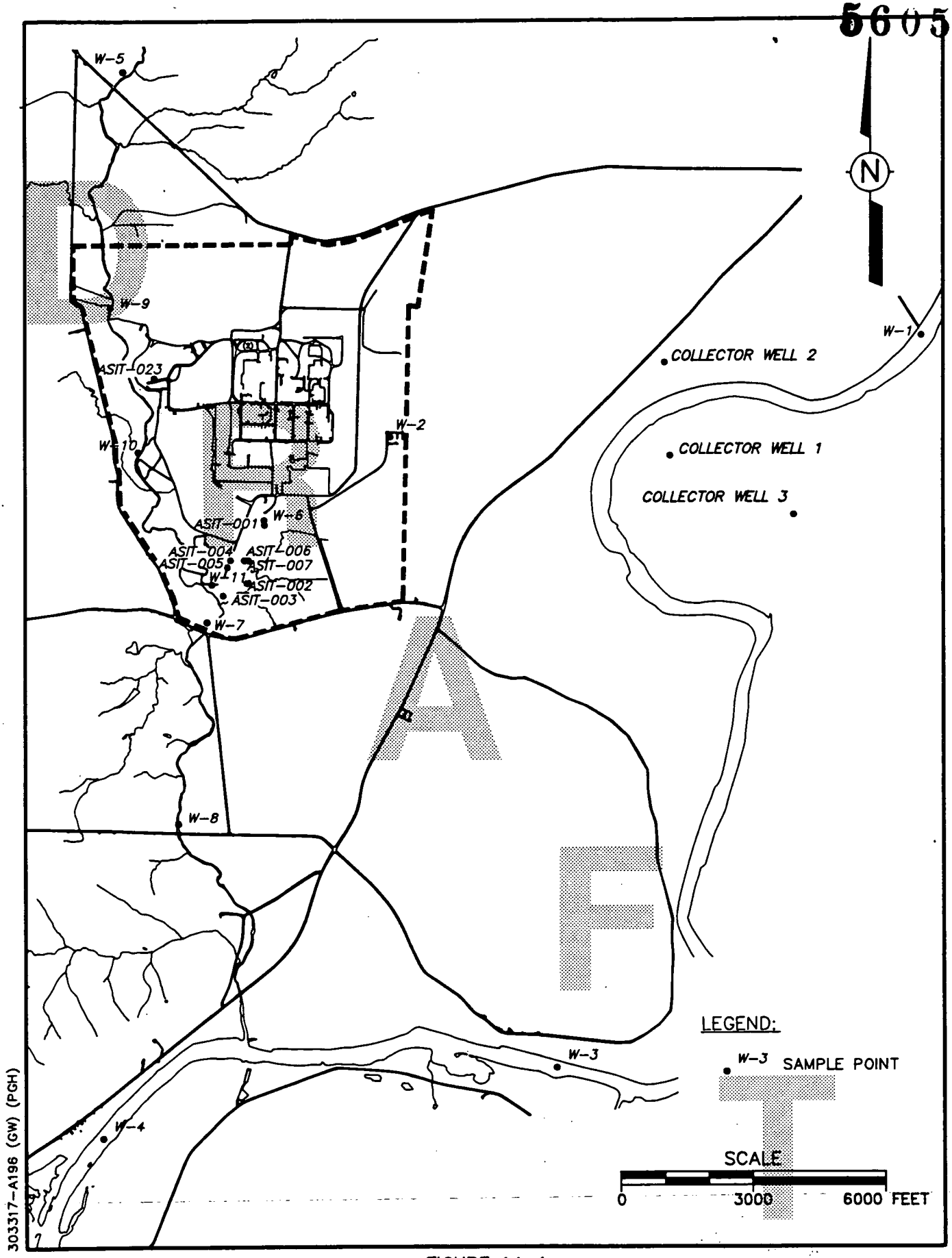

FIGURE 14-1

SURFACE WATER AND SEDIMENT
SAMPLING LOCATION

TABLE 14-1

PADDYS RUN SURFACE WATER
GENERAL CHEMISTRY AND METALS

Sampling Location	W-10				W-11				W-7			
Sampling Dates	1/12/89 5/23/89				1/12/89 5/14/89				1/12/89 5/15/89			
	Average	Range			Average	Range			Average	Range		
General Chemistry (mg/L)												
Ammonia as N	0.25	0.1	-	0.409	0.28	0.1 U	-	0.452	0.13	0.1U	-	0.163
Chloride	13.25	12	-	14.5	18.25	16.5	-	19.99	17.10	16	-	18.19
Fluoride	0.21	0.2	-	0.225	0.20	0.18	-	0.215	0.22	0.21	-	0.225
Nitrate as N	2.36	2.12	-	2.6	3.46	2.31	-	4.6	4.00	2.7	-	5.3
Phenols	0.01 U	0.01 U	-	0.01 U	0.01 U	0.01 U	-	0.01 U	0.01U	0.01U	-	0.01U
Total Phosphorus	0.37	0.255	-	0.482	0.02 U		a		0.21	0.032	-	0.39
Sulfate	45.85	39.5	-	52.24	7.18	37	-	57.36	8.28	39.2	-	57.36
Alkalinity as HCO3	–		NA		21		a		256.5		a	
pH	–		NA		8.58		a		8.38		a	
Total Dissolved Oxygen	–		NA		11.8		a		10.2		a	
Total Kjeldahl Nitrogen	1.39	1.09	-	1.68	1.08	0.347	-	1.81	0.74	0.347	-	1.14
Total organic carbon	1 U		b		1 U		a		4.848		e	
Total Organic Halides	0.031		b		0.01		a		0.01U		e	
Total Organic Nitrogen	1.13	0.99	-	1.27	0.85	0.347	-	1.36	0.66	0.347	-	0.977
Metals												
Aluminum	0.451		c		0.0764	0.0764	-	0.15 B	0.06U		e	
Antimony	0.0025 B		c		0.0005 U		c		–		NA	
Arsenic	0.010	0.002 U	-	0.0188	0.002 U	0.002 U	-	0.002 U	0.002		e	
Barium	0.029	0.0288	-	0.0658 B	0.0313	0.0313	-	0.0552 B	0.0374		e	

See footnotes at end of table.

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TABLE 14-1
(Continued)

Sampling Location	W-10				W-11				W-7	
Sampling Dates	5/23/89				1/12/89 5/14/89				1/12/89 5/15/89	
	Average	Range			Average	Range			Average	Range
Beryllium	0.001 B		c		0.0011 B		c		–	NA
Cadmium	0.003	0.0032	-	0.0032 B	0.002 U	0.002 U	-	0.0028 B	0.002	e
Calcium	50.9	45.2	-	56.6	62.05	52.3	-	71.8	84.7	e
Chromium	0.021	0.0173	-	0.0243	0.01195	0.01 U	-	0.0138	0.01 U	e
Cobalt	0.01 U		c		0.01 U		c		–	NA
Copper	0.01 U	0.01 U	-	0.0147 B	0.01 U	0.01 U	-	0.01 U	0.01 U	e
Cyanides	0.01 U		c		0.01 U		c		–	e
Iron	0.51	0.464	-	0.556	0.12075	0.0415	-	0.0286	0.0286	e
Lead	0.002	0.0021	-	0.0027 B	0.00565	0.002 U	-	0.0093	0.0074	e
Magnesium	11.84	9.97	-	13.7	16.8	12.7	-	20.9	21.4	e
Manganese	0.027	0.0265	-	0.0278	0.016	0.0121	-	0.0199	0.0199	e
Mercury[d]	0.24	0.2 U	-	0.29	0.25	0.2 U	-	0.3	0.3	e
Molybdenum	0.01 U	0.01 U	-	0.0205 B	0.01 U	0.01 U	-	0.0205 B	0.01	e
Nickel	0.02 U	0.02 U	-	0.02 U	0.02 U	0.02 U	-	0.02 U	0.02 U	e

See footnotes at end of table.

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TABLE 14-1
(Continued)

Sampling Location	W-10				W-11				W-7		
Sampling Dates	1/12/89 5/23/89				1/12/89 5/14/89				1/12/89 5/15/89		
	Average	Range			Average	Range			Average	Range	
Metals (ug/L)											
Potassium	2.72	2.72	-	3.19 B	1.68	1.68	-	2.77 B	1.55	e	
Selenium	0.009	0.002 U	-	0.0169	0.002 U	0.002 U	-	0.002 U	0.002	e	
Silicon	–		NA		2.25		a		1.73	e	
Silver	0.01 U	0.0005 U	-	0.01 U	0.01 U	0.0005 U	-	0.01 U	0.01 U	e	
Sodium	7.567	5.903	-	9.23	9.04	8.39	-	9.69	9.93	e	
Thallium	0.002 U		c		0.002 U		c		–	NA	
Vanadium	0.0177 B		c		0.01 U	0.01 U	-	0.0136 B	0.01 U	e	
Zinc	0.0368		c		0.0111 BE		c		–	NA	

[a]The parameter was only analyzed during May 14, 1989 sampling.

[b]The parameter was only analyzed during May 23, 1989 sampling.

[c]The parameter was only analyzed during January 12, 1989 sampling.

[d]In ug/L.

[e]The parameter was only analyzed during May 15, 1989 sampling.

NA: The parameter was not analyzed.

Station W-10 and diethyl phthalate at Station W-11 were the only HSL organic compounds detected, and both of these were detected at concentrations below the contract required quantitation limit. It appears that the FMPC is not contributing any nonradiological contamination to Paddys Run water. Although upstream background samples are not available for comparison, the paucity of detections of heavy metals and HSL organic compounds and the constancy of the major chemical composition of Paddys Run water from sample Station W-10 to Station W-7 support this conclusion.

14.1.2 Radionuclides

Table 14-2 shows the results of RI/FS sampling of Paddys Run stream water for radionuclides. Total uranium and uranium isotopes are detected in samples from Stations W-10, W-11, and W-7. Table 14-3 shows that total uranium concentrations increased threefold in Paddys Run stream water from Station W-10 to Station W-7 during the May 1989 sampling. However, during the January 1989 sampling, uranium concentrations did not increase in the downstream direction. The difference between the two sampling events is possibly due to the difference in runoff conditions which prevailed at the time of sampling. The distribution of uranium in Paddys Run water should be a function of the duration and intensity of a precipitation event and possibly also antecedent conditions.

It is clear that uranium is entering Paddys Run at some point or points upstream of Station W-10. This is because the average total uranium concentration of Paddys Run stream water at Station W-5 is approximately 1 ug/L, based on WMCO monitoring during 1988 (WMCO 1989a). Station W-5 is located north (upstream) of the FMPC, immediately south of the State Route 126 bridge over Paddys Run (Figure 14-1). The increase in the uranium concentration of Paddys Run stream water between Stations W-5 and W-10 is most likely attributable to inflow of uranium-contaminated runoff from part of the Waste Storage Area and possibly the Production Area. Runoff from the area nearest to and including Waste Pits 1, 2, and 3 flows into the Clearwell, and is subsequently pumped to the FMPC general sump (ASI/IT 1987). However, runoff from a large part of the Waste Storage Area flows into Paddys Run at a point upstream of the silos. RI/FS sampling at Station ASIT-003 (Figure 14-1) yielded a total uranium concentration in the runoff of this drainage of 433 ug/L. WMCO (1989b) estimates that the mass loading of uranium to Paddys Run from this drainage is 210 pounds per year. A planned removal action by DOE is intended to eliminate this discharge to Paddys Run.

Runoff from another small drainage enters Paddys Run at a point approximately 500 feet downstream of the K-65 silos. This drainage collects runoff from an area around the K-65 silos,

TABLE 14-2

PADDYS RUN SURFACE WATER - RADIOLOGICAL SUMMARY

Sampling Location	W-10		W-11		W-7	
Sampling Dates	1/12/89 5/23/89		1/12/89 5/14/89		1/12/89 5/15/89	
	Average	Range	Average	Range	Average	Range
Cs-137	< 20	a	< 20	a	< 20	a
Np-237	< 1	a	< 1	a	< 1	a
Pu-238	< 1	a	< 1	a	< 1	a
Pu-239/240	< 1	a	< 1	a	< 1	a
Ra-226	< 1	a	< 1	a	< 1	a
Ra-228	< 3	a	< 3	a	< 3	a
Ru-106	< 150	a	<150	a	<150	a
Sr-90	< 5	a	< 5	a	< 5	a
Tc-99	< 30	a	< 30	a	< 30	a
Th-228	< 1	a	< 1	a	< 1	a
Th-230	< 1	a	< 1	a	< 1	a
Th-232	< 1	a	< 1	a	< 1	a
Th-Total[b]	< 3	c	< 6	c	< 2	c
U-234	2.1	1.3 - 2.8	3.8	2.5 - 5	2.4	1.6 - 3.2
U-235/236	< 1	a	< 1	a	< 1	a
U-238	3.1	2 - 4.2	4.7	2.6 - 6.8	4.3	4 - 4.5
U-Total[b]	8.5	5 - 12	14	9 - 19	12	9 - 15

[a]Parameter not detected in any sample.

[b]In ug/L.

[c]Only one sample.

TABLE 14-3

PADDYS RUN SURFACE WATER
ANALYTICAL RESULTS FOR TOTAL URANIUM CONCENTRATION (ug/L)

Sampling Location	Sampling Month 1/89	5/89
W-10	12	5
W-11	19	9
W-7	9	15

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the K-65 slurry trench, and the southwestern edge of the Production Area. The total uranium concentration of runoff in the drainage ranged from 231 to 2219 ug/L during RI/FS sampling. WMCO (1986b) estimates that the mass loading of uranium to Paddys Run from this drainage is 50 pounds per year.

14.2 STORM SEWER OUTFALL DITCH

Surface water was collected from Storm Sewer Outfall Ditch Stations ASIT-001, ASIT-002, and ASIT-003 during the RI/FS sampling program. These sampling locations are shown in Figure 14-1. Station ASIT-001 is furthest upstream and is situated near the spillway of the oldest storm water retention basin. Station ASIT-002 is located just below the Active Fly Ash pile. Station ASIT-003 is furthest downstream and is located approximately 25 feet upstream from the confluence of the Storm Sewer Outfall Ditch and Paddys Run.

14.2.1 General Chemistry and Metals

Only Stations ASIT-002 and ASIT-003 were sampled for metals and general chemistry. Storm Sewer Outfall Ditch surface water was not sampled for HSL organic compounds.

Table 14-4 presents metal and general chemical concentrations of surface water samples from Storm Sewer Outfall Ditch sampling STations ASIT-002 and ASIT-003. Each location was sampled once; therefore, average concentrations and ranges were not determined. The major constituent chemistry of the surface water sample from Station ASIT-003 is very similar to that of Paddys Run stream water. However, calcium is relatively lower and magnesium and sodium are relatively higher in the sample from Station ASIT-002 (Table 14-4). Similar to Paddys Run, heavy metals were either not detected or detected at very low concentrations in surface water samples from the Storm Sewer Outfall Ditch.

14.2.2 Radionuclides

Table 14-5 lists the results of RI/FS sampling of Storm Sewer Outfall Ditch water for radionuclides. Uranium is detected in samples from Stations ASIT-001, ASIT-002, and ASIT-003. The total uranium concentrations of surface water samples from Stations ASIT-001 and ASIT-002 are 18 and 24 ug/L, respectively. These concentrations are considered similar enough that no explanation of differences is warranted. However, total uranium concentrations observed at Station ASIT-003 range from 2 to 7 ug/L, and are lower compared with those from the upstream stations. The lower uranium concentrations occurring at Station ASIT-003 may be due to dilution by runoff from a drainage which enters the Storm Sewer Outfall Ditch approximately 100 feet downstream from

TABLE 14-4

STORM SEWER OUTFALL DITCH SURFACE WATER GENERAL CHEMISTRY AND METALS

Sampling Location	ASIT-002	ASIT-003
Sampling Dates	3/21/89	5/15/89
General Chemistry (mg/L)		
Ammonia as N	0.162	0.126
Chloride	29	34
Fluoride	0.21	0.19
Nitrate as N	0.71	5.44
Phenols	0.01 U	0.01 U
Total Phosphorus	0.194	0.161
Sulfate	47.6	51.3
Alkalinity as HCO3	NA	200.5
pH	NA	8.57
Total Dissolved Oxygen	NA	8.6
Total Kjeldahl Nitrogen	0.977	0.691
Total Organic Carbon	NA	1 U
Total Organic Halides	0.05 U	0.01 U
Total Organic Nitrogen	0.815	0.565
Metals (mg/L)		
Aluminum	NA	0.0866
Arsenic	0.002 U	0.002 U
Barium	0.0271	0.0399
Cadmium	0.001 U	0.002 U
Calcium	39	72.3
Chromium	0.0072	0.01 U
Copper	0.0105	0.01 U
Iron	0.292	0.0659
Lead	0.0022	0.0026
Magnesium	107	19.9
Manganese	0.0084	0.0097
Mercury[a]	0.26	0.2 U
Molybdenum	0.003 U	0.01 U
Nickel	0.006 U	0.02 U
Potassium	1.88	1.84
Selenium	0.002 U	0.002 U

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See footnotes at end of table.

TABLE 14-4
(continued)

Sampling Location	ASIT-002	ASIT-003
Sampling Dates	3/21/89	5/15/89
Silicon	NA	3.89
Silver	0.0005 U	0.01 U
Sodium	138	14.6
Vanadium	NA	0.01 U

[a]In ug/L.

NA - The parameter was not analyzed.

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TABLE 14-5

STORM SEWER OUTFALL DITCH SURFACE WATER - RADIOLOGICAL SUMMARY

Sampling Location:	ASIT-001		ASIT-002		ASIT-003	
Sampling Dates	3/29/89		3/21/89		3/21/89 5/15/89	
	Average	Range	Average	Range	Average	Range
Cs-137	a		a		< 20	b
Np-237	a		a		< 1	b
Pu-238	a		a		< 1	b
Pu-239/240	a		a		< 1	b
Ra-226	< 1	b	< 1	b	< 1	c
Ra-228	< 3	b	< 3	b	< 3	c
Ru-106	a		a		< 150	b
Sr-90	a		a		< 5	b
Tc-99	a		a		< 30	b
Th-228	a		a		< 1	b
Th-230	a		a		< 1	b
Th-232	a		a		< 1	b
Th-Total[d]	a		a		< 6	b
U-234	a		a		< 1	b
U-235/236	a		a		< 1	b
U-238	a		a		1.3	b
U-Total[d]	18	b	24	b	4.5	2-7

[a]Not analyzed for this parameter.

[b]Only one sample.

[c]Parameter not detected in any sample.

[d]In ug/l.

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Station ASIT-002. This tributary to the Storm Sewer Outfall Ditch drains a large area extending to the south of the FMPC.

Surface water samples from stations in the vicinity of the Active Fly Ash pile show a wide range of total uranium concentrations. Stations ASIT-004 and ASIT-005 are located in a small drainage between Southfield and the Active Fly Ash pile, and Stations ASIT-006 and ASIT-007 are located on the north side of the Active Fly Ash pile (Figure 14-1). Elevated total uranium concentrations of 1692 and 499 ug/L, respectively, are observed in runoff samples from Stations ASIT-004 and ASIT-005. These concentrations did not cause an observable increase in uranium concentrations in the Storm Sewer Outfall Ditch or Paddys Run, indicating that the rate of flow in the drainage was very small compared to that in the receiving streams, or that infiltration and/or dilution occurred between the sampling locations and the point of discharge into Paddys Run. Total uranium concentrations of 14 and 24 ug/L, respectively, are observed in samples of runoff from Stations ASIT-006 and ASIT-007.

14.3 GREAT MIAMI RIVER

RI/FS samples of Great Miami River water were collected at Stations W-1, W-3, and W-4. (Figure 14-1). Station W-1, located near the Ross Bridge, is upstream from the FMPC effluent pipeline. Samples from Station W-1 were used to establish the background water quality of the Great Miami River. Station W-3 is located downriver of the effluent pipeline near the New Baltimore Bridge, and Station W-4 is situated downriver of the confluence of Paddys Run and the Great Miami River.

14.3.1 General Chemistry and Metals

Table 14-6 shows the concentration of metals and general chemical parameters in samples of Great Miami River water. Each station was sampled several times for general chemistry; however, each was sampled only once for metals. Samples of Great Miami River water were not analyzed for HSL organic compounds.

The major chemical composition of the Great Miami River water is similar to that of the groundwater. Calcium is the dominant cation, followed by magnesium, sodium, and potassium. Major anionic constituents are sulfate, chloride, and nitrate. Although not measured, it is assumed that bicarbonate is also a major constituent. Based on the low concentrations of iron and manganese in the Great Miami River water (Table 14-6), the water is most likely well-oxygenated. The concentrations of several anionic constituents, such as chloride and nitrate, are quite variable.

TABLE 14-6

GREAT MIAMI RIVER SURFACE WATER GENERAL CHEMISTRY AND METALS

Sampling Location	W-1				W-3				W-4			
Sampling Dates	6/16/88 8/29/88 4/3/89				6/17/88 8/29/88 4/3/89				6/17/88 8/29/88 4/4/89			
	Average	Range			Average	Range			Average	Range		
General Chemistry (mg/L)												
Ammonia as N	0.47	0.1	-	1.2	0.50	0.188	-	1.1	0.50	0.2	-	0.8
Chloride	159.33	17.99	-	325	97.00	16	-	149	99.67	10	-	154
Fluoride	0.68	0.31	-	0.9	0.67	0.3	-	0.9	0.64	0.26	-	0.88
Nitrate as N	3.39	0.4	-	6.58	3.39	0.5	-	6.76	2.24	0.1 U	-	4.12
Phenols	0.01	0.01 U	-	0.01 U	0.01	0.01 U	-	0.01	0.01 U	0.01 U	-	0.01 U
Total Phosphorus	0.66	0.299	-	1.1	0.51	0.05	-	1.1	1.50	0.9	-	2.3
Sulfate	1520.97	114.9	-	4310	101.43	85	-	111	139.63	101	-	191.9
Total Kjeldahl Nitrogen	1.84		a		1.343		a		2.615		b	
Total Organic Carbon	18.5		c		21.9		d		21.2		d	
Total Organic Halides	0.09	0.0189	-	0.19	0.05	0.0211	-	0.07	0.05 U	0.0426	-	0.05U
Total Organic Nitrogen	1.01	0.2	-	1.73	0.64	0.1 U	-	1.155	1.14	0.1 U	-	2.125

See footnotes at end of table.

TABLE 14-6
(continued)

Sampling Location	W-1		W-3		W-4	
Sampling Dates	6/16/88 8/29/88 4/3/89		6/17/88 8/29/88 4/3/89		6/17/88 8/29/88 4/4/89	
	Average	Range	Average	Range	Average	Range
Metals						
Arsenic	0.002 U	a	0.002 U	a	0.002 U	b
Barium	0.0493	a	0.0479	a	0.0379	b
Cadmium	0.0098	a	0.0025	a	0.0017	b
Calcium	61.2	a	60.8	a	48.6	b
Chromium	0.002 U	a	0.002 U	a	0.002 U	b
Copper	0.0091	a	0.0105	a	0.0056	b
Iron	0.164	a	0.194	a	0.41	b
Lead	0.0054	a	0.0029	a	0.0051	b
Magnesium	21.5	a	21.2	a	16.4	b
Manganese	0.0089	a	0.0093	a	0.0117	b
Mercury[e]	9.51	a	0.2 U	a	0.00185	b
Molybdenum	0.003 U	a	0.003	a	0.003 U	b
Nickel	0.0105	a	0.0107		0.006 U	b
Potassium	2.3	a	2.26	a	2.17	b
Selenium	0.002 U	a	0.002 U	a	0.002 U	b
Silver	0.0005 U	a	0.0005 U	a	0.0005 U	b
Sodium	12.9	a	13.2	a	13.2	b

[a]The parameter was only analyzed during May 14, 1989 sampling.

[b]The parameter was only analyzed during May 15, 1989 sampling.

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TABLE 14-6
(continued)

[c]The parameter was only analyzed during May 23, 1989 sampling.

[d]The parameter was only analyzed during January 12, 1989 sampling.

[e]In ug/L.

NA - The parameter was not analyzed.

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This may be because sampling was conducted over a variety of flow conditions. The chemistry of surface flows can also be influenced by seasonal factors, such as farming activities and road salting.

Based on RI/FS sampling, the FMPC does not appear to be a source of nonradiological contamination to the Great Miami River. No heavy metal concentrations are elevated in river water at Stations W-3 and W-4, relative to concentrations observed at background Station W-1. Total phosphorus appears to be elevated in samples from Station W-4, relative to upstream samples (Table 14-6). However, the total phosphorus concentration of Paddys Run water leaving the FMPC (Station W-7) is quite low relative to Great Miami River water. Thus, the FMPC is most likely not the source of the elevated total phosphorus occurring at Station W-4. As discussed in Chapter 15.0, elevated total phosphorus has been observed in groundwater at Wells 2094 and 3094, south of the industries along Paddys Run Road.

14.3.2 Radionuclides

Table 14-7 lists the results of RI/FS sampling of Great Miami River water for radionuclides. The detection of various radionuclides at the sampling stations is as follows:

- Ra-228 W-4
- Th-228 W-3
- Th-230 W-4
- U-234 W-1, W-3, W-4
- U-238 W-3, W-4
- U-Total W-1, W-3, W-4

The detections of radium and thorium are one-time, near-detection limit occurrences which are not considered to be significant. The average total uranium concentrations observed at Stations W-3 and W-4, 2.8 and 2 ug/L, respectively, are higher than those occurring at background station W-1, where the average total uranium concentration is 1 ug/L. This may indicate that FMPC effluent has slightly increased the uranium concentration of Great Miami River water during the period of sampling.

A detailed study of the effects of the FMPC effluent outfall on the Great Miami River was conducted by IT in 1987 and 1988 (IT 1988). The results of this study would indicate that the potential increase in the uranium concentration of river water caused by the FMPC effluent would be less than that observed. However, the 1988 RI/FS sampling occurred during a drought-induced low flow condition, and the relative effects of the FMPC effluent on river water quality would be expected to be enhanced.

TABLE 14-7
GREAT MIAMI RIVER SURFACE WATER - RADIOLOGICAL SUMMARY

Sampling Location	W-1		W-3		W-4	
Sampling Dates	6/16/88 6/30/88 8/29/88 12/18/88 4/3/89		6/17/88 6/29/88 8/29/88 12/18/88 4/3/89		6/17/88 6/29/88 8/29/88 12/18/88 4/4/89	
	Average	Range	Average	Range	Average	Range
Cs-137	< 20	a	< 20	a	< 20	a
Np-237	< 1	a	< 1	a	< 1	a
Pu-238	< 1	a	< 1	a	< 1	a
Pu-239/240	< 1	a	< 1	a	< 1	a
Ra-226	< 1	a	< 1	a	< 1	a
Ra-228	< 3	a	< 3	a	3.4	<3 - 5
Ru-106	< 150	a	< 150	a	< 150	a
Sr-90	< 5	a	< 5	a	< 5	a
Tc-99	< 30	a	< 30	a	< 30	a
Th-228	< 1	a	1.2	<1 - 1.8	< 1	a
Th-230	< 1	a	< 1	a	1.1	<1 - 1.3
Th-232	< 1		< 1	a	< 1	a
U-234	1.0	<1 - 1.1	1.2	<1 - 1.9	1.0	<1 - 1.1
U-235/236	< 1	a	< 1	a	< 1	a
U-238	< 1	a	1.1	<1 - 1.8	1.0	<1 - 1
U-Total[b]	1	<1 - 1	2.4	1 - 5	2.2	2 - 3

[a]Parameter not detected in any sample.

[b]In ug/L.

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