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HYDROGEOLOGIC STUDY OF FMPC DISCHARGE TO THE GREAT MIAMI RIVER
FINAL REPORT
AUGUST 1, 1988

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IT CORPORATION/WMCO
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~~STUDY~~ REPORT

HYDROGEOLOGIC STUDY OF FMPC DISCHARGE TO THE GREAT MIAMI RIVER

FINAL REPORT

by

IT Corporation
Pittsburgh, PA

August 1, 1988

Prepared for the
FEED MATERIALS PRODUCTION CENTER
WESTINGHOUSE MATERIALS COMPANY of OHIO
P. O. BOX 398704
CINCINNATI, OHIO 45239-8704

Under Contract DE-AC05-86OR21600
U. S. Department of Energy
OAK RIDGE OPERATIONS OFFICE

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EXECUTIVE SUMMARY

As required by Order 14B of the Director's Orders and Findings, a hydrogeologic study of the Feed Materials Production Center (FMPC) discharge to the Great Miami River was performed. The purpose of the study was to determine if the discharge from the FMPC effluent pipeline is located within the zone of influence of the production well field operated by the Southwestern Ohio Water Company (SOWC) or any other major production field, and to qualitatively and quantitatively determine any associated adverse environmental impact.

The scope of work for this study centered on analytical and numerical modeling studies of the surface water and ground water environments. Models were used to establish the approximate boundaries of the zone of influence of the SOWC wells, and to quantify the effects of three mixing processes on the impacts caused by the FMPC discharge. These processes included the mixing of the effluent discharge with background water in the Great Miami River, the mixing of induced infiltration from reaches of the river upstream from the FMPC discharge with that from impacted reaches downstream from the discharge, and the mixing of the ground water flow component originating from the river with the regional aquifer flow and other sources of recharge prior to reaching the SOWC wells.

An extensive review of available data and a limited field program provided both the input data base for the models and the calibration data used to test model performance. A sensitivity analysis was also completed to test the sensitivity of the model results and study conclusions to the assumed site conditions and parameter values. The results of the data review and modeling studies allow the following three general conclusions to be made:

1. The discharge from the FMPC effluent pipeline likely occurs within a reach of the Great Miami River that contributes flow, via induced infiltration, to the SOWC collector wells. The relative contribution of flow to the SOWC wells from the river downstream from the discharge is, however, a small fraction of the flow contributed from upstream reaches of the river. The sensitivity testing of the model indicates that the FMPC discharge could actually be outside of the capture zone of the SOWC wells if the river infiltration rate is greater than assumed.

2. Even if the FMPC discharge is within the zone of influence of the SOWC wells, the incremental impact of the effluent on the water quality of the pumped water lies within the range of variability of previous observations and is below analytical detection limits under average conditions. Therefore, no observable improvements in water quality would result in the SOWC wells from eliminating the effluent effects (e.g., by relocating the pipeline).

3. A mass balance of the sources of uranium observed in the SOWC collector wells cannot be performed at this time.

Based on the results of this study and the conclusions drawn therefrom, no further studies specifically addressing the impact of the FMPC discharge on the SOWC collector wells are recommended.

The SOWC collector wells, the river, and the regional ground water flow system assessed in this study remain of utmost importance to the overall issues being addressed in the sitewide Remedial Investigation and Feasibility Study (RI/FS) and other related studies. The results of these modeling studies have been of value in expanding the current understanding of the sitewide and regional RI/FS issues. Additional investigations that will address the remaining uncertainties will be performed as part of the sitewide RI/FS.

1.0 INTRODUCTION

1.1 OBJECTIVE OF STUDY

As required by Order 14B of the Director's Orders and Findings, the objectives of the hydrogeologic study of the Feed Materials Production Center (FMPC) discharge to the Great Miami River are to determine if the discharge from the FMPC effluent pipeline is located within the "zone of influence" of the production well field operated by the Southwestern Ohio Water Company (SOWC) or any other major production field, and to qualitatively and quantitatively determine any associated adverse environmental impact.

The site features of principal interest to this study are identified in Figure 1.1-1. The limits of the study area extend beyond the area shown in this figure since the modeling studies require consideration of regional-scale conditions to establish appropriate boundary conditions and to fully account for the capture zone of the SOWC wells.

1.2 SCOPE OF WORK

The scope of work for the hydrogeologic study of the FMPC discharge was developed around a series of analytical and field tasks to provide both the theoretical mechanisms for predicting the extent of influence and impacts, and an extended data base for model input and calibration. The following five tasks were completed.

Task 1 - Geologic/Hydrogeologic Description and Historical Overview

A description of the local geology and hydrogeology in the vicinity of the outfall pipe and collector wells was completed. This description was derived from available project and historic data. Cross sections were constructed for the local area.

Task 2 - Sensitivity Study

Numerical and analytical modeling was utilized to study contaminant dispersion and dilution in both the surface water and ground water environments, including the hydraulic interconnection between the collector wells and the Great Miami River. This computer modeling included an evaluation of the surface water and hydrogeologic regimes, as well as sensitivity analysis to

characterize the level of confidence in the results in relation to the study objectives.

Task 3 - Evaluation of River Sediments

The study also entailed an evaluation of river bed sediment properties to determine the mechanisms for transport of contaminant particles through the sediments. Approximately six grab samples of river bed sediment were taken for grain size analysis to evaluate stream bed hydraulic properties.

Task 4 - Water Quality Studies

Surface water samples were taken to evaluate the distribution of uranium and other radionuclides in the Great Miami River near the SOWC well field. The Model STRIP1B was used to simulate uranium concentrations downstream of the effluent discharge for field conditions, as well as extremes of flow.

Task 5 - Piezometric Studies

An aquifer water level elevation study was completed for the area surrounding the SOWC well field. Monthly water level measurements made over a period of 12 months provided the data base. The study incorporated available SOWC data and pertinent Miami Conservancy District (MCD) and Westinghouse Materials Company of Ohio (WMCO) data.

The results of this hydrogeologic study were based directly on the completion of Task 2. The data review completed in Task 1 provided the hydrologic and geologic settings that formed the basis of the input data base to the models, and also proved useful in model calibration. Historic data were also used to satisfy the intent of Task 5, and provided the primary ground water model calibration data and illustrated the long-term stability of ground water flow patterns. Field observations completed in Tasks 3 and 4 were used to confirm model assumptions. A variation of the field program will be performed under the sitewide RI/FS and the results will be evaluated in terms of any potential effects on the conclusions of this study.

2.0 PROJECT SETTING: REVIEW OF EXISTING INFORMATION

2.1 GEOLOGIC AND HYDROGEOLOGIC SETTING

The geology of the area surrounding the oxbow meander "Big Bend" of the Great Miami River near Ross (Venice), Ohio has been described by Fenneman (1916), Durrell (1961), and Spieker (1968a). The bedrock consists of predominantly flat-lying Ordovician shales with thin, interbedded layers of limestone. This bedrock unit, which is part of the Cincinnatian Series, reaches a total thickness of approximately 800 feet. Unconformably overlying the Cincinnatian Series are approximately 150 feet of Pleistocene glacial valley fill deposits. Ohio was covered by continental ice sheets four times during the Pleistocene epoch. During an interglacial period prior to the Illinoisan and Wisconsin glaciation events, the ancestral Great Miami River became entrenched in its present bedrock valley to depths of 200 feet. As indicated in the hydrogeologic cross sections (Figures 2.1-1 through 2.1-10), 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.

During the subsequent Illinoisan and Wisconsin glaciations, the valley of the Great Miami River was filled with glaciofluvial sand and gravel deposited by the meltwaters of the younger ice sheets. Interbedded glacial till deposits occur within the outwash deposits, but are in most cases of limited lateral extent. The till deposits are composed primarily of poorly sorted pebbles, cobbles, and boulders in a predominantly clay matrix. Within the study area, till deposits of Illinoisan and Wisconsin Age overlie the bedrock uplands where they form the thick unconsolidated sediment layers beneath the soil zone. The western part of the FMPC is built on an abandoned trough of the ancestral Ohio River, also known as the New Haven Trough. In this trough, the sand and gravel aquifer is overlain by up to 90 feet of glacial till (Figures 2.1-2 through 2.1-4).

Watkins and Spieker (1971) performed extensive seismic refraction surveys to determine the thickness and extent of water-bearing 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 to the valley floor. The top of bedrock map provided in this report

(Figure 2.1-11) was derived from the top of bedrock map produced by Watkins and Spieker (1971) and additional information provided by Leow (1985) and Vormelker (1985). Cross sections through the bedrock valley (Figures 2.1-2 through 2.1-10) depict geologic conditions throughout the model area including the top of bedrock. Figures 2.1-2, 2.1-9, and 2.1-10 more specifically categorize the local geologic conditions around the oxbow meander in the Great Miami River that is the focal point of this report.

Large ground water supplies occur in the outwash deposits and are recharged by three principal sources: recharge from bedrock, precipitation recharge, and recharge by induced stream infiltration. Although the shales and limestones have a low permeability, small amounts of water do occur in erratically distributed joints and cracks producing seepage into the glacial deposits. The permeability of the bedrock has been estimated by Dove (1961) to be five gallons per day (gpd) per square foot. Recharge by precipitation amounts to approximately 570,000 gpd per square mile of catchment area (Dove 1961). Under natural conditions, the gradient of ground water flow is from the aquifer to the river, except during dry periods when the gradient is reversed. In recent years, however, increased aquifer usage has resulted in induced infiltration from the river. This will be more fully described in Section 2.3.

Regional hydrogeologic environments of the buried channel aquifer have been investigated and reported by the U.S. Geological Survey (USGS). A hydrogeologic environment describes a portion of an aquifer possessing hydrologic and geologic properties that differ from the properties of aquifers in adjacent areas. Five major hydrogeologic environments have been identified and mapped by Spieker (1968a) in the Great Miami River Valley (Figure 2.1-12). Of the five hydrogeologic environments in the Great Miami River Valley, the Type I Hydrogeologic Environment most closely describes the hydrogeologic conditions in the vicinity of the oxbow meander.

The Type I Hydrogeologic Environment is found along the floodplain 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 or fine-grained material may exist anywhere in the environment; however,

these lenses are not of sufficient thickness or areal extent to act as semiconfining layers or to otherwise affect ground water movement. The potential for induced stream infiltration exists in these areas. Transmissivity generally ranges from 300,000 to 500,000 gpd per foot [40,000 to 67,000 square feet per day (ft^2/day)] and the Type I aquifer may be classified with a storage coefficient (S) of about 0.2. Individual wells can yield as much as 3,000 gallons per minute (gpm) (Spieker 1968a).

Other hydrogeologic environments shown in Figure 2.1-12 that are taken into consideration in this modeling study include the following:

- Type II: Sand and Gravel Aquifer - This consists of Types II-A-1, II-A-2, II-B-1, and II-B-2 (Spieker 1968a); only Type II-A-2 has been determined to exist in the study area
- Type III: Sand and Gravel Aquifer Overlain by Clay
- Type V: Shale and Limestone Bedrock Overlain by Till

The Type II Hydrogeologic Environment is characterized by 150 to 200 or more feet of sands and gravels with no areally extensive interstratified clay layers present. Recharge by induced stream infiltration is not available. The coefficient of storage is about 0.2. Large ground water supplies are not generally available from the Type II aquifer due to its limited areal extent and proximity to bedrock valley walls.

The Type III Hydrogeologic Environment is characterized by 50 feet or more of clayey till overlying the main buried channel aquifer. In the region of the FMPC, the buried channel aquifer is divided into an upper and lower part by a semipervious clay layer approximately 10 to 20 feet thick occurring approximately 140 feet below land surface. Hence, the lower aquifer is classed 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 35,000 to 300,000 gpd per foot (4,700 to 40,000 ft^2/day).

The Type V Hydrogeologic Environment includes all of the area outside of the buried channel. These areas are uplands which consist of shale with interbedded limestone overlain by 50 feet or less of clay-rich till. Large quantities

of ground water 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 material and, in some cases, wells completed in these units may yield up to 50 gpm.

The Type IV Hydrogeologic Environment was not considered in this study. It is typified by valleys filled largely with clay. No examples of this environment are found within the study area.

Ground water contour maps were constructed from data supplied by WMCO and MCD. These maps, which are presented in Figures 2.1-13 through 2.1-25, represent ground water flow patterns for April 1986 and on a monthly basis from September 1986 until August 1987, inclusive. Figure 2.1-13 for April 1986 incorporates additional data from a larger area within the buried channel aquifer. This data was used as the basis for calibration of the steady state condition for the ground water zone of influence modeling study. Table 2.1.1 lists completion details and selection rationale for the wells used to construct the ground water contour maps.

Several conclusions can be drawn from the ground water flow maps. The ground water flows from the west, north, and east towards the center of the study area. Ground water generally exits the study area by flowing southwest through the branch of the buried channel aquifer near New Baltimore. The SOWC pumping wells produce a pronounced and persistent cone of depression in the potentiometric surface centered on the pumping wells. Bedrock geometry plays an important part in the shape of the cone of depression which extends more in the west-east direction than the north-south direction. The ground water flow maps indicate that ground water flows to the east from the northern portion of the FMPC site and to the south in the southwestern portion of the site. The implications here are that water traveling through the northern part of the FMPC site would move towards the SOWC wells and water traveling through the southwestern part of the FMPC site would move south towards Fernald.

The monthly water level maps show only relatively minor fluctuations in ground water elevations, which is probably due to seasonal recharge variations and a variable pumping schedule of the SOWC wells. The persistence of a relatively

stable cone of depression was used to justify the use of steady state analysis in the ground water modeling described in Section 3.2 and Appendix A.

Hydrographs of selected wells were plotted against the river hydrograph at the Ross Bridge. These hydrographs are presented in Figures 2.1-26 through 2.1-29. A more detailed river hydrograph is presented in Figure 2.1-30, which shows the limited river stage data at Ross compared with the daily stage recorded at Hamilton. This figure shows the constantly varying river stage at the Hamilton Gage, a condition which would also be expected at the Ross Gage. Table 2.1.2 shows the maximum, minimum, and mean ground water elevations for January 1, 1986 through September 1, 1987 for the wells shown in the hydrographs (data was supplied by MCD). The monitoring wells and collector wells show a broad cyclic trend on a yearly basis. High ground water elevations generally occur in the late fall and early winter months (November, December, and January). Low ground water elevations generally occur during the late summer months (August, September, and October).

Figure 2.1-26 shows hydrographs from the two active SOWC collector wells plotted against monthly river elevations measured at Ross Bridge. Neither collector well hydrograph shows regular seasonal variation or follows changes in the river stage. Influences on the ground water levels include infiltration, river stage, and SOWC wells pumping schedule. No information was available on the latter, but this factor is most likely to have the primary influence on ground water levels and thereby account for the hydrograph pattern.

Rivers which penetrate aquifers are sources of recharge to pumping wells whose cone of influence intersects the river bed. The Great Miami River is a partially penetrating river and, therefore, while the river will contribute to flow at the pumping wells, a component of flow will also come from the aquifer on the opposite side of the river. This is evidenced by the contour maps and the hydrographs. The contour maps show cones of depression around the pumping wells extending past the river. This is more clearly shown by studying the hydrographs for Collector Well 2 (Figure 2.1-26) and Monitoring Wells S-2 and SW-1 (Figure 2.1-27). Collector Well 2 is located northwest of the river. Monitoring Well S-2 is on the same side of the river as Collector Well 2 but

to the west of the oxbow. Monitoring Well SW-1 is located southeast of the river, on the opposite side of the river as Collector Well 2 (inside the oxbow) as seen in Figure 2.1-1. The fluctuations in water levels shown by these monitoring wells are synchronized with Collector Well 2 from October to December 1986.

Monitoring wells close to the river, but away from the influence of the SOWC pumping wells, exhibit fluctuations in ground water levels which are correlated to changes in the river level. An example is Monitoring Well BU-13, which is shown in Figure 2.1-29.

2.2 HYDROLOGY OF GREAT MIAMI RIVER

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. It flows to the southwest and has a drainage area of 3,630 square miles at the Hamilton gage, which is located approximately 10 miles upstream from the FMPC discharge pipe. The river in the area of interest exhibits meandering patterns that result in sharp directional changes over distances of less than 3,000 feet (Figure 2.2-1). Directly east of the FMPC, and within the immediate study area, the river passes through a 180-degree curve known as "Big Bend." 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 river at Hamilton, based on 55 years of records, is 3,305 cubic feet per second (ft^3/s). Using drainage area scaling, the corresponding average flow at the FMPC point of discharge has been estimated to be 3,460 ft^3/s. The maximum discharge ever recorded on 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 of five retarding basins in 1922 was 108,000 ft^3/s and occurred on January 21, 1959. The ten-year flood discharge was calculated as 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, computed by the USGS for the Hamilton Gage (MCD). This translates to 280 ft^3/s at the site reach.

Figure 2.1-30 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. Also shown in Figure 2.1-30 are flow values recorded at the Ross Bridge during WMCO's routine monitoring program. The general pattern of variability is similar to that observed at the Hamilton gage.

The hydrologic characteristics of the Great Miami River throughout the area of interest were investigated using the HEC-2 computer model developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The program was developed for the calculation of water surface profiles and related hydrologic parameters such as flow velocity for steady, gradually varied flow in natural or manmade channels. The effects of various obstructions such as bridges, culverts, weirs, and structures in the floodplain were considered in the computations. The computational procedure is based on the solution of the one-dimensional energy equation, with energy loss due to friction evaluated using Manning's equation.

The input data for the HEC-2 program included flow regimes, discharges, cross-sectional geometry, starting water surface elevation, reach lengths, and energy loss coefficients. All input data for the Great Miami River was obtained from the U.S. Army Corps of Engineers, Louisville District. Data was provided on 21 sections in a reach extending over five miles from a point downstream from the City of New Baltimore to a point just upstream from the Ross Bridge (Figure 2.2-1). Of particular interest were the five sections spanning a river distance of approximately 1.5 miles near the FMPC discharge, with two river sections (I and J) located upstream from the discharge and three river sections (F, G, and H) located downstream. A starting water surface elevation of 455.0 feet mean sea level (MSL) at the confluence of the Ohio River and the Great Miami River was used to initiate the program for average flow conditions. Various river surface elevation values and river discharges were used to represent high flow (ten-year flood stage) conditions, low flow (seven-day, ten-year low flow) conditions, and observed field conditions for the period of September 11 through 14, 1987.

The hydrologic parameters used for purposes of this study were based on the HEC-2 model results for various flows. These results are summarized in Table 2.2.1. Representative values for water depth, velocity, channel width, and hydraulic radius were computed using an average of the values for the aforementioned five river sections (F-J). The following values were obtained for the mean flow case:

Water Depth = 5.4 feet
Flow Velocity = 2.1 feet per second (ft/s)
Channel Width = 345 feet

$$\text{Hydraulic Radius} = \frac{\text{area of channel}}{\text{wetted perimeter}} = 5.3 \text{ feet}$$

Additionally, the parameter values for high, low, and field flow conditions are also shown in Table 2.2.1 and were used along with the average flow values for surface water modeling of contaminant transport in the Great Miami River to indicate the sensitivity of the model to input parameters, as described in Chapter 3.0.

As a check of the representativeness of the averaged (Sections F to J) flow parameter values, they were compared to the following values which were derived by averaging values all 21 sections along the Great Miami River for the mean flow case:

Water Depth = 5.7 feet
Flow Velocity = 2.3 ft/s
Channel Width = 302 feet
Hydraulic Radius = 5.6 feet

This comparison of values indicates that the hydrologic characteristics of the river in the vicinity of the FMPC discharge point are similar to overall river conditions. Consequently, the use of the weighted average values for the five local stations is justified for subsequent modeling studies.

2.3 RIVER/AQUIFER INTERACTION

Sand and gravel deposits of the buried valley aquifer underlie much of the Great Miami River bed. The ground water within these deposits is

hydraulically connected with the river (Dove 1961 and Spieker 1968a). The natural ground water flow is from the aquifer to the river; that is, ground water discharges into the river. Pumping the SOWC wells, which are located close to the river, induces recharge to the aquifer by stream infiltration. This occurs by reversing the local hydraulic gradient and causing flow from the river to the aquifer.

The rate of such recharge by stream infiltration varies widely with respect to both place and time. Factors which influence the recharge rate include fluctuating river levels, different hydraulic gradients, and changing stream bed conditions. Seasonal changes in water temperature can also affect the infiltration rate since the viscosity of the water varies with temperature.

Two studies of river bed infiltration rate were conducted during the summers of 1956 near Ross (Dove 1961) and 1962 in Fairfield Township (Spieker 1968a). Infiltration rates were calculated to be 240,000 and 492,000 gpd per acre of stream bed, respectively. Both tests were performed in similar terrains under low streamflow conditions at water temperatures of approximately 80 degrees Fahrenheit.

2.4 FMPC MAIN EFFLUENT LINE

The FMPC discharge pipeline to the Great Miami River represents a permitted discharge of wastewater from the FMPC to the surface waters of the State. The discharge is regulated by an National Pollutant Discharge Elimination System (NPDES) permit, with compliance monitoring performed at Manhole 175 before the effluent leaves the site boundary. The wastewater conveyed by the main effluent line comes from three principal sources:

- Treated effluent from the general sump via the biodenitrification surge lagoon (previously via the clearwell)
- Treated effluent from the sanitary wastewater treatment plant
- Storm water runoff, principally from the production area

The effluent line, which is a 4,650-foot-long, 16-inch-diameter cast-iron pipe, was constructed in 1952. Seven concrete manholes are located along the line for access and maintenance purposes. The depth of burial of the pipeline

ranges from approximately 4 to 16 feet, with a maximum and minimum slope of 12.9 and 0.1 percent, respectively. The invert of the concrete-encased submerged discharge is located near the bottom of the Great Miami River, approximately 15 inches below the lowest recorded water level at the discharge point. River flow in this reach, which is within the 180-degree "Big Bend," has been observed to be turbulent.

In 1986, the average rate of discharge from the pipeline was 0.5 million gallons per day (MGD) or 0.78 ft^3/s (WMCO, 1987). The maximum discharge rate observed in 1986 was 1.1 MGD (1.7 ft^3/s), and the minimum flow rate was 0.2 MGD (0.31 ft^3/s) (WMCO, 1987). The NPDES permit requires monitoring for flow rate, pH, suspended solids, ammonia, oil and grease, residual chlorine, and nitrate. A summary of NPDES data is presented in Table 2.4.1. The Department of Energy (DOE) also requires daily sampling for radionuclides, with the daily samples being composited on a weekly basis for laboratory analysis. Table 2.4.2 presents average annual concentrations of monitored radionuclide parameters at Manhole 175. The concentrations at the upstream and closest downstream locations in the river are also shown.

The radiological constituent investigated in this study was total uranium. Based on the weekly composites, the average concentration of total uranium in the FMPC effluent discharge in 1986 was found to be 450 picocuries per liter (pCi/ℓ). This was less than the average value of 661 pCi/ℓ measured in 1985 (WMCO, 1986 and 1987). The selection of total uranium as the parameter of concern to this study was based on the following three reasons:

- Total uranium has represented the key parameter of study in most previous investigations and monitoring programs at the FMPC site. Consequently, the available data base for total uranium far exceeds that for other radionuclides.

- With the exception of technetium-99, the average concentration of uranium in the FMPC effluent greatly exceeded that of other radionuclides. The concentration of total uranium also represented the largest percentage (82 percent) of the allowable standard among the radionuclides, indicating its foremost importance when investigating potential impacts. For comparison, the average technetium-99 concentration represented only 2.2 percent of the standard (WMCO, 1987).

- The solubility and attenuation properties of total uranium are representative of those of other radionuclides; thus, the selection

of total uranium for transport and impact evaluation would not be deficient in terms of neglecting species with exceptionally higher mobility.

The potential need to consider other radionuclides or NPDES constituents in future impact studies is addressed in Chapter 5.0.

2.5 DESCRIPTION OF SOWC WELL FIELD AND OPERATION

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 (Figure 1.1-1). A generalized schematic of the collector well is shown in Figure 2.5-1. The collector well was pumped at an average rate of 10 MGD from 1952 to 1955. Its effective radius, as shown in Figure 2.5-2, 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 for the SOWC 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 (1968b) and Dove (1961) concluded that from 60 to 76 percent of the total flow from the collector wells comes from induced recharge from the river (values are representative for ranges of historical pumping rates).

Water which is pumped from Collector Wells 1 and 2 is piped about 24 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 SOWC 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 (MCD).

Additional significant pumping centers located within the model study area are the FMPC (P3) and Albright and Wilson (AW) wells (Figure 1.1-1). The AW well is located about 2,000 feet south of the FMPC along Paddy's Run Road. Their estimated average pumping rates are 0.5 and 0.14 MGD, respectively.

3.0 MODELING STUDIES

3.1 GREAT MIAMI RIVER WATER QUALITY MODEL

The objective of the modeling studies was to provide qualitative and quantitative information on any environmental impacts of the FMPC discharge on pumping centers in the area, including the SOWC collector wells. These studies focused on surface and subsurface flow models to determine if contaminants can reach the wells, and if so, at what concentration. Field studies conducted to support the modeling are presented in Chapter 4.0.

Any effluent from the FMPC discharge pipeline potentially reaching the pumping wells first passes through the Great Miami River system. The Great Miami River water quality model was used to quantify the resultant dilution and the profile of uranium concentration in the river. The results of the river modeling were used with the ground water modeling studies. The studies focused on the SOWC wells because these are the closest to the Great Miami River (and FMPC effluent discharge) and because they pump large volumes of water.

The zone of influence of the SOWC wells could potentially span that portion of the river receiving effluent discharge from the pipeline; therefore, it was necessary to evaluate the contaminant concentration profile in the Great Miami River downstream of the point of discharge. The preferred modeling approach would be to use a hydrodynamic dispersion model that accounts for the progressive longitudinal and transverse spread of the contaminant plume away from the source. On the other hand, the fact that the discharge occurs near the channel bottom in a zone of turbulent flow and river meanders would promote the potential for nearly complete mixing of the effluent across the channel. The trade-off between the simplicity of a complete mix model and the additional resolution provided by a more data-intensive hydrodynamic dispersion model was assessed by analyzing each as an extreme case. The complete mix model provided a lower bound on local concentrations due to the necessary "averaging" of the effluent effects across the channel. The hydrodynamic dispersion model, on the other hand, tended to overestimate concentrations in portions of the river if calculated dispersion coefficients are used, since the model assumptions are based on flow in a straight channel and initial mixing caused

by the momentum of the discharge was neglected. The results of the two models are evaluated within the context of the ground water modeling needs in Section 3.1.3.

3.1.1 Complete Mix Model

The underlying assumption of the complete mix model is that the total mass flux of uranium in the effluent mixes completely and instantaneously with the background mass flux of uranium in the river. Since the mass flux can be represented by the product of flow rate and uranium concentration, the concentration in the river after mixing can be calculated as:

$$C_{river} = (Q_p C_{eff} + Q_r C_{back})/(Q_p + Q_r) \qquad (1)$$

where

C_{river} = Concentration of uranium in the river after mixing,
Q_p = Rate of effluent discharge from the pipe,
Q_r = Flow rate in the Great Miami River,
C_{eff} = Concentration of uranium in the effluent, and
C_{back} = Background concentration of uranium in the river upstream from the point of discharge.

Two effects of the use of the complete mix model are the following:

- The concentration of uranium is taken to be constant across a given cross section (i.e., no transverse or vertical gradients are considered)
- If Q_r remains constant (i.e., any gains or losses in river flow are neglected), the uranium concentration does not change in the longitudinal (downstream) direction under steady-state conditions

Average river conditions can be evaluated by assigning the following average values, as reported in Chapter 2.0, to the parameters:

- Q_r = 3,460 cubic feet per second (ft^3/s)
- Q_p = 0.78 ft^3/s
- C_{back} = 1.2 pCi/ℓ
- C_{eff} = 450 pCi/ℓ
- C_{river} = 1.3 pCi/ℓ

The background concentration of 1.2 pCi/ℓ uranium in the river was the average of 52 water samples collected on a weekly basis by WMCO in 1986 (WMCO, 1987) at the Ross Bridge (Figure 1.1-1). This sampling location is approximately two miles east and upstream from the FMPC. Consequently, it was considered beyond the influence of surface drainage and discharges from the site. Using Eq. (1), the resulting concentration of uranium in the river below the FMPC discharge was determined to be 1.3 pCi/ℓ. The impact of the effluent discharge on the river was observed to be an approximate 8 percent increase in uranium concentration over background. This small increase results from the extremely small percentage of total flow, and thus total mass flux, represented by the higher concentration effluent stream.

Several other flow conditions were investigated for analysis of the complete mix model. Values observed during the September 1987 sampling program (Chapter 4.0, Appendix B) are given below, along with the calculated C_{river}:

- $Q_r = 534\ ft^3/s$
- $Q_p = 0.72\ ft^3/s$
- $C_{back} = 1.2\ pCi/\ell$
- $C_{eff} = 907\ pCi/\ell$
- $C_{river} = 2.4\ pCi/\ell$

Further evaluations of the extremes of C_{river} were made using measured ranges of Q_p and C_{eff} from the 1987 water year and the range of Q_r between the ten-year flood and seven-day, ten-year low flow values. Consequently, the extreme cases can be represented by the following combinations of parameters:

- Minimum impact:

  $Q_r = Q_r max = 81{,}455\ ft^3/s$
  $Q_p = Q_p min = 0.31\ ft^3/s$ (one day minimum for 1987 water year)
  $C_{back} = 1.2\ pCi/\ell$
  $C_{eff} = C_{eff}\ min = 67.7\ pCi/\ell$ (one day minimum for 1987 water year)
  $C_{river} = 1.2\ pCi/\ell$

- Maximum impact:

  $Q_r = Q_r min = 280\ ft^3/s$ (one day maximum for 1987 water year)
  $Q_p = Q_p max = 1.7\ ft^3/s$
  $C_{back} = 1.2\ pCi/\ell$
  $C_{eff} = C_{eff}\ max = 1{,}665\ pCi/\ell$ (one day maximum for 1987 water year)
  $C_{river} = 11.2\ pCi/\ell$

The minimum impact is insignificant and likely nondetectable. The maximum impact would occur under low flow conditions in the river and high mass loading from the pipeline. The increase in uranium concentration for the maximum impact is based on a seven-day, ten-year low flow condition, and therefore is an extreme, short duration increase in uranium concentrations in the river. Table 3.1.1 shows monthly averages of Q_r, Q_p. and C_{eff} for the 1987 water year. In general, high flows in the discharge pipe do not occur during low flows in the river and vice versa; therefore, C_{river} for the maximum and minimum impact cases are extremes which are unlikely to be encountered.

The value used for background uranium concentration, 1.2 pCi/ℓ, was determined based on historical field records and is consistent with the values obtained from field sampling on September 11 through 14, 1987 (Station 11, Table 4.4.1). The uranium concentration in river water sampled at Station W3, 3.1 miles downstream from the sewer outfall, ranged from 0.81 to 2.4 pCi/ℓ, with a mean value of 1.4 pCi/ℓ (WMCO, 1987). This exceeds the value of C_{river} of 1.3 pCi/ℓ calculated for the average case; however, it is close to the average value and well within the limits of minimum and maximum impact cases. A sensitivity analysis was carried out using STRIP1B, as described in Section 3.1.2.3, to look at variability in contaminant concentrations with respect to various flow and dispersion conditions.

3.1.2 Surface Flow Hydrodynamic Dispersion Model

The use of a hydrodynamic dispersion model more adequately accounts for the contaminant distribution in the vicinity of the discharge pipe. The discharge itself is considered as a point source of uranium release to the river. Convective and dispersive transport relationships are used to account for the longitudinal and transverse distributions of uranium concentration within the river water.

3.1.2.1 Governing Equations

For turbulent flow in a prismatic open channel, the differential equation for hydrodynamic dispersion in the three-dimensional case is (Fisher, 1973, p. 60, Eq. 4; Li, 1983, p. 549):

$$\frac{\partial \bar{C}}{\partial t} + \bar{u}\frac{\partial \bar{C}}{\partial x} + \bar{v}\frac{\partial \bar{C}}{\partial y} + \bar{w}\frac{\partial \bar{C}}{\partial z} = \tag{2}$$

$$\frac{\partial}{\partial x}\left(D_x \frac{\partial \bar{C}}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y \frac{\partial \bar{C}}{\partial y}\right) + \frac{\partial}{\partial z}\left(D_z \frac{\partial \bar{C}}{\partial z}\right)$$

in which $\bar{C}$ is the concentration; x, y, and z are the coordinates in the longitudinal, vertical, and transverse directions, respectively; $\bar{u}$, $\bar{v}$, and $\bar{w}$ are the velocities in the x, y, and z directions, respectively; D_x, D_y, and D_z are the dispersion coefficients in the x, y, and z directions, respectively; and t is the time. The velocity components $\bar{v}$ and $\bar{w}$ are those of the secondary convective currents in the plane of the cross section, with $\bar{w}$ representing transverse velocity and $\bar{v}$ representing vertical velocity. Figure 3.1-1 presents this modeling framework and the associated parameters.

The two-dimensional form of Eq. (2), which is based on the assumption of complete mixing in the vertical direction with a velocity field that is primarily unidirectional such that the secondary convective currents can be neglected, is the following (Shen, 1978, page 36, Eq. 3):

$$\frac{\partial \tilde{C}}{\partial t} + V\frac{\partial \tilde{C}}{\partial x} = \bar{D}_x \frac{\partial^2 \tilde{C}}{\partial x^2} + \bar{D}_z \frac{\partial^2 \tilde{C}}{\partial z^2} \tag{3}$$

where $\tilde{C}$ is the average concentration and V is the constant velocity in the longitudinal direction. Although the transverse and vertical velocity components ($\bar{v}$, $\bar{w}$) have been dropped from Eq. (3), the associated convective effects remain accounted for in the empirically-based values of the longitudinal and transverse dispersion coefficients ($\bar{D}_x$, $\bar{D}_z$).

Many empirical formulas have been suggested for $\bar{D}_x$ and $\bar{D}_z$ in natural streams. For example, Liu (1977, as presented by Li, 1983, p. 550, Eq. 13-76) proposed the following equation for the calculation of $\bar{D}_x$:

$$\bar{D}_x \approx 0.18 \left(U_*/V\right)^{1.5} \frac{Q^2}{U_* R^3} \qquad (4)$$

where Q is the discharge, R is the hydraulic radius, and U_* is the shear velocity given by the following equation (Li, 1983, p. 549):

$$U_* = (\tau_o/\rho)^{0.5} = (gHS_o)^{0.5} \qquad (5)$$

in which τ_o is the shear stress, ρ is the mass per unit volume, g is the gravitational acceleration, S_o is the channel slope, and H is the depth of flow (river depth).

For the transverse dispersion coefficient,

$$\bar{D}_z = 0.23HU_* = 0.23H\ (gHS_o)^{0.5} \qquad (6)$$

has been suggested for relatively straight channels. Larger values should be used for meandering streams (Li, 1983, p. 550). The river reach of interest to this evaluation is a sharply curving meander, so it would be expected that $\bar{D}_x$ and $\bar{D}_z$ values calculated from Eqs. (4) and (6) would be much smaller than actual values.

The average flow depth (for average flow conditions) was reported in Section 2.2 to be 5.4 feet. The channel slope for the five river sections of interest was found from the HEC-2 input to be 0.0008741 feet/feet. Using these values, the shear velocity for the average flow case was calculated using Eq. (5) to be:

$$U_* = (32.2 \times 5.4 \times 8.741 \times 10^{-4})^{0.5}$$
$$= 0.39 \text{ foot per second (ft/s)}$$

Using the average velocity of 2.1 ft/s and average hydraulic radius of 5.3 feet, the longitudinal dispersion coefficient for the average flow case was calculated using Eq. (4) to be:

$$\bar{D}_x = 0.18 \left(\frac{0.39}{2.1}\right)^{1.5} \frac{(3{,}460)^2}{(0.39)(5.3)^3}$$

$$= 2{,}979 \text{ square feet per second } (ft^2/s)$$

The transverse dispersion coefficient for the average flow case was calculated using Eq. (6) to be:

$$\bar{D}_z = (0.23)(5.4)(0.39)$$

$$= 0.5 \text{ ft}^2/s$$

Fisher (1973, p. 73 Table 2) lists the results of experiments on longitudinal dispersion in laboratory channels, natural streams, and canals. Using the values in this table for natural streams, the reported range of the longitudinal dispersion coefficient is:

$$\frac{\bar{D}_x}{HU_*} = 74 \text{ to } 7{,}500 \qquad (7)$$

With H = 5.4 ft and U_* = 0.39 ft/s,

$$\bar{D}_x = 155.8 \text{ to } 15{,}795 \text{ ft}^2/s$$

The value of 2,979 ft^2/s for $\bar{D}_x$ for the average flow case computed above for the Great Miami River is well within this range.

Fisher (1973, p. 68) also deduced, from secondary velocity profiles, a corresponding range for transverse dispersion coefficients in a uniform open channel as:

$$\frac{\bar{D}_z}{HU_*} = 0.51 \text{ to } 2.4 \qquad (8)$$

With H = 5.4 ft and U_* = 0.39 ft/s,

$$\bar{D}_z = 1.1 \text{ to } 5.1 \text{ ft}^2/s$$

The computed value of 0.5 ft^2/s for $\bar{D}_z$ for the average flow case for the Great Miami River is slightly below this range.

3.1.2.2 Model Assumptions

The previous section described a widely used river dispersion model for predicting the change in concentration in both the longitudinal and transverse directions from a point source of contamination. Values representative of conditions in the Great Miami River were shown to be generally consistent with published results of field and laboratory studies. Before applying this model to the case of the FMPC effluent discharge, however, it is appropriate to consider the following principal assumptions underlying the model. Reference is made to Figure 3.1-1 for a schematic representation of the river, as used in the model.

- The cross sections of the river can be represented by an average width and average depth that will remain unchanged in the longitudinal direction.

- The longitudinal velocity of the water at any section is constant across the section (a condition not fully consistent with site conditions , since the river flow is within a meander curve) and does not change from section to section in the longitudinal direction. Any potential dispersion of contaminants caused by transverse velocity gradients is accounted for in the use of empirically derived dispersion coefficients.

- The width of the river ($D_1 + 2B + D_2$) is constant.

- The effluent discharging into the river has a constant concentration (C_{eff}). The significance of this assumption has been discussed in Section 3.1.1.

- The discharge point of the pipeline has a width of 2B and can be located at any place along the cross section.

- The banks of the river are impervious; i.e., the contaminants cannot migrate beyond these boundaries. This assumption is conservative since the loss of contaminants as a result of induced infiltration would reduce the actual mass loading in the longitudinal direction.

- Along the z axis (stream width) at the point of discharge, the incremental concentration caused by the effluent is zero at all locations except for the discharge width 2B.

- The radionuclides are transported only by convection due to the velocity of the flowing water and dispersive effects; any gravitational effects on radionuclide particles are neglected, since complete dissolution is being assumed. In reality, any uranium

attached to suspended solids would not migrate to the SOWC wells; thus, this assumption makes all uranium available for release.

- The source is assumed to be vertically continuous throughout the water column at the point of discharge, as discussed in the next section.

- The secondary currents are neglected, including any entrainment mixing that would occur as the result of the momentum of the discharge. This will conservatively overestimate the concentration field.

- The temperature and/or density effects on mixing between the river water and effluent are accounted for by using empirically derived dispersion coefficients.

3.1.2.3 Model Application

A two-dimensional analytical model, called STRIP1B (IT, 1987), was used for the solution of the dispersion model, in accordance with Eq. (3). STRIP1B was developed by the staff of IT Corporation (IT) and has been extensively verified with the use of IT's flow and solute transport code called GEOFLOW (IT, 1986) and Princeton Transport Code (PTC) developed by the staff of Princeton University (Babu, 1987). These comparisons are presented in a paper recently submitted for publication (Batu, 1988).

The governing partial differential equation of STRIP1B is Eq. (3). Although STRIP1B was developed for solute transport in porous media, it can be used for the solution of the partial differential equation for surface flow solute transport because the governing partial differential equations for solute transport in ground water flow and surface water flow are essentially the same. The key difference is that appropriate dispersion coefficients must be used for the surface water flow case (Batu 1988). STRIP1B calculates the concentrations and convective-dispersive flux components from a time-dependent solute "strip" source in a uniform flow field bounded by two impervious boundaries. Either unsteady or steady-state conditions can be simulated. As can be seen from Figure 3.1-1, the source can be located at any place between the impervious boundaries.

The results from the STRIP1B model are given in terms of a normalized concentration, C/C_0, where C is the concentration of uranium at any point (x,z) along the river resulting from the introduction of uranium at concentration,

C_o, at the "strip" of river representing the mixing zone for the FMPC effluent line outfall. The resultant concentration must be added to the background concentration in the river to yield the total uranium concentration. This can be mathematically represented as:

$$C_r = C_o\ [(C/C_o)_{model}] + C_b \qquad (9)$$

where:

C_r = Concentration of uranium at a given point (x,z) in the river downstream from the FMPC discharge (pCi/ℓ),

C_o = Concentration of uranium from the effluent discharge at the point of initial mixing (pCi/ℓ),

$(C/C_o)_{model}$ = Normalized concentration predicted by the model for the point (x,z), and

C_b = Background concentration of uranium in the river = 1.2 pCi/ℓ.

For the average flow case,

$$C_r = 23.7\ (C/C_o)_{model} + 1.2 \qquad (10)$$

The value of C_o, the original concentration in the strip (source concentration in the river), was established by assuming that the effluent from the FMPC pipeline mixes instantaneously with only that portion of the river flow within a 1.4-foot vertical section. The width of this section corresponds to the diameter of the effluent pipeline. The value of Co is computed from:

$$C_o = Q_p\ C_{eff}/(Q_{2B} + Q_p)\ (pCi/\ell) \qquad (11)$$

where

Q_p = Flow in the effluent pipeline (ft^3/s),

C_{eff} = Uranium concentration in effluent (pCi/ℓ),

Q_{2B} = Flow through the "strip" = $\frac{Q_r \cdot 2B}{W}$,

where

Q_r = Flow in the river (ft^3/s),

2B = Width of spread zone (ft), and

W = Width of river (ft).

The mixing over the full depth of the river is not only consistent with the two-dimensional nature of the model, but field observations of "bubbling" at the water surface also suggest that the entrainment velocity of the effluent entering at the bottom of the river penetrates the full depth of flow. When the effluent is mixed with this "strip" of river flow, the resultant initial concentration C_o becomes 23.7 pCi/ℓ.

The initial model run using STRIP1B was achieved by following the procedure outlined below. Field data from September 11 through 14, 1988 (Chapter 4.0, Appendix B) were used to determine the following parameters for STRIP1B input:

- Q_r = 534 ft^3/s (Mean of data measured at Hamilton gage from 9/11/87 through 9/14/87, adjusted for site reach)
- Q_p = 0.72 ft^3/s (Mean of data measured from 9/11/87 through 9/14/87)
- C_{eff} = 907 pCi/ℓ (Mean of data measured from 9/11/87 through 9/14/87)
- C_{back} = 1.2 pCi/ℓ (From data at Location 11, samples collected on 9/11/87, Table 4.4.1)
- C_o = 164 pCi/ℓ (Calculated from Equation 11)
- W = 230 feet (from HEC2 Model)
- D_1 = 0 feet
- D_2 = 228.6 feet
- 2B = 1.4 feet
- V = 1.35 ft/s (From Location 4, data measured on 9/12/87, Table 4.3.1)
- $\bar{D}_x$ = 820 ft^2/s (Calculated from Equation 4)
- $\bar{D}_z$ = 0.2 ft^2/s (Calculated from Equation 6)

The results of the model run using the above information are shown in Table 3.1.2. Calibration of the model was achieved by performing additional simulations, varying only $\bar{D}_x$ and $\bar{D}_z$, until an acceptable match of the computed values of uranium in the river was found with the uranium values in samples of river water collected from September 11 through 14, 1987. Table 3.1.2 shows the measured and computed values of uranium in the Great Miami River at observation points for the case with $\bar{D}_x$ and $\bar{D}_z$ calculated from initial river data and for the calibrated (best fit) model case. For calibration, $\bar{D}_x$ was approximately 10 times greater than calculated and $\bar{D}_z$ was approximately 100 times greater than calculated. This indicated that actual $\bar{D}_x$ and $\bar{D}_z$ values may be larger than values calculated using Eqs. (4) and (6) for all river flow cases. The equations for calculations of $\bar{D}_x$ and $\bar{D}_z$ are based on flow in straight channels; however, turbulent flow, possible transverse velocity components, and velocity changes across the channel exist due to the meandering nature of the Great Miami River at the site reach. Cross sections of the river bottom (Figures 4.3-1 and 4.3-2) show the nonuniform channel shape. This field condition will result in dispersion coefficients larger than accounted for by the given equations.

The input to the dispersion model for the average flow case was developed from the calculated values previously described (Sections 3.1.2.1 and 2.2), and includes the following (refer to Figure 3.1-1):

- D_1 = 0.0 feet (i.e., discharge is assumed to occur at the west bank of the river)
- D_2 = 345 feet (channel width) - 1.4 feet (mixing zone) = 343.6 feet
- 2B = 1.4 feet
- V = $\bar{u}$ = 2.1 ft/s
- $\bar{D}_x$ = 2,980 ft^2/s (approximate value used)
- $\bar{D}_z$ = 0.5 ft^2/s

The model results, in terms of both the normalized concentrations $(C/C_o)_{model}$ and the corresponding values of C_r from Eq. (10), are given in tabular form for selected river locations in Table 3.1.3. The value of z is the transverse distance from the west bank of the river, while the value of x is the

longitudinal distance downstream from the point of discharge from the FMPC effluent pipeline. The results presented in Table 3.1.3 indicate a rapid decrease in solute concentration in both the transverse and longitudinal directions away from the source. The decrease is more dramatic in the transverse direction since the uranium is both dispersing and mixing with a relatively high volumetric rate of river flow.

The general result shown from the convective-dispersive mixing model is a gradual "smoothing" of the lateral concentration profile in the downstream direction. As the longitudinal coordinate (x) becomes longer, the results of the dispersion model will match those of the complete mix model since the uranium in the effluent will have spread uniformly across the channel. Concentrations exceeding the complete mix value of 1.3 pCi/ℓ (Table 3.1.3) occur only near the right bank (z = 0 - 20 ft) until large longitudinal distances are achieved. Even at a distance of x = 5,000 feet, the complete mix value (1.3 pCi/ℓ) is exceeded only for a distance of less than 80 feet in the transverse direction. At this downstream distance, the maximum uranium concentration of 1.8 pCi/ℓ near the right bank is within 50 percent of the background value.

As was indicated by the calibration runs, $\bar{D}_x$ and $\bar{D}_z$ may be greater than actually calculated for each case. To illustrate how this would translate with respect to the average flow case, STRIP1B was run a second time with the value of $\bar{D}_x$ 10 times larger than that calculated and with the value of $\bar{D}_z$ 100 times larger than that calculated ($\bar{D}_x$ = 29,800 ft^2/s, $\bar{D}_z$ = 50 ft^2/s). As expected, the results of the dispersion model (Table 3.1.4) more quickly match those of the complete mix model in the longitudinal and transverse directions. Complete mix is achieved within 5,000 feet downstream of the model source.

A sensitivity analysis was performed using STRIP1B to illustrate impacts during river low flow (7-day, 10-year low flow), Q_r = 280 ft^3/s, conditions and high flow (10-year flood), Q_r = 81,455 ft^3/s, conditions. Each of these cases was run once using the values of $\bar{D}_x$ and $\bar{D}_z$ calculated from Eq. (4) and (6) (Run 1) and once using adjusted $\bar{D}_x$ and $\bar{D}_z$ values (Run 2). The input data to STRIP1B for the low- and high-flow cases are indicated below.

	LOW FLOW	HIGH FLOW
Q_r	280 ft^3/s	81,455 ft^3/s
Q_p	0.78 ft^3/s	0.78 ft^3/s
C_{eff}	450 pCi/ℓ	450 pCi/ℓ
C_{back}	1.2 pCi/ℓ	1.2 pCi/ℓ
C_o	129.0 pCi/ℓ	15.6 pCi/ℓ
W	202 feet	5,240 feet
D_1	0.0 feet	2,450 feet
D_2	200.6 feet	2,789.6 feet
2B	1.4 feet	1.4 feet
V	0.81 ft/s	4.64 ft/s
$\bar{D}_x$	(Run 1) = 319 ft^2/s, (Run 2) = 3,190 ft^2/s	(Run 1) = 149,600 ft^2s, (Run 2) = 1,496,000 ft^2/s
$\bar{D}_z$	(Run 1) = 0.2 ft^2/s, (Run 2) = 20 ft^2/s	(Run 1) = 1.0 ft^2/s, (Run 2) = 100 ft^2/s

For the low-flow case, with calculated values of $\bar{D}_x$ and $\bar{D}_z$ (Run 1), (Table 3.1.5), the dispersion is much slower in both longitudinal and transverse directions. At 5,000 feet in the longitudinal direction, the solute has not completely dispersed across the channel. However, the dispersive mixing model for the low flow case with adjusted $\bar{D}_x$ and $\bar{D}_z$ (Run 2) with all of other parameters remaining the same reaches complete mix by 4,000 feet in the downstream (longitudinal) direction with an average concentration of 2.1 pCi/ℓ (Table 3.1.6).

For the high flow case, the effluent outfall is located approximately 2,450 feet from the existing left bank (due to flooding on the floodplain); therefore, the solute will disperse towards the left and right banks, as well as downstream. Table 3.1.7 shows the case for the calculated values $\bar{D}_x$ and $\bar{D}_z$ (Run 1). Because of the high velocity and high value of $\bar{D}_x$ with respect to $\bar{D}_z$, the solute dispersion rate is lower in the transverse directions. Even at 5,000 feet downstream, the plume remains relatively narrow, and the solute has not completely mixed across the channel. Table 3.1.8 shows the case for high flow with adjusted $\bar{D}_x$ and $\bar{D}_z$ values (Run 2) with all other parameters remaining the same. The plume is more dispersed in the transverse directions because of the increased value of $\bar{D}_z$ with respect to $\bar{D}_x$. However, the plume is confined to approximately 50 feet on either side of the effluent discharge

point, and complete mix is still not achieved 5,000 feet downstream. However, the values obtained are close to background.

The importance of mixing in the vicinity of the source can be ascertained from the rapid decrease in concentrations away from the source in all cases. The assumption that no lateral mixing of the effluent discharge occurs outside of the 1.4-foot "strip" could lead to predicted uranium concentrations from STRIP1B being larger than actual concentrations in the immediate vicinity of the outfall. It is also likely that pumping of the large SOWC collector well located within the river bend to the east would preferentially draw water from the eastern portions of the river channel affecting the transverse velocity profile. The constant change in direction of river flow within the meander bend would also affect the transverse velocity profile. These conditions would create secondary currents across the river which, in turn, would promote transverse mixing and dilution. This is illustrated by the fact that $\bar{D}_z$ had to be increased by two orders of magnitude to achieve a concentration distribution across the channel. The uranium concentrations predicted by the hydrodynamic dispersion model, when using calculated values of $\bar{D}_x$ and $\bar{D}_z$, would consequently be overestimates of actual values.

3.1.3 Application of Results to Ground Water Model

The application of both a complete mix model and a hydrodynamic dispersion model for the Great Miami River had as a principal objective the development of a representative uranium source term for the ground water solute transport model which will be developed as part of the sitewide RI/FS. The results of the two surface water modeling efforts indicate that for ground water model input a complete mix model provides an acceptable approximation of actual river conditions downstream from the FMPC discharge. The corresponding concentration of uranium at all points in the river could, therefore, be set equal to 1.3 pCi/ℓ for the average flow case. In the downstream river reach, the actual concentration profile, however, will fall between the complete, uniformly mixed case and the results of the dispersion models given in Tables 3.1.3 through 3.1.8.

An evaluation of the appropriateness of these two models must be accomplished within the context of the data requirements of the sitewide RI/FS ground water

solute transport model. Individual grid cells of the ground water modeling grid, for which input data are required on a one-to-one basis, have minimum dimensions of approximately 250 feet by 250 feet in the vicinity of the FMPC discharge to the river. Consequently, the entire width of the river may be contained within a single cell and the average uranium concentration used as model input would have to equal the complete mix value of 1.3 pCi/ℓ, for average flow conditions, in order to conserve mass. To assume any larger concentration value throughout the cell, in order to at least partially account for the lateral concentration distribution, would be erroneous since the resultant total mass of uranium in the section would exceed the mass of uranium actually available. A straightforward and conceptually acceptable solution would be to assign the complete mix value of 1.3 pCi/ℓ to all river cells downstream from the FMPC outfall.

Two potential improvements to this approach have been considered. The first was to reduce the size of the ground water modeling grid to better accommodate the lateral concentration profile of uranium in the river. This modification would only be of value if the resultant plume to the SOWC wells would remain identifiable and not well mixed with other ground water prior to reaching the wells at depth. This is highly unlikely, however, given the small percentage of flow originating in any single, small river cell. Further, to create a scenario in which the concentration differences are meaningfully different would require cells with lengths on the order of tens of feet. The additional complexities and levels of effort of modeling this situation cannot be justified by the technical requirements of this study. In the end, any potential changes in uranium concentration in the SOWC wells would likely remain within the error bars of the overall modeling study and no recognizable improvement would have been achieved.

A second possible modification would account for the model result that, within the first mile, transverse mixing occurs only within the westernmost half of the river channel. In those cases where the ground water model grid intersects the river, the entire mass of uranium from the FMPC effluent could be allocated to the modeling cell to the west. The corresponding uranium concentration in the western cell would be 1.4 pCi/ℓ, which is consistent with the scenario that only half of the river flow is completely mixing with the

effluent. The concentration of uranium in the corresponding cell to the east would remain at the background value of 1.2 pCi/ℓ. Whereas this modification would appear to produce higher concentrations of uranium at the SOWC wells than the complete mix case, such would not be true if the eastern cell preferentially contributes more water to the wells. That is, if more water is yielded by the eastern cell, the total mass of uranium reaching the SOWC wells could be higher by maintaining a 1.3 pCi/ℓ value in both cells rather than allocating all uranium to the western cell. Because initial ground water modeling results indicate that relatively more flow is, in fact, contributed by the eastern cells, a final decision was made to retain the complete mix value of 1.3 pCi/ℓ for use in all river sections in future solute transport modeling.

In summary, the results of the surface flow hydrodynamic dispersion models indicate significant increased uranium concentrations in the river only at a length scale of hundreds of feet from the point of discharge. Since any release to the subsurface environment from such small areas would represent a low percentage of flow to the SOWC wells, the identity of such a plume of elevated concentration would be lost prior to reaching the wells. Consequently, the concentration gradients are of little importance to a quantitative evaluation of the impacts of the FMPC discharge on the SOWC wells. The use of a complete mix model to establish an average uranium concentration of 1.3 pCi/ℓ, for average flow conditions, in the river is considered appropriate to satisfy the study objectives.

3.2 GROUND WATER MODEL

3.2.1 Model Selection

The selection of the most appropriate computer code for a given project is generally driven by the technical requirements and objectives of the study, the types and amount of data available, and the accessibility of the code and its compatibility with available equipment. The situation for the Fernald site is no exception. However, in the case of Fernald, certain site features and study requirements have necessitated the selection of a state-of-the-art computer code with advanced capabilities. The satisfaction of these minimum requirements eliminated most computer codes from further consideration in the selection process.

For reasons discussed in the following sections, the SWIFT III computer code was selected for use in both this hydrogeologic study of the FMPC discharge and the overall, sitewide RI/FS. Use was also made of IT's GEOFLOW model to fully satisfy the initial requirements of the FMPC discharge study reported herein. The reasons for this dual modeling effort are explained in Section 3.2.1.3.

3.2.1.1 Selection Criteria

The ground water modeling component of the hydrogeologic study of the FMPC discharge could have been performed independently of other current and future efforts of the sitewide RI/FS. However, the need to avoid any redundancy of effort and to eventually achieve a consistency of results with the overall RI/FS dictated that the subject modeling study be performed in anticipation of future RI/FS modeling requirements. This programmatic approach is fully consistent with the RI/FS Work Plan, which calls for the performance of a preliminary modeling study to refine the planned field investigations. As such, the technical and operational criteria for model selection were developed in terms of the full set of current and future study requirements.

For purposes of both this study and the overall RI/FS, four minimum requirements of the modeling code were established. These included the following:

- Codes were only considered that had three-dimensional or quasi-three-dimensional modeling capabilities. This is necessary to account for vertical flow through varying types of geologic strata, and to simulate the effects of vertical hydraulic gradients caused by regional pumping at depth.

- The capacity to quantitatively predict contaminant concentration at receptor locations is considered necessary to fully satisfy the requirements of the RI/FS. Therefore, only codes with options to model solute transport and associated attenuation/retardation processes were considered.

- Only models that have been adequately verified and previously applied under similar project settings were considered. This criterion was necessary due to the sensitive nature of the Fernald work and the magnitude of future decisions that could be based on model predictions.

- The immediate availability of the modeling code and accompanying documentation within the public domain was necessary to satisfy near-term deliverables.

Available modeling codes were evaluated against these four criteria to establish a "short list" of codes for additional evaluation. Four codes were found to satisfy these criteria, consisting of SWIFT II/III, GEOFLOW, SWENT, and the Princeton Transport Code.

Numerous other selection criteria were also established to refine the selection process in terms of the specific site conditions and study requirements. These included:

- The capacity to model unconfined flow regimes is a preferred option in case unsaturated flow beneath the river or waste storage units is eventually found to be a critical process
- Although the radionuclides of most concern do not require the consideration of daughter products, the capacity to model decay chains would become a consideration if other radionuclides are found to be important
- The mathematical representation of attenuation/retardation processes (e.g., adsorption) and decay processes would provide flexibility in the range of constituents that can eventually be modeled
- The capacity to handle a wide variety of boundary conditions is preferred so as not to limit the available options for best representing actual site conditions
- Although not considered necessary, the option to consider density variations and temperature or concentration effects on fluid viscosity could be beneficial to best simulate certain critical processes (e.g., leakage through the river bed)
- The convenience of model application was considered based on features such as pre- and postprocessing capabilities, user documentation, mesh generation, solution method, restart capability, applicability to available computer systems, and user familiarity

3.2.1.2 Selection of the SWIFT III Code

Table 3.2.1 has been prepared to summarize these selection criteria for the four models that remained after the initial screening process. Following a critical evaluation of the relative benefits and deficiencies of the respective codes, a decision was made to select SWIFT III as the primary code for use in both the hydrogeologic investigation of the FMPC discharge area of influence and the sitewide RI/FS. SWIFT III most comprehensively satisfied the full set of selection criteria, and no significant limitations were identified.

A noteworthy benefit of the SWIFT III code is that the SWIFT series of models has been successfully applied on similar projects. Most notably, these applications have included two studies in or near the Fernald site area. These were an evaluation of ground water corrective action at the Chem-Dyne hazardous waste site at Hamilton, Ohio (Ward, D. S., et al., 1987a for the OEPA) and a preliminary characterization study of the ground water flow system near the FMPC (GeoTrans, 1985 for the OEPA), which incorporated the area of the FMPC discharge and SOWC wells.

3.2.1.3 Dual Use of the GEOFLOW Model

The aforementioned operational complexities of the SWIFT III model, in addition to a lack of direct user experience with the SWIFT III code, created an uncertainty in relation to the deliverables required as part of the FMPC discharge study. For this reason, a decision was made to perform a concurrent, parallel modeling study using IT's GEOFLOW model. The GEOFLOW code satisfies the four principal criteria for model selection, although the overall attributes of the model fall short of those of the SWIFT III code.

The immediate availability of the GEOFLOW code on IT's computer system, along with a high level of user familiarity due to IT's past extensive usage on similar projects, allowed the conceptualization, calibration, and sensitivity testing to proceed on an accelerated schedule as the work on the SWIFT III model progressed at a more uncertain pace. Whereas both codes eventually produced a calibrated ground water flow model with consistent results, as reported in later sections and Appendix A, progress on the GEOFLOW model continued at the accelerated pace. Consequently, the findings reported herein represent GEOFLOW model results. The intent, however, is to proceed with the SWIFT III model for the long-term application to the sitewide RI/FS due to its additional features and preferred status.

The parallel modeling efforts provide several additional advantages. The first is that the independently produced results from the two models can serve as a direct quality assurance check of model performance. The GEOFLOW code has been thoroughly tested against more routinely used and widely-accepted ground water flow models (e.g., the USGS' McDonald and Harbaugh model [McDonald and Harbaugh, 1984]). Consequently, a close matching of results

from the GEOFLOW and SWIFT III models indirectly validates the SWIFT III code against standard flow models that did not satisfy the minimum criteria for use on the Fernald project. It should also be noted that the accelerated efforts on the GEOFLOW model greatly enhanced the calibration of the SWIFT III model and thus reduced the time and effort that would have been required if SWIFT III had been used alone.

3.2.2 Model Description

3.2.2.1 SWIFT III

The SWIFT model has been developed, maintained, and applied by Sandia National Laboratories. The U.S. Nuclear Regulatory Commission (NRC) sponsored this work under its high-level nuclear waste program. Between 1982 and 1985, the capability of SWIFT was expanded to include fractured media, a free water surface, and extended boundary conditions (SWIFT II). Since 1985, GeoTrans has further modified the code. The newest code is designated as SWIFT III. The three models, SWIFT, SWIFT II, and SWIFT III, are fully transient (with steady state options), three-dimensional, finite-difference codes which solve the coupled equations for flow and transport in geologic media.

Listed below are the significant benchmark versions of the code used in the development of SWIFT III.

CODE	DEVELOPER	SOURCE OF FUNDING	REFERENCES
SWIP	Intercomp	USGS	Intercomp, 1976
SWIPR	Intera	USGS	Intera, 1979
SWIFT	Intera	NRC	Dillon, et al., 1978 Cranwell and Reeves 1981 Finley and Reeves, 1982 Ward, et al., 1984

SWIFT II	GeoTrans	NRC	Reeves, et al., 1986a Reeves, et al., 1986b Reeves, et al., 1986c
SWIFT III	GeoTrans	GeoTrans	Ward, 1987b

The following paragraphs summarize the evolution of each version.

SWIP (Survey Waste Injection Program) - 1976
Under funding by the USGS, Intercomp developed a three-dimensional model for assessing the effects of deep well injection of wastes into saline aquifers. The code is a hybrid of hydrologic and petroleum technology. Capabilities include the coupled solution of equations for ground water flow, heat, and brine transport. Additional features include variable density, viscosity, well bore friction, and heat loss. The documentation report contains several verification and validation problems.

SWIPR (Survey Waste Injection Program Revised) - 1979
Under contract to the USGS, Intera, a former division of Intercomp, extended the SWIP model to include a free water surface, adsorption, and decay for contaminant transport. Both SWIP and SWIPR are designed for Control Data mainframes with Fortran 4. Also, both codes are inactive; that is, updates have not been issued.

SWIFT (Sandia Waste-Isolation Flow and Transport) - 1981
Under contract to the NRC, Intera extended the code to simulate transport of chains of radionuclides. In contrast to the brine equation, nuclides are assumed to be of trace quantities; that is, the concentration does not affect the fluid density. A steady-state flow option was included. The code is intended for performance assessment of high-level nuclear waste repositories. In support of the code, two documents were prepared. The SWIFT self-teaching curriculum (Finley and Reeves, 1982) includes 11 application problems. The verification and field comparison document (Ward, et al., 1984) details 11 more problems, demonstrating that the code compares favorably with analytical and field data. Data input instructions are given in Cranwell and Reeves(1981).

SWIFT II (Sandia Waste-Isolation Flow and Transport for Fractured Media) - 1986
Under contract to the NRC, GeoTrans, a former subsidiary of Intera, extended the SWIFT code to include fractured media, an enhanced free water surface routine, and extended boundary conditions. To provide the user with complete information, a document on the theory and implementation of the model was prepared (Reeves, et al., 1986a). The mathematical development is fully detailed in this 200-page report. Data input instructions are given in Reeves, et al., (1986b). In a supplemental document, eight problems and data sets were prepared for self-instruction (Reeves, et al., 1986c).

SWIFT III (Sandia Waste-Isolation Flow and Transport for Fractured Media) - 1987
GeoTrans modified the SWIFT II code to use the FORTRAN 77 language and to create a more computer general model. The SWIFT III model permits local one-dimensional subsystems to be attached, as desired, to the grid blocks comprising the global system. The local units may be used either to characterize the secondary porosity of a fractured media or to extend the boundaries of the system in a relatively inexpensive manner. Data input instructions are given in Ward (1987b).

The SWIFT III program consists of a main routine and about 70 supporting subroutines. The basic organization is focused upon the three global integration modules ITER, ITERS, and ITERC. Subroutine ITER solves the coupled partial differential equations for fluid flow, heat transport, and brine transport under transient conditions; ITERS integrates the flow and brine transport under transient conditions; and ITERC solves the coupled partial differential equations for transport of a radionuclide chain. All other routines provide support functions for the integration.

3.2.2.2 GEOFLOW

The computer program GEOFLOW is a finite element program capable of numerically simulating fluid flow and solute mass transport in a two-dimensional or quasi-three-dimensional ground water system. GEOFLOW was developed in 1976 and has been continually improved since then. The aquifer can be confined, semiconfined (leaky), or unconfined. Both transient and steady-state models of fluid flow and solute mass transport can be solved. In the fluid flow simulations, the aquifer can be nonhomogeneous, anisotropic,

and of nonuniform thickness. Multiple wells with time-dependent flow rates can also be specified in the model. In the solute mass transport simulations, geochemical reactions such as adsorption, acid neutralization, and radioactive decay can be incorporated by specifying proper characteristic coefficients.

The main routine of GEOFLOW contains two mutually dependent finite element subprograms; one is the flow model which solves the ground water flow equations, and the other is the solute mass transport model which solves the hydrodynamic dispersion equation. Results reported at user-specified times in the simulation period include piezometric heads, velocity and flow (discharge) vectors, concentrations, saturated thicknesses, and retardation factors for acid-front neutralization. To supplement the numerical results produced by GEOFLOW, a graphical postprocessing program permits the plotting of potentiometric contours, velocity vectors, and isopachs.

The GEOFLOW program has been verified extensively with the use of analytical solutions taken from the literature and developed by IT's staff and by the successful reproduction of predicted results with those of other established models such as the USGS' McDonald and Harbaugh model. Additionally, the program has been used in numerous projects to predict the flow and solute transport rates. A complete documentation of the GEOFLOW program and verification testing is provided in the GEOFLOW User's Manual (IT, 1986).

3.2.3 Conceptualization of the Model

IT utilized previously published work as well as a knowledge of the site to develop a conceptual design for the ground water model. The main objective of the model was to determine the relationships between the Great Miami River, the aquifers in the region, and major pumping centers. For this reason, the model area was chosen to cover the entire area of possible ground water influence by the various pumping centers (Figure 3.2-1). With reference to Figure 3.2-1, the grid north was oriented 30 degrees west of true north to orient the bedrock trough approximately west to east across the grid. This accommodated the establishment of boundary conditions parallel to the grid lines.

In the grid east-west direction, the grid extends from about two miles west of the FMPC to approximately one-half mile east of Ross. In the grid north-south direction, it extends from about three-quarters of a mile south of Shandon to about one-half mile south of New Baltimore.

At the extremities of the model area, where little detail is required, the finite difference grid size is 2,000 by 2,000 feet. The element size becomes gradually smaller inward and reaches a minimal size of 250 by 250 feet in the area covering the SOWC pumping wells and the meander loop on the Great Miami River. More details on the grid system, including figures showing the model grid for both GEOFLOW and SWIFT III, are provided in Appendix A.

For purposes of this study of the impacts of the FMPC discharge, the ground water flow model was developed for steady state conditions in two dimensions. For the sitewide RI/FS study, the model is being expanded into three dimensions and the geologic/hydrogeologic complexities in the vertical direction are being incorporated into discrete layers. Figure 3.2-2 presents a simplified cross section west to east across the model area. The hydrogeologic environments are the same as those described by Spieker, 1968a, and in Section 2.1 of this report. Hydrogeologic Environment I represents the eastern portion of the study area and incorporates the SOWC well field and the Great Miami River. Hydrogeologic Environment III represents the western portion of study area, overlain by till. The clay layer shown in the figure is a discontinuous layer, but acts to reduce vertical hydraulic conductivity in much of this portion of the study area. The three-dimensional model will eventually take into account the various geologic and hydrogeologic units shown in Figure 3.2-2, and is expected to consist of 3 to 6 vertical layers. The two-dimensional modeling efforts described in Appendix A did not account for these vertical nonhomogenities, but considered conditions and flow properties to be uniform throughout the entire thickness of the aquifer. Appendix A provides a discussion of the GEOFLOW and SWIFT III ground water flow model development and the subsequent aquifer analysis for this study.

3.2.4 Model Calibration

As described in Appendix A and Table 3.2.2, the initial input for the ground water flow models was developed from a careful interpretation and extrapolation of data from numerous sources. The initial model results reproduced the general ground water flow patterns throughout the study area; nevertheless, a refinement was achieved through a series of calibration runs using revised parameter values and/or modified boundary conditions (Figure 3.2-3). The model results are compatible with actual values recorded in April 1986 (Figure 2.1-13).

The performance criterion for model calibration focused on how well the predicted water surface elevations at specific grid locations matched field observations of water levels in wells at these same grid locations. As shown in Tables 3.2.3 and 3.2.4, the calibrated version of both the SWIFT III and GEOFLOW models achieved an excellent fit with field observations from April 1986. Note that only one calibration run was required for SWIFT III since the input data had already been refined via GEOFLOW runs. The successful calibration of both models using essentially the same input data base serves as a direct quality assurance check of model performance. Details of the respective calibration runs are given in Appendix A.

The total lack of anomalous predictions in Tables 3.2.3 and 3.2.4 indicates that the models are satisfactorily reproducing important flow processes and boundary conditions throughout the model area. The values assigned to geologic and hydraulic parameters in the final calibration run are all within the range of expected values. This not only increases the confidence in the predicted results, but would tend to minimize the chance that newly collected field data will force major revisions to the preliminary models.

3.2.5 Sensitivity Testing

The purpose of sensitivity testing was twofold. First, sensitivity testing was used to determine the possible errors introduced into the predictions by uncertainties in the critical input parameter values. Second, sensitivity testing provided a means for evaluating the range of results that would be expected due to seasonal or other predictable changes in important parameters. In either case, the outcome depends on how sensitive the model results are to changes in the parameters of interest.

To perform the sensitivity testing on the calibrated models, numerous runs were made. Each run corresponded to a change in one parameter value within the expected range of values for that parameter, while holding all other parameters constant. A summary of the range of values for sensitivity analysis are presented in Table 3.2.5. Due to the compressed schedule for this work, only the GEOFLOW model was available for extensive sensitivity testing (Appendix A). Similar results would be expected for the SWIFT III model.

The principal results of the sensitivity testing are summarized in Table 3.2.6. The parameters shown to most highly influence the model results are the rate of vertical leakage through the river bottom and the hydraulic conductivity of the aquifer. Since the aquifer hydraulic conductivity is relatively well understood, a decision was made to hold this parameter constant while varying the river bed leakage during subsequent sensitivity testing. Little quantitative information is currently available on the rate of vertical movement of water through the river bottom. This same parameter is also highly affected by seasonal flow and temperature fluctuations, localized changes in river bed sediment properties, and even external activities such as dredging. Any future field or analytical studies for the purposes of refining the model near the SOWC wells must prioritize a more detailed evaluation of the dynamics of flow through the river bottom.

3.2.6 Model Results

3.2.6.1 Zone of Influence (Capture Zone)

The principal objective of the ground water flow model was to establish whether the FMPC discharge to the Great Miami River is within the zone of influence of the SOWC collector wells and other pumping centers. The term "zone of influence" as used in relation to this study is best interpreted as a "capture zone" or the area from which any water originating from a point within that zone would eventually reach the pumping centers. Focusing on the SOWC collector wells, the limits of the capture zone were developed from a plot of velocity vectors generated by GEOFLOW, as shown in Figure 3.2-3 for the calibrated model case. By following consecutive velocity vectors, the final disposition of a water particle, and thus whether or not a given

location is within the capture zone, can be determined. As indicated by the "best fit" line in Figure 3.2-4, the zone of influence developed from the calibrated model would in fact encompass the FMPC discharge. However, the discharge can be observed in Figure 3.2-4 to lie near the southern, downgradient boundary of the zone of influence. It was therefore necessary to test the sensitivity of this result to the model parameters. Since the calibrated model was found to be most sensitive to the rate of river leakage, the predicted bounds on the zone of influence were evaluated by assigning values equal to 0.5 and 10 times the calibrated value to the river leakage factor (river leakage factors outside this range create unacceptable model calibration for collector well discharges of 18.4 MGD).

The resultant "range of model uncertainty" in terms of the zone of influence is also illustrated in Figure 3.2-4. The upper bound on the zone of influence corresponds to the lower leakage factor, since water would have to be drawn to the collector wells from a greater area within the aquifer to make up for the lower river recharge. The FMPC discharge point does, in fact, fall within the range of model uncertainty; therefore, it could lie outside the capture zone under conditions of high river recharge to the aquifer. If the river leakage factor increases toward the high value used in the model sensitivity analysis, then the edge of the zone of influence would shift to the east and take the FMPC effluent line out of the zone of influence of the SOWC wells. A similar uncertainty is associated with much of the FMPC property, including the waste storage area. Both of these areas lie within the predicted zone of model uncertainty.

The Albright and Wilson well and FMPC pumping well were included in the model as pumping centers. The flow vector plot for the model calibration run, shown in Figure 3.2-3, indicates no deflection towards these pumping centers from the direction of the FMPC effluent discharge point on the Great Miami River. This indicates that the radius of influence for the Albright and Wilson and FMPC pumping centers are not large enough to capture water infiltrating through the riverbed due to their relatively low pumping rates and large distance from the effluent discharge point. The FMPC discharge to the Great Miami River does not, therefore, affect water pumped from the Albright and Wilson and FMPC wells.

3.2.6.2 Impacts on the SOWC Collector Wells

The finding that the FMPC discharge could lie within the zone of influence of the SOWC collector wells dictated that the potential impacts of that hydraulic connection be evaluated. The long-term intent of the sitewide RI/FS is to apply a calibrated ground water solute transport model to help resolve such issues. To proceed with such a model under this study was considered premature, because of the high degree of uncertainty regarding other potentially important influences. These included, for example, the potential contribution of radionuclides from the FMPC via the ground water system, and the related need to establish and account for meaningful background concentrations in ground water.

Even without the support of a calibrated solute transport model, the results of this study were able to be used to quantify potential impacts on the SOWC wells at a level of accuracy that permitted the development of general conclusions. Figure 3.2-3 depicts each flow component of the model that contributes to the quality of ground water being pumped from the SOWC collector wells. Table 3.2.7 has been prepared from the GEOFLOW results to summarize the relative contribution from the river (Q_R in Figure 3.2-5) to the 18.4 MGD pumping rate of the SOWC wells (Q_D). The quantification of river leakage from the GEOFLOW model output was determined by extracting induced infiltration rates from each river element from the ground water model output. The values of all elements within the zone of influence were totalled and the percentage determined for both upstream and downstream river elements relative to the point of effluent discharge.

The calibrated model predicted that about 76 percent of the 18.4 MGD flow being pumped from the SOWC wells, or 14.0 MGD, is due to induced infiltration from the river along its full length within the zone of influence (Figure 3.2-4). Of this amount, approximately 8 percent is from river reaches downstream of the FMPC effluent discharge point. The amount and percentage of flow from upstream and downstream of the effluent pipe for three river leakage cases is given in Table 3.2.8. For the decreased river leakage factor case (0.175 day^{-1}), the river flow component downstream of the effluent pipe, Q_d, increased to about 11 percent (~2 MGD) and for the increased river leakage factor case (3.5 day^{-1}), Q_d decreased to about 5 percent (~1 MGD). Thus, only

a small percentage of the river segment contributing to the collector wells lies downstream from the FMPC discharge (Figure 3.2-4). The reason for this situation is that the strong regional gradient south of the SOWC collector wells is sufficient to maintain a net southern velocity component and the SOWC collector wells can more easily draw water from upgradient locations.

If the component of flow from the river upstream of the effluent pipe, at an average uranium concentration of 1.2 pCi/ℓ (background concentration in the river), and the component of flow from the river downstream of the effluent pipe, at an average uranium concentration of 1.3 pCi/ℓ (complete mix for the average flow case), directly mixes with "clean" ground water from the sand and gravel aquifer, the resultant complete mix value in the SOWC wells would be 0.968 pCi/ℓ for the calibrated ground water model case (Table 3.2.9, Case 2). This value is close to the observed values in SOWC Collector Well No. 1 (average for 12 samples over 1986 was 0.81 pCi/ℓ). The SOWC Collector Well No. 2 has exhibited lower concentrations (average for 12 samples over 1986 was 0.55 pCi/ℓ) but even this would be expected since this well is located on the outside of the river bend further upstream of the effluent discharge point and would tend to draw a lesser flow contribution from the downstream river reach. This is a remarkably close comparison, considering that the model is a two-dimensional simplification of the ground water flow system.

Assuming a uranium concentration of 1.3 pCi/ℓ complete with model for average flow conditions in the river below the point of discharge, the simplified model gives an average uranium concentration of 0.968 pCi/ℓ in the SOWC wells as described above (Table 3.2.9, Case 2). Uranium concentrations in ground water pumped from the SOWC wells (C_w) were also calculated using a greater range of river flow and uranium values (C_r, Q_d, and Q_u) based on the surface water modeling sensitivity runs (Table 3.2.9). Case 1 in Table 3.2.9 gives a uranium concentration of 0.960 pCi/ℓ in the ground water extracted from SOWC collector wells with no uranium from the effluent pipeline (C_w). The incremental contribution from the FMPC discharge, therefore, is 0.008 pCi/ℓ or only a 0.8 percent increase over the value that would result if only background river water had contributed to the SOWC wells. Using Q_d and C_r values five times greater than those best estimated, the uranium concentration in the

SOWC wells was increased from 0.960 to 3.13 pCi/ℓ. The U.S. EPA has proposed a drinking water standard of 30 pCi/ℓ for uranium based on allowing the same level of risk for uranium as for radium (U.S. EPA, 1987). Consequently, the modeling and data analysis conducted under this study indicates that it is highly unlikely that uranium discharged from the FMPC effluent line into the Great Miami River would increase ground water uranium concentrations at the SOWC collector wells to the proposed standard.

Even though this simplified view of potential impacts may not be fully representative of actual field conditions, it provides an upper bound on the effects of the river uranium concentrations on the ground water quality at the SOWC wells. Any retardation or attenuation of uranium in the river sediments and subsurface environment will directly reduce the predicted impact. In addition, any contribution to the uranium concentrations observed in the SOWC wells that is coming from natural, background conditions or other sources such as the FMPC would require a reduction in the river contribution in order to maintain a mass balance.

The background concentration, even at low levels, would likely have a much greater impact than the FMPC effluent discharge when evaluating a mass balance at the SOWC wells. A statistical analysis of the March 1986 ground water sampling results was performed to estimate the "background" uranium concentration. Wells 1NH, State 8, State 10, State 16, H-113, 12-3, and 2-CW were selected as being beyond the potential influence of the site and possibly representative of background uranium concentrations.

The frequency distribution of uranium concentrations observed was distinctly bimodal. Wells State 8, State 10, and H-113 formed one cluster, while State 16, 1NH, and 12-3 formed a second. This bimodality is probably attributable to two different geologic material source areas within the hydrogeologic regime or geologic matrix. One source area is from the northeast beyond Ross and the other is from the northwest beyond Shandon. The first group of wells, State 8, State 10, and H-113, produce water containing very low concentrations of uranium (0.04 to 0.12 pCi/ℓ) which is in the range of the analytical detection limits. The second group of wells, 1NH, 12-3, and State 16, produce water containing nearly three times as much uranium (0.17 to 0.35 pCi/ℓ) as the first group.

The Student's t-test was used to evaluate the difference in average uranium concentration found in the two groups. The northwest quadrant wells (State 8, State 10, and H-113) contain significantly less uranium than the southwest quadrant wells (northwest group mean = 0.07 pCi/ℓ; southwest group mean = 0.233 pCi/ℓ). The corresponding t-statistic was -4.84, indicating that the probability that this difference is due to chance is less than 2 percent at a 95 percent confidence level.

In light of these findings, the average uranium concentration for the southwest quadrant could serve as an estimate of the background concentration of uranium. This value of 0.233 pCi/ℓ is only a point estimate of the background uranium concentration. Actual background uranium concentrations are subject to seasonal and analytical variability. Nevertheless, the magnitude of this value far exceeds the 0.008 pCi/ℓ incremental impact caused by the FMPC discharge for the calibrated average flow case.

4.0 FIELD PROGRAM

4.1 INTRODUCTION

Sampling of the Great Miami River water and bottom sediments was performed from September 11 through 14, 1987 to accomplish the following objectives:

- To establish background (upstream) levels of dissolved uranium in the river water
- To assess the rate of dilution downstream from the FMPC outfall of dissolved uranium discharged to the river
- To provide qualitative estimates of the hydraulic properties of the stream bed as they relate to induced infiltration of the river water (hydraulic conductivity) and channel roughness (Manning coefficient, n)

To accomplish the above-stated objectives, the following tasks were performed, each of which is described further in the following sections:

- River water sampling for uranium concentration downstream from the Ross bridge to about one mile below the FMPC outfall, including background stations
- Flow velocity measurement at river sampling locations
- River stage measurement at the "Ross Bridge" at Route 126, 1.3 miles upstream, and at the bridge at New Baltimore, three miles downstream from the FMPC outfall
- Channel depth profiling at the Ross Bridge (Location 11, Figure 4.1-1) and approximately 100 yards downstream from the FMPC outfall (Location 6, Figure 4.1-1) and channel observations at other selected river locations
- River bottom sediment sampling for grain-size analysis and visual descriptions of river-reach hydraulic characteristics.
- Stream channel observations to assess the applicability of using historical data and reports

The surface water and sediment sampling locations referred to in this section are shown in Figure 4.1-1 and described in Table 4.1.1. Sampling of river bottom sediments and surface water were in accordance with applicable sections of the Fernald RI/FS Quality Assurance Project Plan (QAPP). Sample collection documentation, chain-of-custody, decontamination, and health and safety procedures established for the RI/FS were followed. Laboratory procedures outlined in the IT Radiological Sciences Laboratory (IT/RSL) Quality Assurance (QA) manual were followed for sample analysis and reporting.

4.2 RIVER BED SEDIMENT PROPERTIES

In order to provide refined estimates of the hydraulic properties of the stream bed as they relate to the interaction between the river and the aquifer, river bottom sediment sampling was performed for grain-size analysis. The river bottom sediment sampling was performed at three locations upstream from the FMPC outfall and at three locations downstream (Figure 4.1-1).

River bottom sediment samples were obtained using a Wildco-Eckman bottom dredge. The dredge consists of an open-ended metal box, one cubic foot in capacity, with spring-operated jaws which close over the bottom. A messenger weight, dropped along the rope from which the dredge was suspended, was used to trigger the jaws.

Three samples were obtained from each bottom sediment sampling location, which were composited by the laboratory for grain-size analysis. Samples were obtained from the same general vicinities as river water samples having corresponding location numbers (Figure 4.1-1 and Table 4.1.1). Individual sampling locations were located to obtain representative coverage of the bottom sediments at each sampling site. Samples were obtained from relatively calm portions of the channel that could be waded. This approach was dictated by the difficulties encountered in operating the dredge in strong current and the need to make certain that fine-grained sediment was not washed from the sample. The loss of fine-grained material would bias the grain size analysis and result in estimating higher hydraulic conductivities for the stream bed than are actually present. Bottom sediment particles greater than two inches in diameter were excluded from samples sent for grain-size analysis.

Samples were composited in the laboratory, except for samples from Location 2, which were considered too dissimilar to composite. Samples were analyzed for grain-size distribution using sieve analysis down to a No. 200 U.S. Standard sieve. Grain-size analysis of sediment samples was performed by the IT laboratory in Export, Pennsylvania. The laboratory results are presented in Appendix B.

4.3 RIVER CHANNEL CHARACTERISTICS

Channel depth profiling at the Ross Bridge (Location 11) and 100 yards downstream from the FMPC outfall (Location 6) were performed using a weighted tape (Figures 4.3-1 and 4.3-2, respectively). Channel observations at these and other selected river locations were performed to assess the general stability of the channel and the applicability of using historical data and reports.

Water velocities were measured on September 11 through 12, 1987 using a Marsh-McBirney velocity meter. The Marsh-McBirney meter determines velocity in ft/s at a discrete depth. A probe, with an open orifice on the downstream side, is lowered to the desired depth. The current velocity is determined from the pressure drop created at the orifice.

Velocity measurements were taken at the center of the channel at Locations 1 through 10 (Figure 4.1-1). Problems with the flow meter precluded measurements at Locations 5 and 6. Table 4.3.1 gives a summary of the measured values. At Location 11, the Ross Bridge, several measurements were taken between the various bridge supports (Table 4.3.2) and an average velocity was determined for the location. A total discharge of 394.5 ft^3/s was calculated for the Great Miami River at the Ross Bridge on September 11, 1987, in accordance with the procedures described in Buchanan and Somers (1969) (Table 4.3.2).

4.4 RIVER WATER QUALITY STUDIES

4.4.1 Sampling Program

River water samples were obtained at 11 locations during September 11 through 14, 1987. The samples were obtained using a Kemmerer discrete depth sampler which consists of an open cylinder with spring-loaded end caps. To obtain a sample, the sampler is lowered to the desired sampling depth. The cylinder ends are closed by releasing a weight which falls along the rope from which the sampler is suspended. The weight triggers a spring-loaded mechanism closing the ends of the sampler. The sampler is then raised and a water sample is removed through a port on the bottom of the device.

Background river water sampling was performed at the Ross Bridge. Samples were obtained at the centers of five cross-sectional subdivisions having approximately equal discharge rates (Figure 4.3-1). The sampling subdivisions were defined by first determining the total river discharge in increments across the channel (Table 4.3.2). The spacing width of each of five sampling subdivisions was weighted by discharge so that each subsample represented approximately 20 percent of the flow. The spacing of each sampling location was determined in the following manner:

- The channel width was divided into 21 subsections, each approximately 12-1/2 feet in width. The vertical guard rail supports on the bridge overhead were used for reference.
- At the center of each subsection, the channel depth was measured using a graduated rod.
- At the center of each subsection, the current velocity was measured at six-tenths the channel depth.
- For each subsection, the discharge through the section was determined from the product of the section width, depth, and current velocity.
- The total discharge of the river at the Ross Bridge was determined by summing the discharges of the individual subsections.
- Five water sampling subdivisions (A through E) were selected by combining subsections used for discharge measurements such that each sampling subdivision represented approximately 20 percent of the total river discharge.
- The center of each of the five sampling subdivisions was designated for use as the sampling location.

Three sampling traverses of the channel were performed. Samples were obtained from the five sampling subdivisions during each traverse and were mixed in the field to generate three replicate composite samples for laboratory analysis.

River water samples also were collected at four locations over the 1.3-mile distance between the Ross Bridge and the FMPC outfall (Locations 7, 8, 9, and 10). Samples were obtained at single locations from the middle of the main portion of the channel at six-tenths the depth. Two replicate samples were obtained at each location.

River water sampling was also completed approximately 100 yards downstream from the FMPC outfall at Location 6. The program consisted of discrete sampling at six-tenths the channel depth at five locations at equal distances across the channel width. Two sampling traverses of the channel width were performed to provide duplicate samples. The spacing of each sampling location was determined by measuring the total channel width, dividing the width into sections of equal width, and determining the centers of the sections for use as the sampling locations. The channel cross section downstream from the outfall, with sampling locations and depths, is shown in Figure 4.3-2.

River water samples were collected at five additional locations over the one-mile distance downstream from the FMPC outfall (Locations 1, 2, 3, 4, and 5). Samples were obtained at single locations from the middle of the main portion of the channel at six-tenths the depth. Two replicate samples were obtained at each location.

4.4.2 Field and Analytical Procedures

River water samples were obtained using a discrete-depth sampler in accordance with the sample handling guidelines presented in "Methods for Determination of Radioactive Substances in Water and Fluvial Sediments" (Thatcher, et al., 1977), and "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases" (Brown, et. al, 1970). River water sampling was conducted in a downstream-to-upstream direction to preclude any problems associated with disturbance of the sediments.

River water samples were tested for gross alpha and gross beta activity, total dissolved uranium, uranium isotopes, cesium-137, ruthenium-106, radium-226, radium-228, and strontium-90. Only total dissolved uranium concentrations were used in the river water quality evaluations. The dissolved fraction is defined as that fraction which passes through a filter having a pore size of 0.45 micron. Field preparation of the water samples obtained at the Ross Bridge included coarse prefiltering through a 0.7-micron filter. This was done prior to the generation of composite samples to remove the majority of suspended solids. Laboratory preparation of all water samples collected included filtering through a 0.45 micron filter and the addition of nitric

acid to prevent subsequent precipitation and adsorption of dissolved constituents (U.S. Department of the Interior, 1977). Water quality laboratory testing was performed by IT/RSL in Oak Ridge, Tennessee and the results are given in Appendix B.

4.5 FINDINGS OF FIELD PROGRAM

4.5.1 Riverbed Sediment Sampling

Bottom sediment descriptions for each sediment sampling location are listed in Table 4.5.1. Locations at which fine-grained material are present correspond to relatively long, still reaches of the river. Generally, the sediments are coarse and can be described as sands or gravels. Some silt was observed in the composite for Location 9. Even though care was taken to obtain representative samples, some of the fine-grained material may have washed out of the samples during sample collection. In general, the sediments are more coarse downstream from the FMPC outfall when compared to upstream sediments. Appendix B contains the grain-size analysis for the samples collected.

4.5.2 River Channel Characteristics

Measured current velocities and channel depths are listed in Table 4.3.1. Observed velocities ranged from 0.45 to 2.10 ft/s in main portions of the channel. The highest current velocity was observed at Location 2, in a constricted channel reach immediately downstream from a set of rapids. The lowest value given in Table 4.3.1, at Location 11, was calculated as a mean of velocity measurements taken across the channel at that location.

Three sets of rapids were observed downstream from the FMPC outfall: immediately upstream from Location 2, immediately upstream from Location 3, and at Location 5. One set of rapids was also encountered between the outfall and the Ross bridge, approximately 500 feet downstream from Location 9. At each section of rapids, current velocities were high, and the bottom material was rocky and relatively free of fine-grained sediments. Channel depths in rapid sections ranged from inches to several feet. The drop in water surface levels through sections of rapids was estimated to range from one to two feet. Directly opposite the FMPC outfall, the current was observed to be swift and turbulent, but relatively deep with no rapids.

Low flow conditions were in existence at the time the field program was implemented. The discharge of the river at the Ross Bridge was calculated as approximately 400 ft^3/s. The probable error in discharge measurement is expected to be plus or minus 15 percent. The average flow recorded at the USGS gaging station at Hamilton over the days of sampling was 510 ft^3/s or 27 percent higher than calculated. One possible source of error in discharge measurement was that a channel obstruction in the form of a tree stump hung on a gravel bar near the left bank and caused drifting of the boat used to take stream measurements. Additionally, some channel subsections used in measuring the discharge represented greater than 5 percent of the total discharge, as specified by Buchanan and Somers (1969). The degree of accuracy obtained for the discharge measurements was acceptable since the values derived were used only to estimate flows during the sampling period and to determine the uniformity of flow across the channel.

A qualitative assessment of channel stability is given in Table 4.5.2. Major deviations from previously documented (Dove, 1961) channel configurations are:

- There is presently a prominent gravel bar in the channel center beginning approximately 250 feet downstream from the FMPC outfall and extending to approximately 200 feet upstream from Location 3
- Channel depths are presently greater in some upstream reaches than previously recorded

In general, however, the position and depth of the main channel have remained relatively stable. Figures 4.5-1 and 4.5-2 compare recently measured cross-sectional channel configurations at the Ross Bridge and near the FMPC outfall with configurations developed in 1961 (Dove, 1961).

4.5.3 River Water Quality

The analytical results of river water quality sampling are given in Appendix B and a summary is provided in Table 4.4.1 for total uranium. Location 11 was chosen to represent background concentration. The mean for the sample location, 1.2 pCi/ℓ, is consistent with previous background measurements. Upstream of the effluent outfall (Locations 7 through 11), the mean concentration of total uranium varies from 1.0 to 1.8 pCi/ℓ. Downstream of the effluent outfall (Locations 1 through 6), the mean concentration of total

uranium varies from 1.5 to 3.0 pCi/ℓ for all samples taken. At Location 6, the concentration of uranium is greatest towards the west bank (3.0 pCi/ℓ at Station A), and falls off quickly towards the east bank (1.8 pCi/ℓ at Stations C and D and 2.0 pCi/ℓ at Station E). The results of the complete mix model for the field data give a value of 2.4 pCi/ℓ, which is close to the values observed at Locations 5, 3, and 1, downstream of the effluent outfall.

4.6 IMPLICATIONS FOR IMPACT OF EFFLUENT FROM FMPC OUTFALL

Based on field observations, the effluent from the FMPC outfall does not appear to mix extensively with river water in the transverse direction immediately in the vicinity of the source. However, the turbulent nature of flow and bubbling observed at the effluent outfall would indicate mixing in the vertical direction. The effluent would be expected to remain relatively close to the west bank of the river towards the outside of the oxbow bend. The probability of this occurring is increased by the presence of an eddy pool immediately downstream from the outfall, which turns water caught within the eddy toward the shore.

A gravel bar presently exists downstream from the FMPC, and splits the channel into two distinct channels during periods of low flow. It appears that the majority of the river flow, and thus the effluent, stays in the western channel. During periods of high flow, it is anticipated that this effect would be lessened due to overtopping of the gravel bar by higher water levels and an increased amount of turbulence.

These field observations are generally consistent with conditions assumed in the surface water modeling studies. Assumptions and results of the river dispersion model are still considered to be conservative by underestimating the amount of initial transverse mixing. Also, the presence of the flow divide around the gravel bar does not affect the results. If most effluent flow stays within the western channel, then the complete mix scenario could also remain as an acceptable approximation. Recalling that the induced infiltration from the river preferentially occurs along the eastern side, the local splitting of flow for lower flow conditions could, in fact, yield a smaller net contribution of uranium to the SOWC wells.

5.0 CONCLUSIONS AND RECOMMENDATIONS

As stated in Chapter 1.0, the purpose of this report is to present the findings of a hydrogeologic study of the FMPC discharge and its relationship to the SOWC collector wells and other pumping centers and to recommend a future course of action based on the results. The results of the data review and modeling studies reported in Chapters 2.0 and 3.0 allow the following general conclusions to be made:

1. The discharge from the FMPC effluent pipeline likely occurs within a portion of the Great Miami River that contributes flow, via induced infiltration, to the SOWC collector wells. The relative contribution of flow to the SOWC wells from the river downstream from the discharge is, however, a small fraction of the flow contributed from upstream reaches of the river. The reasons are that the SOWC wells are located upstream from the discharge, and a strong regional gradient of ground water flow to the south (i.e., downstream) exists as the width of the buried valley aquifer narrows in this area. The sensitivity testing of the model indicates that the extent of the zone of influence of the SOWC wells is variable, depending on the river leakage value given. The FMPC discharge could actually be outside of the capture zone of the SOWC wells if the river infiltration rate is greater than assumed. If the river leakage factor increases towards the high value used in the model sensitivity analysis, then the edge of the zone of influence would shift to the east and take the FMPC effluent line out of the zone of influence of the SOWC wells.

2. Even if the FMPC discharge is within the zone of influence of the SOWC wells, the incremental impact of the effluent on the water quality of the pumped water lies within the range of variability of previous observations and may not be detected under average conditions. Therefore, no observable improvements in water quality would result in the SOWC wells from eliminating the effluent effects (e.g., by relocating the pipeline). The principal reasons for this nondetectable incremental impact are the small percentage of total uranium mass flux contributed by the effluent discharge to the river, and the aforementioned small percentage of the total induced river flow that originates downstream from the discharge pipeline.

3. The radius of influence for the Albright and Wilson and FMPC pumping centers are not large enough to capture water infiltrating through the riverbed near the FMPC discharge due to their relatively low pumping rates and large distance from the effluent discharge point. Consequently, the FMPC discharge to the Great Miami River does not affect water pumped from the Albright and Wilson and FMPC wells.

4. A mass balance of the sources of uranium observed in the SOWC collector wells was not performed. The model results indicate a potential eastward component of flow from the FMPC Production Area and waste storage units to the SOWC wells. This finding is consistent with previously reported interpretations of regional data on ground water elevations and gradients. However, both the Production Area and the waste storage units are within the area of modeling uncertainty in relation to the capture zone of the SOWC wells, and will be studied further under the sitewide RI/FS. The background concentration of uranium in ground water, even at low levels, also remains an unresolved issue that may be significant when quantifying a mass balance at the SOWC wells.

Based on the results of this study and the conclusions that could be drawn, no further studies specifically addressing the impact of the FMPC discharge on the SOWC collector wells are considered necessary. These would include, for example, an extension of the analysis to include parameters other than uranium or the conduct of tracer studies to evaluate the local mixing patterns near the effluent discharge to the Great Miami River. The types of criteria evaluated in deciding whether other constituents required consideration included: the mass or concentration in the effluent, river, or well of concern; the migration potential of the constituent (i.e., solubility, retardation factor, etc.); and the associated toxicological or radiological significance. As discussed in Section 2.4, the choice of total uranium as the only parameter of interest for this study appeared justified based on previously collected data. The decision not to extend the impact study to other radionuclides remains appropriate in light of the results of this study.

Any attempt to quantify the impacts of inorganic parameters monitored under the NPDES program could introduce unresolvable technical complexities. For example, the modeling of nitrates will force more consideration of other sources and background conditions (in the river and wells) due to the extensive agricultural activity and other possible industrial discharges. The chemical transformations of nitrogen compounds would also have to be considered. Residual chlorine would require consideration of the gaseous phase and transfer dynamics at the air-water interface. These complexities, in addition to the fact that the discharge is currently regulated for these parameters, provide little justification to include any NPDES parameters in the impact analysis at this time.

The SOWC collector wells, the river, and the regional ground water flow system assessed in this study are of utmost importance to the overall issues being addressed in the sitewide RI/FS and other related studies. The results of the zone of influence modeling studies have been of value in expanding the current understanding of these sitewide and regional issues. In the following paragraphs, additional investigations are described that could address the remaining uncertainties as part of the sitewide RI/FS.

Although the conclusions discussed above can be justified within the context of the modeling results obtained to date, extension of the SWIFT III model is being made for the resolution of the mass balance at the SOWC collector wells and other issues important to the RI/FS. For the overall RI/FS, SWIFT III modeling is proceeding using a two-phased approach specifically structured to provide the best reflection of the existing hydrogeologic environment and at the same time maintain a high level of quality assurance. The first phase emphasizes three-dimensional ground water flow, and the second phase couples solute transport to flow. The three-dimensional model will permit a refinement of the local river effects when pumping from depth, and could influence the predicted extent of the capture zone since the direction of small, vertically integrated velocity vectors near the currently predicted boundaries of the capture zone could be altered once a third dimension is considered. The solute transport model will address contaminant dispersion as well as contaminant retardation. The latter is particularly important due to its influence on the rate of plume migration, which typically lags the velocity of ground water flow.

The parallel calibration of both the GEOFLOW and SWIFT III models has sufficiently established the reliability of the results for the model components applied in this study. However, the verification completed to date on the SWIFT III model is not of a complexity and scope consistent with the projected level of modeling to be performed for the RI/FS. The future use of additional capabilities of SWIFT III is being verified, as necessary, as part of the RI/FS. The continued parallel use of GEOFLOW represents one approach. A comparison of SWIFT III results with the three-dimensional flow component of the USGS' McDonald and Harbaugh model is also being made for verification purposes, due to the widespread use and acceptability of the

latter model. SWIFT III is also being verified with respect to analytical models.

The regional issues to be addressed in the RI/FS will require the establishment of representative background concentrations for uranium in ground water. The available data base indicates that natural variations in uranium concentration occur in the vicinity of the site, possibly the result of different geologic settings. The regional influences of major pumping systems on ground water flow patterns, and thus contaminant transport patterns, add complexity to the issue of background concentration. The resolution of this issue is a proposed objective of the sitewide remedial investigation.

The model sensitivity runs performed to date indicate a high degree of sensitivity to the rate of induced infiltration from the river. A representative value for the leakage factor has not yet been directly measured in the field in the local study area; however, the value of river infiltration predicted by the calibrated model falls within the range of previously published values of this parameter within the general vicinity of the site. Further, the results of the model have established a range of possible values of leakage factors beyond which the predicted results lose credibility in relation to field observations. The overall conclusions of this study do not change for any assumed leakage factor within this range. It is proposed, however, that a direct field determination of the leakage factor be completed as part of the sitewide RI/FS due to the possible sensitivities of the overall extent of the capture zone on this parameter. If the field measurements fall significantly outside of the currently assumed range, the results and conclusions of this study will be reevaluated.

The sediment sampling and grain-size analysis program described in Chapter 4.0 will be of limited value in quantifying the leakage factor in the river since only the top several inches of the active sediment layer has been collected and tested. It is recommended that a more extensive program be conducted that could involve the installation of piezometers in the river bed with subsequent slug testing. The program should be repeated at multiple locations to develop representative values and during different seasons to establish a relationship with water depth and water temperature. An alternative to the above program

would be to conduct a series of river flow measurements in the "Big Bend" reach to directly quantify the amount of induced leakage. This scope of work has not yet been approved under the current sitewide RI/FS.

The calibration of the comprehensive ground water model for areas to the east of the FMPC and in the vicinity of the SOWC wells will be enhanced by the proposed installation of additional monitoring wells in these areas. The principal purpose in installing these wells will be to provide additional ground water elevation data to the west and south of the SOWC wells since these directions are the most important to any investigation of the FMPC and the effluent line. The wells can also serve as additional ground water quality monitoring points at off-site locations.

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TABLES

FIGURES

TABLES

TABLE 2.1.1

SUMMARY OF SELECTED MONITORING WELL DATA

WELL I.D.	STATE PLANE COORDINATES(a) E	N	GROUND SURFACE ELEVATION (feet MSL)	SCREEN ELEVATION TOP-BOTTOM (feet MSL)	MONITORED ZONE	SOURCE OF DATA(b)	RATIONALE FOR SELECTION
River	1393780	481730	555.84	-	-	MCD	-
Coll-1	1388610	479530	555.48	NA	Sand & Gravel	MCD	Pumping well - not used to construct ground water contour maps
Coll-2	1388520	481400	535.14	NA	Sand & Gravel	MCD	Pumping well - not used to construct ground water contour maps
SW-4A	1387625	479375	536.38	NA	Sand & Gravel	MCD	Geographical location indicates well is completed in sand and gravel aquifer
SW-3A	1388150	479300	535.98	NA	Sand & Gravel	MCD	Geographical location indicates well is completed in sand and gravel aquifer
R-7	1388650	480250	535.10	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
SW-1	1390860	478810	540.61	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
K-2N	1388670	481202	538.75	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
K-1	1388830	480830	540.34	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
K-4	1389860	481090	542.01	NA	Sand & Gravel	MCD	Geographical location indicates well is completed in sand & gravel aquifer
EL-1	1390170	482100	536.01	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
K-3	1388380	481680	541.01	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
B-1	1387034	480633	540.80	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
B-2	1386136	481180	538.30	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
B-3	1385018	481514	535.50	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
B-4	1388045	480443	539.30	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
IT-4	1384984	481528	536.64	502-492	Upper Sand & Gravel	IT	Monitors sand & gravel aquifer
H-127	1385433	479115	540.80	478-476	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
O-2W	1384500	477800	534.85	404	Sand & Gravel	MCD	Monitors sand & gravel aquifer
O-2E	1384520	477800	534.09	492	Sand & Gravel	MCD	Monitors sand & gravel aquifer
BLK	1383957	476918	574.20	494-489	Sand & Gravel	ODNR/IT	Monitors sand & gravel aquifer
BHMHP-D	1384467	475625	575.50	475-465	Sand & Gravel	ODNR/IT	Monitors sand & gravel aquifer
O-3	1388090	485250	554.10	NA	Sand & Gravel	MCD	Geographical location indicates well is completed in sand & gravel aquifer
WW-1	1391730	485970	551.23	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
LB-1	1392490	483630	554.01	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
WK-1	1393890	482660	543.05	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
ER-1	1392220	480970	535.75	NA	Sand & Gravel	MCD	Monitors sand & gravel aquifer
IT-6	1380706	476416	574.07	498-488	Upper Sand & Gravel	IT	Monitors sand & gravel aquifer
STATE 16	1372807	479621	610.40	490-485	Sand & Gravel	ODNR/IT	Monitors sand & gravel aquifer
12-S	1373903	474575	611.70	507-505	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
12-7A	1373785	473520	604.10	NA	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
16-1-S	1385401	467800	521.70	NA	Sand & Gravel	IT/GS	Elevation of base of well (490 ft. msl) is in sand & gravel aquifer
H-129	1383418	469993	539.10	496-489	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
H-124	1381284	469780	519.20	463-459	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
H-128	1379929	469765	516.00	NA	Sand & Gravel	IT/GS	Elevation of base of well (497 ft. msl) is in sand & gravel aquifer
H-126	1382261	471596	531.70	NA	Sand & Gravel	IT/GS	Elevation of base of well (509 ft. msl) is in sand & gravel aquifer
DE	1382241	473619	600.10	NA	Sand & Gravel	IT/GS	Elevation of base of well (502 ft. msl) is in sand & gravel aquifer
RE	1380243	472495	525.69	NA	Sand & Gravel	IT/GS	Geographical location indicates well is completed in sand & gravel aquifer
H-115	1379932	472521	528.50	448.5-432.5	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
H-122	1378810	474290	540.00	NA	Sand & Gravel	IT/GS	Elevation of base of well (456 ft. msl) is in sand & gravel aquifer
7-8A	1379607	474344	529.30	NA	Upper Sand & Gravel	IT/GS	Elevation of base of well (482 ft. msl) is in upper sand & gravel aquifer
D-S	1379666	474775	546.70	NA	Sand & Gravel	IT/GS	Monitors sand & gravel aquifer
HK-D	1380047	475864	578.90	403-393	Lower Sand & Gravel	ODNR/IT	Monitors sand & gravel aquifer
FMPC-15-S	1380201	476149	577.70	498-493	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
BPH	1377655	477575	576.60	491-487	Upper Sand & Gravel	ODNR/IT	Monitors upper sand & gravel aquifer
H-105	1378612	476121	570.80	NA	Upper Sand & Gravel	IT/GS	Monitors upper sand & gravel aquifer
FMPC-17-D	1379163	476265	534.20	470-465	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-18-S	1378660	479300	571.31	517-512	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-9	1378050	479570	555.40	457-452	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
IT-5	1382029	476752	594.22	499-489	Upper Sand & Gravel	IT	Monitors upper sand & gravel aquifer
FMPC-14-D	1379579	476805	533.90	491-486	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-16-S	1378900	477700	540.50	510-503	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
IT-1	1381891	478683	577.93	500-490	Upper Sand & Gravel	IT	Monitors upper sand & gravel aquifer
FMPC-P3	1379901	479820	579.34	390-369	Lower Sand & Gravel	FMPC	Pumping well - not used to construct ground water contour maps
IT-2	1382997	479761	593.22	501-491	Upper Sand & Gravel	IT	Monitors upper sand & gravel aquifer
IT-3	1383292	481657	609.70	503-493	Upper Sand & Gravel	IT	Monitors upper sand & gravel aquifer
FMPC-13-S	1382100	481700	588.73	515-510	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-10	1379840	481730	586.56	480-460	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-3	1379000	481870	558.80	474-454	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
FMPC-11	1377958	482271	583.58	510-455	Upper Sand & Gravel	FMPC	Monitors upper sand & gravel aquifer
RB	1376759	485834	579.90	NA	Sand & Gravel	IT	Monitors sand & gravel (IT data)
PALLET CO	1376516	482407	579.20	509-505	Upper Sand & Gravel	ODNR/IT	Monitors upper sand & gravel aquifer

(a) The coordinates are shown in Figure 2.1-1.

(b) FMPC = Feed Materials Production Center

MCD = Miami Conservancy District

GS = U.S. Geological Survey

IT = IT Corporation

ODNR = Ohio Department of Natural Resources

TABLE 2.1.2

SUMMARY OF GROUND WATER LEVEL FLUCTUATIONS IN SELECTED WELLS

WELL NO.[a]	MAXIMUM[b] WATER LEVEL	DATE OF OBSERVATION	MINIMUM WATER LEVEL	DATE OF OBSERVATION	MEAN WATER LEVEL	RANGE	NO. OF OBSERVATIONS[c]
Coll. 1	506.27	01/31/86	475.27	8/11/86	492.90	31.00	19
Coll. 2	512.37	04/29/87	497.54	9/26/86	504.91	14.83	19
SW-1S	515.39	10/02/87	505.25	9/26/86	510.68	10.14	19
SW-2S	507.05	10/02/87	482.85	8/11/86	497.34	24.20	19
ER-1	525.89	03/27/86	519.76	3/06/87	522.38	6.13	19
O-2E	522.44	03/27/86	518.26	9/26/86	519.93	4.18	19
BU-13	528.71	03/15/86	521.18	9/11/86	524.14	7.53	385

[a]Refer to Figure 2.1-1 for well locations.

[b]All elevations are in feet above mean sea level.

[c]The data base was compiled by Miami Conservancy District and covers the period from January 1, 1986 through September 1, 1987.

TABLE 2.2.1

A SUMMARY OF VALUES CALCULATED FROM HEC2 MODEL FOR THE SITE REACH OF THE GREAT MIAMI RIVER, USED AS A BASIS FOR INPUT TO STRIP1B MODEL

1. High Flow Conditions (10-year flood)

   River Discharge,[a] Q = 81,455 ft^3/s

SECTION	F	G	H	I	J	MEAN OF FIVE SECTIONS
Velocity of flow, V (ft/s)	3.94	3.56	3.71	5.06	6.95	4.64
Water surface elevation (ft M.S.L.)	541.31	542.69	543.39	543.79	544.14	-
River width, W (ft)	3,600	5,410	6,335	5,686	5,166	5,239
River depth, H (ft)	11.84	9.38	8.81	5.74	5.40	8.2
Hydraulic radius (ft)[b]	11.80	9.36	8.80	4.80	6.33	8.22

2. Low Flow Conditions (7-day, 10-year low flow)

   River Discharge,[c] Q = 280 ft^3/s

SECTION	F	G	H	I	J	MEAN OF FIVE SECTIONS
Velocity of flow, V (ft/s)	0.65	1.52	4.97[d]	0.84	0.22	0.81
Water surface elevation (ft M.S.L.)	511.70	513.04	518.08	520.17	520.19	-
River width, W (ft)	188	39[e]	80	262	276	202
River depth, H (ft)	3.00	6.89	0.75	1.47	3.6	3.1
Hydraulic radius (ft)[b]	2.33	4.37	0.71[d]	1.30	4.76	3.19

See footnotes at end of table.

TABLE 2.2.1
(Continued)

3. Average Flow Conditions (Mean flow for period of record)
River Discharge,[c] Q = 3,460 ft^3/s

SECTION	F	G	H	I	J	MEAN OF FIVE SECTIONS
Velocity of flow, V (ft/s)	1.77	2.16	3.08	2.19	1.39	2.12
Water surface elevation (ft M.S.L.)	517.30	520.06	522.78	524.26	524.48	-
River width, W (ft)	306	420	322	365	312	345
River depth, H (ft)	6.48	4.19	4.03	4.55	7.92	5.4
Hydraulic radius (ft)[b]	6.49	3.82	3.55	4.41	8.08	5.27

4. Field Conditions (September 11 through 14, 1987)
River Discharge,[c] Q = 534 ft^3/s

SECTION	F	G	H	I	J	MEAN OF FIVE SECTIONS
Velocity of flow, V (ft/s)	0.79	1.81	3.20	1.06	0.37	1.45[f]
Water surface elevation (ft M.S.L.)	512.78	514.83	519.14	520.82	520.87	-
River width, W (ft)	256	47[e]	119	273	274	230
River depth, H (ft)	2.61	4.78	0.97	2.12	4.30	3.0
Hydraulic radius (ft)[b]	2.66	3.18	0.95	1.76	5.35	2.78

[a]Extrapolated from data for river mouth provided in HEC2 model.

[b]Hydraulic radius (ft) = $\frac{\text{Total area of Channel } (ft^2)}{\text{Total Wetted Perimeter (ft)}}$

[c]Extrapolated from Hamilton gage data.

[d]Critical depth assumed in HEC2. Value not used for calculation of mean value.

[e]Channel is split into two deep, but narrow channels; therefore, the value was not included in calculating the mean.

[f]Field measurement, V = 1.35 ft/s (Station 4, 9/12/87) was used as model input.

TABLE 2.4.1

SUMMARY OF 1986 NPDES DATA AT MANHOLE 175

PARAMETER	UNITS	NUMBER OF SAMPLES	DAILY MINIMUM	DAILY MAXIMUM	ANNUAL AVERAGE	NPDES PERMIT LIMITS DAILY MAXIMUM	NPDES PERMIT LIMITS MONTHLY AVERAGE	PERCENT COMPLIANCE
pH	pH Units	Daily Grab	6.9	9.7	NA[a]	Range = 6.5 to 10.0		100
Nitrate	kg/day as N	53	6	849	148	3,180	1,590	100
Ammonia	kg/day as N	53	0.1	4	0.8	43	28	100
Residual Chlorine	mg/l	26	<0.02	0.09	<0.03	0.1	NA	100
Oil & Grease	mg/l	53	<5	9	<5	15	NA	100
Suspended Solids	mg/l	53	<2	31	<5.5	60	20	100
Flow Rate	MGD	Continuous	0.199	1.092	0.501	NA	NA	NA

[a]NA = not applicable.

Reference: Feed Materials Production Center
Environmental Monitoring Annual Report for 1986
Table 28.

TABLE 2.4.2

SUMMARY OF AVERAGE ANNUAL CONCENTRATIONS
OF RADIONUCLIDES FROM MANHOLE 175 AND GREAT MIAMI RIVER

PARAMETER	SAMPLING LOCATION[a]		
	W1 (pCi/l)	MANHOLE 175 (pCi/l)	W3 (pCi/l)
Gross Alpha	3	NA[b]	3
Gross Beta	5	NA	5.8
Cs-137	<8	<1.5	<7
Np-237	NA	<0.015	NA
Pu-238	NA	<0.015	NA
Pu-239/240	NA	<0.015	NA
Ra-226	<0.5	<6.6	<0.5
Ra-228	<0.5	<6	<0.6
Ru-106	NA	<15	NA
Sr-90	<1.3	1.3	1.7
Tc-99	3	2200	6
Th-232	NA	0.78	NA
U-234	0.74	160	0.83
U-235	0.030	8.5	0.040
U-236	0.0060	29	0.0090
U-238	0.75	250	0.90
Uranium	1.2	450	1.4

[a]Refer to Figure 1.1-1 for sampling locations.

[b]NA = Not analyzed.

Reference: Feed Materials Production Center
Environmental Monitoring Annual Report for 1986
Tables 12 and 13, April 1987.

TABLE 3.1.1

MEAN RIVER DISCHARGE, MEAN EFFLUENT DISCHARGE, AND MEAN EFFLUENT URANIUM CONCENTRATION FOR 1987 WATER YEAR

MONTH	MEAN RIVER DISCHARGE(a) (ft^3/s)	MEAN EFFLUENT DISCHARGE (ft^3/s)	MEAN URANIUM CONCENTRATION IN EFFLUENT (pCi/ℓ)
October 1986	6,728	0.795	433
November 1986	3,917	0.939	467
December 1986	6,128	1.301	515
January 1987	2,065	0.766	399
February 1987	1,858	0.729	311
March 1987	2,269	0.973	494
April 1987	5,148	1.126	609
May 1987	1,998	0.753	494
June 1987	3,226	0.990	697
July 1987	4,867	1.330	907
August 1987	756	0.995	819
September 1987	513	0.599	731

(a)At Hamilton gage.

TABLE 3.1.2

MEASURED AND COMPUTED URANIUM CONCENTRATIONS IN GREAT MIAMI RIVER

SAMPLE LOCATION(a)	STRIP MODEL COORDINATES (x,y)	MEASURED CONCENTRATION(b) (pCi/ℓ)	COMPUTED CONCENTRATION(c) (pCi/ℓ)	
			INITIAL MODEL RUN(d)	CALIBRATED MODEL RUN(e)
6A	200,20	3.0	2.0	4.6
6B	200,40	2.8	1.3	2.3
6C	200,80	1.8	1.2	1.5
6D	200,120	1.8	1.2	1.3
6E	200,140	2.0	1.2	1.3
5	900,60	2.1	1.3	2.6
4	1650,20	1.5	6.0	2.9
3	2500,20	2.3	6.2	2.5

(a)Refer to Figures 4.1-1 and 4.3-2 for sample locations.

(b)Taken from Table 4.4.1.

(c)C_r = concentration in river (pCi/ℓ) = C_o $[C/C_o]$ + C_b, where C_o = original concentration in strip = 164.0 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

(d)$\bar{D}_x$ = 820 ft^2/s, $\bar{D}_z$ = 0.2 ft^2/s.

(e)$\bar{D}_x$ = 5000 ft^2/s, $\bar{D}_z$ = 20 ft^2/s.

TABLE 3.1.3

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR AVERAGE FLOW CONDITIONS ($\bar{D}_x$ = 2,980 ft ^{2}/s, $\bar{D}_z$ = 0.5 ft ^{2}/s)

X-AXIS (ft)		Z-AXIS (ft) 0	20	40	60	80	120	160	200
0	C/C_o [a]	1.00000[c]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	C_r [b]	24.9	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	C/C_o	0.73786	0.00163	0.00017	0.00030	0.00006	0.00011	0.00008	0.00005
	C_r	18.7	1.2	1.2	1.2	1.2	1.2	1.2	1.2
100	C/C_o	0.54232	0.00245	0.00038	0.00015	0.00004	0.00002	0.00001	0.00000
	C_r	14.0	1.3	1.2	1.2	1.2	1.2	1.2	1.2
200	C/C_o	0.33566	0.00492	0.00087	0.00026	0.00009	0.00002	0.00000	0.00000
	C_r	9.2	1.3	1.2	1.2	1.2	1.2	1.2	1.2
300	C/C_o	0.24081	0.00747	0.00134	0.00039	0.00014	0.00002	0.00001	0.00000
	C_r	6.9	1.4	1.2	1.2	1.2	1.2	1.2	1.2
400	C/C_o	0.18855	0.00999	0.00183	0.00054	0.00020	0.00003	0.00001	0.00000
	C_r	5.7	1.4	1.2	1.2	1.2	1.2	1.2	1.2
500	C/C_o	0.15581	0.01242	0.00234	0.00070	0.00025	0.00004	0.00001	0.00000
	C_r	4.9	1.5	1.3	1.2	1.2	1.2	1.2	1.2
1000	C/C_o	0.08735	0.02201	0.00503	0.00158	0.00058	0.00010	0.00002	0.00001
	C_r	3.3	1.7	1.3	1.2	1.2	1.2	1.2	1.2
2000	C/C_o	0.05109	0.02835	0.00997	0.00364	0.00144	0.00027	0.00006	0.00001
	C_r	2.4	1.9	1.4	1.3	1.2	1.2	1.2	1.2
3000	C/C_o	0.03825	0.02749	0.01315	0.00568	0.00247	0.00051	0.00012	0.00003
	C_r	2.1	1.9	1.5	1.3	1.2	1.2	1.2	1.2
4000	C/C_o	0.03149	0.02534	0.01473	0.00738	0.00353	0.00081	0.00019	0.00005
	C_r	1.9	1.8	1.5	1.4	1.3	1.2	1.2	1.2
5000	C/C_o	0.02724	0.02328	0.01533	0.00863	0.00451	0.00115	0.00029	0.00008
	C_r	1.8	1.8	1.6	1.4	1.3	1.2	1.2	1.2

[a] C/C_o = normalized concentration.

[b] C_r = concentration of uranium in river (pCi/ℓ) = C_o $[C/C_o]$ + C_b, where C_o = original concentration in strip = 23.7 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,0).

TABLE 3.1.4

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR AVERAGE FLOW CONDITIONS ($\bar{D}_x$ = 29,800 ft^2/s, $\bar{D}_z$ = 50 ft^2/s)

X-AXIS (ft)		Z-AXIS (ft) 0	20	40	60	80	120	160	200
0	C/C_o [a]	1.00000 [c]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	C_r [b]	24.9	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	C/C_o	0.38243	0.00455	0.00114	0.00051	0.00029	0.00013	0.00008	0.00005
	C_r	10.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2
100	C/C_o	0.21042	0.00884	0.00228	0.00102	0.00058	0.00027	0.00016	0.00011
	C_r	6.2	1.4	1.3	1.2	1.2	1.2	1.2	1.2
200	C/C_o	0.10854	0.01581	0.00444	0.00203	0.00116	0.00053	0.00031	0.00022
	C_r	3.8	1.6	1.3	1.2	1.2	1.2	1.2	1.2
300	C/C_o	0.07302	0.02016	0.00636	0.00298	0.00172	0.00080	0.00047	0.00032
	C_r	2.9	1.7	1.4	1.3	1.2	1.2	1.2	1.2
400	C/C_o	0.05508	0.02223	0.00797	0.00387	0.00227	0.00106	0.00063	0.00043
	C_r	2.5	1.7	1.4	1.3	1.3	1.2	1.2	1.2
500	C/C_o	0.04427	0.02274	0.00926	0.00468	0.00278	0.00132	0.00079	0.00054
	C_r	2.2	1.7	1.4	1.3	1.3	1.2	1.2	1.2
1000	C/C_o	0.02263	0.01830	0.01165	0.00728	0.00480	0.00248	0.00153	0.00107
	C_r	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.2
2000	C/C_o	0.01190	0.01124	0.00966	0.00784	0.00622	0.00398	0.00273	0.00202
	C_r	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.2
3000	C/C_o	0.00842	0.00821	0.00765	0.00688	0.00605	0.00454	0.00345	0.00273
	C_r	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3
4000	C/C_o	0.00676	0.00667	0.00641	0.00603	0.00558	0.00464	0.00382	0.00321
	C_r	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3
5000	C/C_o	0.00582	0.00577	0.00564	0.00543	0.00517	0.00457	0.00399	0.00351
	C_r	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

[a] C/C_o = normalized concentration.

[b] C_r = concentration of uranium in river (pCi/ℓ) = C_o $[C/C_o]$ + C_b, where C_o = original concentration in strip = 23.7 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,0).

TABLE 3.1.5

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR LOW FLOW CONDITIONS ($\bar{D}_x$ = 319 ft^2/s, $\bar{D}_z$ = 0.2 ft^2/s)

X-AXIS (ft)		Z-AXIS (ft) 0	20	40	60	80	120	160	200
0	C/C_o [a]	1.00000[c]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	C_r [b]	130.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	C/C_o	0.56568	0.00177	0.00020	0.00004	0.00001	0.00000	0.00000	0.00000
	C_r	74.2	1.4	1.2	1.2	1.2	1.2	1.2	1.2
100	C/C_o	0.35990	0.00372	0.00043	0.00008	0.00002	0.00000	0.00000	0.00000
	C_r	47.6	1.7	1.3	1.2	1.2	1.2	1.2	1.2
200	C/C_o	0.20894	0.00794	0.00096	0.00018	0.00004	0.00000	0.00000	0.00000
	C_r	28.2	2.2	1.3	1.2	1.2	1.2	1.2	1.2
300	C/C_o	0.15130	0.01225	0.00158	0.00031	0.00007	0.00001	0.00000	0.00000
	C_r	20.7	2.8	1.4	1.2	1.2	1.2	1.2	1.2
400	C/C_o	0.12104	0.01630	0.00227	0.00045	0.00011	0.00001	0.00000	0.00000
	C_r	16.8	3.3	1.5	1.3	1.2	1.2	1.2	1.2
500	C/C_o	0.10230	0.01985	0.00303	0.00062	0.00015	0.00001	0.00000	0.00000
	C_r	14.4	3.8	1.6	1.3	1.2	1.2	1.2	1.2
1000	C/C_o	0.06267	0.02923	0.00722	0.00175	0.00045	0.00003	0.00000	0.00000
	C_r	9.3	5.0	2.1	1.4	1.3	1.2	1.2	1.2
2000	C/C_o	0.04027	0.02944	0.01335	0.00478	0.00156	0.00016	0.00002	0.00000
	C_r	6.4	5.0	2.9	1.8	1.4	1.2	1.2	1.2
3000	C/C_o	0.03167	0.02628	0.01569	0.00741	0.00302	0.00041	0.00005	0.00001
	C_r	5.3	4.6	3.2	2.2	1.6	1.3	1.2	1.2
4000	C/C_o	0.02688	0.02359	0.01622	0.00913	0.00442	0.00078	0.00011	0.00003
	C_r	4.7	4.2	3.3	2.4	1.8	1.3	1.2	1.2
5000	C/C_o	0.02375	0.02149	0.01606	0.01014	0.00557	0.00125	0.00022	0.00006
	C_r	4.3	4.0	3.3	2.5	1.9	1.4	1.2	1.2

[a] C/C_o = normalized concentration.

[b] C_r = concentration of uranium in river (pCi/ℓ) = C_o [C/C_o] + C_b, where C_o = original concentration in strip = 129.0 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,0).

TABLE 3.1.6

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR LOW FLOW CONDITIONS ($\bar{D}_x$ = 3,190 ft^2/s, $\bar{D}_z$ = 20 ft^2/s)

X-AXIS (ft)		Z-AXIS (ft) 0	20	40	60	80	120	160	200
0	C/C_o [a]	1.00000 [c]	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
	C_r [b]	130.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
50	C/C_o	0.21778	0.00860	0.00223	0.00101	0.00059	0.00029	0.00020	0.00017
	C_r	29.3	2.3	1.5	1.3	1.3	1.2	1.2	1.2
100	C/C_o	0.11287	0.01555	0.00436	0.00201	0.00117	0.00058	0.00040	0.00035
	C_r	15.8	3.2	1.8	1.5	1.4	1.3	1.3	1.2
200	C/C_o	0.05766	0.02237	0.00794	0.00388	0.00232	0.00117	0.00080	0.00070
	C_r	8.6	4.1	2.2	1.7	1.5	1.4	1.3	1.3
300	C/C_o	0.03907	0.02297	0.01034	0.00547	0.00337	0.00174	0.00120	0.00106
	C_r	6.2	4.2	2.5	1.9	1.6	1.4	1.4	1.3
400	C/C_o	0.02979	0.02138	0.01164	0.00671	0.00430	0.00229	0.00160	0.00142
	C_r	5.0	4.0	2.7	2.1	1.8	1.5	1.4	1.4
500	C/C_o	0.02424	0.01938	0.01216	0.00760	0.00508	0.00281	0.00200	0.00177
	C_r	4.3	3.7	2.8	2.2	1.9	1.6	1.5	1.4
1000	C/C_o	0.01338	0.01262	0.01082	0.00880	0.00707	0.00481	0.00373	0.00340
	C_r	2.9	2.8	2.6	2.3	2.1	1.8	1.7	1.6
2000	C/C_o	0.00857	0.00847	0.00819	0.00778	0.00730	0.00640	0.00577	0.00555
	C_r	2.3	2.3	2.3	2.2	2.1	2.0	1.9	1.9
3000	C/C_o	0.00744	0.00741	0.00734	0.00722	0.00708	0.00678	0.00654	0.00645
	C_r	2.2	2.2	2.1	2.1	2.1	2.1	2.0	2.0
4000	C/C_o	0.00709	0.00709	0.00706	0.00703	0.00698	0.00688	0.00680	0.00677
	C_r	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
5000	C/C_o	0.00698	0.00698	0.00697	0.00696	0.00695	0.00691	0.00689	0.00688
	C_r	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1

[a] C/C_o = normalized concentration.

[b] C_r = concentration in river (pCi/ℓ) = C_o $[C/C_o]$ + C_b, where C_o = original concentration in strip = 129.0 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,0).

TABLE 3.1.7

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR HIGH FLOW CONDITIONS ($\bar{D}_x$ = 149,597 ft ^{2}/s, $\bar{D}_z$ = 1.0 ft ^{2}/s)

X-AXIS (ft)		Z-AXIS (ft) 2000	2400	2440	2450	2460	2500	3000
0	C/C_o [a]	0.00000	0.00000	0.00000	1.00000 [c]	0.00000	0.00000	0.00000
	C_r [b]	1.2	1.2	1.2	16.8	1.2	1.2	1.2
50	C/C_o	0.00101	0.00316	0.02277	0.10491	0.03762	0.00569	0.00008
	C_r	1.2	1.2	1.6	2.8	1.8	1.3	1.2
100	C/C_o	0.00098	0.00306	0.02299	0.10338	0.03754	0.00552	0.00008
	C_r	1.2	1.2	1.6	2.8	1.8	1.3	1.2
200	C/C_o	0.00093	0.00288	0.02341	0.10042	0.03738	0.00518	0.00007
	C_r	1.2	1.2	1.6	2.8	1.8	1.3	1.2
300	C/C_o	0.00087	0.00269	0.02379	0.09758	0.03721	0.00485	0.00007
	C_r	1.2	1.2	1.6	2.7	1.8	1.3	1.2
400	C/C_o	0.00082	0.00252	0.02414	0.09485	0.03703	0.00454	0.00007
	C_r	1.2	1.2	1.6	2.7	1.8	1.3	1.2
500	C/C_o	0.00077	0.00235	0.02445	0.09222	0.03683	0.00424	0.00006
	C_r	1.2	1.2	1.6	2.6	1.8	1.3	1.2
1000	C/C_o	0.00057	0.00158	0.02557	0.08051	0.03572	0.00295	0.00004
	C_r	1.2	1.2	1.6	2.5	1.8	1.2	1.2
2000	C/C_o	0.00031	0.00037	0.02622	0.06280	0.03314	0.00105	0.00002
	C_r	1.2	1.2	1.6	2.2	1.7	1.2	1.2
3000	C/C_o	0.00017	0.00054	0.02563	0.05044	0.03044	0.00024	0.00001
	C_r	1.2	1.2	1.6	2.0	1.7	1.2	1.2
4000	C/C_o	0.00010	0.00125	0.02446	0.04161	0.02786	0.00115	0.00001
	C_r	1.2	1.2	1.6	1.8	1.6	1.2	1.2
5000	C/C_o	0.00006	0.00183	0.02305	0.03515	0.02551	0.00185	0.00001
	C_r	1.2	1.2	1.6	1.7	1.6	1.2	1.2

[a] C/C_o = normalized concentration.

[b] C_r = concentration of uranium in river (pCi/ℓ) = C_o $[C/C_o]$ + C_b, where C_o = original concentration in strip = 15.6 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,2450).

TABLE 3.1.8

RESULTS OF HYDRODYNAMIC DISPERSION MODEL AT SELECTED RIVER LOCATIONS FOR HIGH FLOW CONDITIONS ($\bar{D}_x$ = 1,495,970 ft^2/s $\bar{D}_z$ = 100 ft^2/s)

X-AXIS (ft)		Z-AXIS (ft) 2000	2400	2440	2450	2460	2500	3000
0	C/C_o [a]	0.00000	0.00000	0.00000	1.00000 [c]	0.0000	0.00000	0.00000
	C_r [b]	1.2	1.2	1.2	16.8	1.2	1.2	1.2
50	C/C_o	0.00095	0.00294	0.02320	0.10142	0.03738	0.00530	0.00008
	C_r	1.2	1.2	1.6	2.8	1.8	1.3	1.2
100	C/C_o	0.00086	0.00264	0.02376	0.09670	0.03703	0.00477	0.00007
	C_r	1.2	1.2	1.6	2.7	1.8	1.3	1.2
200	C/C_o	0.00071	0.00209	0.02463	0.08811	0.03626	0.00381	0.00006
	C_r	1.2	1.2	1.6	2.6	1.8	1.3	1.2
300	C/C_o	0.00058	0.00160	0.02519	0.08054	0.03541	0.00299	0.00005
	C_r	1.2	1.2	1.6	2.5	1.8	1.2	1.2
400	C/C_o	0.00048	0.00115	0.02552	0.07386	0.03451	0.00227	0.00004
	C_r	1.2	1.2	1.6	2.4	1.7	1.2	1.2
500	C/C_o	0.00040	0.00075	0.02564	0.06794	0.03357	0.00165	0.00004
	C_r	1.2	1.2	1.6	2.3	1.7	1.2	1.2
1000	C/C_o	0.00016	0.00076	0.02450	0.04678	0.02883	0.00051	0.00002
	C_r	1.2	1.2	1.6	1.9	1.6	1.2	1.2
2000	C/C_o	0.00006	0.00247	0.01959	0.02675	0.02108	0.000257	0.00003
	C_r	1.2	1.2	1.5	1.6	1.5	1.2	1.2
3000	C/C_o	0.00006	0.00345	0.01538	0.01818	0.01600	0.00360	0.00004
	C_r	1.2	1.3	1.4	1.5	1.4	1.3	1.2
4000	C/C_o	0.00007	0.00403	0.01239	0.01370	0.01269	0.00419	0.00005
	C_r	1.2	1.3	1.4	1.4	1.4	1.3	1.2
5000	C/C_o	0.00009	0.00433	0.01028	0.01098	0.01044	0.00448	0.00006
	C_r	1.2	1.3	1.4	1.4	1.4	1.3	1.2

[a] C/C_o = normalized concentration.

[b] C_r = concentration of uranium in river (pCi/ℓ) = $C_o[C/C_o] + C_b$, where C_o = original concentration in strip = 15.6 pCi/ℓ, C_b = background concentration in river = 1.2 pCi/ℓ.

[c] Effluent discharge is at (0,2450).

TABLE 3.2.1

EVALUATION OF THREE-DIMENSIONAL TRANSPORT CODES FOR MODELING OF THE FERNALD SITE

			SPECIAL FLUID FLOW OPTIONS			SPECIAL TRANSPORT OPTIONS				BOUNDARY CONDITIONS			SOLUTION METHOD	PROBLEM SIZE RESTRICTIONS	PRE/POST PROCESSING	VERIFICATION
PROGRAM NAME	AVAILABILITY	COMPUTERS/ (LANGUAGE)	UNCONFINED/ CONFINED FLOW	DENSITY VARIATIONS	TEMPERATURE/ CONCENTRATION DEPENDENT VISCOSITY	ADSORPTION	PARTICLE TRACKING(a)	RADIONUCLIDE DECAY CHAINS	DECAY OF SINGLE SPECIES	PRESCRIBED FLUXES, HEADS & CONCENTRATIONS	CARTER-TRACEY INFINITE RESERVOIR QRS RESERVOIR INFLUENCE FUNCTION	WASTELEACH MODEL	(NUMERICAL MODEL,) EQUATION SOLVER)		(PLOTTING GRID GENERATION) RESTART, ETC.) (PLOTTERS SUPPORTED UNKNOWN)	
SWIFT II/ SWIFT III	Swift II will be offered to public in future. Date is unknown. GEOTRANS will provide SWIFT III	Prime 550 VAX CDC and others (Fortran 77)	Yes	Yes	Yes	Nonlinear	Yes (in post processor)	Yes	Yes	Yes	Yes	Yes	Finite Difference Iterative (two-line successive over-relaxation) (Direct for small problems)	Unknown Large problems would require grid refinement	Contour Plotting Time Series Plotting Restart Facility	25 test problems
GEOFLOW	2-D source code in-house; 3-D version flow portion of code is in-house; 3-D solute transport under development. Could be available within six weeks if needed.	Prime 750 IBM-PC (Fortran 77)	Yes	No	No	Linear	No	No	Yes	Yes	No	No	Finite element for each horizontal layer; finite difference for vertical direction; direct solution	Depends on number of layers and band width of horizontal model; Typically greater than 2,000 elements by 30 layers are possible on PRIME	2-D contour plotting available; 3-D version in preparation; restart in preparation for 3-D version	2-D large set of test problems; 3-D could be prepared within 6 to 8 weeks
SWENT	Source code is in-house	CRAY, CYBER/ (Adheres closely to Fortan 77)	No	Yes	Yes	Nonlinear	No	Yes	Yes	Yes	Yes	Yes	Finite difference iterative (direct for small problems)	1,000 grid blocks on CDC	Printer plotting	Six simple test problems
PRINCETON TRANSPORT CODE	Source code in-house	PRIME 750 (Fortran 77)	Yes	No	No	Nonlinear	No	No	Yes	Yes	No	No	Same as 3-D version of GEOFLOW	1,000 to 2,000 elements by 30 layers	Limited plotting	Small set of test problems
McDONALD/ HARBAUGH CODE	Source code in-house	PRIME 750 (Fortran 77)	Yes	No	No	No	No	No	No	Yes	No	No	Finite difference iterative - strongly implicit	3,000+ cells	Limited plotting	Large set of test problems

(a)Particle tracking algorithms could be written for any flow code. However, only SWIFT III has this algorithm as of this date.

TABLE 3.2.2

HYDROGEOLOGIC PARAMETERS
COMPILED FROM VARIOUS SOURCES(a)

SOURCE OF DATA	TRANSMISSIVITY T (gpd/ft)(b)	STORAGE COEFFICIENT S	HORIZONTAL HYDRAULIC CONDUCTIVITY K_h (gpd/ft^2)	VERTICAL HYDRAULIC CONDUCTIVITY K_v (ft/day)	THICKNESS-AQUIFER (ft)	THICKNESS-TILL (ft)	THICKNESS-CLAY (ft)	VERTICAL HYDRAULIC CONDUCTIVITY K_v (CLAY)	RECHARGE(c) (FROM PRECIPITATION) (in/yr)	RECHARGE (FROM RIVER) (gpd/acre)	RECHARGE (FROM INFLOW)
Dove 1961 (SOWC well field; Ross, Ohio)	370,000	0.2	2,466		150				12	240,000	
Smith 1962(d)/Klaer 1968(d) (Cincinnati Bolton well field)	158,000 258,000 400,000	0.23	2,460 900						21		200,000 gpd/mile of valley wall(k)
Kazmann 1950(d) (SOWC well field; Ross, Ohio)	285,600 331,200		2,380 2,760		120-125						
Schaefer & Walton 1956 (SOWC well field; Ross, Ohio)	292,800 333,600		2,440 2,780		120				8.5		
Klaer & Kazmann 1943 (Hamilton south well field)	350,000 450,000		2,340-2,420		>150 >202						
Spieker & Norris 1962 (unpub.) (FMPC site; Fernald, Ohio)	140,000(e) LA(f) 300,000 (combined) (III)	0.01(e)(g) 0.001 (III)	2,000 (III)		70 LA (III)		12 (III)	2.5 gpd/ft^2 (III) 3.2 gpd/ft^2 (III)			
Lewis 1968 (SOWC well field; Ross, Ohio)			2,500 3,020								
Smith 1960(d) (New Miami-Mouth of Four-Mile Creek)	521,000	0.0003(e)	5,790		90						
Smith 1962(d) (Ross Township Section 16 - West Bank, Great Miami River)	676,000		4,000		178						
Spieker 1968a (Hamilton south well field)	300,000-500,000 35,000(e)-300,000 (III)	0.2 0.002-0.01 (III)	2,000-3,340(h)		150-200 (UA = 70-120, LA = 70-90)(i)(j)	>50 (III)	10 (III)				
GeoTrans 1985 (Compilation from various sources)	150,000 LA (III)		350 ft/day 250 ft/day (III)	35 2.5 (III)			10-20 (III)	0.025 ft/day (III)	15 6 (III)		
Spieker 1968b (Hamilton south well field)	400,000 300,000 (III)	0.2 0.1 (III)			150-250 200 (III)				15.2(k) 6-21(k)	24,000-500,000	38 gpd/linear foot of valley wall (k)

Notes:

(a)Parameters refer to Hydrogeologic Environment I unless otherwise specified with (III) which refers to Hydrogeologic Environment III (refer to Figure 2.1-12).

(b)Conversion from gallons per day (gpd) to feet^3/day approximately x 7.481.

(c)Recharge generally occurs during the months of October, November, March, and April (Spieker 1968a).

(d)Taken from GeoTrans, 1985.

(e)Values were not used in calculations because they are either suspect or are not directly relevant to this problem.

(f)LA = Lower aquifer, Area III.

(g)GeoTrans, 1985 gives S = 0.01 from Spieker & Norris, 1962. The reference itself gives S = 0.001 for the lower aquifer in Hydrogeologic Unit Area III.

(h)Calculated from transmissivity and aquifer thickness values.

(i)UA = Upper aquifer, Area III.

(j)Thicknesses from cross sections.

(k)Values are given for the entire area, including Areas I and III.

TABLE 3.2.3

COMPARISON OF APRIL 1986 OBSERVED GROUND WATER LEVELS AND SWIFT III COMPUTED VALUES (USING MODEL RUN 2)

WELL IDENTIFICATION	SWIFT III(a) COLUMN I	ROW J	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFFERENCES (ft)
12-7A	2	32	527.4	531.8	-4.4	4.4
STATE 16	4	41	526.3	529.9	-3.6	3.6
H-124	5	8	505.8	506.8	-0.8	0.8
H-122	5	25	521.4	523.8	-2.4	2.4
RE	6	16	515.7	516.7	-1.0	1.0
H-115	5	17	518.7	517.6	1.1	1.1
7-8A	6	24	520.7	522.6	-1.9	1.9
H-105	6	31	523.4	525.3	-1.9	1.9
BPH	6	35	525.0	526.8	-1.8	1.8
FMPC-17-D	7	31	523.9	525.0	-1.1	1.1
H-129	8	6	507.7	504.7	3.0	3.0
H-126	8	10	512.6	511.4	1.2	1.2
HK-	8	28	521.5	523.8	-2.3	2.3
FMPC-16-S	8	34	524.8	525.9	-1.1	1.1
FMPC-9	9	38	526.4	526.9	-0.5	0.5
DE	10	16	519.9	518.4	1.5	1.5
FMPC-18-S	9	37	525.3	526.6	-1.3	1.3
PALLET CO	9	41	525.4	529.1	-3.7	3.7
16-1-S	9	3	504.3	503.6	0.7	0.7
FMPC-3	13	40	524.9	527.5	-2.6	2.6
FMPC-14-D	8	32	524.1	525.1	-1.0	1.0
IT-5	13	27	522.7	522.9	-0.2	0.2
IT-1	14	33	523.2	523.9	-0.7	0.7
FMPC-10	14	39	523.6	526.2	-2.6	2.6
BLK	16	24	522.5	522.2	0.3	0.3
IT-2	17	33	522.9	523.1	-0.2	0.2
FMPC-13-S	18	37	522.9	523.7	-0.8	0.8
02-E	18	26	522.2	521.9	0.3	0.3
IT-3	20	36	522.5	522.8	-0.3	0.3
H-127	21	29	522.3	521.2	1.1	1.1
IT-4	24	34	521.9	521.6	0.3	0.3
B-3	24	34	520.2	521.6	-1.4	1.4
B-2	27	32	520.6	520.5	0.1	0.1
SW-4A	28	25	519.1	518.1	1.0	1.0
B-1	29	31	521.3	519.6	1.7	1.7
SW-3A	30	24	518.3	513.4	4.9	4.9
R-7	34	26	520.7	516.0	4.7	4.7
B-4	32	28	520.3	518.1	2.2	2.2

See footnote at end of table.

TABLE 3.2.3
(Continued)

WELL IDENTIFICATION	SWIFT III(a) COLUMN I	SWIFT III(a) ROW J	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFFERENCES (ft)
K-4	40	27	520.6	521.1	-0.5	0.5
EL-1	42	30	522.9	521.5	1.4	1.4
03	42	38	526.5	522.9	3.6	3.6
ER-1	45	21	525.9	523.7	2.2	2.2
LB-1	47	30	522.3	523.8	-1.5	1.5
WK1	48	24	525.5	523.8	1.7	1.7
WW-1	48	35	528.2	524.8	3.4	3.4

SUM OF DIFFERENCES/NUMBER OF OBSERVATIONS	-0.07 feet
SUM OF ABSOLUTE DEVIATIONS/NUMBER OF OBSERVATIONS	1.69 feet
STANDARD DEVIATION OF DIFFERENCES	2.10 feet

(a)Refer to Figure A-1 for grid cell locations.

TABLE 3.2.4

COMPARISON OF APRIL 1986 OBSERVED GROUND WATER LEVELS AND GEOFLOW COMPUTED VALUES (USING MODEL RUN 46)

WELL IDENTIFICATION	GEOFLOW ELEMENT NUMBER(a)(b)	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFF. (ft)
12-7A	50	527.4	531.0	-3.6	3.6
STATE 16	86	526.3	531.0	-4.7	4.7
H-124	91	505.8	504.5	1.3	1.3
H-122	109	521.4	523.8	-2.4	2.4
RE	140	515.7	516.0	-0.3	0.3
H-115	101	518.7	516.5	2.2	2.2
7-8A	189	520.7	522.0	-1.3	1.3
H-105	196	523.4	525.0	-1.6	1.6
BPH	199	525.0	526.5	-1.5	1.5
FMPC-17	238	523.9	525.0	-1.1	1.1
H-129	256	507.7	505.0	2.7	2.7
H-126	260	512.6	511.0	1.6	1.6
HK-	278	521.5	523.5	-2.0	2.0
FMPC-16-S	283	524.8	525.5	-0.7	0.7
FMPC-9	288	526.4	527.0	-0.6	0.6
DE	309	519.9	517.0	2.9	2.9
FMPC-18-S	364	525.3	526.0	-0.7	0.7
PALLET CO	334	525.4	529.0	-3.6	3.6
16-1-S	296	504.3	504.0	0.3	0.3
FMPC-3	368	524.9	528.0	-3.1	3.1
FMPC-14-D	399	524.1	526.0	-1.9	1.9
IT-5	421	522.7	523.0	-0.3	0.3
IT-1	458	523.2	524.0	-0.8	0.8
FMPC-10	464	523.6	526.5	-2.9	2.9
BLK	547	522.5	522.0	0.5	0.5
IT-2	589	522.9	523.0	-0.1	0.1
FMPC-13-S	593	522.9	524.0	-1.1	1.1
02-E	615	522.2	522.0	0.2	0.2
IT-3	660	522.5	523.0	-0.5	0.5
H-127	727	522.3	522.0	0.3	0.3
IT-4	806	521.9	522.0	-0.1	0.1
B-3	841	520.2	522.0	-1.8	1.8
B-2	948	520.6	521.0	-0.4	0.4
SW-4A	978	519.1	521.0	-1.9	1.9
B-1	1015	521.3	521.0	0.3	0.3
SW-3A	1040	518.3	517.0	1.3	1.3
R-7	1158	520.7	519.0	1.7	1.7
B-4	1187	520.3	520.0	0.3	0.3
K-4	1277	520.6	522.0	-1.4	1.4
EL-1	1343	522.9	522.0	0.9	0.9
03	1351	526.5	524.0	2.5	2.5
ER-1	1375	525.9	524.0	1.9	1.9
LB-1	1449	522.3	524.0	-1.7	1.7

TABLE 3.2.4
(Continued)

WELL IDENTIFICATION	GEOFLOW ELEMENT NUMBER(a)(b)	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFF. (ft)
WK1	1463	525.5	524.0	1.5	1.5
WW-1	1473	528.2	525.5	2.7	2.7

SUM OF DIFFERENCES/NUMBER OF OBSERVATIONS -0.39 feet

SUM OF ABSOLUTE DEVIATIONS/NUMBER OF OBSERVATIONS 1.50 feet

STANDARD DEVIATION OF DIFFERENCES 1.80 feet

(a)Wells were assumed to be located in upper left corner of element.
(b)Refer to Figure A-2 for grid element locations.

TABLE 3.2.5

SUMMARY OF MODEL INPUT PARAMETERS - INITIAL AND RANGE OF VALUES FOR SENSITIVITY ANALYSIS

	ZONE I		ZONE III		
	RANGE OF VALUES FOR SENSITIVITY ANALYSIS	INITIAL VALUES	RANGE OF VALUES FOR SENSITIVITY ANALYSIS	INITIAL VALUES	NOTES AND REFERENCES
Aquifer Values					
Porosity	0.2 - 0.3	0.25	0.2 - 0.3	0.25	Estimated from geologic logs and site experience
S (storage)	N/A(a)	0.2	N/A	0.2/.05(b)	Mean of various sources
K_h (horizontal hydraulic conductivity) (feet/day)	100 - 800	400	100 - 800	400	Statistically derived from various sources
K_v (vertical hydraulic conductivity) (feet/day)	$K_h/10 - K_h$	$K_h/3$	$K_h/10 - K_h$	$K_h/3$	Estimated from site experience
b (aquifer thickness) (feet)	N/A	Variable	N/A	Variable	From contour plots of bedrock and top of aquifer
Recharge (from precipitation) (inches/year)	8 - 20	14	3 - 12	6	
Daily pumping ($feet^3$/day):					
- FMPC wells	N/A	N/A	N/A	64,000	
- Southwestern Ohio Water Company wells					
(Collector 1)	N/A	1,600,000	N/A	N/A	Estimated
(Collector 2)	N/A	800,000	N/A	N/A	Estimated
- Albright and Wilson well	N/A	N/A	N/A	19,000	Information obtained by IT for 1986

TABLE 3.2.5
(Continued)

	ZONE I		ZONE III		
	RANGE OF VALUES FOR SENSITIVITY ANALYSIS	INITIAL VALUES	RANGE OF VALUES FOR SENSITIVITY ANALYSIS	INITIAL VALUES	NOTES AND REFERENCES
River stage (feet MSL)	520.5 - 528.6	524 at Ross Bridge	N/A	N/A	
River water temperature (°F)	N/A	60	N/A	N/A	
Ground water temperature (°F)	N/A	54	N/A	54	
Interbed Values					
K_v clay (vertical hydraulic conductivity of clay) (feet/day)	N/A	N/A	3×10^{-5} - 3×10^{-2}	3×10^{-3}	Estimated
b clay (thickness of interbed) (feet)	N/A	N/A	10 - 25	20	
Porosity of clay	N/A	N/A	0.45 - 0.75	0.6	Assumed (Freeze & Cherry, 1979, pg. 37)
Bedrock Values					
K_hB (horizontal hydraulic conductivity of bedrock) (feet/day)	3×10^{-5} - 3×10^{-1}	3×10^{-3}	3×10^{-5} - 3×10^{-1}	3×10^{-3}	Estimated
Porosity of bedrock	0 - 0.1	0.1	0 - 0.1	0.1	Assumed (Freeze & Cherry, 1979, pg. 37)

(a)N/A = Not applicable.
(b)0.2/0.05 - The first value refers to the upper aquifer and the second value refers to the lower aquifer.

TABLE 3.2.6

SUMMARY OF GEOFLOW SENSITIVITY RUNS

	CALIBRATION RUN	SENSITIVITY RUN NUMBERS 1	2	3	4	5	6	7
Input Parameter								
Aquifer hydraulic conductivity (feet/day)								
Zone 1	400	400	400	400	400	400	400	400
Zone 2	-	-	-	-	-	-	-	-
Zone 3	300	300	300	300	300	300	300	300
Zone 4	150	150	150	150	150	150	150	150
Recharge from precipitation (inches/year)								
Zone 1	14	20	10	14	14	14	14	14
Zone 2	-	-	-	-	-	-	-	-
Zone 3	6	8	4	6	6	6	6	6
Zone 4	6	8	4	6	6	6	6	6
River bed leakage (factor) (day^{-1})	0.35(1.0)	0.35(1.0)	0.35(1.0)	0.035(0.1)	0.175(0.5)	0.70(2.0)	3.5(10.0)	35.0(100.0)
Comparison of observed versus computed results (Model Output) (feet)								
All 45 Wells:								
Mean difference(a)	-0.39	-0.89	+0.07	+3.52	+0.29	-0.76	-1.10	-1.17
Mean absolute difference(b)	1.50	1.81	1.42	3.87	1.66	1.73	2.03	2.10
Standard deviation of algebraic difference(c)	1.80	1.92	1.81	3.50	2.03	1.91	2.00	2.02

TABLE 3.2.6
(Continued)

	CALIBRATION RUN	SENSITIVITY RUN NUMBERS 1	2	3	4	5	6	7
Wells 12-7A, State 16, PALLET CO, FMPC-3, and WW-1 excluded:								
Mean difference(a)	-0.14	-0.63	+0.28	+4.01	+0.63	-0.54	-0.89	-0.97
Mean absolute difference(b)	1.24	1.55	1.24	4.03	1.41	1.52	1.83	1.91
Standard deviation of algebraic difference(c)	1.47	1.64	1.60	3.23	1.63	1.70	1.82	1.85

(a)Sum of observed minus computed values divided by number of wells.

(b)Sum of absolute value of observed minus computed value divided by number of wells.

(c)Standard deviation of observed minus computed values.

TABLE 3.2.7

WATER BALANCE FROM MODEL OUTPUT FOR COLLECTOR WELL DISCHARGE

Water Balance

$$Q_D = Q_{BR} + Q_P + Q_A + Q_R$$

where:

Q_D = pumping discharge from collector wells

Q_{BR} = component from bedrock aquifer(a)

Q_P = component from precipitation recharge(b)

Q_A = component from sand and gravel aquifer(c)

Q_R = component from entire river

Model Sensitivity Cases

Case 1 = river leakage factor for model calibration run = 0.35 day^{-1}

Case 2 = river leakage factor 0.5 times calibration factor = 0.175 day^{-1}

Case 3 = river leakage factor ten times calibration factor = 3.5 $days^{-1}$

Results

$$Q_D = (Q_{BR} + Q_P + Q_A) + Q_R$$

Case 1 Q_D = 24 percent + 76 percent

Case 2 Q_D = 30 percent + 70 percent

Case 3 Q_D = 12 percent + 88 percent

(a)Q_{BR} is assumed zero for model; however, it has been estimated to be 38 gpd per linear foot of valley wall (Spieker, 1986b).

(b)Q_P is 6 inches/year in Model Zone 3, 14 inches/year Model Zone 1, based on model calibration.

(c)Q_A will be determined in the ongoing RI/FS.

TABLE 3.2.8

COMPONENT OF FLOW AT SOWC COLLECTOR WELLS DERIVED FROM RIVER FLOW

River Leakage Factor (Day^{-1})	0.35(a)	3.5(b)	0.175(c)
Total leakage from River (Q_R)			
Q_R, ft^3/day	1,870,232.9	2,167,976.3	1,717,359.9
Q_R, MGD	13.99	16.22	12.85
% of flow at SOWC wells[d]	76.0	88.1	69.8
Leakage upstream of effluent pipe (Q_u)			
Q_u, ft^3/day	1,668,320	2,036,205.6	1,450,850
Q_u, MGD	12.48	15.23	10.84
% of flow at SOWC wells	67.8	82.8	59.0
Leakage downstream of effluent pipe (Q_d)			
Q_d, ft^3/day	201,912.9	131,770.7	266,509.9
Q_d, MGD	1.51	0.99	1.99
% of flow at SOWC wells	8.2	5.4	10.8

(a)Includes elements on Great Miami River "big bend" downstream of GEOFLOW Element 1335 to Elements 824 and 860 (inclusive).

(b)Includes elements on Great Miami River "big bend" downstream of GEOFLOW Element 1335 to Elements 830 and 866 (inclusive).

(c)Includes elements on Great Miami River "big bend" from GEOFLOW Element 1335 to Element 1057 (inclusive).

(d)SOWC wells are assumed to be pumping at a combined rate of 18.4 MGD.

TABLE 3.2.9

CALCULATION OF POSSIBLE CONCENTRATION OF URANIUM AT SOWC COLLECTOR WELLS FOR VARIOUS Q_d AND C_r FOR AVERAGE RIVER FLOW CONDITIONS

CASE NO(a)	1	2	3	4	5
Q_d(%)	-	8.2	41	8.2	41
C_r(pCi/ℓ)	-	1.3	1.3	6.5	6.5
Q_u(%)	76.0	67.8	35.0	67.8	35.0
C_b(pCi/ℓ)	1.2	1.2	1.2	1.2	1.2
Q_{gw}(%)	24.0	24.0	24.0	24.0	24.0
C_{gw}(pCi/ℓ)	0.2	0.2	0.2	0.2	0.2
C_w(pCi/ℓ)(b)	0.960	0.968	1.00	1.40	3.13

(a)Case 1 represents the situation with no FMPC effluent discharge. The river leakage is equivalent to the total river leakage (Q_R Table 3.2.8) for the calibrated ground water flow model case.

Case 2 represents the calibrated ground water flow model case with river leakage factor = 0.35 day^{-1}.

Case 3 represents the case with Q_d 5 times greater than in Case 1.

Case 4 represents the case with C_r 5 times greater than in Case 1.

Case 5 represents the case with Q_d and C_r 5 times greater than in Case 1.

(b)C_w = Concentration of uranium at SOWC collector wells (pCi/ℓ)

$$= C_r \times \frac{Q_d}{100} + C_b \times \frac{Q_u}{100} + C_{gw} \times \frac{Q_{gw}}{100}$$

where:

C_r = Concentration of uranium in river water downstream of effluent discharge point for average flow (complete mix model) (pCi/ℓ)

Q_d = Component of flow from downstream of effluent pipe flowing to SOWC collector wells (%)

C_b = Background concentration of uranium in river water (pCi/ℓ)

Q_u = Component of river flow from upstream of effluent pipe flowing to SOWC collector wells (%)

C_{gw} = Background concentration of uranium in ground water (pCi/ℓ)

Q_{gw} = Component of flow from ground water flowing to SOWC collector wells (%)

TABLE 4.1.1

RIVER SAMPLING LOCATIONS

LOCATION NO.	LOCATION DESCRIPTION[a]	NUMBERS AND TYPES OF SAMPLES COLLECTED
1	4,400 feet downstream of FMPC outfall in channel center	2 discrete water samples
2	3,600 feet downstream of FMPC outfall, right center of channel	2 discrete water samples 1 composite sediment sample
3	2,300 feet downstream of FMPC outfall, right center of channel, 200 feet downstream of gravel bar in channel center	2 discrete water samples 1 composite sediment sample
4	1,600 feet downstream of FMPC outfall, center of channel to right of gravel bar, 100 feet upstream of gas pipeline crossing	2 discrete water samples
5	900 feet downstream of FMPC outfall, channel on right side of gravel bar	2 discrete water samples 1 composite sediment sample
6	200 feet downstream of FMPC outfall, at five equally-spaced channel subdivisions	10 discrete water samples from 2 sampling traverses 2 composite water samples from 2 sampling traverses
7	600 feet upstream of FMPC outfall, right center of channel	2 discrete water samples 1 composite sediment sample
8	3,200 feet upstream of FMPC outfall, right center of channel	2 discrete water samples 1 composite sediment sample
9	5,600 feet upstream of FMPC outfall, left center of channel	2 discrete water samples 1 composite sediment sample
10	7,000 feet upstream of FMPC outfall, channel center	2 discrete water samples 1 composite sediment sample
11	8,000 feet upstream of FMPC outfall at Ross Bridge, at five channel subdivisions, spacing weighted by discharge	3 composite water samples from 3 sampling traverses

[a]Orientation of view for sampling location descriptions--looking downstream.

TABLE 4.3.1

SUMMARY OF SURFACE WATER VELOCITY MEASUREMENTS OF GREAT MIAMI RIVER 9/11/87 TO 9/12/87

LOCATION[a]	DEPTH OF WATER D (ft)	VELOCITY (ft/s)	DEPTH OF VELOCITY MEASUREMENT = 0.6 x D (ft)	DATE MEASURED
1	9.1	0.5	5.5	9/12/87
2	2.9	2.1	1.7	9/12/87
3	5.3	1.5	3.2	9/12/87
4	2.5	1.35	1.5	9/12/87
5	3.4	c	-	9/12/87
6	3.5	c	-	9/12/87
7	5.3	0.55	3.2	9/11/87
8	7.0	0.45	4.2	9/11/87
9	7.3	0.5	4.4	9/11/87
10	5.4	0.5	3.2	9/11/87
11[b]	-	0.4	-	9/11/87

[a]Sample locations are shown in Figure 4.1-1. Where channel is split, measurements were taken in left channel.

[b]Mean of all sections measured (refer to Table 4.3.2 for individual sections).

[c]Velocity meter not working.

TABLE 4.3.2

VELOCITY AND DISCHARGE MEASUREMENTS AT ROSS BRIDGE (LOCATION 11)[a] TAKEN ON 9/11/87

BRIDGE SUPPORT NUMBER	DISTANCE FROM RIGHT BANK (ft)	SECTION WIDTH, W (ft)	SECTION DEPTH, D (ft)	VELOCITY, V (ft/sec)/ DEPTH OF MEASUREMENT (ft)	SECTION DISCHARGE Q = WDV (ft^3/s)
8	48.0	-	-	-	-
9	54.3	12.6	1.0	0.25/0.6	3.2
10	60.6	-	-	-	-
11	66.9	12.6	2.1	0.10/1.3	2.6
12	73.2	-	-	-	-
13	79.5	12.6	2.0	0.50/1.2	12.6
14	85.8	-	-	-	-
15	92.1	12.6	1.0	0.20/0.6	2.5
16	98.4	-	-	-	-
17	104.7	12.6	4.8	0.15/2.9	9.1
18	111.0	-	-	-	-
19	117.3	12.6	4.4	0.75/2.6	41.6
20	123.6	-	-	-	-
21	129.9	12.6	6.2	0.60/3.7	46.9
22	136.2	-	-	-	-
23	142.5	12.6	6.6	0.70/4.0	58.2
24	148.8	-	-	-	-
25	155.1	12.6	6.2	0.65/3.7	50.8
26	161.4	-	-	-	-
27	167.7	12.6	5.3	0.45/3.2	30.1
28	174.0	-	-	-	-
29	178.0	10.3	4.2	0.45/2.5	19.5
30	184.3	-	-	-	-
31	190.6	12.6	3.4	0.50/2.0	21.4
32	196.9	-	-	-	-
33	203.2	12.6	3.1	0.50/1.9	19.5
34	209.5	-	-	-	-
35	215.8	12.6	2.8	0.50/1.7	17.6
36	222.1	-	-	-	-
37	228.4	12.6	2.3	0.45/1.4	13.0
38	234.7	-	-	-	-
39	241.0	12.6	2.4	0.40/1.4	12.1
40	247.3	-	-	-	-
41	253.6	12.6	2.4	0.40/1.4	12.1
42	259.9	-	-	-	-
43	266.2	12.6	2.2	0.35/1.3	9.7
44	272.5	-	-	-	-
45	278.8	12.6	1.9	0.25/1.1	6.0
46	285.1	-	-	-	-
47	291.4	15.0	1.8	0.20/1.1	5.4
48	296.7	-	-	-	-
49	303.0	6.0	2.0	0.05/1.2	0.6
				$\bar{V}$ = 0.4	ΣQ = 394.5.

[a]Sample location is shown in Figure 4.1-1.

TABLE 4.4.1

ANALYTICAL RESULTS FOR SURFACE WATER SAMPLES FROM THE GREAT MIAMI RIVER
9/11/87 to 9/14/87

SAMPLE LOCATION[a]	SAMPLE NO.	SAMPLE I.D.	U-TOTAL (μg/ℓ)	2-SIGMA (μg/ℓ)	U-TOTAL MEAN FOR SAMPLE LOCATION (μg/ℓ)	U-TOTAL MEAN FOR SAMPLE LOCATION (pCi/ℓ)[b]
1	1-1	01012	3.8	1.5	3.5	2.3
	1-2	01013	3.2	1.4		
2	2-1	01014	2.0	0.9	2.7	1.8
	2-2	01015	3.3	1.1		
3	3-1	01016	3.4	1.2	3.4	2.3
	3-2	01017	3.4	1.1		
4	4-1	01018	2.3	0.9	2.3	1.5
	4-2	01019	2.2	0.9		
5	5-1	01020	1.9	0.9	3.2	2.1
	5-2	01021	4.4	1.7		
6[c]	6-1	01022	2.8	1.0	3.8	2.5
	6-2	01023	4.8	1.9		
	6-1A	01025	4.0	1.6	4.5	3.0
	6-2A	01030	5.0	2.1		
	6-1B	01026	4.5	1.8	4.2	2.8
	6-2B	01031	3.8	1.6		
	6-1C	01027	2.9	1.4	2.7	1.8
	6-2C	01032	2.5	1.2		
	6-1D	01028	2.7	1.7	2.7	1.8
	6-2D	01033	2.6	1.2		
	6-1E	01029	3.2	1.6	3.1	2.0
	6-2E	01034	2.9	1.4		
7	7-1	01000	2.9	1.2	2.7	1.8
	7-2	01001	2.4	1.2		
8	8-1	01002	1.9	1.3	1.5	1.0
	8-2	01003	<1.0	-		
9	9-1	01004	1.9	1.0	1.8	1.2
	9-2	01005	1.7	1.0		

See footnotes at end of table.

TABLE 4.4.1
(Continued)

SAMPLE LOCATION[a]	SAMPLE NO.	SAMPLE I.D.	U-TOTAL (μg/ℓ)	2-SIGMA (μg/ℓ)	U-TOTAL MEAN FOR SAMPLE LOCATION (μg/ℓ)	U-TOTAL MEAN FOR SAMPLE LOCATION (pCi/ℓ)[b]
10	10-1	01006	2.0	1.1	2.2	1.4
	10-2	01007	2.3	1.2		
11[d]	11-1	01008	1.8	1.0		
	11-2	01009	1.9	1.0	1.8	1.2
	11-3	01010	1.8	1.1		
Blank-1		01011	1.3	0.9	-	
Blank-2		01024	<1.0	-		

[a]Sample locations are shown on Figure 4.1-1. Where channel is split, samples were taken in left channel (looking upstream).

[b]Converted from μg to pCi using 1 μg = 0.67 pCi (Wrenn, M. E., P. W. Durbin, B. Howard, J. Lipsztein, J. Rundo, E. T. Still, and D. L. Willis, 1985, "Metabolism of Ingested U and Ra," Health Physics, Vol. 48, pp. 601-633.).

[c]At location 6, samples 6-1 and 6-2 were taken at the center of the left channel. Other samples were taken as follows:

SECTION	TRAVERSE	DISTANCE FROM LEFT BANK (ft)
A	1	~15
	2	~15
B	1	~40
	2	~40
C	1	~80
	2	~80
D	1	~120
	2	~120
E	1	~140
	2	~140

[d]At location 11, three traverses were made. Samples were taken at various points along the traverse and composited.

TABLE 4.5.1

DESCRIPTION OF BOTTOM SEDIMENTS
AT RIVER SEDIMENT SAMPLING LOCATIONS

LOCATION NO.[a]	MAJOR SEDIMENT CHARACTERISTICS
2	Clean medium sand, with little (up to 20%) coarse sand, decreasing amounts of coarse sand to medium gravel towards main channel; increasing amounts of fine sand and traces of silt towards eddy pool
3	Clean, well-graded gravel (rounded pebbles up to 1/2-inch diameter) with no fine sand or silt
5	Primarily rounded cobbles and flat stones (up to five inches in size) with sediment between consisting of well-graded silty sand
7	Clean, well-graded medium to coarse sand with some fine gravel, trace to no silt
8	Well-graded medium to coarse sand with some coarse gravel (up to 1.5 inches in diameter), trace fine sand
9	Very soft silty organic muck, with trace to little medium sand

[a]Refer to Figure 4.1-1 for sampling locations.

TABLE 4.5.2

QUALITATIVE ASSESSMENT OF CHANNEL STABILITY

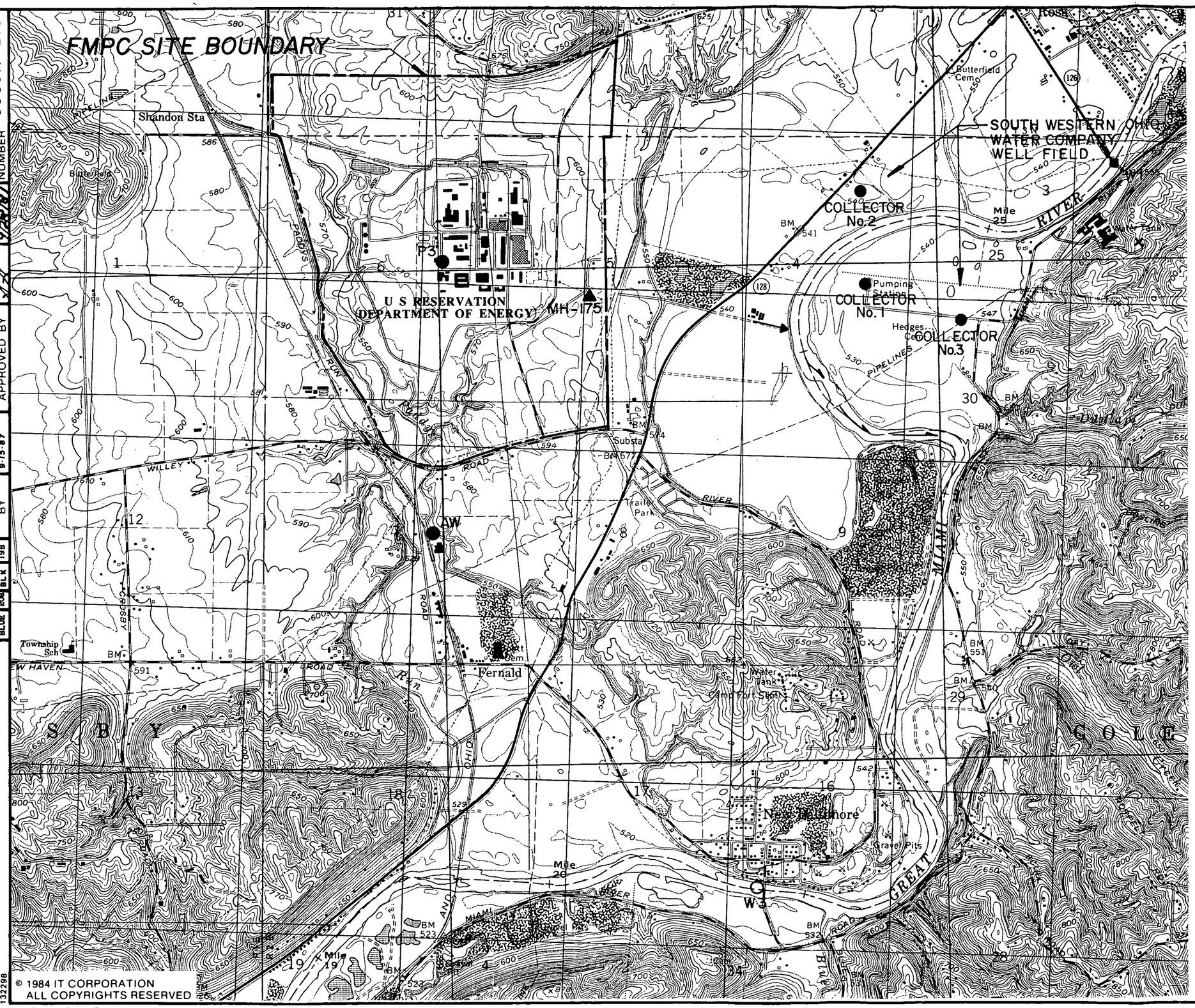
LOCATION NO.[a]	MAJOR CHANNEL CONFIGURATION	COMPARISON WITH PREVIOUSLY DOCUMENTED CONFIGURATION (DOVE, 1961)
1	90-degree turn to south, gravel bar to inside, depth greater than six feet over majority of width, deeper to outside of bend.	No cross section available.
2	Main portion of channel center-right (looking downstream), edd, pool to left, depths approximately three feet.	Present channel shallower, position of main channel appears stable.
3	Main portion of channel center-right (looking downstream), depths less than three feet.	Similar.
4	Main portion of channel to right (looking downstream), major gravel bar divides channel upstream of location.	Gravel bar does not appear on previously documented sections.
5	Main channel to right (looking downstream) of prominent gravel bar.	Gravel bar not documented in past, but main channel consistently to right.
6	Main channel to right, depths up to four feet.	Similar.
7	Main channel to right-center.	Similar.
8	Main channel in approximate center, depths up to seven feet.	Shallower in previously documented sections.
9	Main channel to left-center (outside of bend), depths up to seven feet or greater.	Similar.

TABLE 4.5.2
(Continued)

LOCATION NO.[a]	MAJOR CHANNEL CONFIGURATION	COMPARISON WITH PREVIOUSLY DOCUMENTED CONFIGURATION (DOVE, 1961)
10	Main channel in approximate center, depths five to six feet.	Similar.
11	Main channel to left-center (looking downstream), depths up to six and one-half feet.	Similar position for main portion of channel, but previous depths are shallower.

[a]Refer to Figure 4.1-1 for sampling locations.

FIGURES



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CHECKED BY	JHW	9-22-87
APPROVED BY		9-28-87

100% BLUE	208	50% BLK	198

132298

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LEGEND

- FMPC EFFLUENT LINE DISCHARGE POINT
- BACKGROUND SURFACE WATER SAMPLING POINT (ROSS BRIDGE)
- RIVER FLOW DIRECTION
- MANHOLE
- PRODUCTION WELLS
- SURFACE WATER SAMPLING POINT

REFERENCES:

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO - IND., SHANDON, OHIO GREENHILLS, OHIO, CINCINNATI WEST, OHIO, ADDYSTON, OHIO - KY, AND HOOVEN OHIO. DATED: 1955 (PRI1981), 1965 (PRI1981), 1965 (PRI1981), 1961 (PRI1981), 1982 AND 1981 SCALE: 1" = 2000'.

SCALE

0 2000 4000 FEET

FIGURE 1.1-1

FMPC RI/FS AREA OF INFLUENCE STUDY AREA

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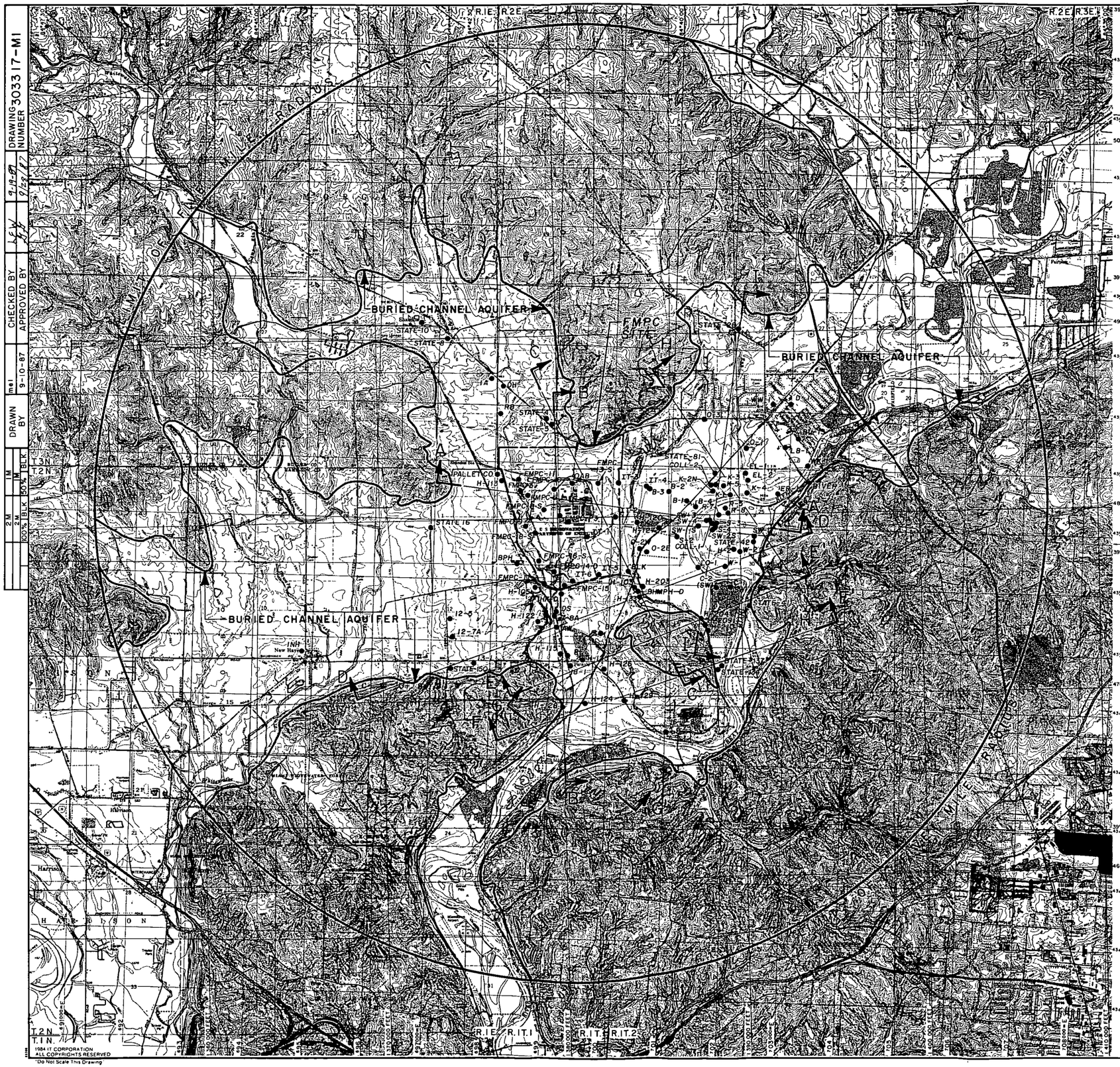

DRAWING NUMBER 303317-M1

CHECKED BY / APPROVED BY — 9-12-87

DRAWN BY — mel 9-10-87

1M 80% BLK 2M 2M 80% BLK 1M

862

LEGEND:

- ● EL-2 — WELL NAME AND LOCATION
- ▲ RIVER — RIVER ELEVATION LOCATION (ROSS BRIDGE)

NOTES:

1. WELL BLK ALSO KNOWN AS M-106 WELL BHMPH-D ALSO KNOWN AS M-106.

REFERENCES:

BASED ON MEASUREMENTS CONDUCTED BY IT CORPORATION IN APRIL, 1986 AND BY THE SOUTHWESTERN OHIO WATER COMPANY ON MARCH 27, 1986.

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO-IND.; SHANDON, OHIO; GREENHILLS, OHIO; CINCINNATI WEST, OHIO; ADDYSTON, OHIO-KY.; AND HOOVEN, OHIO. DATED: 1955 (PR1981), 1955 (PR1981), 1965 (PR1981), 1961 (PR1981), 1982, AND 1981. SCALE: 1" = 2000'.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO 303063-M5, PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER, 1986.

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-1

SELECTED WELL AND CROSS SECTION LOCATIONS

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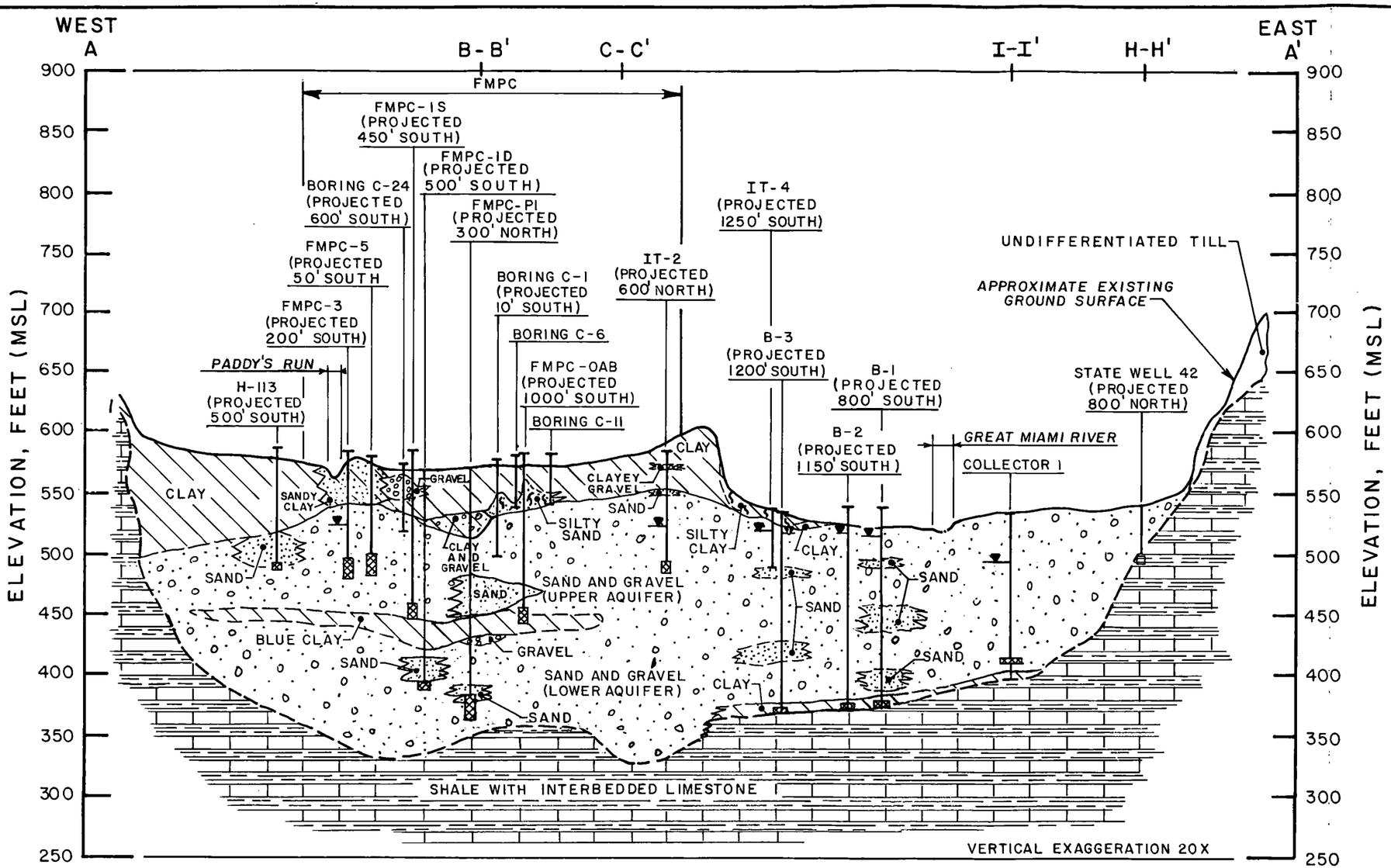

LEGEND:

OPEN INTERVAL

WATER LEVELS (MEASURED 3/27/86 THRU 4/11/86.)

REFERENCES:

MODIFIED FROM U.S.G.S. PROFESSIONAL PAPER No. 605-A USING AVALIABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASKS A AND C REPORTS AND IT 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)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:

FOR LOCATION OF CROSS SECTION A-A' SEE FIGURE 2.1-1.

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.

FIGURE 2.1-2

HYDROGEOLOGIC CROSS SECTION A-A'

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9-11-87 9/18/87

CHECKED BY L.E.W. APPROVED BY

J. LOGRECO 9-11-87

DRAWN BY

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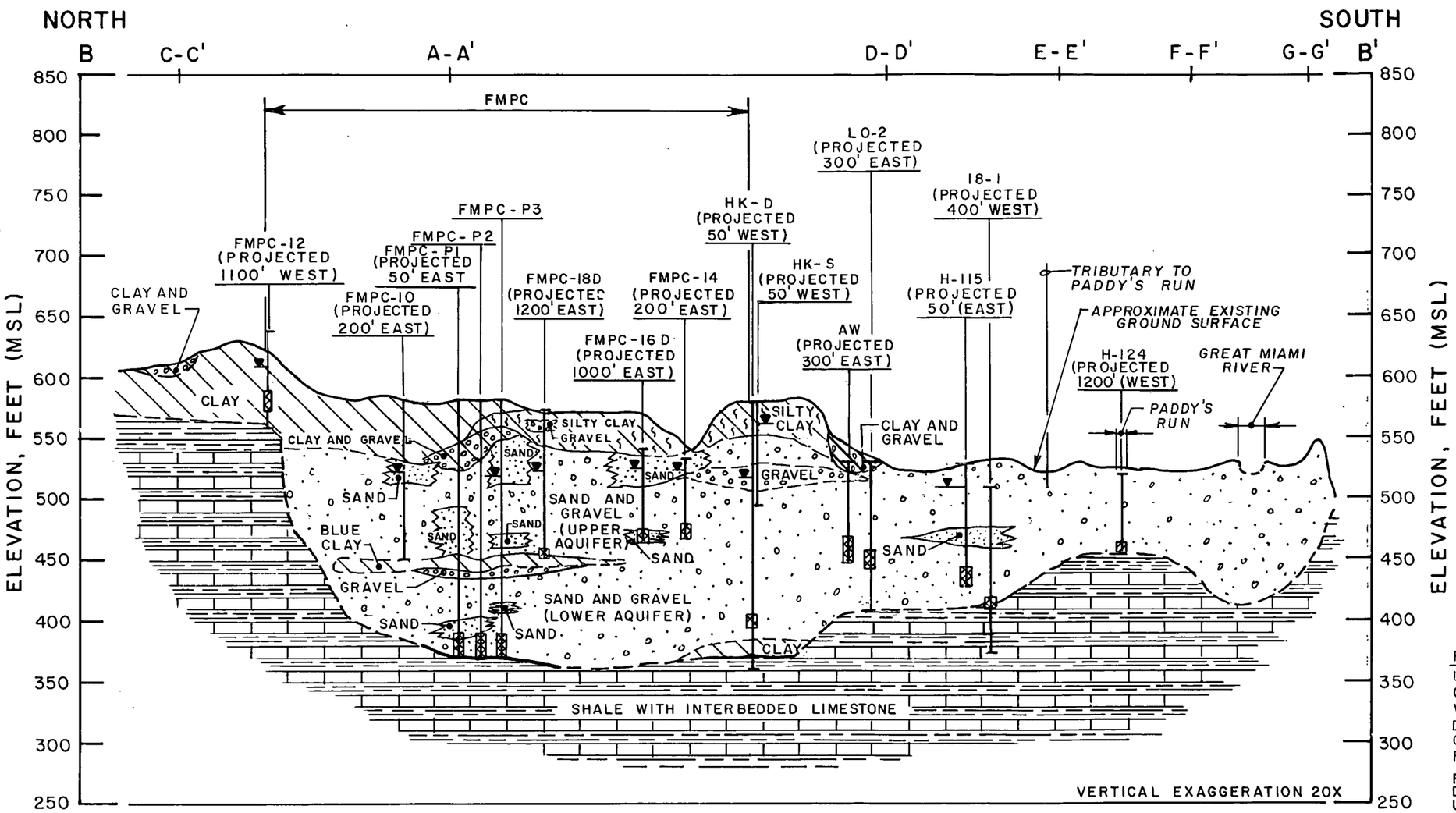

LEGEND:

OPEN INTERVAL

WATER LEVELS (MEASURED 3/27/86 TO 4/11/86.)

REFERENCES:

U.S.G.S PROFESSIONAL PAPER No. 605-A, OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT AND IT BORING LOGS.

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

CROSS SECTION B-B'

(LOOKING EAST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:

FOR LOCATION OF CROSS SECTION B-B' SEE FIGURE 2.1-1.

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.

FIGURE 2.1-3

HYDROGEOLOGIC CROSS SECTION B-B'

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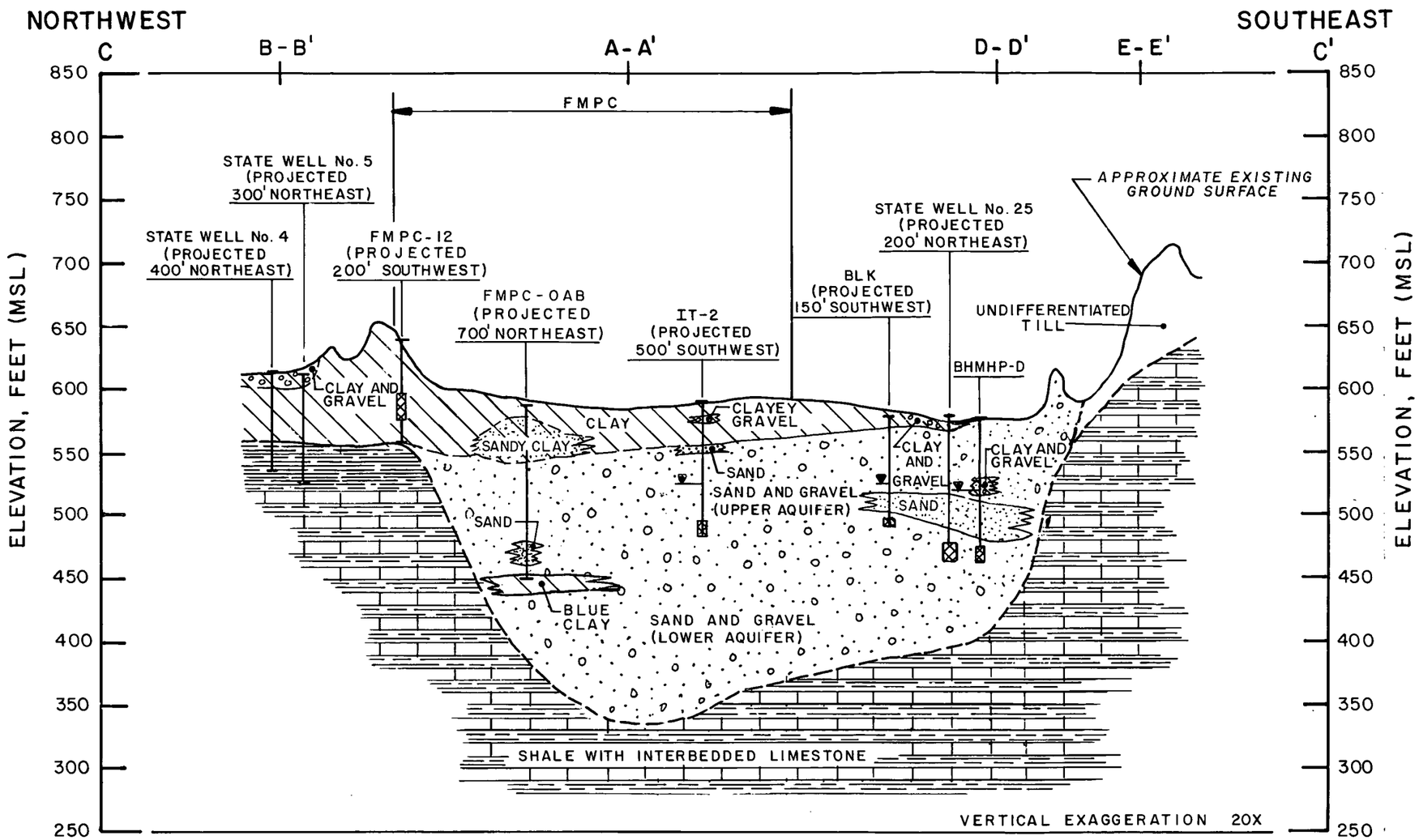

LEGEND:

OPEN INTERVAL

WATER LEVELS (MEASURED 3/27/86 THRU 4/11/86.)

REFERENCES:

U.S.G.S. PROFESSIONAL PAPER No. 605-A, OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT TASK C REPORT, AND IT BORING LOGS.

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

CROSS SECTION C-C'

(LOOKING NORTHEAST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:

FOR LOCATION OF CROSS SECTION C-C' SEE FIGURE 2.1-1.

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.

FIGURE 2.1-4

HYDROGEOLOGIC CROSS SECTION C-C'

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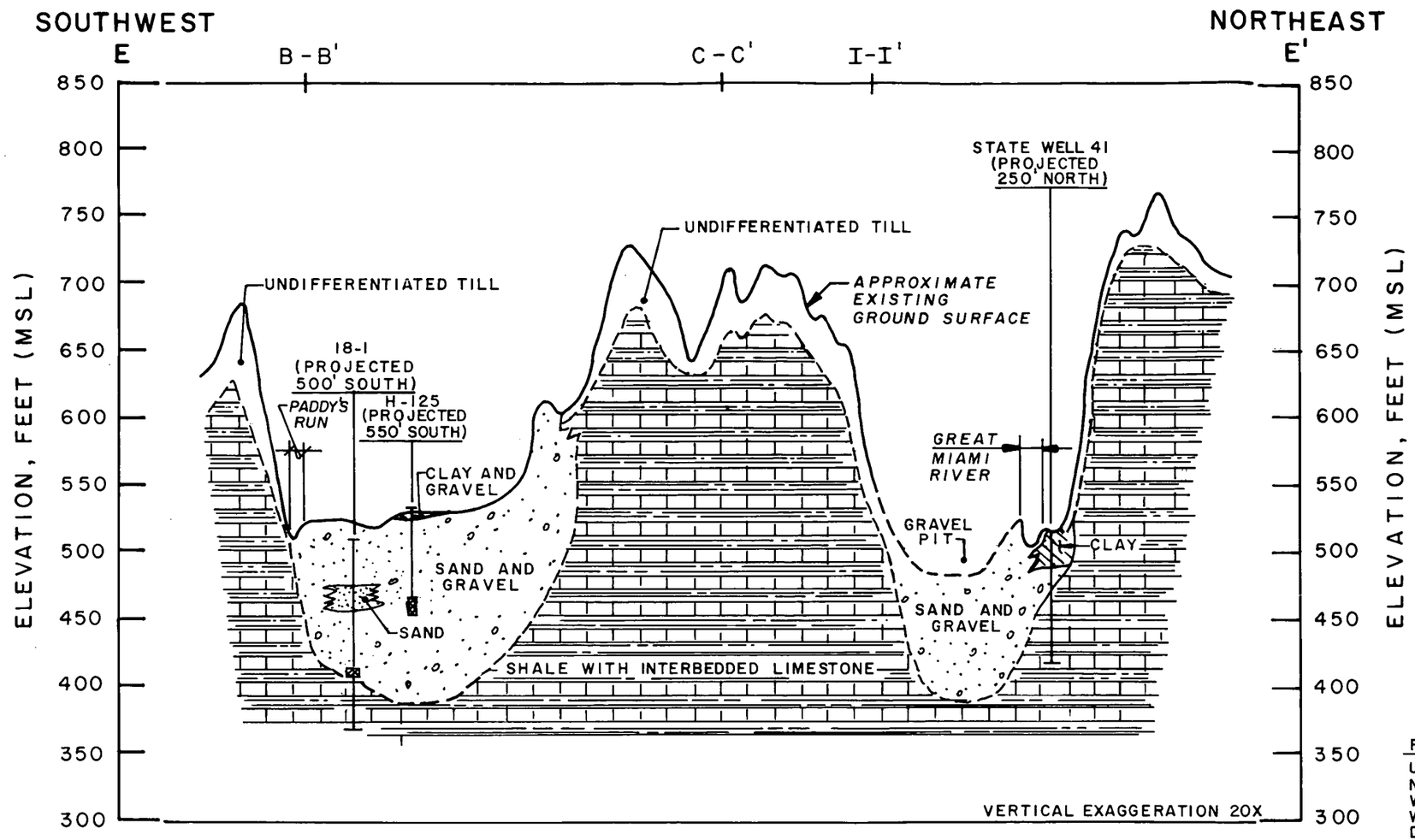

LEGEND

OPEN INTERVAL

WATER LEVELS (MEASURED 3/27/86 THRU 4/11/86.)

CROSS SECTION E-E'

(LOOKING NORTHWEST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:

FOR LOCATION OF CROSS SECTION E-E' SEE FIGURE 2.1-1.

REFERENCES:

U.S.G.S. PROFFESSIONAL PAPER No.605-A, OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT AND IT BORING LOGS.

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

FIGURE 2.1-6

HYDROGEOLOGIC CROSS SECTION E-E'

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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.

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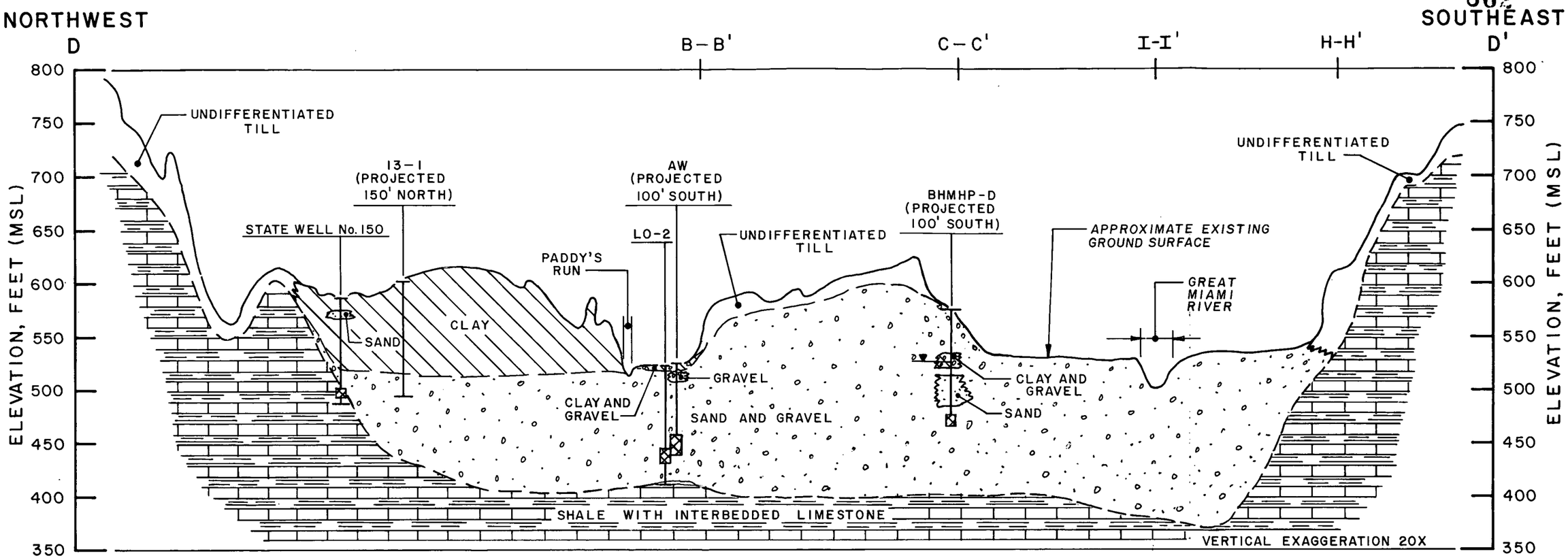

CROSS SECTION D-D'

(LOOKING NORTHWEST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

REFERENCES:

U.S.G.S. PROFESSIONAL PAPER No.605-A, OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT AND IT BORING LOGS.

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

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.

NOTE:

FOR LOCATION OF CROSS SECTION D-D' SEE FIGURE 2.1-1.

LEGEND

OPEN INTERVAL

WATER LEVELS (MEASURED 3/27/86 THRU 4/11/86.)

FIGURE 2.1-5

HYDROGEOLOGIC CROSS SECTION D-D'

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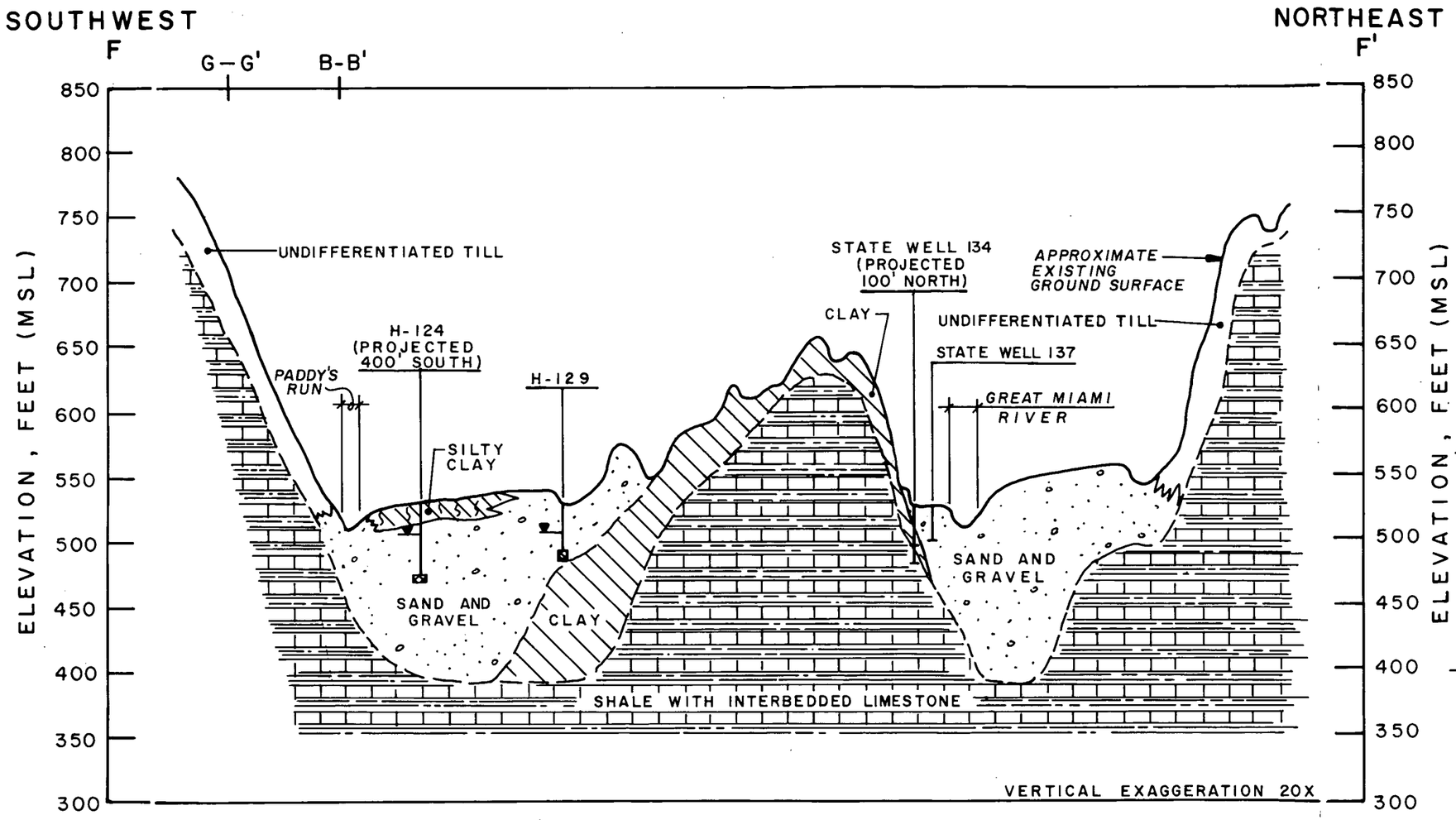

LEGEND

OPEN INTERVAL

WATER LEVEL (MEASURED 3/27/86 THRU 4/11/86.)

REFERENCES:

U.S.G.S. PROFESSIONAL PAPER No. 605-A USING AVAILABLE OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT, AND IT BORING LOGS.

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

CROSS SECTION F-F'

(LOOKING NORTHWEST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:

FOR LOCATION OF CROSS SECTION F-F' SEE FIGURE 2.1-1.

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.

FIGURE 2.1-7

HYDROGEOLOGIC CROSS SECTION F-F'

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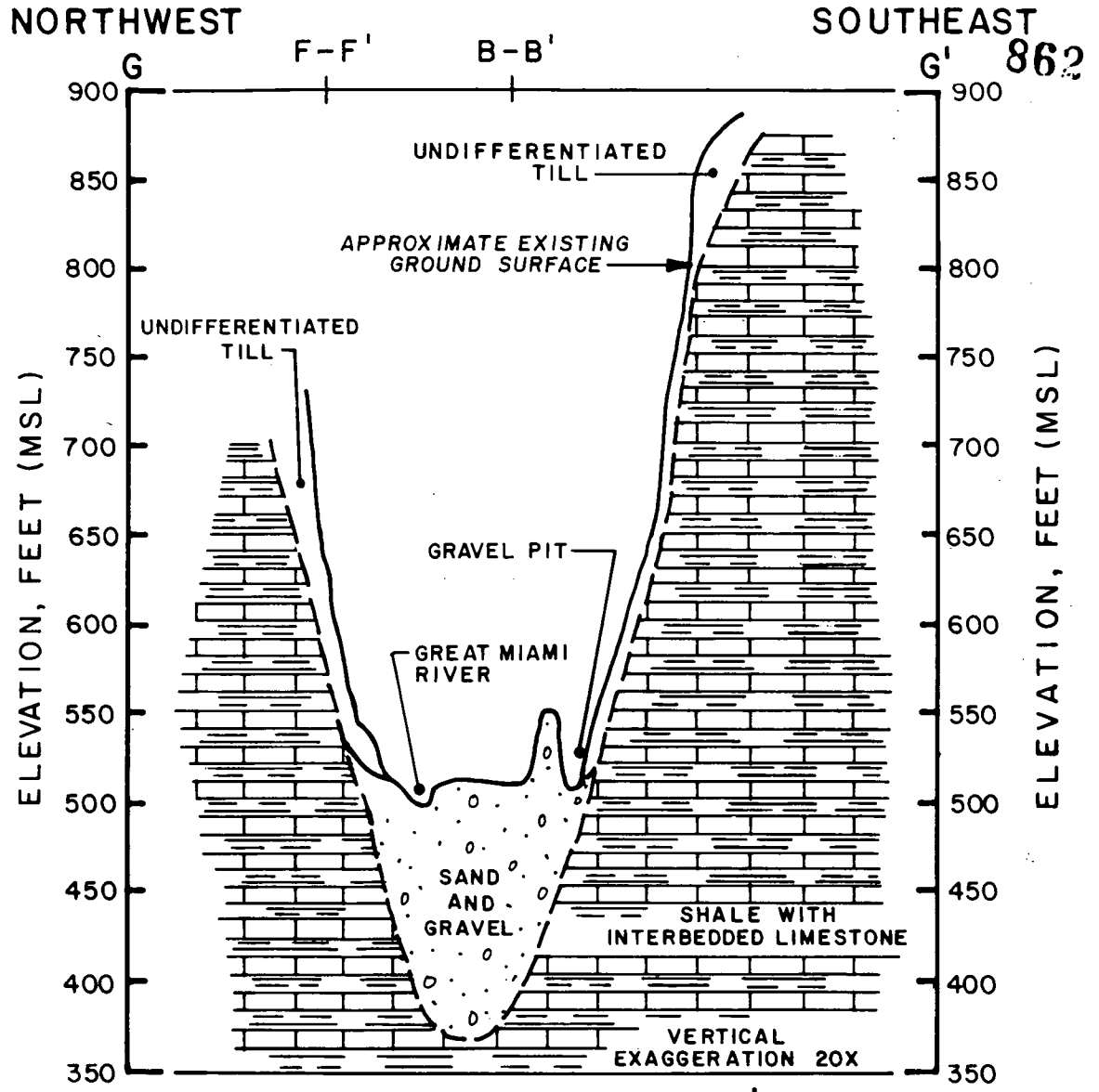

CROSS SECTION G-G'

(LOOKING NORTHEAST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

NOTE:
FOR LOCATION OF CROSS SECTION G-G' SEE FIGURE 2.1-1.

REFERENCES:
U.S.G.S. PROFESSIONAL PAPER No.605-A, OHIO STATE WATER WELL RECORDS, SOWC WATER WELL DATA, DAMES AND MOORE DOE, FEED MATERIALS PRODUCTION CENTER GROUND WATER STUDY TASK C REPORT AND IT BORING LOGS.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO.303063-A17. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER, 1986.

FIGURE 2.1-8

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.

HYDROGEOLOGIC
CROSS SECTION G-G'

PREPARED FOR

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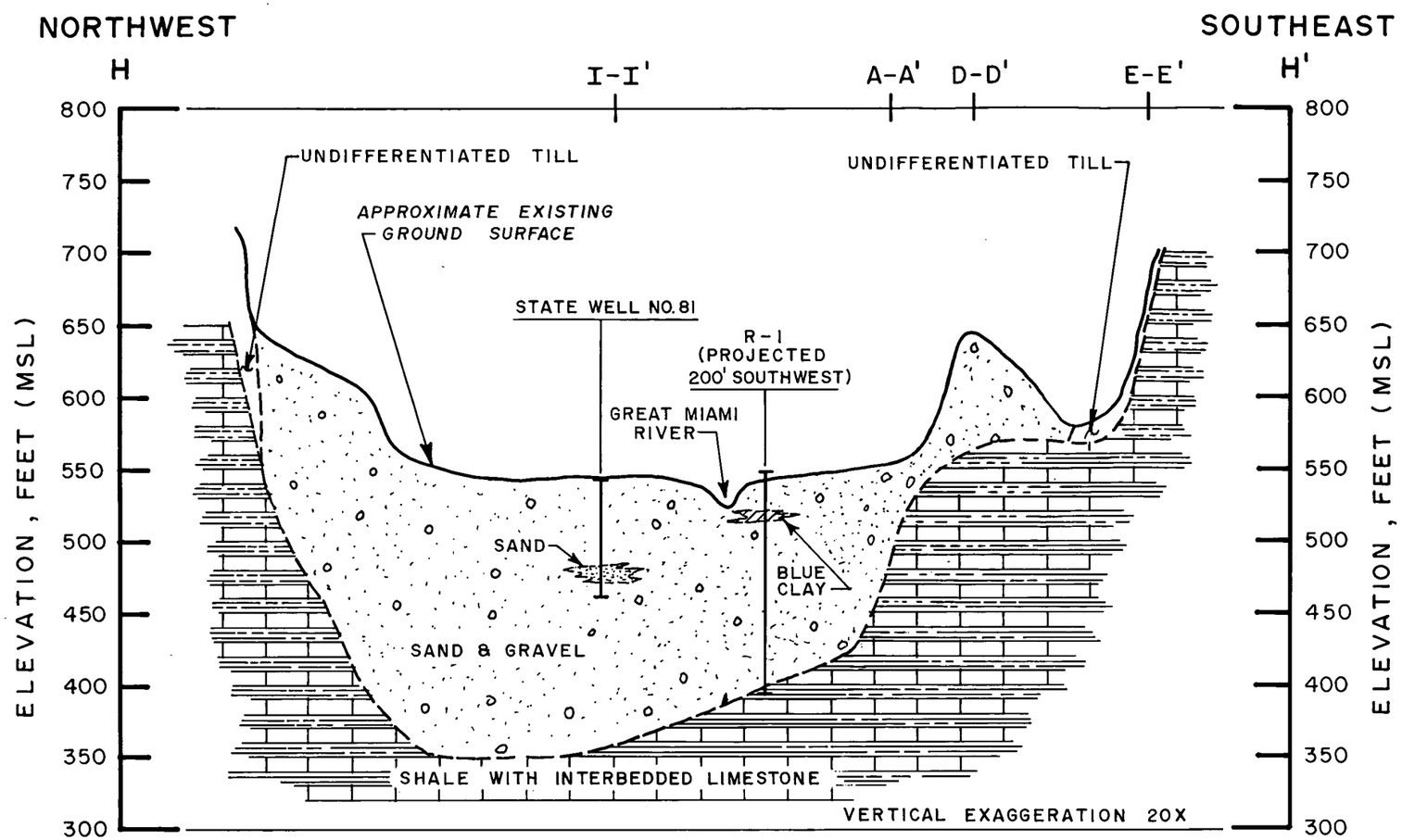

CROSS SECTION H-H'

(LOOKING NORTHEAST)

LEGEND

OPEN INTERVAL

REFERENCES:

U.S.G.S. PROFESSIONAL PAPER NO. 605-A, OHIO STATE WATER WELL RECORDS.

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

NOTE:

FOR LOCATION OF CROSS SECTION H-H' SEE FIGURE 2.1-1.

FIGURE 2.1-9

HYDROGEOLOGIC CROSS SECTION H-H'

PREPARED FOR

FERNALD RI/FS
U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS

DRAWN BY B. KUMPF 31 AUG 87
CHECKED BY LEW 9-19-87
APPROVED BY 9-22-87
DRAWING NUMBER 303317-87

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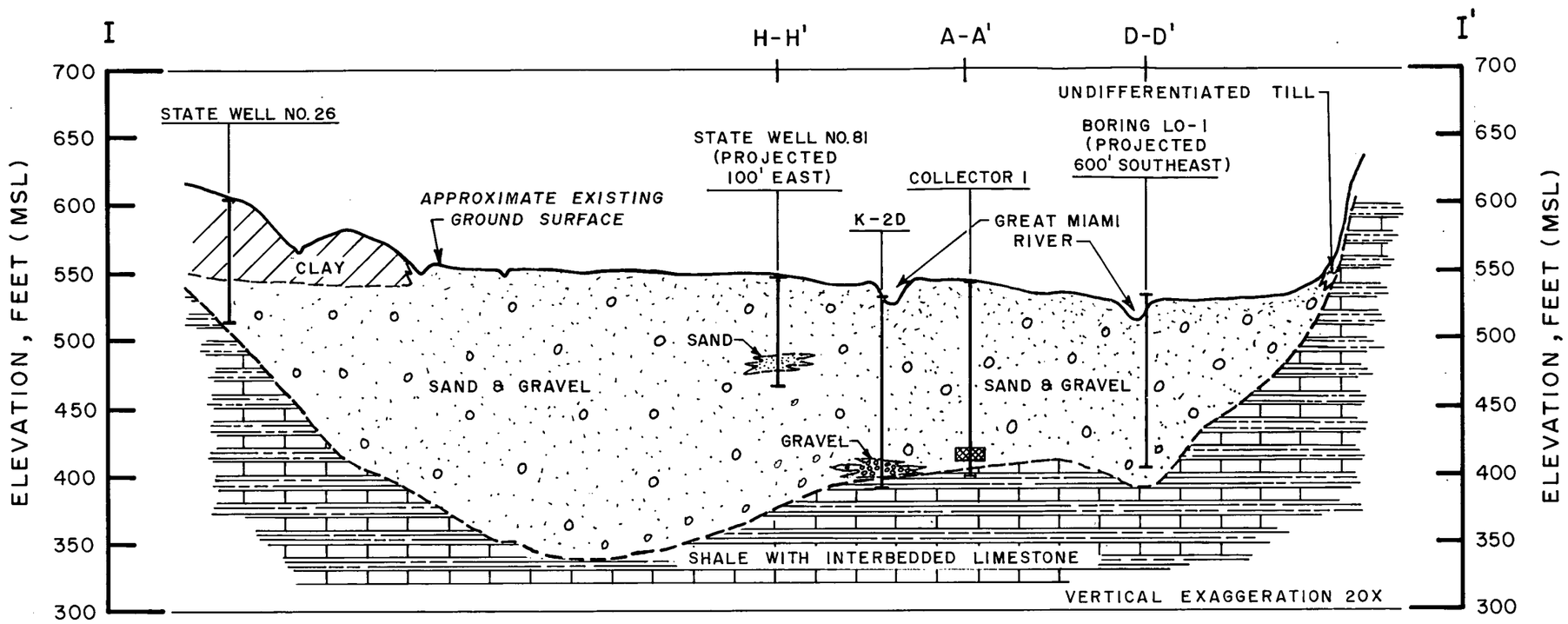

LEGEND:

OPEN INTERVAL

CROSS SECTION I-I'

(LOOKING EAST-SOUTHEAST)

VERTICAL SCALE

0 100 200 FEET

HORIZONTAL SCALE

0 2000 4000 FEET

REFERENCES:

OHIO STATE WATER WELL RECORDS, STATE OF OHIO DEPARTMENT OF NATURAL RESOURES DIVISION OF WATER TECHNICAL REPORT NO. 4, AND REPORT PREPARED FOR OHIO ENVIRONMENTAL PROTECTION AGENCY BY GEO-TRANS, INC.

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

NOTE:

FOR LOCATION OF CROSS SECTION I-I' SEE FIGURE 2.1-1.

FIGURE 2.1-10

HYDROGEOLOGIC CROSS SECTION I-I'

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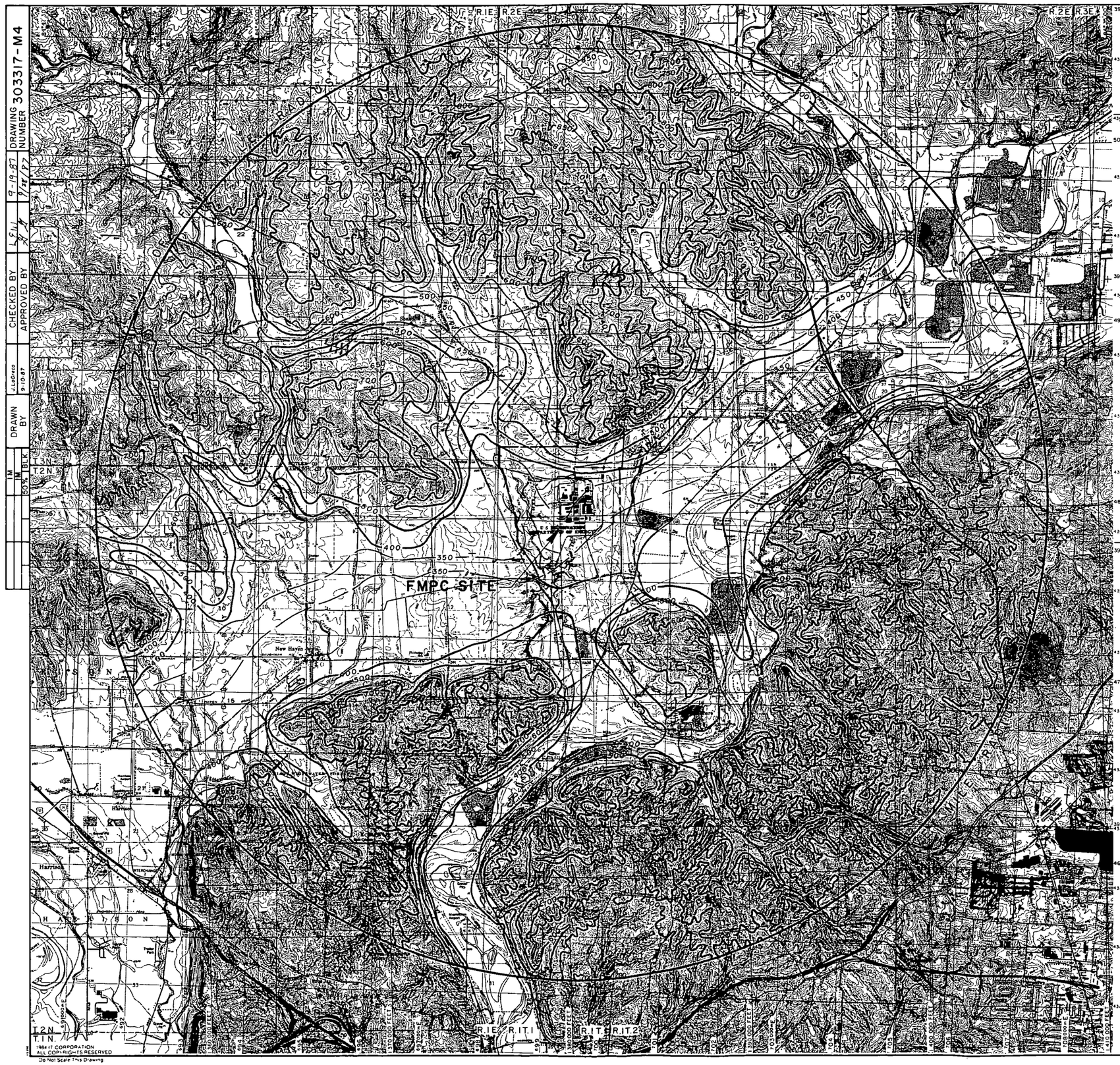

LEGEND

— 700 — BEDROCK SURFACE CONTOURS CONTOUR INTERVAL AS SHOWN (FEET MSL)

REFERENCES:

DWG. TITLED: TOP OF ROCK MAP OF BUTLER, COUNTY OHIO, OPEN FILE MAP 224 STATE OF OHIO, DNR DIVISION OF GEOLOGICAL SURVEY BY: JACK A. LEOW. DATE: JULY 1985, SCALE: 1" = 4000' CONTOUR INTERVAL 50 FEET.

DWG. TITLED: TOP OF ROCK MAP OF HAMILTON COUNTY OHIO, OPEN FILE MAP 229 STATE OF OHIO, DNR DIVISION OF GEOLOGICAL SURVEY BY: VORMELKER, JOEL. DATE: JULY 1985, SCALE: 1" = 4000' CONTOUR INTERVAL 100 FEET

DWG. TITLED: SEISMIC REFRACTION SURVEY OF PLIESTOCENE DRAINAGE CHANNELS IN THE LOWER GREAT MIAMI RIVER VALLEY, OHIO, U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 605-B, 1971, BY: J.S. WATKINS AND A.M. SPICKER. CONTOUR INTERVAL 50 FEET.

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO-IND.; SHANDON, OHIO; GREENHILLS, OHIO; CINCINNATI WEST, OHIO; ADDYSTON, OHIO-KY.; AND HOOVEN, OHIO. DATED: 1955 (PR 1981), 1965 (PR 1981), 1965 (PR 1981), 1961 (PR 1981), 1982 AND 1981. SCALE: 1" = 2000'.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO. 303063-M19. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER, 1986

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-11

TOP OF BEDROCK SURFACE CONTOUR MAP

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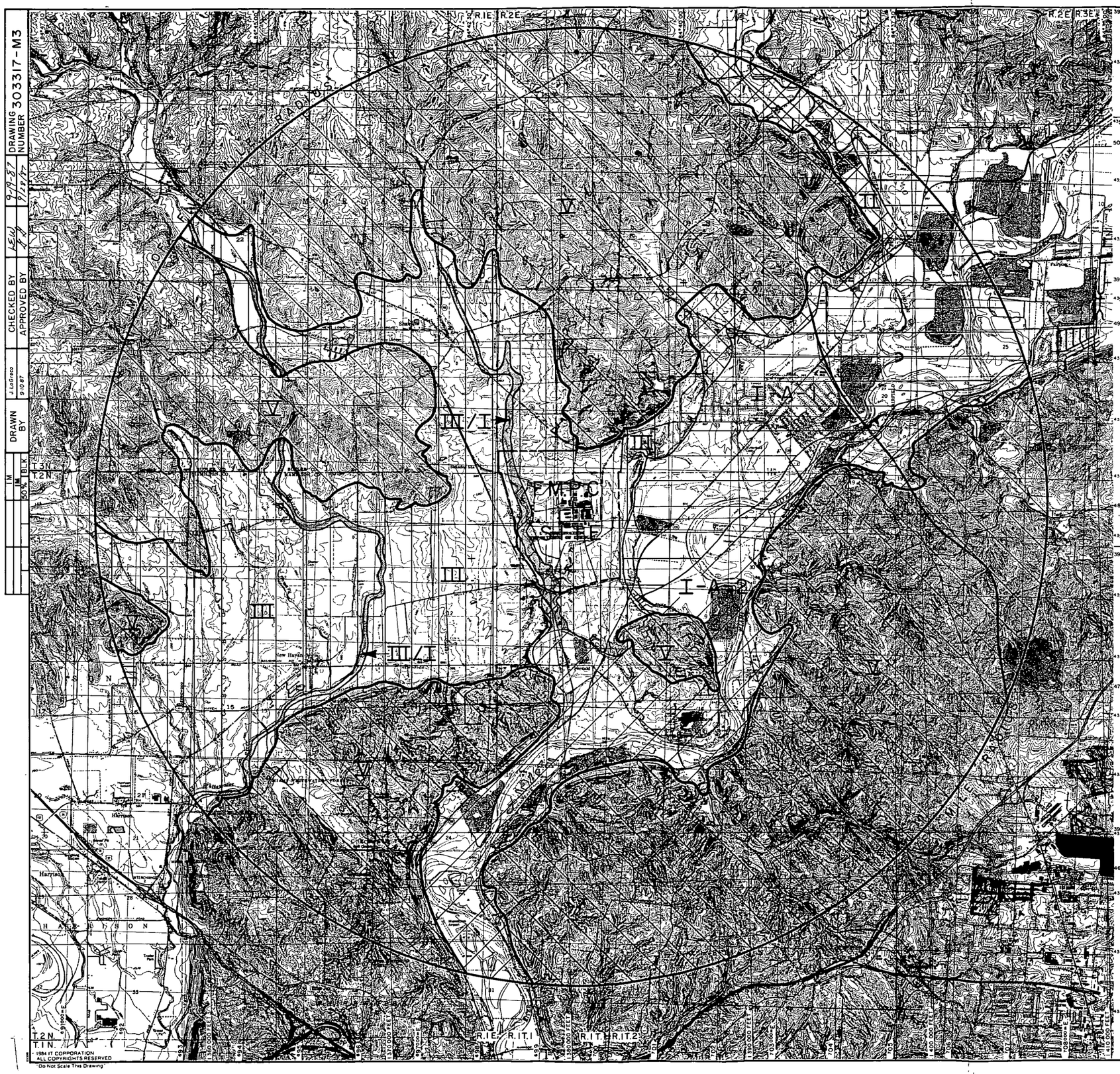

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LEGEND

- I-A-1 — SAND AND GRAVEL AQUIFER, 150-200 FEET OR MORE THICK; NO AERIALLY EXTENSIVE CLAY LAYERS PRESENT; RECHARGE BY INDUCED STREAM INFILTRATION AVALIABLE
- I-A-2 — SAND AND GRAVEL AQUIFER, LESS THAN 150 FEET THICK, NO AERIALLY EXTENSIVE CLAY LAYERS PRESENT; RECHARGE BY STREAM INFILTRATION AVALIABLE
- II — SAND AND GRAVEL AQUIFER, LESS THAN 150 FEET THICK; NO AERIALLY EXTENSIVE CLAY LAYERS PRESENT; RECHARGE BY STREAM INFILTRATION NOT AVALIABLE.
- III — SAND AND GRAVEL AQUIFER, OVERLAIN BY CLAY; STREAM RECHARGE GENERALLY NOT AVALIABLE
- V — SHALE BEDROCK OVERLAIN BY 50 FEET OR LESS OF RELATIVELY IMPERMEABLE TILL
- III/I — STREAM VALLEYS POTENTIALLY INCISED THROUGH TILL TO SAND AND GRAVEL AQUIFER
- FMPC SITE BOUNDARY

REFERENCES:

MODIFIED FROM GROUND WATER HYDROLOGY AND GEOLOGY OF THE LOWER GREAT MIAMI RIVER VALLEY OHIO, U.S.G.S. REPORT NO. 605-A USING SOIL SURVEYS OF BUTLER COUNTY (1980) AND HAMILTON COUNTY (1982) AND IT FIELD OBSERVATIONS.

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO-IND., SHANDON, OHIO; GREENHILL S, OHIO; CINCINNATI WEST, OHIO; ADDYSTON, OHIO-KY., AND HOOVEN, OHIO. DATED: 1955 (PR1981), 1965 (PR1981), 1965 (PR1981), 1951 (PR1981), 1982, AND 1981. SCALE: 1" = 2000'.

FIGURE ADAPTED FROM FERNALD LITIGATION DRAWING NO 303063-M18. PREPARED FOR U.S. DEPARTMENT OF ENERGY BY IT CORPORATION, NOVEMBER, 1986.

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-12

HYDROGEOLOGIC ENVIRONMENTS

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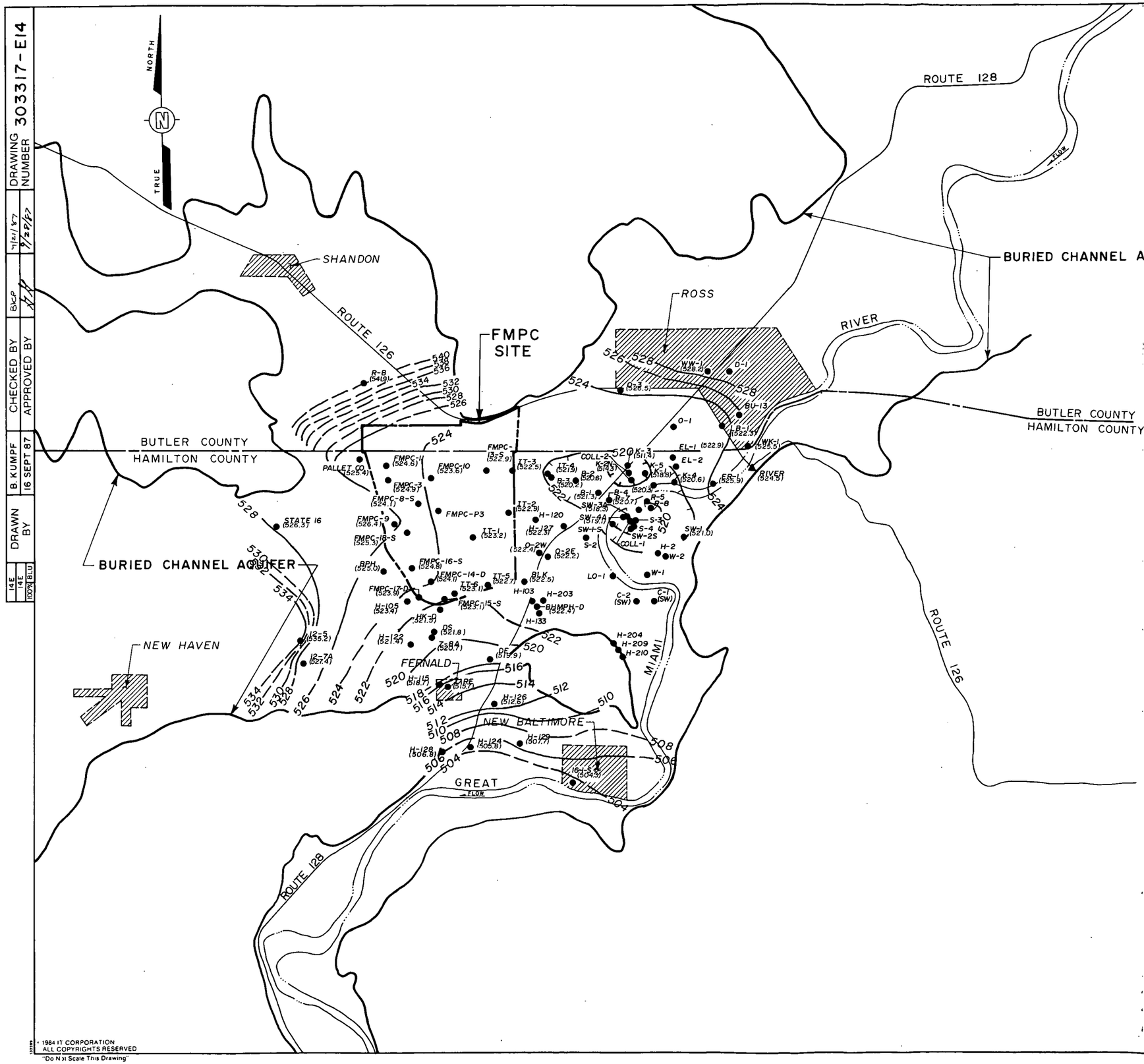

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS WERE MEASURED DURING THE PERIOD MARCH 27 THROUGH APRIL 11, 1986.
3. GROUND WATER ELEVATIONS AT PUMPING WELLS; FMPC-P3, COLL-1 AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(520.9)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
~524~	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
— — —	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-13

APRIL 1986
GROUND WATER CONTOUR MAP

PREPARED FOR

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DRAWING NUMBER	303317-E14
	7-21-87
CHECKED BY	BJCP
APPROVED BY	
B. KUMPF	16 SEPT 87
DRAWN BY	
14E	
14E	
100%	BLU

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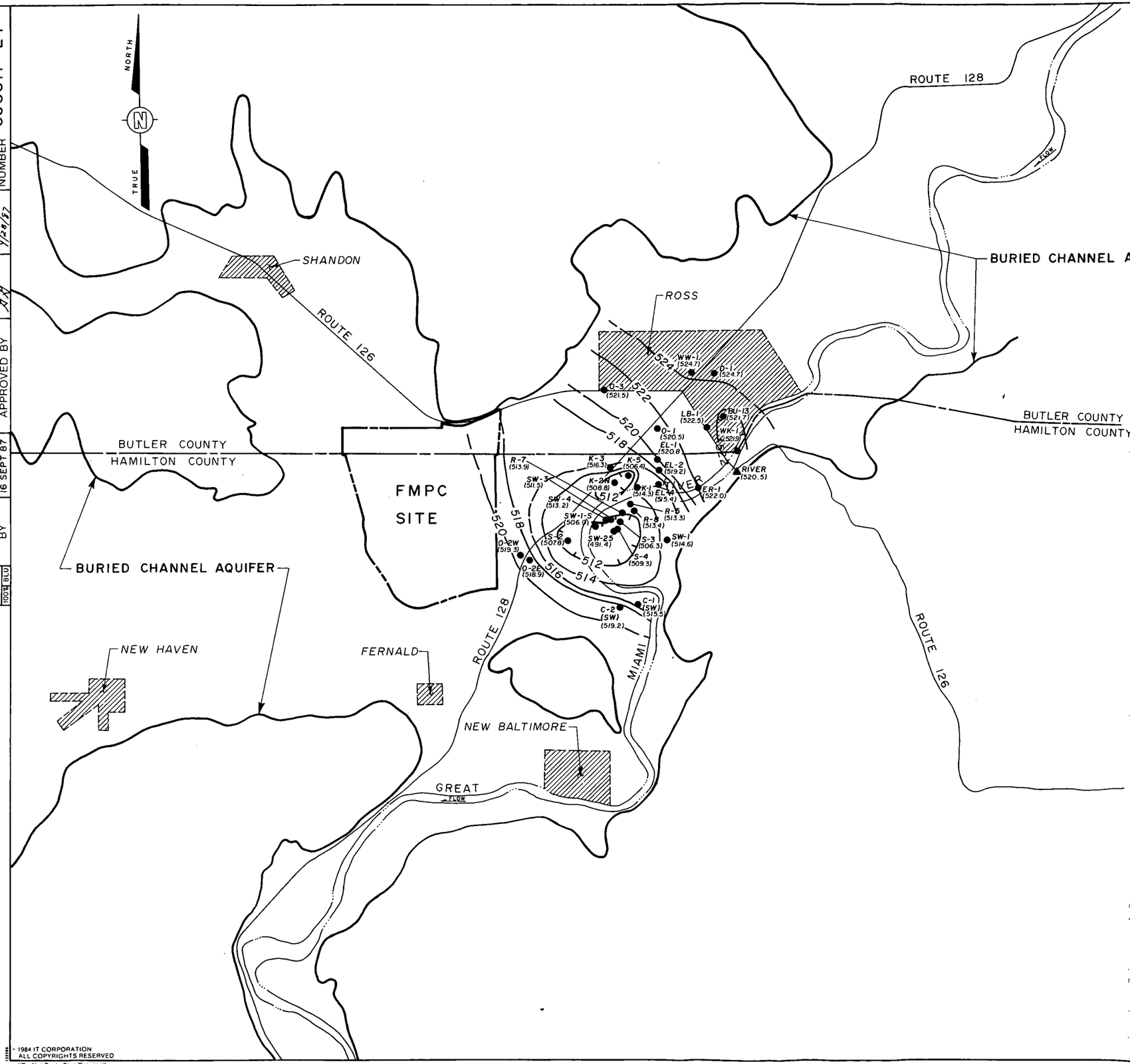

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON AUGUST 28, 1986.

LEGEND:

● D-1	WELL NAME AND LOCATION
(524.7)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
— — —	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-14

SEPTEMBER 1986
GROUND WATER CONTOUR MAP

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DRAWING NUMBER	303317-E4
	9/28/87
CHECKED BY	BCP
APPROVED BY	HH
DRAWN BY	B. KUMPF 16 SEPT 87
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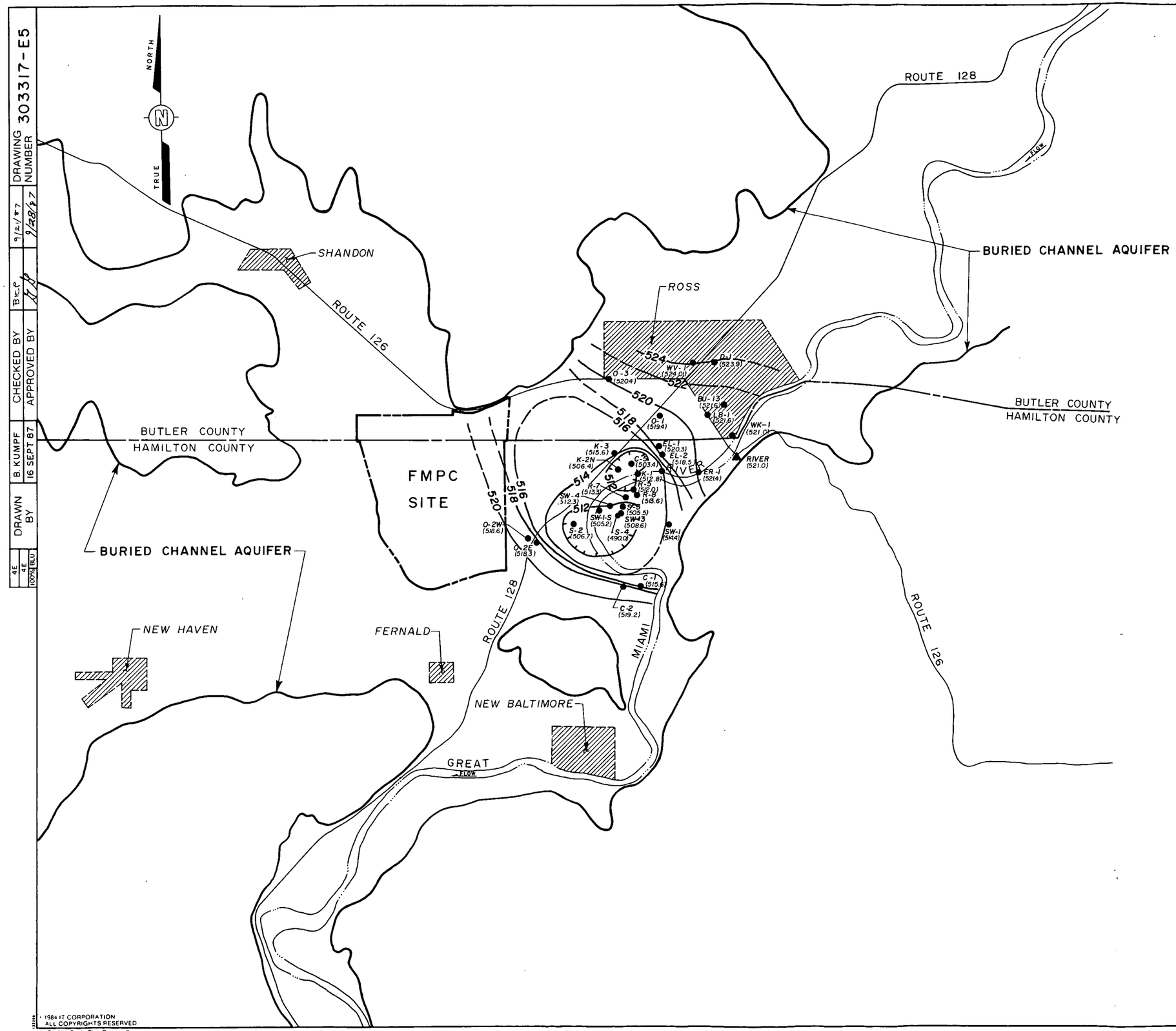

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON SEPTEMBER 26, 1986.

LEGEND:

- ● LB-1 — WELL NAME AND LOCATION
- (520.9) — MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
- 524 — GROUND WATER CONTOUR (FEET MSL)
- ▲ RIVER — RIVER ELEVATION LOCATION
- — — — INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-15

OCTOBER 1986
GROUND WATER CONTOUR MAP

PREPARED FOR

FERNALD RI/FS
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OAK RIDGE OPERATIONS

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DRAWING NUMBER	303317-E5
	9/25/87
	9/28/87
CHECKED BY	BCP
APPROVED BY	
DRAWN BY	B KUMPF 16 SEPT 87
	4E 4E 100% BLU

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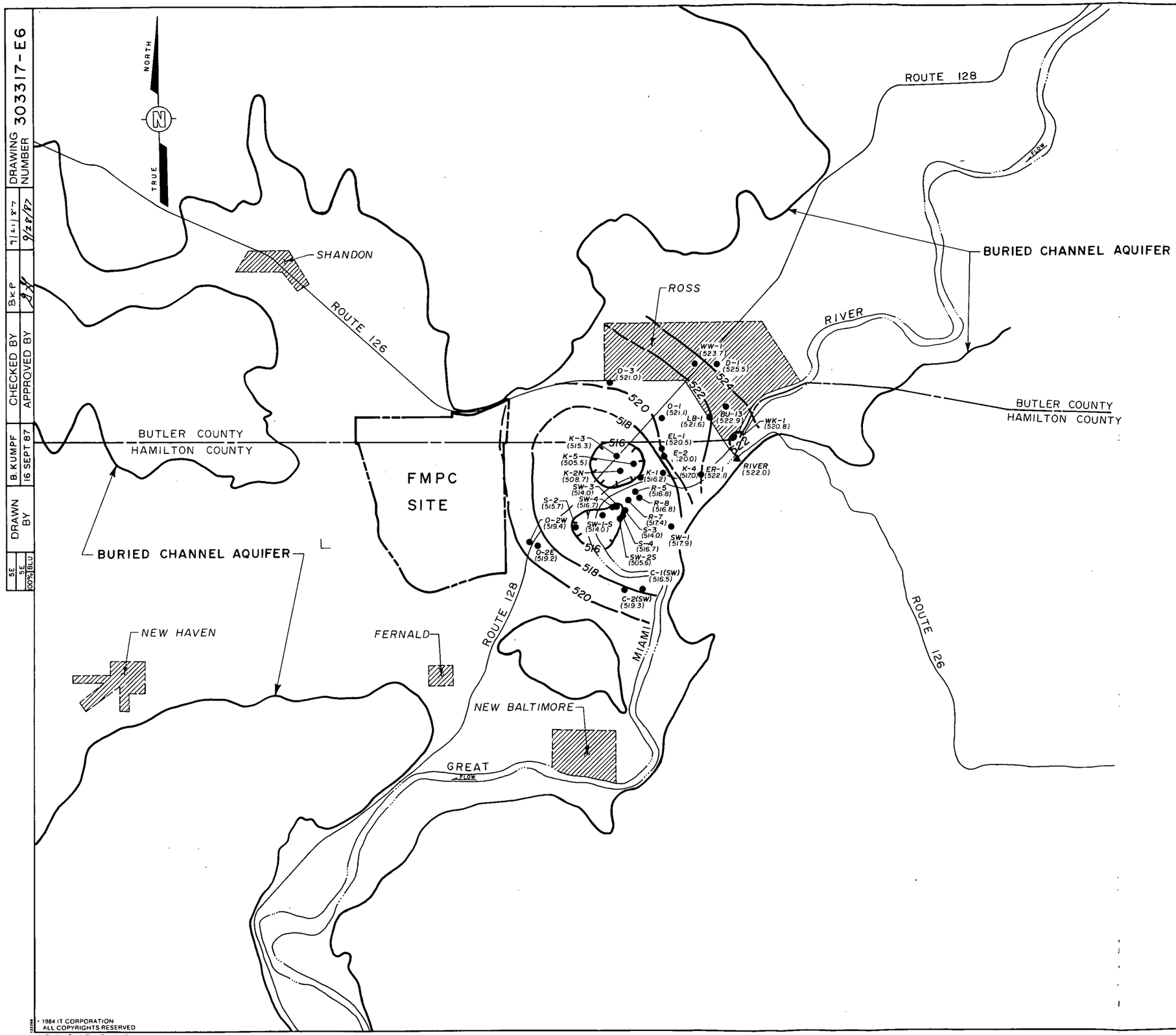

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON OCTOBER 30, 1986.

LEGEND:

- LB-1 — WELL NAME AND LOCATION
- (520.9) — MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
- 524 — GROUND WATER CONTOUR (FEET MSL)
- RIVER — RIVER ELEVATION LOCATION
- INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-16

NOVEMBER 1986
GROUND WATER CONTOUR MAP

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		APPROVED BY		9/28/87	

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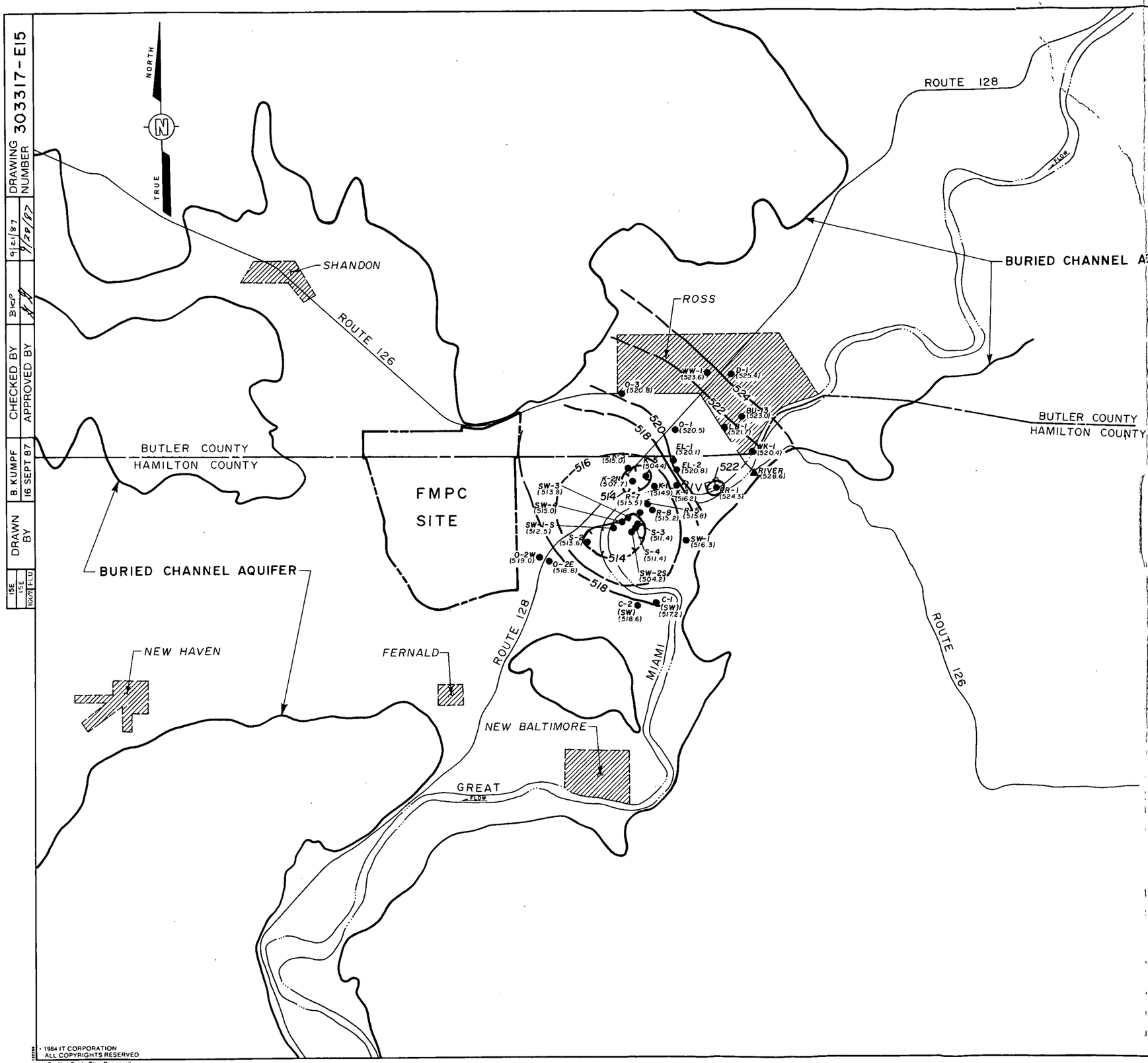

DRAWN BY	B. KUMPF 16 SEPT 87	CHECKED BY	BKP	9/21/87	DRAWING NUMBER 303317-E15
		APPROVED BY		9/22/87	

15E 15E 100% FLO

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON NOVEMBER 26, 1986.

LEGEND:

- ● LB-1 — WELL NAME AND LOCATION
- (521.7) — MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
- — 524 — GROUND WATER CONTOUR (FEET MSL)
- ▲ RIVER — RIVER ELEVATION LOCATION
- — — — INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-17

DECEMBER 1986
GROUND WATER CONTOUR MAP

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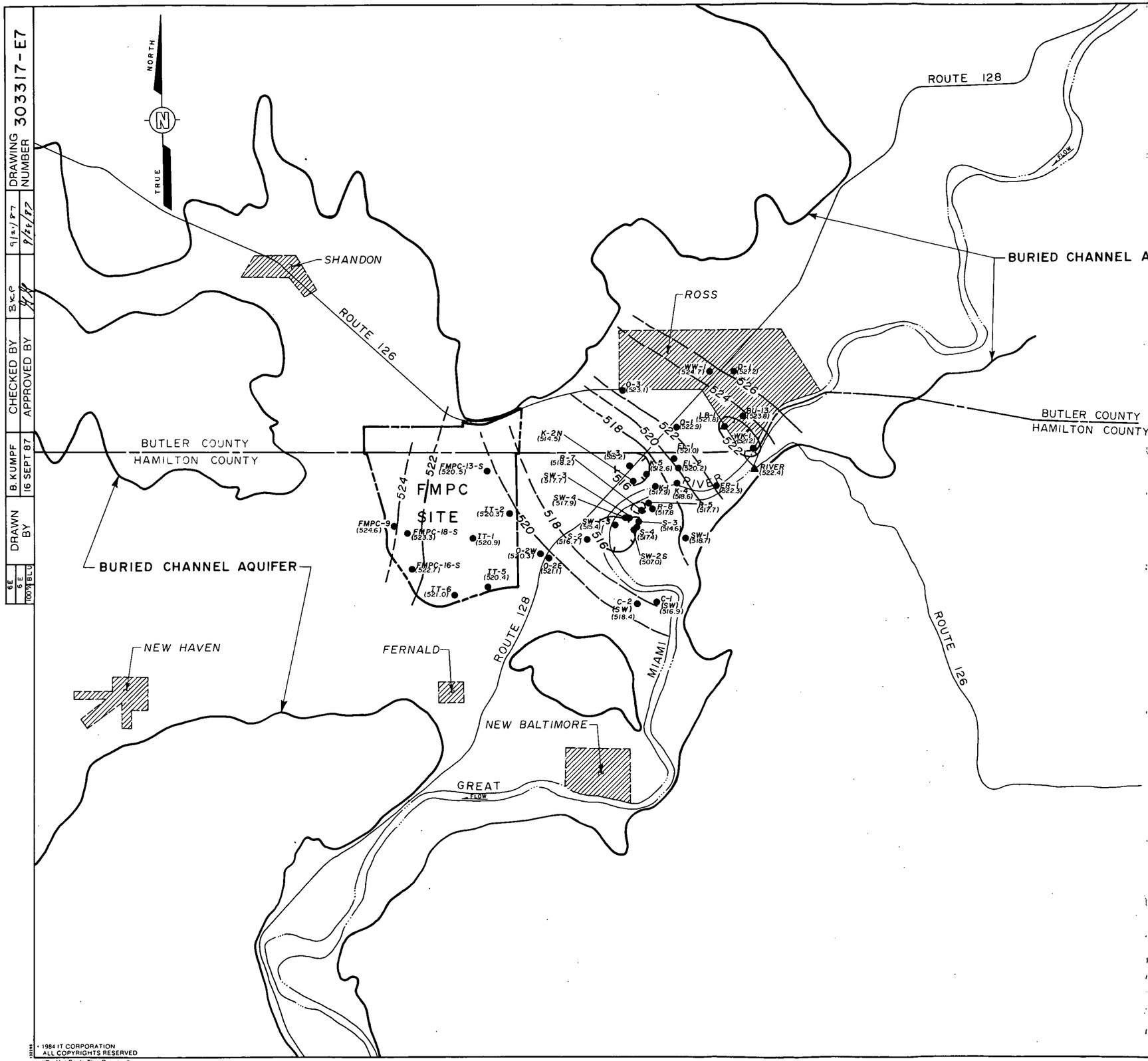

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON JANUARY 21, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(521.8)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
— — —	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-18

JANUARY 1987
GROUND WATER CONTOUR MAP

PREPARED FOR

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OAK RIDGE OPERATIONS

DRAWING NUMBER 303317-E7
9/24/87 9/24/87
B.K.P.
CHECKED BY
APPROVED BY
B. KUMPF 16 SEPT 87
DRAWN BY
6E 6E BLU

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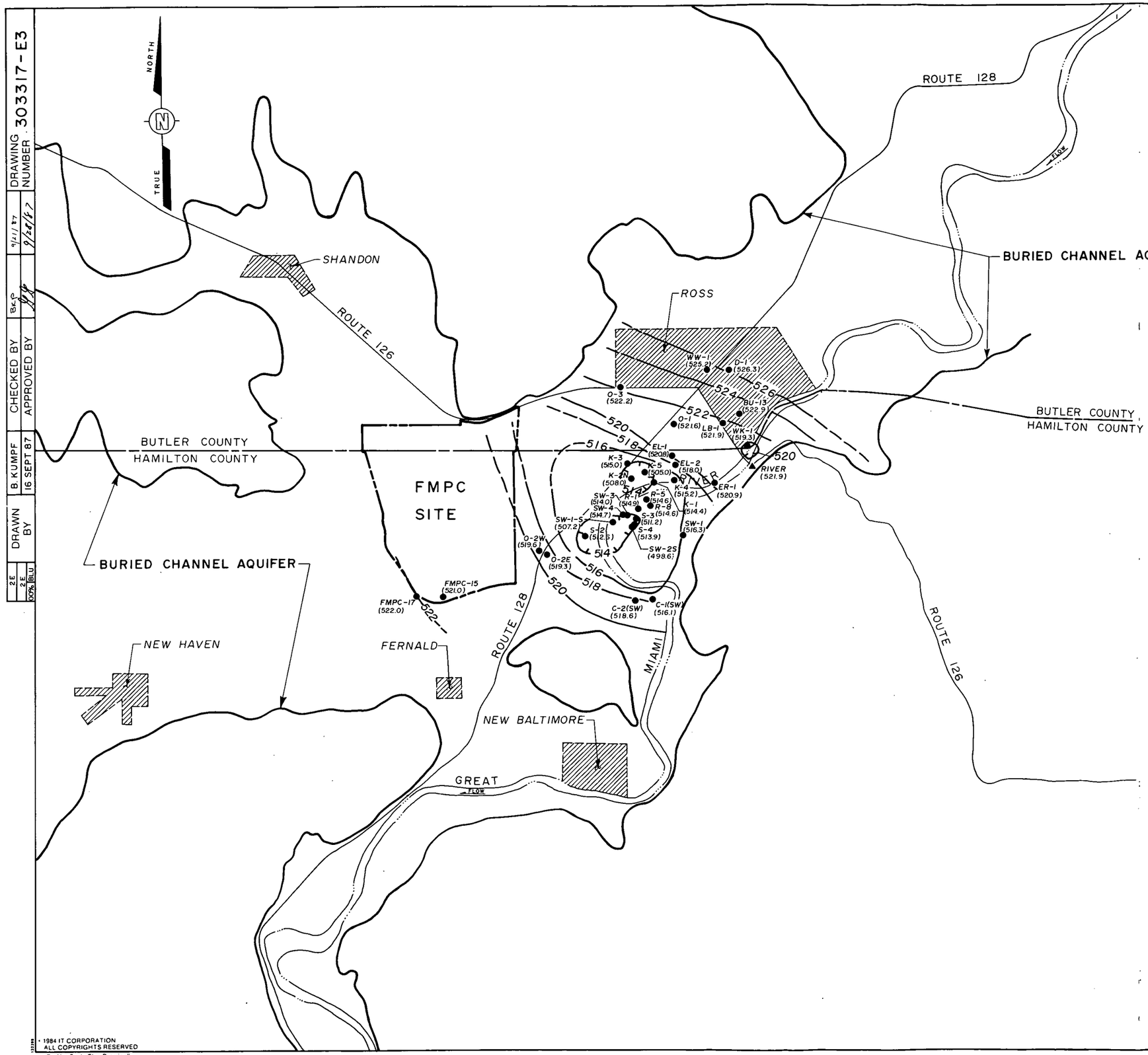

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS FOR WELLS WERE MEASURED ON FEBRUARY 2, 1987.

LEGEND:

- ● LB-1 — WELL NAME AND LOCATION
- (520.9) — MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
- 524 — GROUND WATER CONTOUR (FEET MSL)
- ▲ RIVER — RIVER ELEVATION LOCATION
- ——— INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 8000 FEET

FIGURE 2.1-19

FEBRUARY 1987
GROUND WATER CONTOUR MAP

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DRAWING NUMBER 303317-E3
9/21/87 9/28/87
B.K.P.
CHECKED BY
APPROVED BY
B. KUMPF 16 SEPT 87
DRAWN BY
2E 2E 00% BLU

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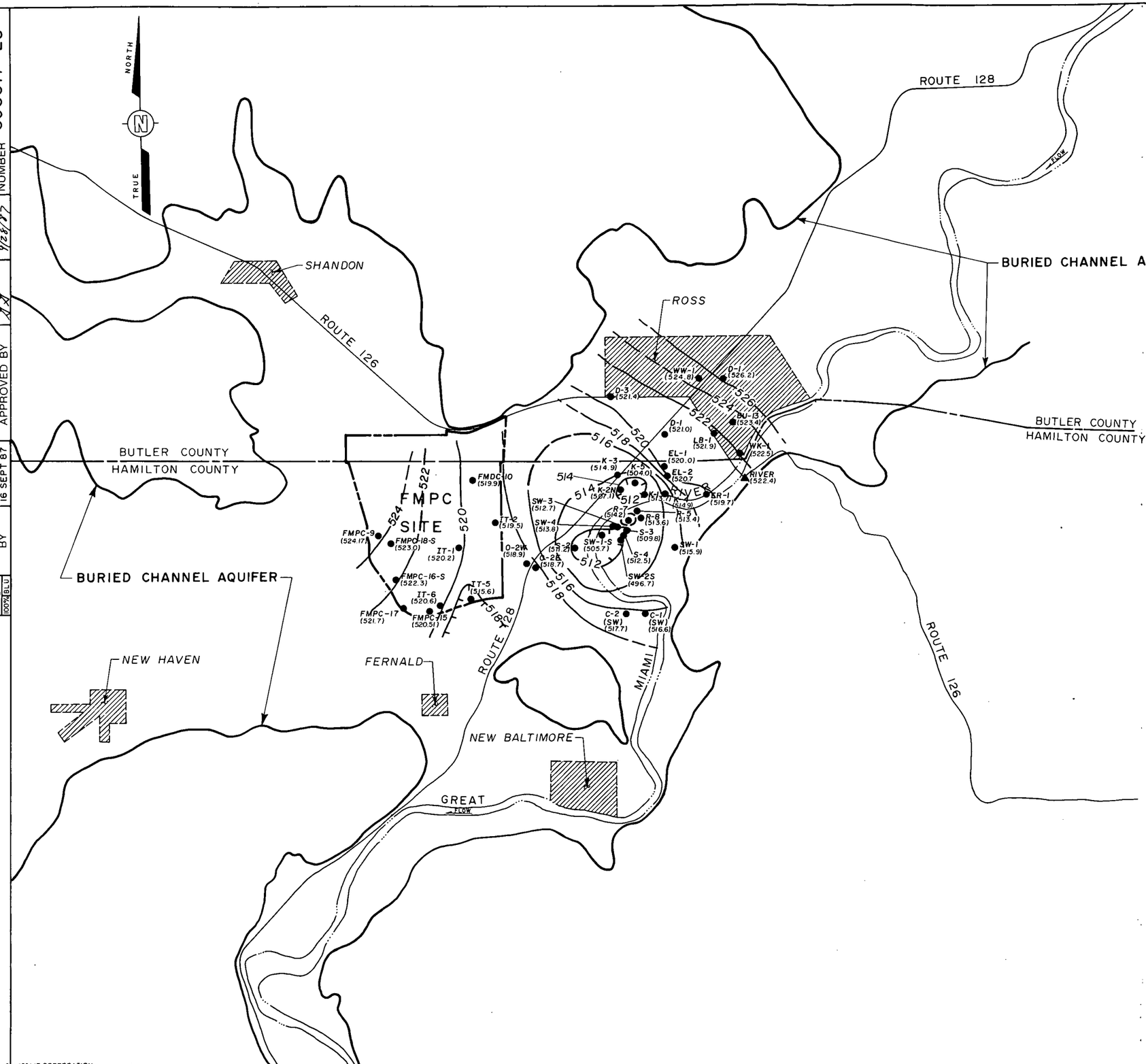

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS ARE FOR MARCH 6, 1987 EXCEPT GROUND WATER ELEVATIONS FOR FMPC SITE WELLS WHICH WERE RECORDED ON MARCH 11, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(521.9)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
— — —	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-20

MARCH 1987
GROUND WATER CONTOUR MAP

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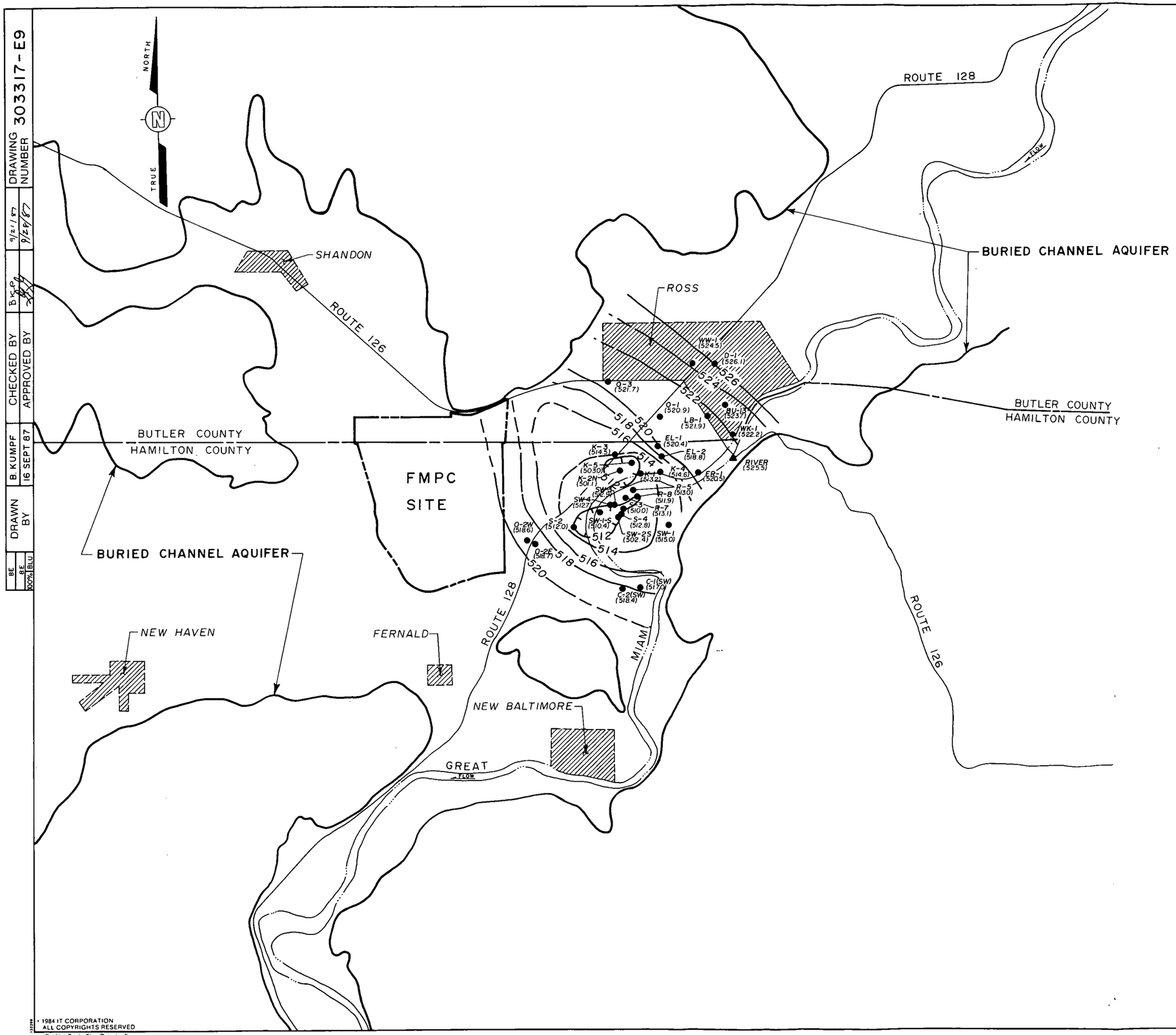

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS ARE FOR APRIL 2, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(520.9)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
———	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-21

APRIL 1987
GROUND WATER CONTOUR MAP

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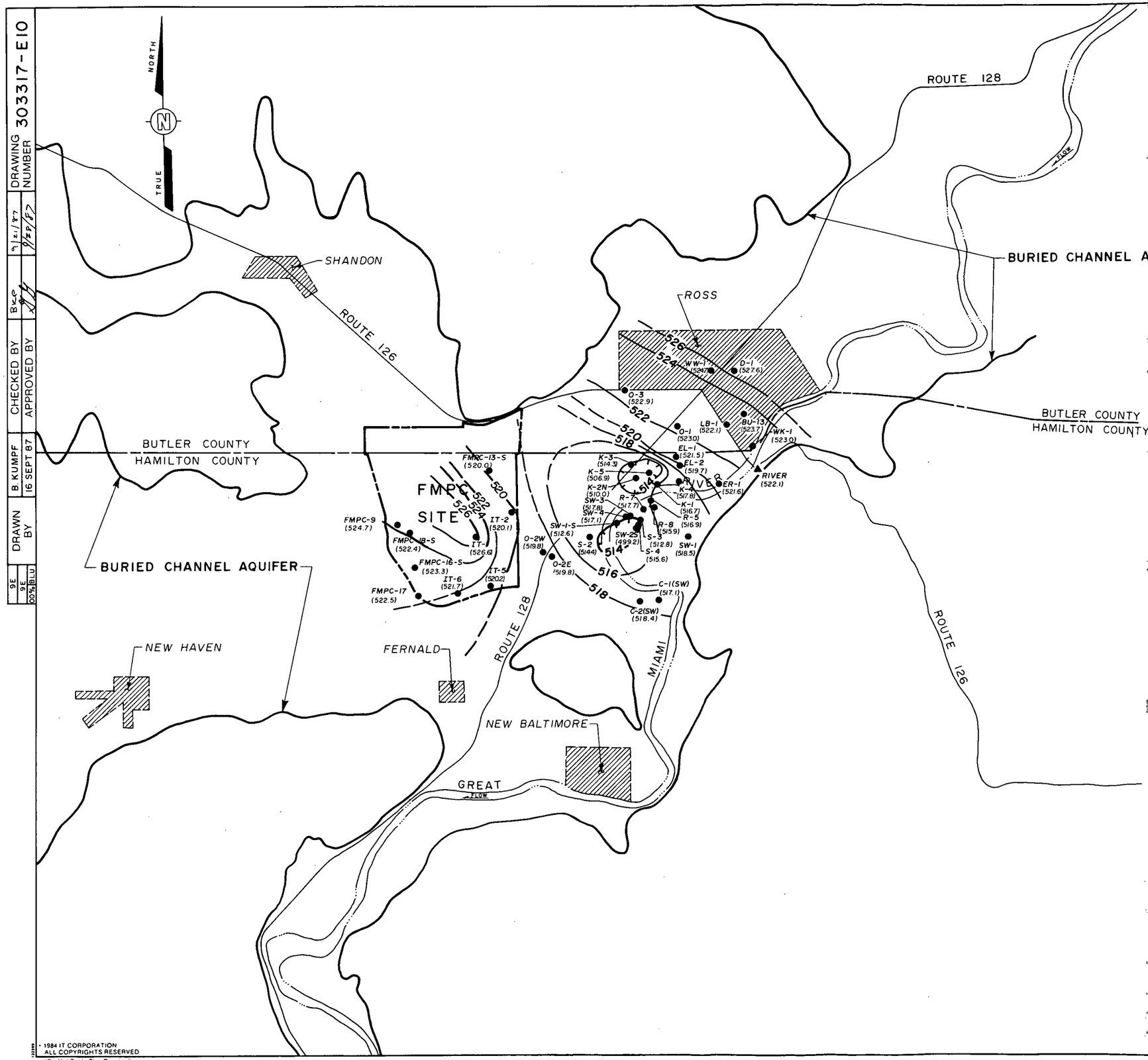

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS ARE FOR APRIL 29, 1987 EXCEPT FMPC SITE WELLS WHICH WERE RECORDED ON APRIL 30, 1987 AND BU-13 WHICH WAS RECORDED ON MAY 3, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(520.9)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
———	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-22

MAY 1987
GROUND WATER CONTOUR MAP

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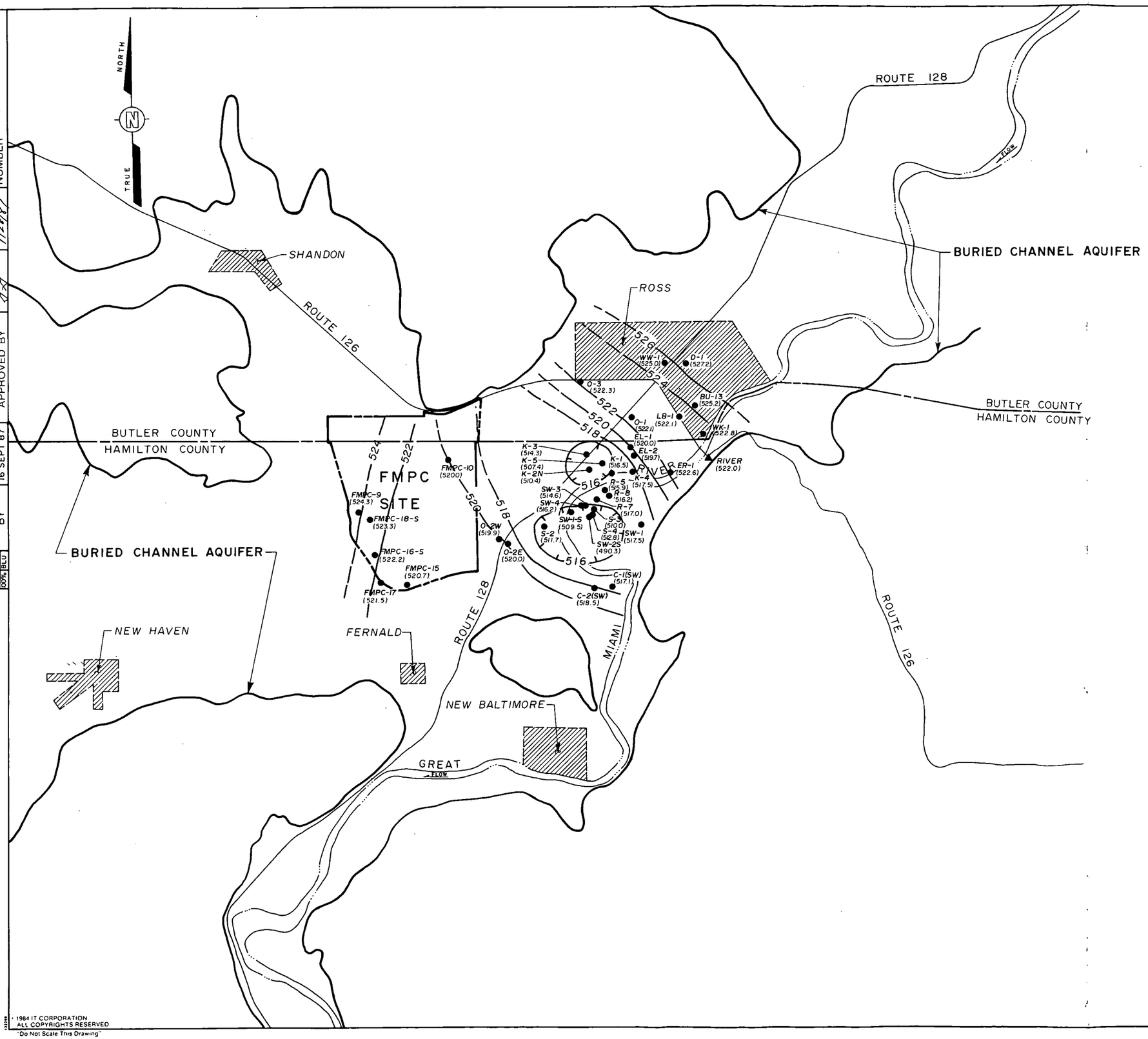

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS ARE FOR JUNE 7, 1987 EXCEPT GROUND WATER ELEVATIONS FOR FMPC SITE WELLS WHICH WERE RECORDED ON JUNE 10, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(520.9)	MEASURSED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
———	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-23

JUNE 1987
GROUND WATER CONTOUR MAP

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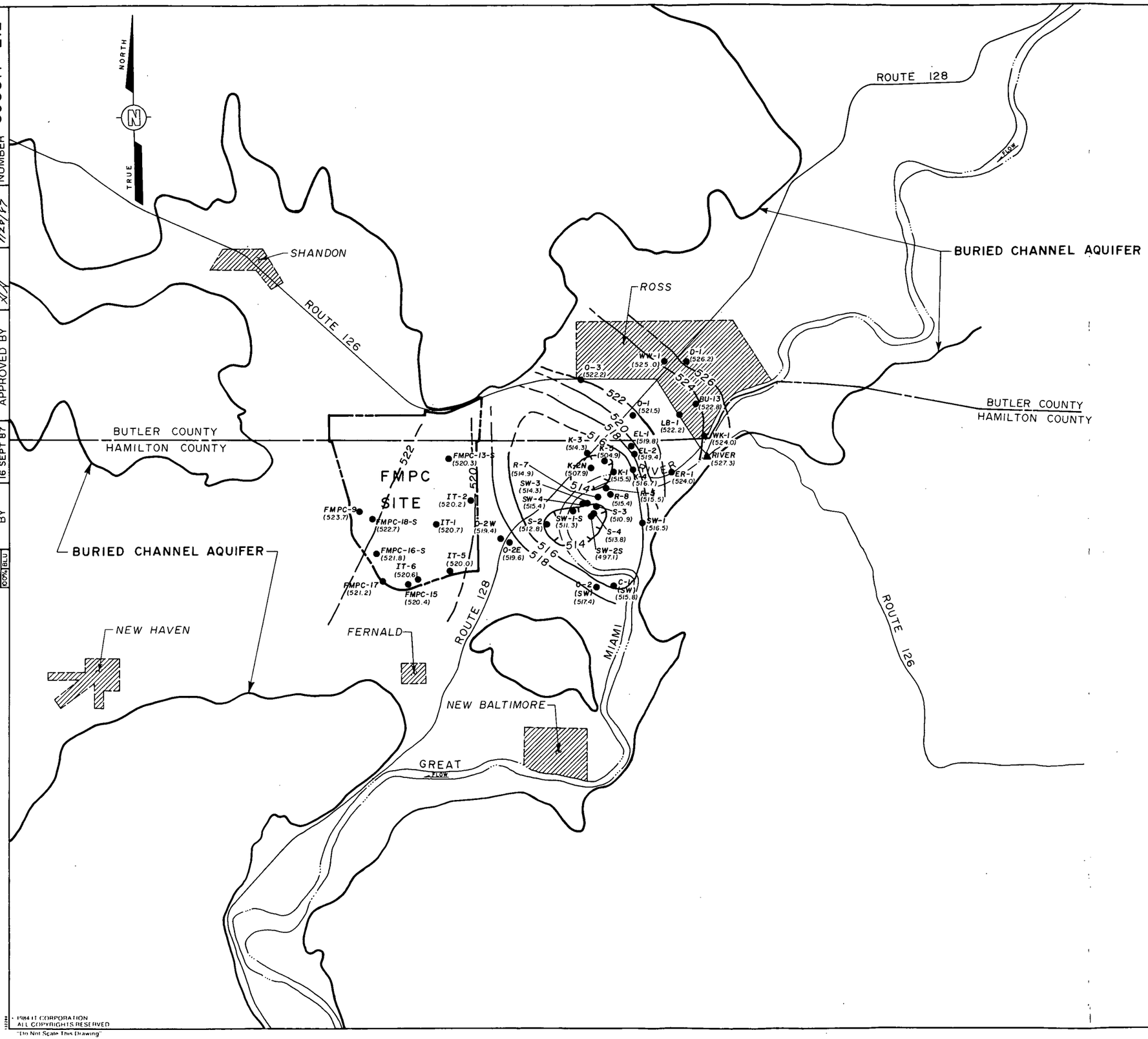

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

2. GROUND WATER ELEVATIONS ARE FOR JULY 2, 1987 EXCEPT GROUND WATER ELEVATIONS FOR FMPC SITE WELLS WHICH WERE RECORDED ON JUNE 24, 1987.

LEGEND:

● LB-1	WELL NAME AND LOCATION
(522.2)	MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
— 524 —	GROUND WATER CONTOUR (FEET MSL)
▲ RIVER	RIVER ELEVATION LOCATION
— — —	INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-24

JULY 1987
GROUND WATER CONTOUR MAP

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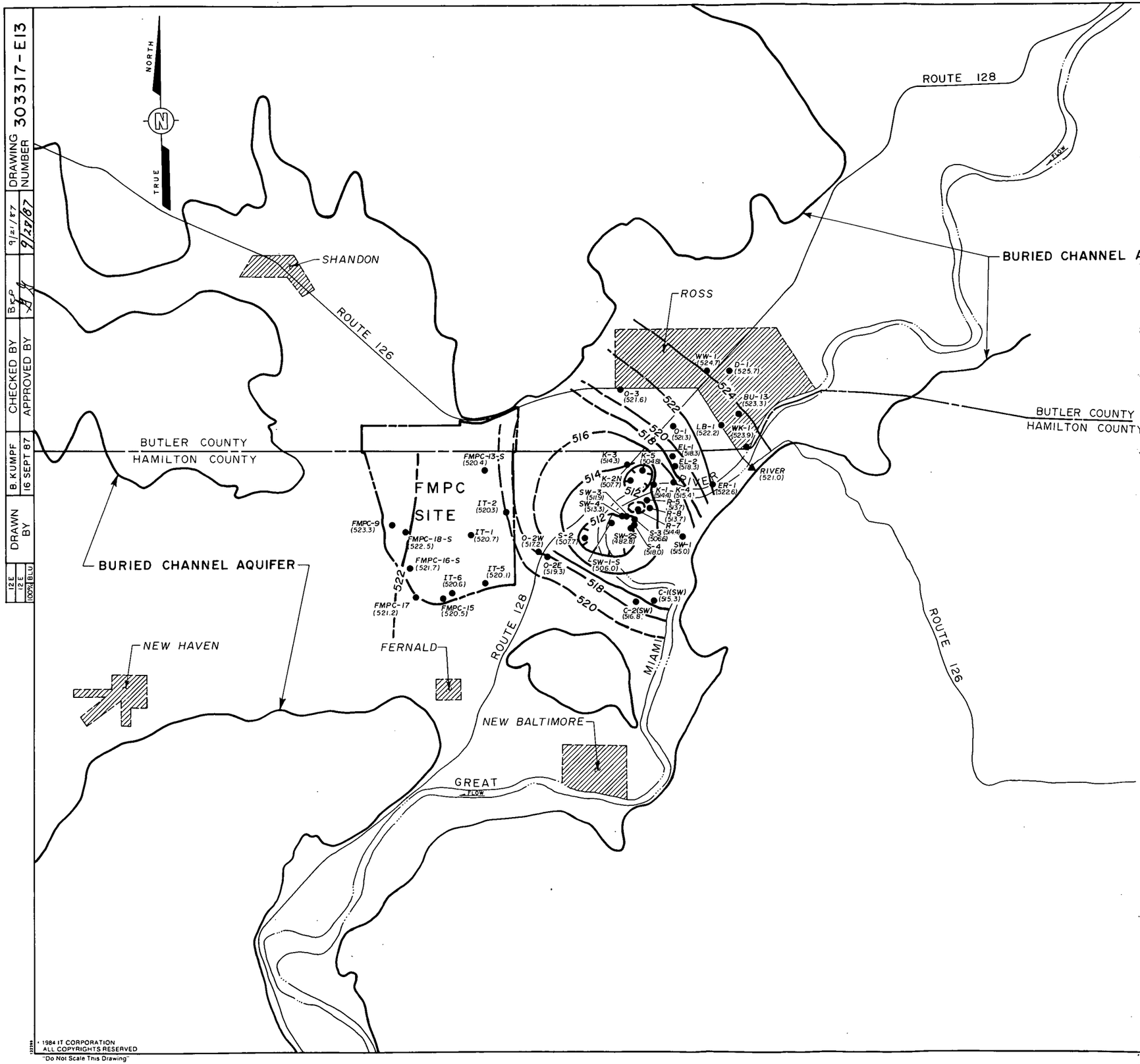

NOTES:

1. THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUND WATER 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, GROUND WATER 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 ON THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.
2. GROUND WATER ELEVATIONS ARE FOR 8 AUGUST 1987 EXCEPT GROUND WATER ELEVATIONS FOR FMPC SITE WELLS WHICH WERE RECORDED ON 24 JULY 87.

LEGEND:

- ● LB-1 — WELL NAME AND LOCATION
- (520.9) — MEASURED GROUND WATER LEVEL ELEVATION (FEET MSL)
- ~524~ — GROUND WATER ELEVATION (FEET MSL)
- ▲ RIVER — RIVER ELEVATION LOCATION
- — — — INDICATES AREA OF UNCERTAINTY

SCALE
0 2000 4000 6000 FEET

FIGURE 2.1-25

AUGUST 1987
GROUND WATER CONTOUR MAP

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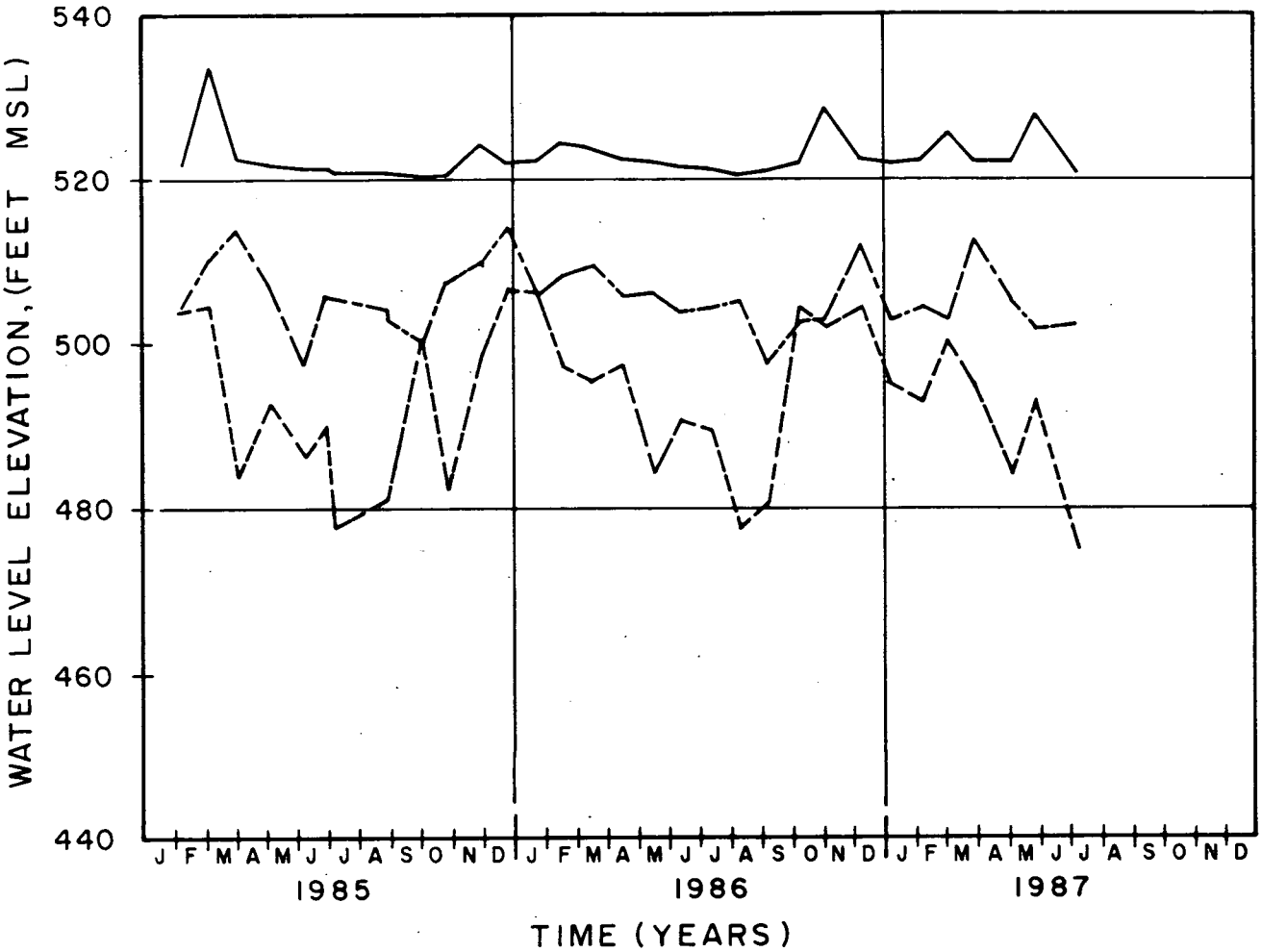

LEGEND:

——— GREAT MIAMI RIVER AT ROSS BRIDGE

—-—- COLLECTOR WELL 1

- - - - COLLECTOR WELL 2

NOTE:

SEE FIGURE 2.1-1 FOR SITE LOCATIONS.

FIGURE 2.1-26

COLLECTOR WELLS AND RIVER HYDROGRAPHS:

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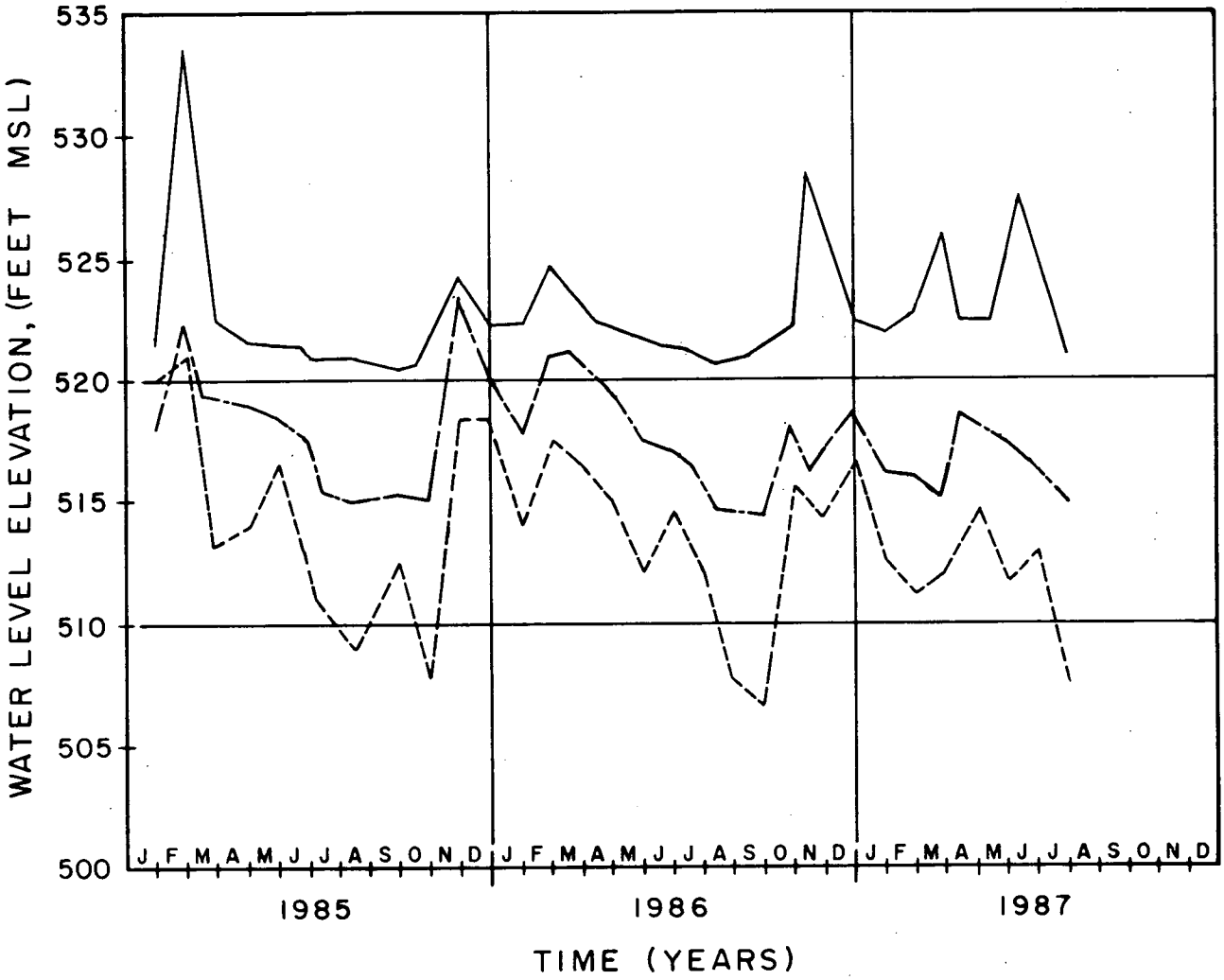

LEGEND:

——— GREAT MIAMI RIVER AT ROSS BRIDGE

– – – – S-2

– – – – SW-1

NOTE:

SEE FIGURE 2.1-1 FOR SITE LOCATIONS.

FIGURE 2.1-27

MONITORING WELL AND RIVER HYDROGRAPHS: WELLS SW-1 AND S-2

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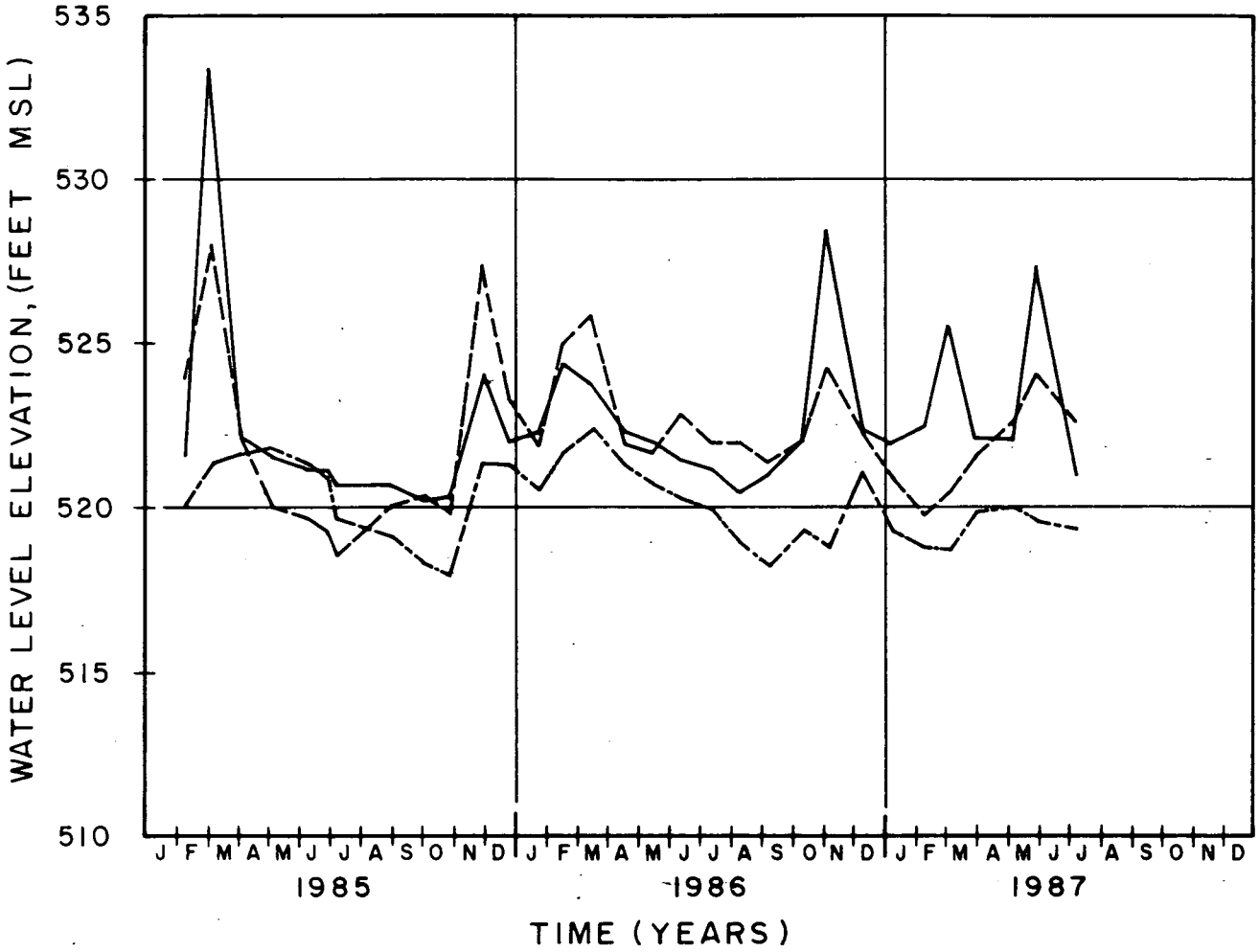

LEGEND:

——— GREAT MIAMI RIVER AT ROSS BRIDGE

– – – – ER-1

—·—·— O-2E

NOTE:

SEE FIGURE 2.1-1 FOR SITE LOCATIONS.

FIGURE 2.1-28

MONITORING WELL AND RIVER HYDROGRAPHS: WELLS ER-1 AND O-2E

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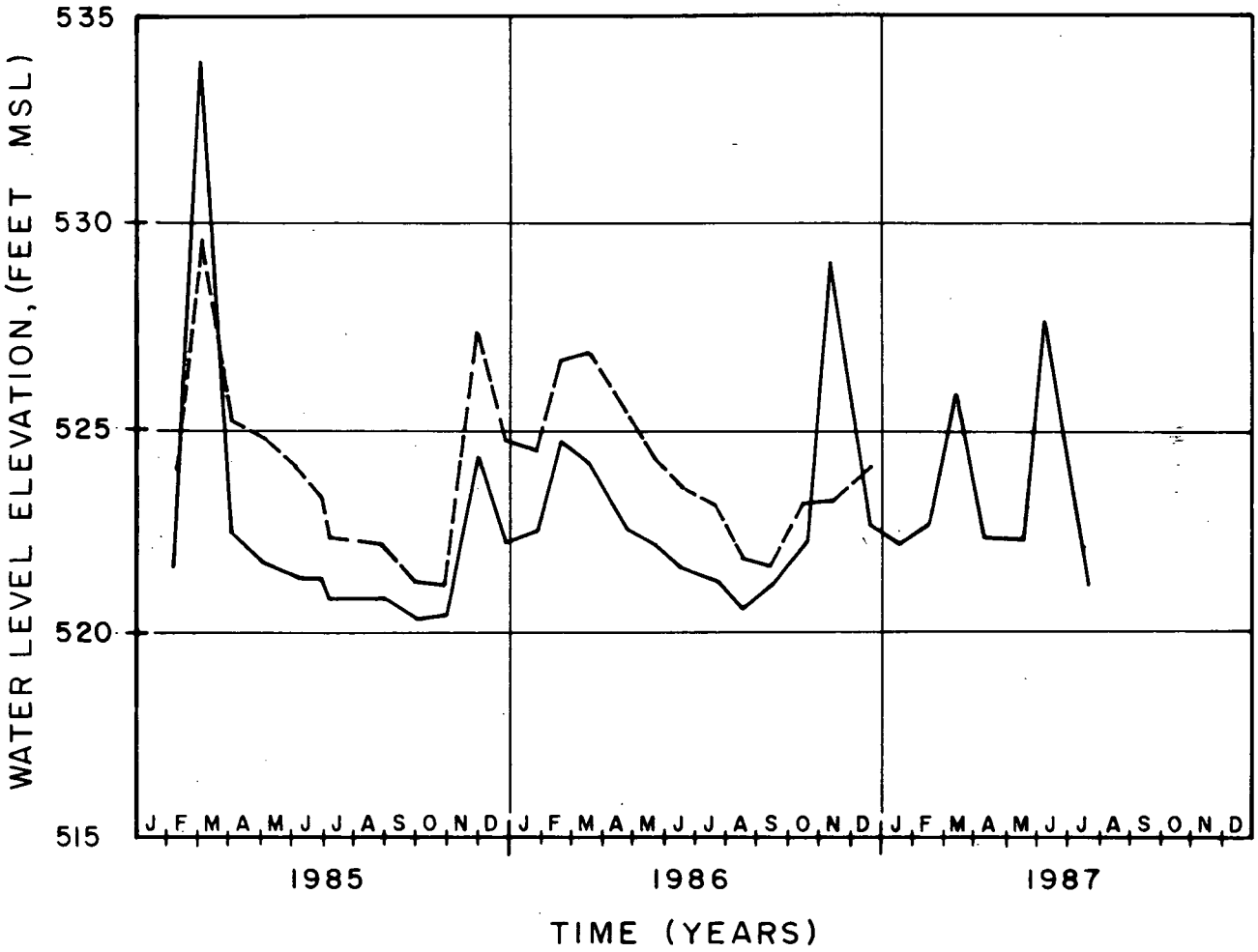

LEGEND:

——— GREAT MIAMI RIVER AT ROSS BRIDGE

– – – – BU-13

NOTE:

SEE FIGURE 2.1-1 FOR SITE LOCATIONS.

FIGURE 2.1-29

MONITORING WELL AND RIVER HYDROGRAPHS: WELL BU-13

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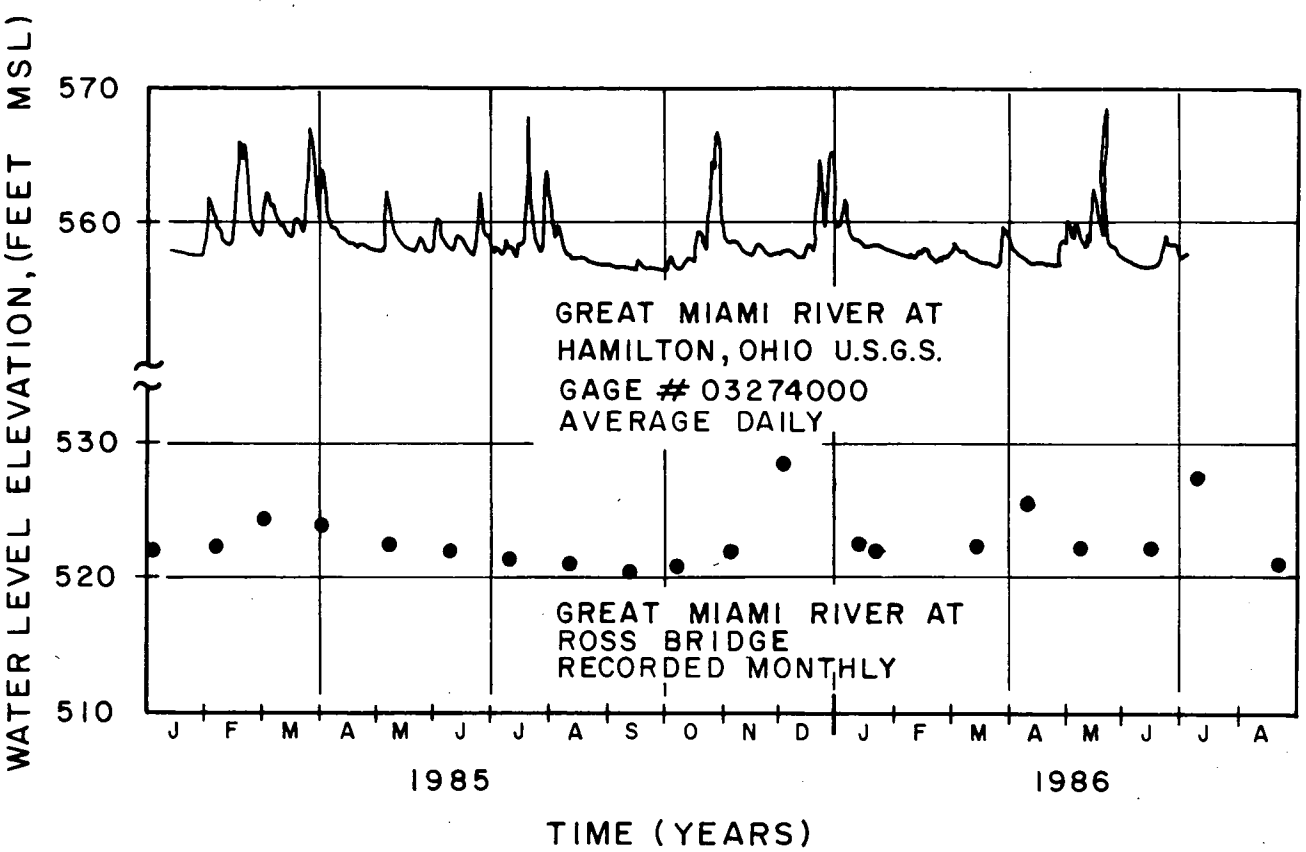

FIGURE 2.1-30

RIVER STAGE AT
HAMILTON AND ROSS
OHIO, 1985 AND 1986

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NOTE:

SEE FIGURE 2.1-1 FOR ROSS BRIDGE LOCATION.

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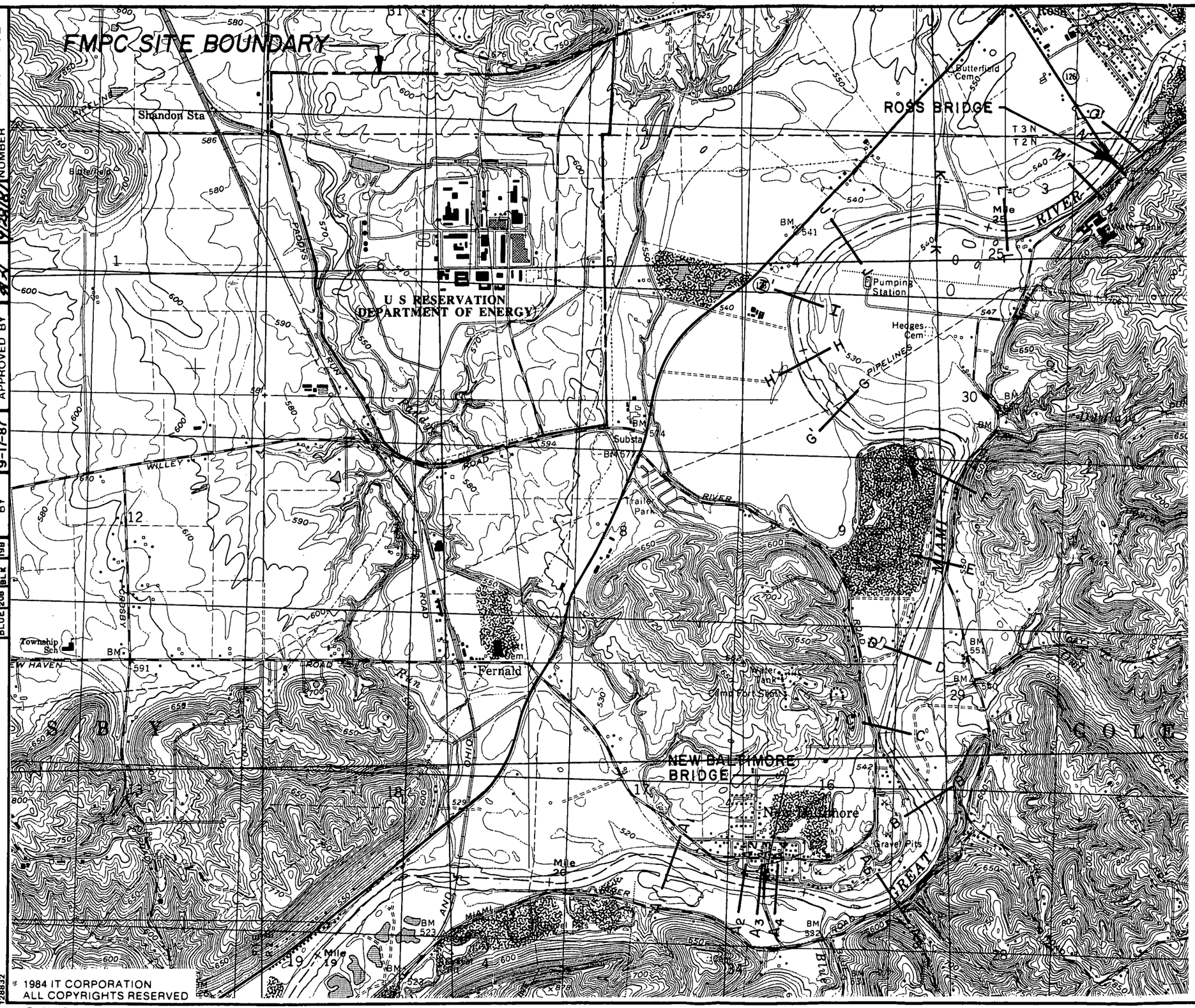

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LEGEND

B'——B RIVER CROSS SECTION LOCATIONS HEC-2 MODELING

REFERENCES:

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO-IND., SHANDON, OHIO GREENHILLS, OHIO, CINCINNATI WEST, OHIO, ADDYSTON, OHIO-KY, AND HOOVEN OHIO. DATED: 1955 (PR1981), 1965 (PR1981), 1965 (PR1981), 1961, PR1981), 1982 AND 1981 SCALE: 1" = 2000'

HEC-2 WATER SURFACE PROFILES US ARMY CORPS OF ENGINEERS COMPUTER PROGRAM VERSION OF NOVEMBER, 1976 UPDATED MARCH, 1982.

SCALE

0 2000 4000 FEET

FIGURE 2.2-1

LOCATION OF RIVER CROSS SECTIONS USED TO OBTAIN HYDRAULIC CHARACTERISTICS

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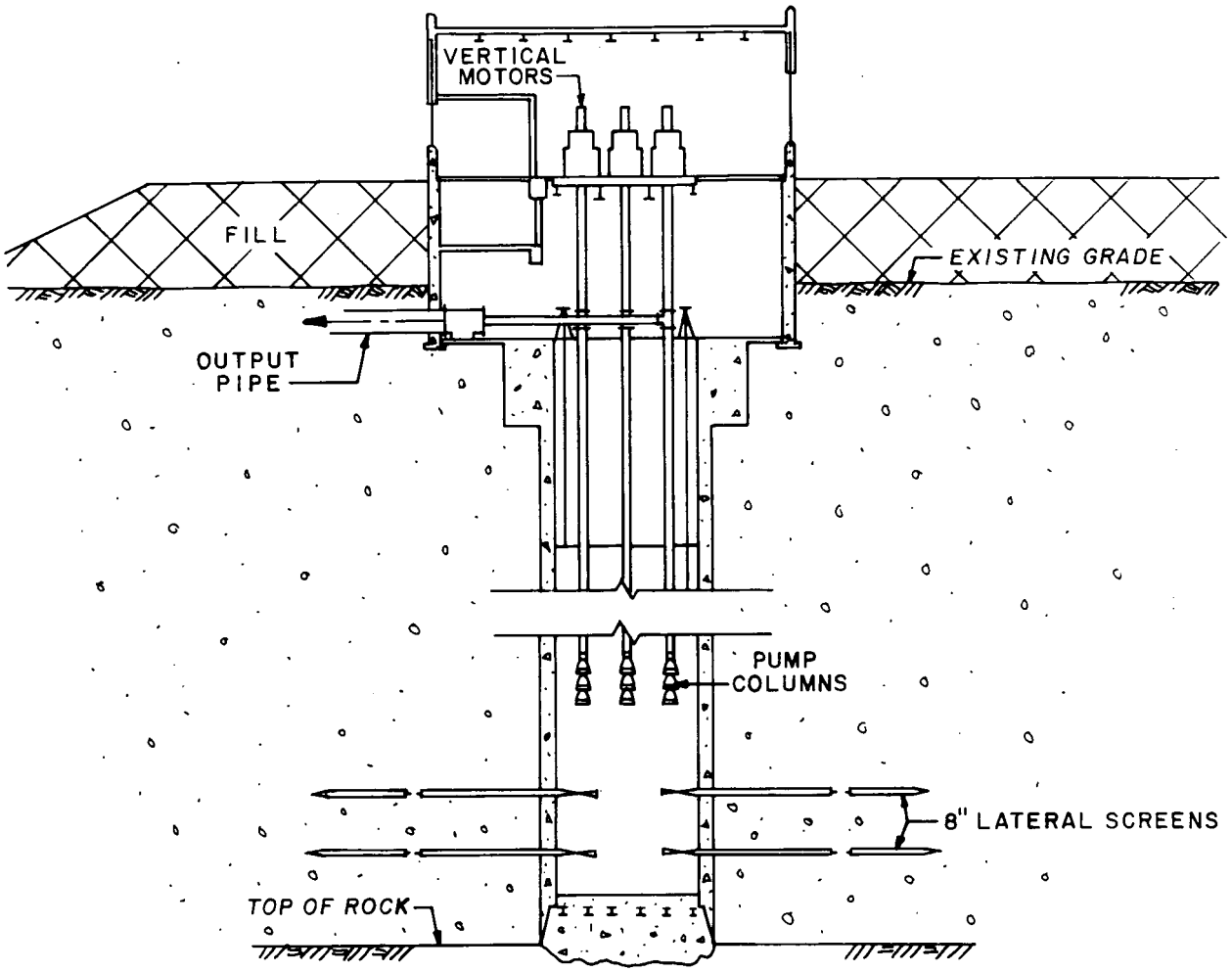

FIGURE 2.5-1

GENERALIZED SECTION OF SOUTHWESTERN OHIO WATER CO. COLLECTOR WELL

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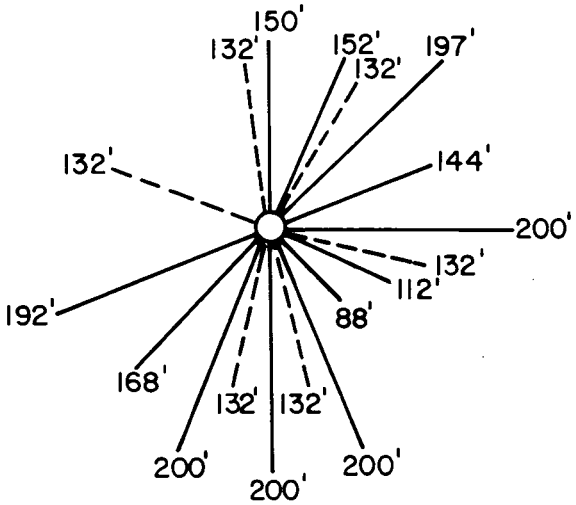
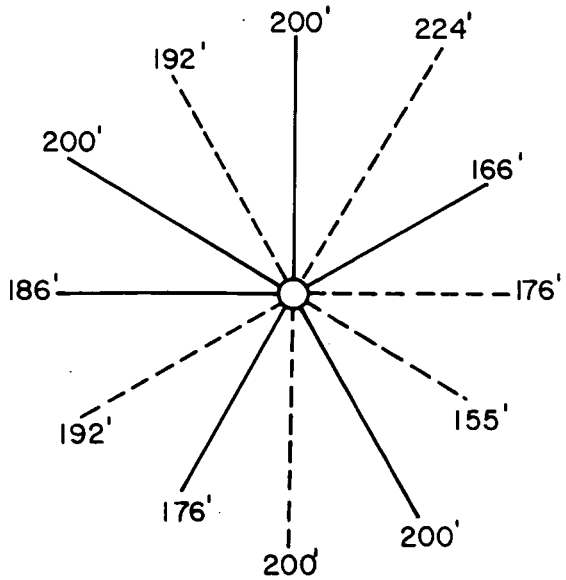


COLLECTOR WELL 1

ELEVATION OF LOWER TIER 409.7 FT.
ELEVATION OF UPPER TIER 433.0 FT.



COLLECTOR WELL 2

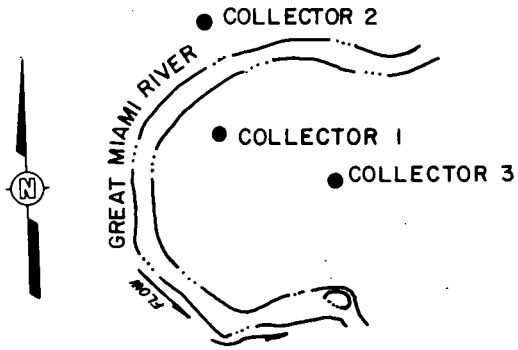
ELEVATION OF LOWER TIER 413.0 FT.
ELEVATION OF UPPER TIER 417.0 FT.

LEGEND

--- LOWER TIER LATERAL SCREENS
—— UPPER TIER LATERAL SCREENS

NOTE:

MIAMI CONSERVANCY DISTRICT REPORTS LATERALS FOR: COLLECTOR WELL 1 AT 409, 431, AND 435 FT; COLLECTOR WELL 2 AT 412, 416, AND 420 FT; AND COLLECTOR WELL 3 HAS LATERALS EXTENDING 100 FT. AT ELEVATION 478 FT.



PLAN

FIGURE 2.5-2

DIAGRAM SHOWING POSITION AND LENGTH OF HORIZONTAL SCREENS IN SOUTHWESTERN OHIO WATER COMPANY COLLECTOR 1 AND COLLECTOR 2

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DOVE, G.D. 1961

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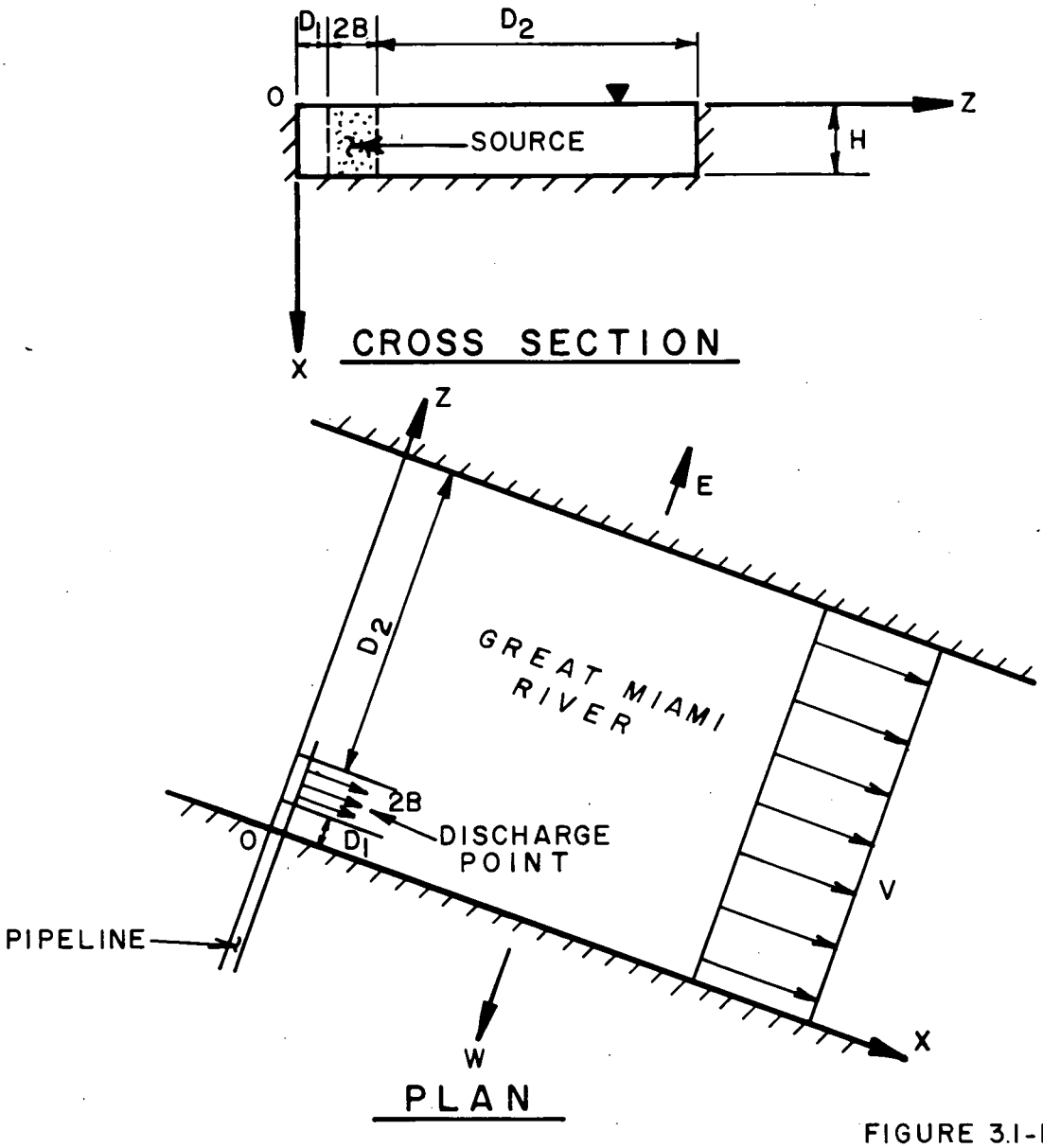

FIGURE 3.1-1

IDEALIZED SCHEMATIC REPRESENTATION OF THE HYDRODYNAMIC DISPERSION MODEL

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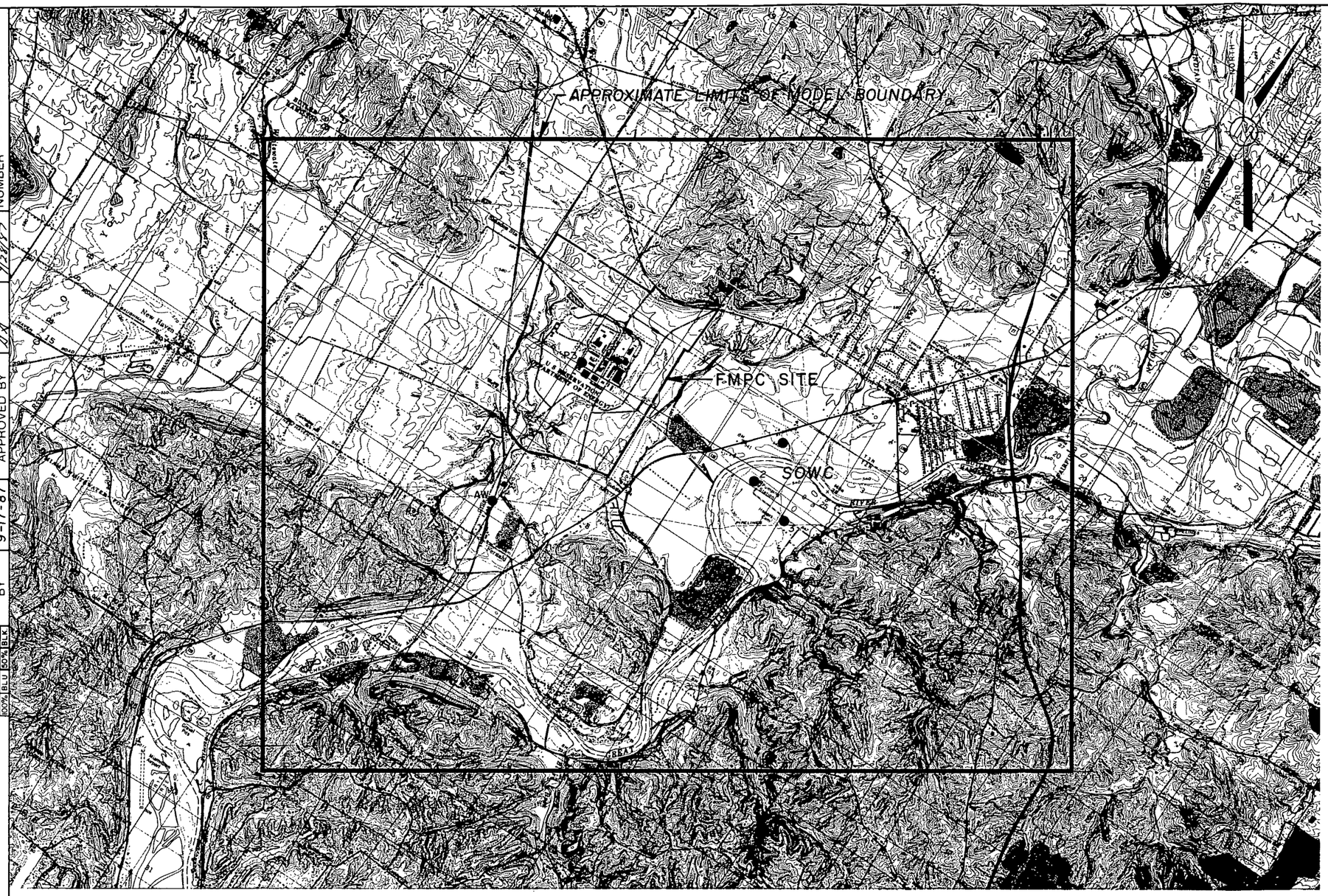

LEGEND:

→ FMPC EFFLUENT LINE DISCHARGE POINT

● PRODUCTION WELLS

SCALE
0 2000 4000 6000 FEET

FIGURE 3.2-1

MODEL AREA LOCATION MAP

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REFERENCES:

7.5' MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO-IND.; SHANDON, OHIO; GREENHILLS, OHIO; ADDYSTON, OHIO-KY. DATED: 1955 (PR 1981), 1965 (PR 1981), 1965 (PR 1981), AND 1982. SCALE: 1" = 2000'.

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19E 13E
19E 13E
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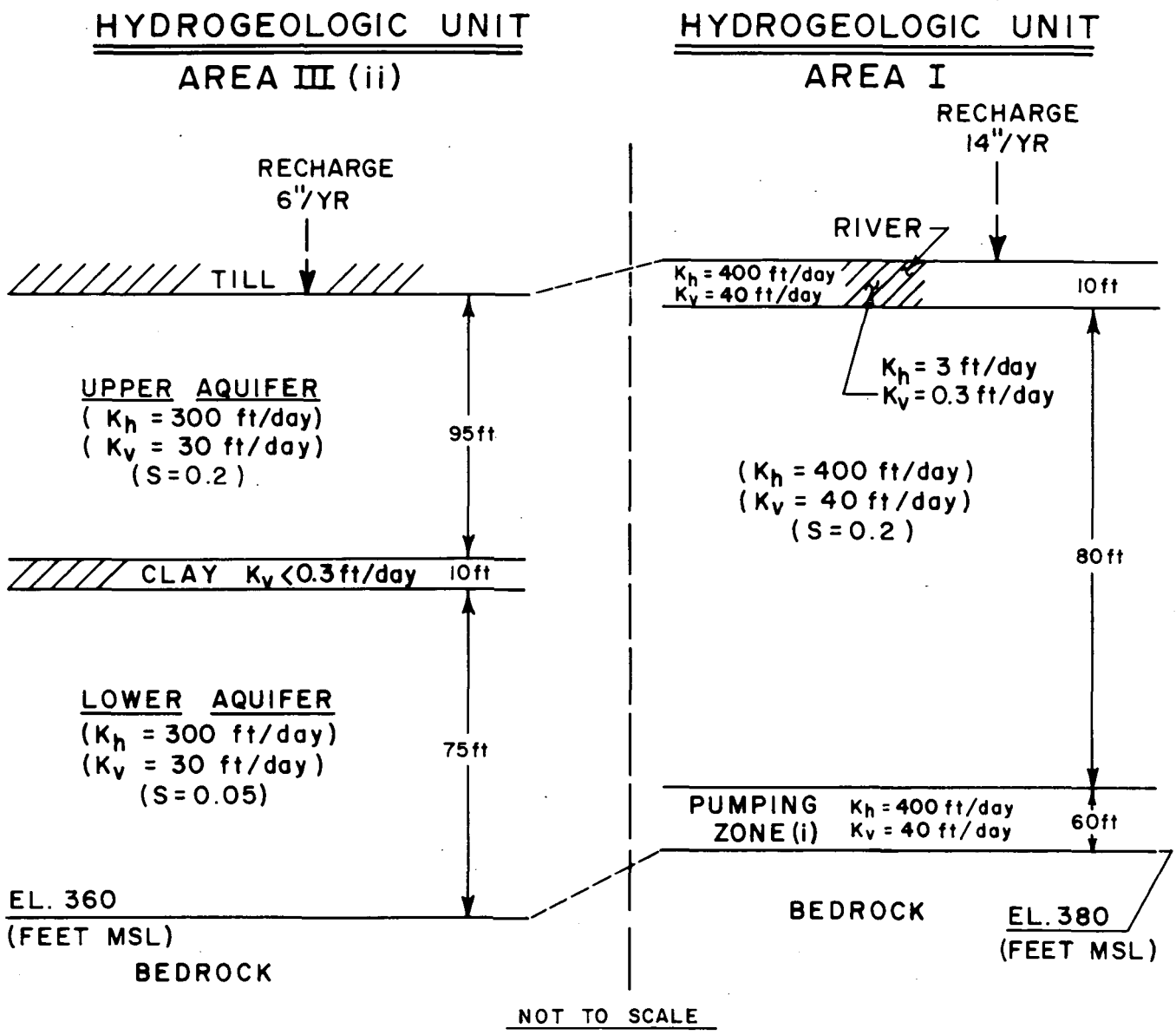

1. THIS DESIGN REPRESENTS A FIRST APPROXIMATION FOR TYPICAL MODEL INPUT PARAMETERS.
2. (i) COLLECTOR WELLS 1 & 2 PUMP WATER BETWEEN ELEV'S 409 & 433 FT.
3. (ii) HYDROGEOLOGIC UNITS ARE DEFINED IN TEXT.
4. K_h = HORIZONTAL HYDRAULIC CONDUCTIVITY
   K_v = VERTICAL HYDRAULIC CONDUCTIVITY

FIGURE 3.2-2

CONCEPTUAL DESIGN FOR "ZONE OF INFLUENCE" GROUNDWATER MODEL

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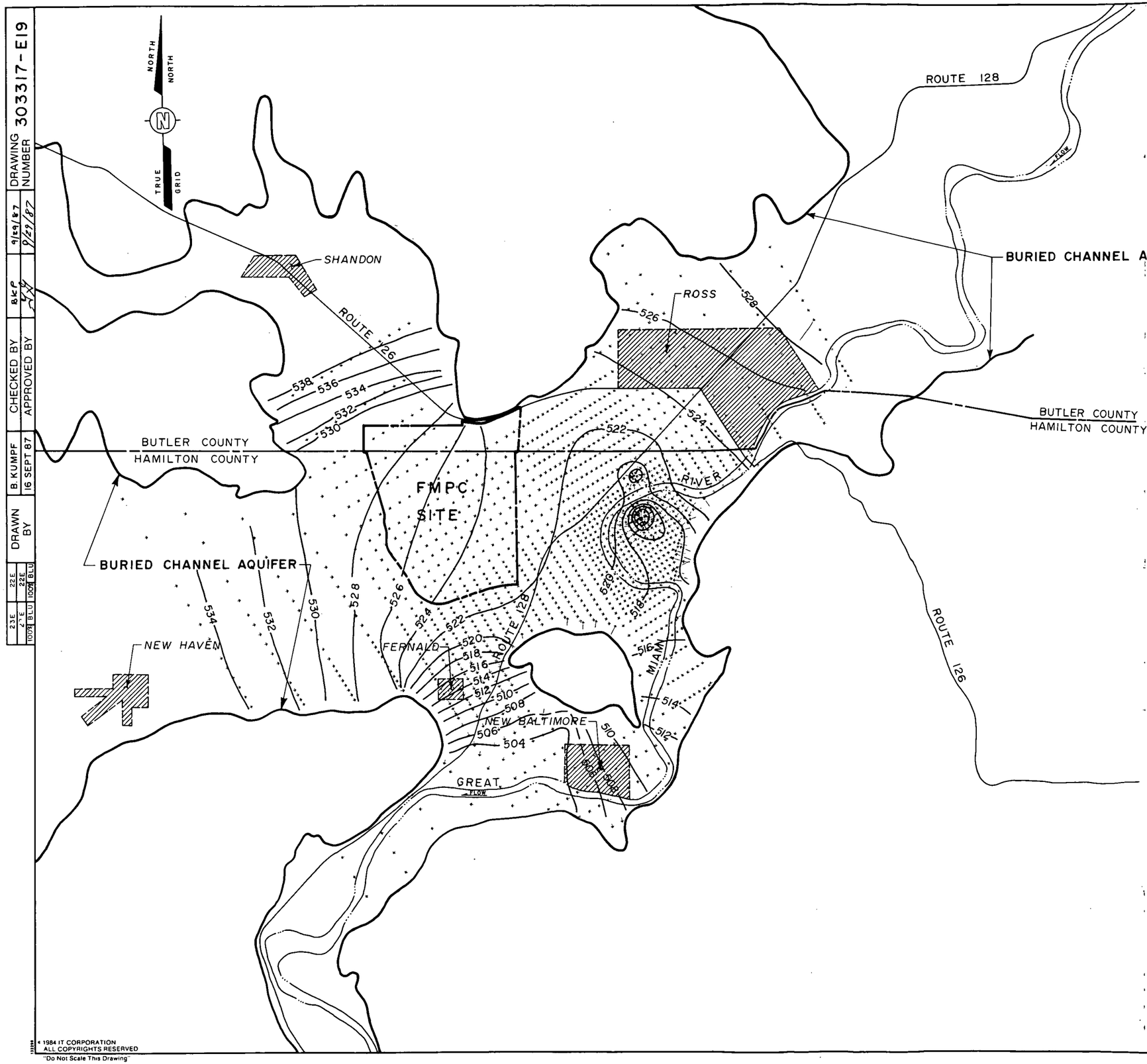

LEGEND:

⟵ GROUND WATER VELOCITY VECTOR

—522— GROUND WATER CONTOUR (FEET, MSL)

SCALE
0 2000 4000 6000 FEET

FIGURE 3.2-3

CALIBRATED GROUND WATER ELEVATIONS AND FLOW VECTORS FOR APRIL 1986 CONDITIONS

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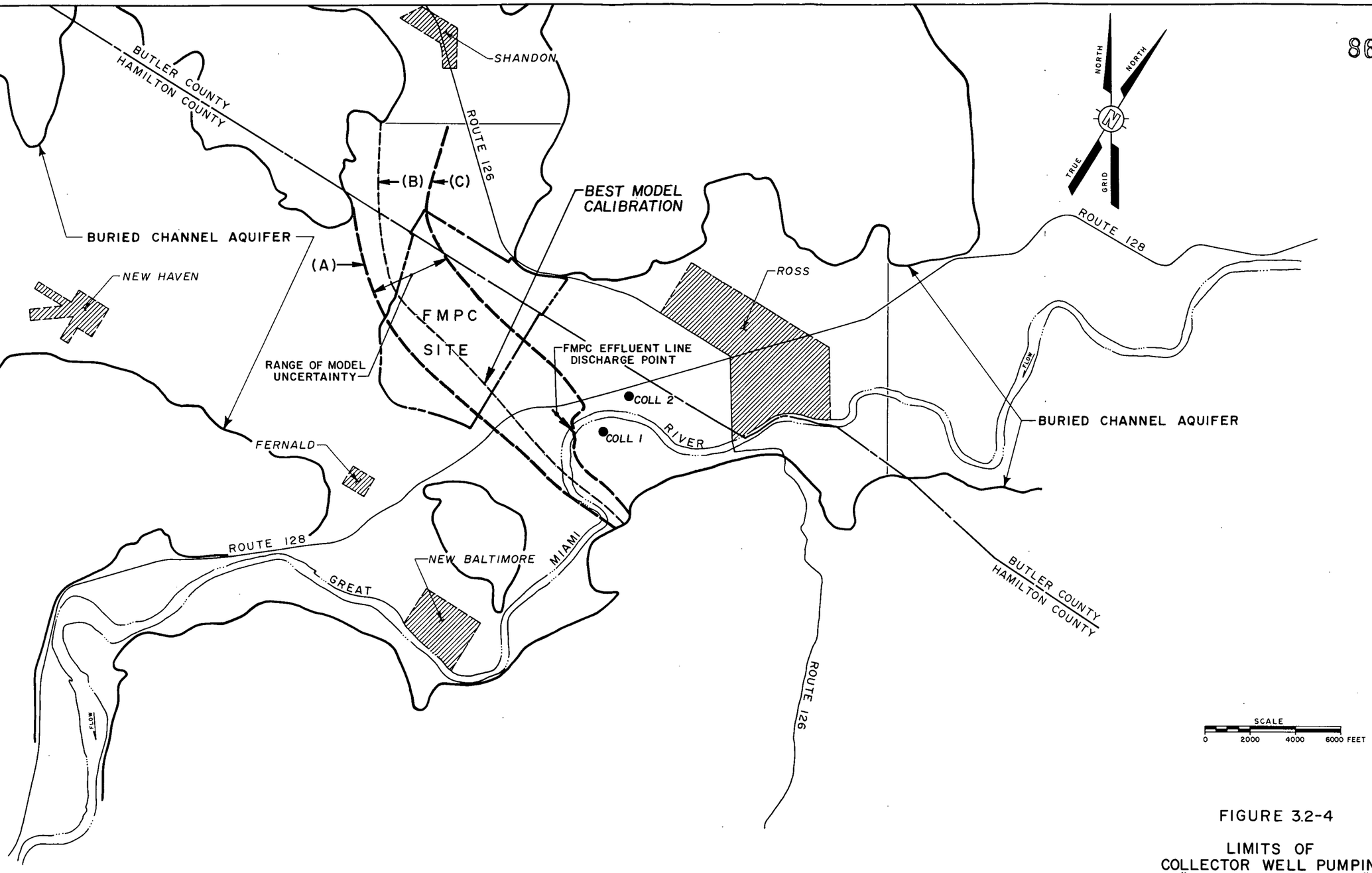

LEGEND

POTENTIAL "ZONE OF INFLUENCE" PREDICTED FROM GROUND WATER MODELING

(A) RIVER LEAKAGE FACTOR 0.17 DAY^{-1}

(B) RIVER LEAKAGE FACTOR 0.35 DAY^{-1}

(C) RIVER LEAKAGE FACTOR 3.5 DAY^{-1}

FIGURE 3.2-4

LIMITS OF COLLECTOR WELL PUMPING "ZONE OF INFLUENCE"

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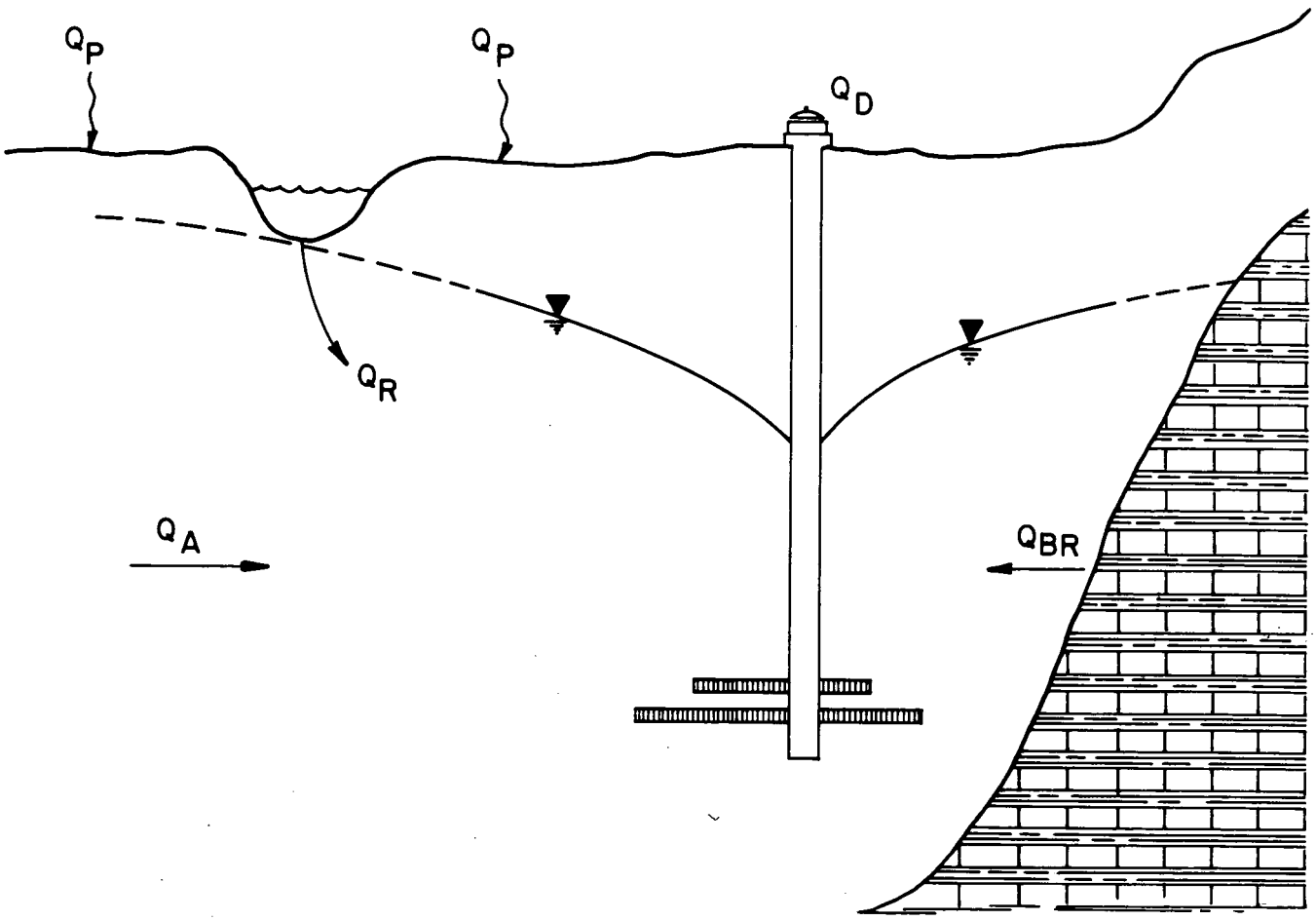

Q_D = PUMPING DISCHARGE FROM COLLECTOR WELLS

Q_P = COMPONENT FROM PRECIPITATION

Q_{BR} = COMPONENT FROM BEDROCK AQUIFER

Q_R = COMPONENT FROM RIVER

Q_A = COMPONENT FROM SAND AND GRAVEL AQUIFER

$Q_D = Q_P + Q_{BR} + Q_R + Q_A$

FIGURE 3.2-5

WATER BALANCE FOR COLLECTOR WELL DISCHARGE

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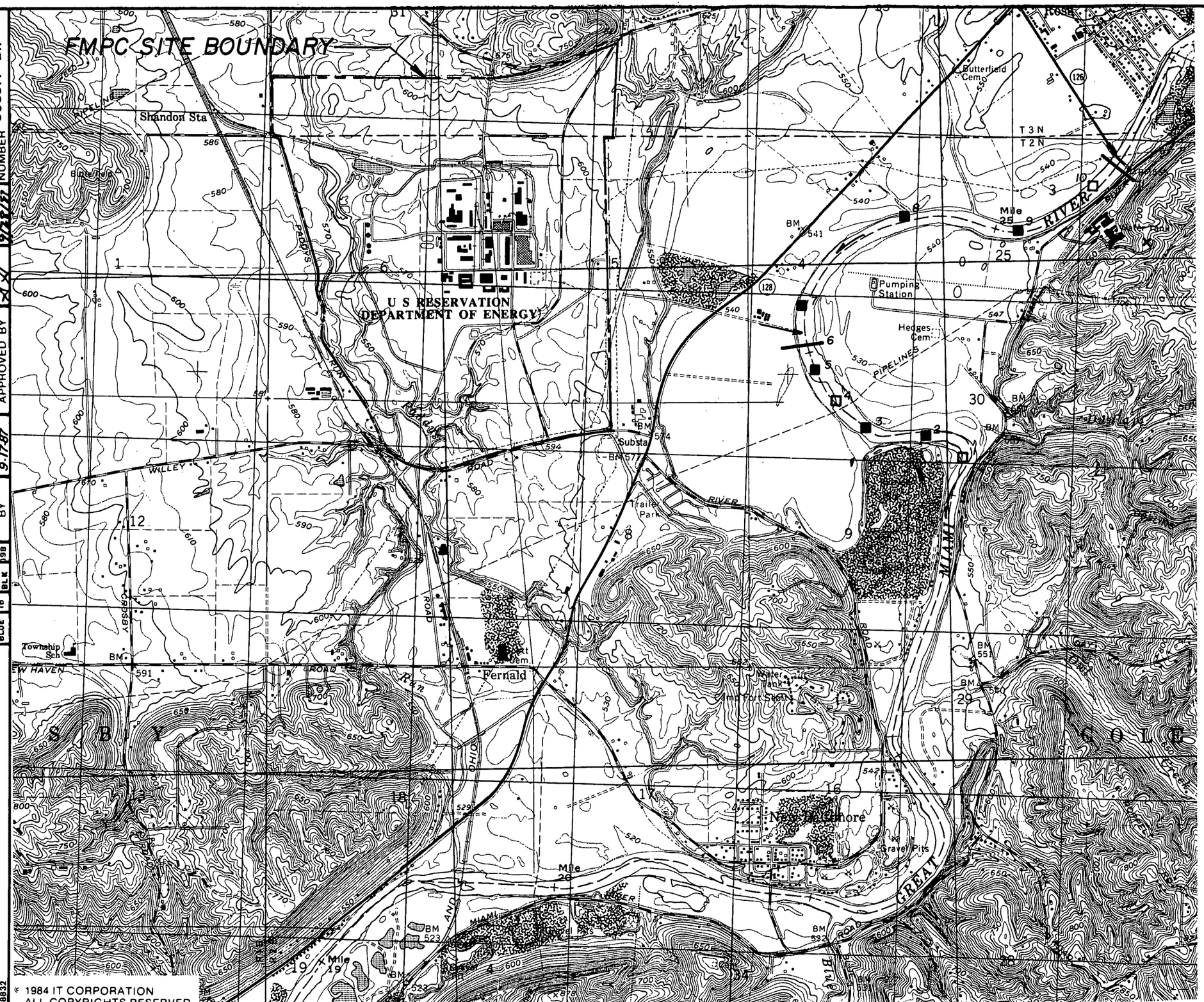

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LEGEND

- $\square^{10}$ POINT SURFACE WATER SAMPLE LOCATION
- $\blacksquare^{7}$ POINT SURFACE WATER AND SEDIMENT SAMPLE LOCATION
- $—^{6}$ MULTIPLE SAMPLE LOCATION
- → FMPC EFFLUENT LINE DISCHARGE POINT
- → RIVER FLOW DIRECTION

REFERENCES:

7.5 MINUTE USGS TOPOGRAPHIC MAPS OF HARRISON, OHIO - IND., SHANDON, OHIO GREENHILLS, OHIO, CINCINNATI WEST OHIO, ADDYSTON, OHIO - KY, AND HOOVEN OHIO. DATED: 1955 (PRI981), 1965 (PRI981), 1965 (PRI981), 1961 (PRI981), 1982 AND 1981 SCALE: 1" = 2000

SCALE

0 2000 4000 FEET

FIGURE 4.1-1

SURFACE WATER AND SEDIMENT SAMPLING POINTS

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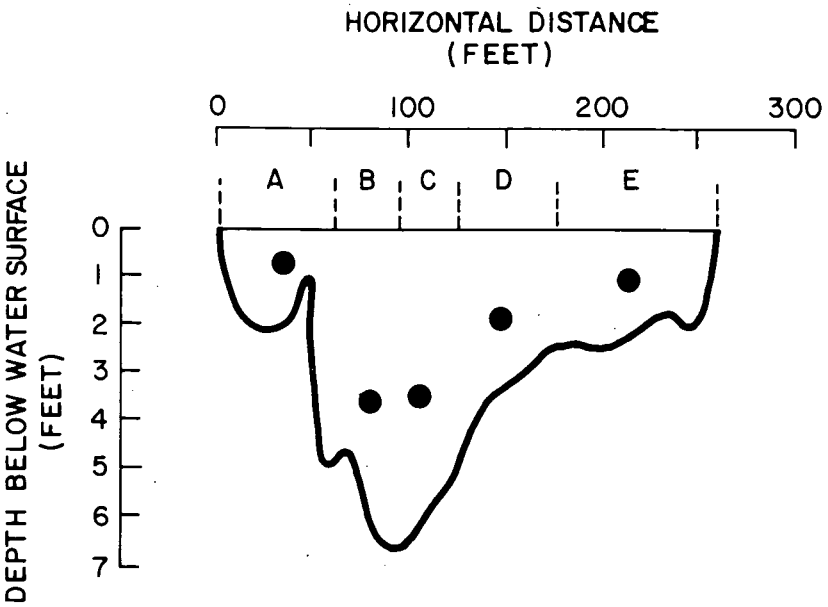

LEGEND

● WATER SAMPLING LOCATIONS

A-E CROSS-SECTIONAL SUBDIVISION DESIGNATION (SPACING WEIGHTED BY DISCHARGE)

NOTES:

1. CROSS-SECTIONAL ORIENTATION LOOKING DOWNSTREAM.
2. VERTICAL EXAGGERATION 25:1.
3. SAMPLES TAKEN FROM 6/10 DEPTH.
4. COMPOSITES FROM THREE SAMPLING TRAVERSES OBTAINED.
5. SECTION LOCATION IS SHOWN ON FIGURE 4.1-1.

FIGURE 4.3-1

CHANNEL CROSS-SECTION WITH SAMPLING LOCATIONS AND DEPTHS ROSS BRIDGE (LOCATION 11)

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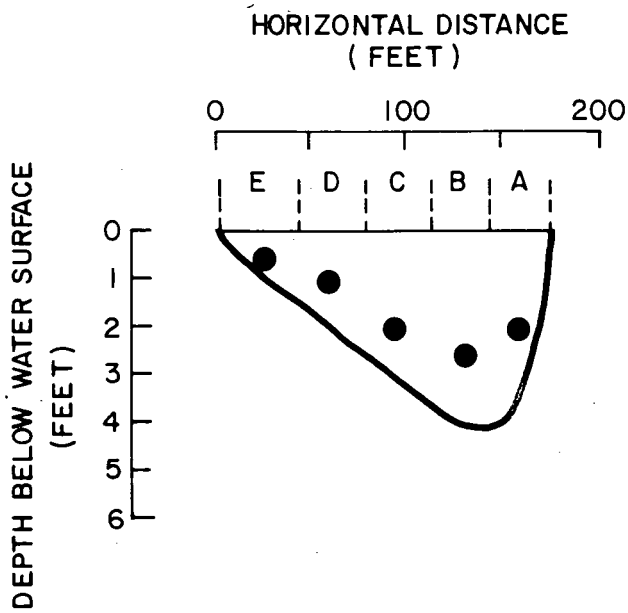

LEGEND

● WATER SAMPLING LOCATION

A-E CROSS-SECTIONAL SUBDIVISION DESIGNATION (SPACING APPROXIMATELY EQUAL)

NOTES:

1. CROSS-SECTIONAL ORIENTATION LOOKING DOWNSTREAM.
2. VERTICAL EXAGGERATION 25:1.
3. SAMPLES TAKEN FROM 6/10 DEPTH.
4. COMPOSITES FROM TWO SAMPLING TRAVERSES OBTAINED 9/12/87; DISCRETE SAMPLES FROM TWO TRAVERSES OBTAINED 9/14/87.
5. SECTION LOCATION IS SHOWN ON FIGURE 4.1-1.

FIGURE 4.3-2

CHANNEL CROSS-SECTION WITH SAMPLING LOCATIONS AND DEPTHS NEAR OUTFALL (LOCATION 6)

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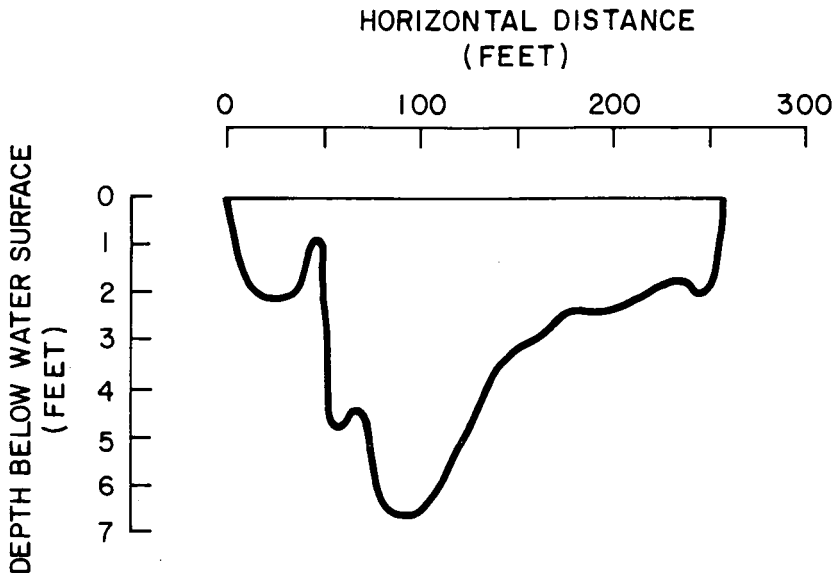
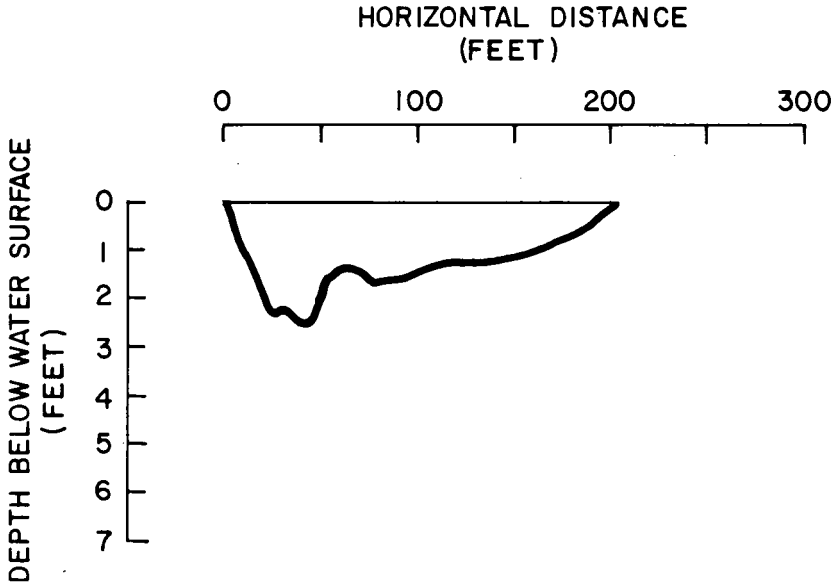


A. MEASURED RIVER BOTTOM CONFIGURATION, SEPT. 11, 1987



B. HISTORICAL RIVER BOTTOM CONFIGURATION, AFTER DOVE (1961)

NOTES:

1. CROSS-SECTIONAL ORIENTATION LOOKING DOWNSTREAM.
2. VERTICAL EXAGGERATION 25:1.
3. SECTION LOCATION IS SHOWN ON FIGURE 4.1-1.

FIGURE 4.5-1

PRESENT VERSUS HISTORICAL BOTTOM CONFIGURATION, ROSS BRIDGE (LOCATION II)

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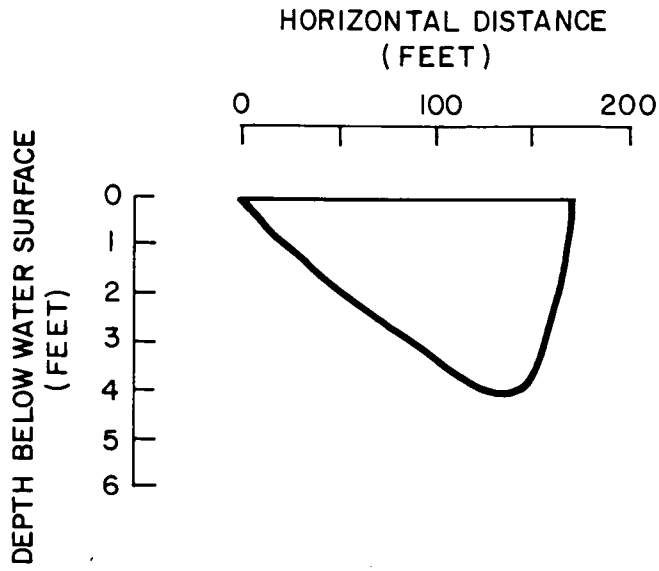
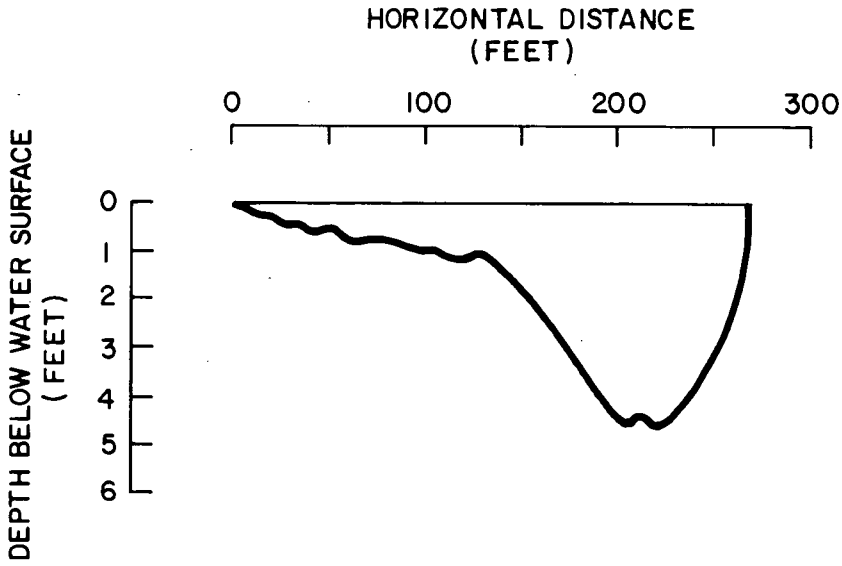


A. MEASURED RIVER BOTTOM CONFIGURATION, SEPT. 12, 1987



B. HISTORICAL RIVER BOTTOM CONFIGURATION, AFTER DOVE (1961)

NOTES:

1. CROSS-SECTIONAL ORIENTATION LOOKING DOWNSTREAM.
2. VERTICAL EXAGGERATION 25:1.
3. SECTION LOCATION IS SHOWN ON FIGURE 4.1-1.

FIGURE 4.5-2

PRESENT VERSUS HISTORICAL BOTTOM CONFIGURATION, NEAR OUTFALL (LOCATION 6)

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APPENDIX
A

APPENDIX A

GROUND WATER MODELING

APPENDIX A

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APPENDIX A

A.1.0 INTRODUCTION

The selection of the most appropriate modeling code for this study was based on specific technical requirements and objectives, the types and amount of data available, the accessibility of the code, and its compatibility with available computer equipment. The SWIFT III computer code was selected for use in both this hydrogeologic study of the FMPC discharge and the overall, sitewide Remedial Investigation and Feasibility Study (RI/FS). Use was also made of IT's GEOFLOW model to fully satisfy the initial requirements of the zone of influence discharge study.

Due to the complexities associated with data input to the SWIFT III code and calibration of the resulting model, IT opted to undertake a parallel effort to prepare and calibrate a finite element model of the hydrogeologic study area using GEOFLOW. This effort has led to the successful development of a 2-D numerical model which adequately reproduces the ground water flow system of the study area. Input parameters used in this calibrated model were transferred to SWIFT III to produce a calibrated SWIFT III model. Since the GEOFLOW model progressed at an accelerated rate, the sensitivities of several model input parameters were tested using GEOFLOW with the results presented in this appendix.

The following sections of this appendix describe the development, calibration, and testing of the GEOFLOW model and preparation and testing of the SWIFT III model.

A.2.0 GEOFLOW MODELING

Calibration of the two-dimensional SWIFT III model was achieved by simultaneously using GEOFLOW to model the region of interest. GEOFLOW, developed by IT, is a two-dimensional (2-D) finite element, ground water flow and solute mass transport computer program that can be applied to confined, semiconfined, or unconfined aquifers. The program consists of two independent subprograms. By providing hydrogeologic parameters such as hydraulic conductivity, storage coefficient, pumping rate, etc., the hydrodynamic subprogram computes ground water elevations and the ground water velocity vectors. If required, the

resulting velocity vectors can be incorporated into the solute transport subprogram to yield the concentration distribution of chemical constituents in the flow domain. Transient and steady-state solutions for both the flow and mass transport equations can be computed by the program. The governing equations, features, and assumptions of the GEOFLOW program are described further in the user's manual (IT, 1986).

The advantages provided by GEOFLOW in completing this modeling task included extensive documentation, user-oriented routines for data input, and a graphical postprocessing program to plot ground water surface contours, velocity vectors, and isopachs from the computer output.

A.2.1 Model Set Up

A conceptual design for the ground water flow model was developed based on historical data (Section 2.0) as well as current information gained from work at the site. The principal objective of the modeling effort was to determine the relationship between the Great Miami River, the aquifers in the region, and the SOWC pumping wells. For this reason, the model grid was chosen to cover the entire area of possible ground water influence by the SOWC pumping wells. The grid north was placed 30 degrees west of the true north to orient the bedrock trough approximately west-east across the grid (Figure A-1). In the grid west-east direction, the grid extends from two miles west of the FMPC to approximately one-half mile east of Ross. In the grid north-south direction, it extends from about three-quarters of a mile south of Shandon to about one-half mile south of New Baltimore. At the extremes of the model area, where less detail was required, elements are 2,000 by 2,000 feet. The element size becomes gradually smaller inward and reaches a minimal size of 250 by 250 feet in the area surrounding the SOWC pumping wells and the meander loop on the Great Miami River. In all, the rectangular grid system consists of 44 rows and 51 columns. The length along the x axis is 32,000 feet and the length along the y axis is 25,000 feet.

GEOFLOW is a finite element program and SWIFT III is a cell-centered finite difference program. The same grid was developed for the two models. The model grid for SWIFT III is shown in Figure A-1 and the model grid for GEOFLOW is shown in Figure A-2. The nodes on the finite element (GEOFLOW) grid

correspond to the corners of the cell-centered finite difference (SWIFT III) grid and likewise the element centers of the finite element grid correspond to the centers of the finite different cells. This permits a one-to-one correlation between cells and elements, and facilitates transfer of information between the two models.

Subsequent to preparation of the initial grid, elements within the study area representing regions of relatively impermeable bedrock were deleted from the GEOFLOW model to improve model efficiency and to conserve computer storage space. These elements are shown as the shaded areas in Figure A-2. A similar option is not available in the SWIFT III model, so the same effect was achieved by assigning a minimum aquifer thickness to blocks outside the buried valley aquifer.

A.2.2. Model Input Data and Assumptions

The hydrodynamic subprogram of GEOFLOW requires input data on the area's geologic units and their characteristics; the type of aquifer (confined, semiconfined, or unconfined); the hydrogeologic characteristics of the aquifer, including hydraulic conductivity and thickness; recharge and discharge zones; and ground water pumpage. The user must also enter either the ground water flow rate or the hydraulic heads (water level elevations) along the boundaries of the study area.

Because of the persistence of a relatively stable, pumping-induced cone of depression in the area surrounding the SOWC collector wells (Section 2.1), a steady-state approach to ground water modeling was taken.

The initial data entered into the model were based on previous study reports, data obtained from field and laboratory measurements, and literature reviews. These data are described below.

Aquifer Type, Thickness, and Hydraulic Conductivity

The geology of the site has been discussed in Section 2.1. The aquifer is composed of highly permeable, well-sorted sand and gravel. For the 2-D model, the study area was modeled as an unconfined aquifer. The study area encompassed several distinct hydrogeologic environments as defined by Spieker

(1968a) and described in Section 2.1 of this report. The following table correlates the model zones used in this study with the hydrogeologic environments described by Spieker.

MODEL ZONE	SPIEKER 1968a HYDROGEOLOGIC ENVIRONMENT	BRIEF DESCRIPTION
1	I	Sand & gravel aquifer with no overlying till
2	V	Bedrock
3	III	Sand and gravel aquifer with overlying till

The river was treated separately with a fourth zone added during model calibration. The Paddy's Run area was also treated as a special case, it is in the Type III Hydrogeologic Environment (Spieker, 1968a), but has the recharge characteristics of the Type I Hydrogeologic Environment.

Bedrock elevations range from 350 to over 700 feet MSL. These elevations were used to represent the base of the aquifer and were incorporated into the model by entering the corresponding elevation for each element of the grid system. Since observed ground water elevations in the study area fall below 550 feet MSL, elements with bedrock base elevations of greater than 575 feet MSL were deleted from the model. The borders that these elements share with elements retained in the grid were treated as no-flow boundaries.

Hydraulic conductivities have been extensively researched in the study area. The assumed initial hydraulic conductivities and ranges expected in Zones 1 (Spieker 1968a, Zone I) and 3 (Spieker 1968a, Zone III) are given in Table 3.2.5.

Recharge

Estimates of recharge from precipitation in the study area range from 8 to 20 inches in Zone 1 and in the Paddy's Run area. Recharge from precipitation ranges from 3 to 12 inches in Zone 3 (Table 3.2.5). The aquifer has the potential to receive recharge from the Great Miami River. Therefore, the river was modeled by assuming that the river bed is equivalent to an overlying semiconfined aquifer. The leakage factor assigned for the confining layer was

based upon a vertical permeability of two to three orders of magnitude lower than the horizontal permeability of the aquifer. The stage in the river was assumed to vary from 525 feet MSL at the upstream end to 494 feet MSL at the downstream end of the study area. These values were obtained from a HEC-2 model of the river, using a river stage of 524 feet MSL at the Ross Bridge (Described in Section 3.1).

Pumping Rates

Four pumping wells were included in the model. These wells and their assigned pumping rates are as follows (Table 3.2.5):

WELL	ASSUMED PUMPING RATE (ft^3/day)
SOWC Collector 1	1,644,000 (12.3 MGD)
SOWC Collector 2	822,000 (6.1 MGD)
FMPC P-3	64,000 (0.5 MGD)
Albright and Wilson	19,000 (.14 MGD)

Ground Water Elevations

The ground water contour map for April 1986 (Figure 2.1-13) was used to calibrate the model. The ground water contours were extrapolated to the model boundaries to obtain ground water elevation at these locations. Ground water levels along the perimeter of the grid within the Hydrogeologic Environments I and III were held constant during the modeling runs by assigning the extrapolated ground water elevations to each of the boundary nodes.

A.2.3 Model Calibration

The objective of GEOFLOW model calibration was to use realistic model input to produce an output consistent with actual values (water levels) observed in the field. An iterative procedure was performed to calibrate the model by comparing computed ground water levels with observed data for April 1986. During this process, the differences between actual and computed ground water elevations were examined and hypotheses developed to explain the observed deviations. If the calibration was not satisfactory, the parameters were modified, within limits consistent with the data presented in Table 3.2.5, and a new simulation was performed. This process of examining the results, explaining the variances, and modifying the necessary input parameters was repeated until results that closely matched the observed data were obtained.

River bed leakage and, to a lesser extent, aquifer hydraulic conductivity were determined to be the most critical factors effecting the flow model calibration. Calibration values for these and other input parameters are presented in Table A.1. It was necessary to add a third hydraulic conductivity zone in the northernmost two rows of elements grid north of the FMPC site (Zone 4) for the final calibration. The aquifer in this area was found to contain more clay; thus, the addition of a zone of lower conductivity in this area is consistent with field observations.

Table A.2 presents a comparison of observed versus computed ground water levels for the calibrated GEOFLOW model for 45 wells in the study area. Differences between observed and computed values range from -4.7 feet to +2.9 feet with 38 percent (N=17, where N is the number of observations) of the values falling within ±1 feet, 75 percent (N=34) falling within ±2 feet, 91 percent (N=41) falling within ±3 feet, and 98 percent (N=44) falling within ±4 feet. The average difference between the observed and computed elevations was -0.39 feet. This average, which is obtained by dividing the sum of the differences, by the the number of observations (wells), shows that there is a net 0.39 feet bias in the computed values. A second statistical parameter was calculated by dividing the sum of the absolute values of the differences by the number of observations. The calculated value of this parameter was 1.50 feet, indicating the average absolute difference between the actual and computed values was approximately 1.5 feet. A third statistical parameter used for comparison was the standard deviation of the differences. This parameter had a value of 1.80 feet. The values calculated for these three parameters were considered acceptable for a ground water flow model encompassing an area of nearly 36 square miles.

The results of the comparison of actual versus computed values was improved by excluding Wells 12-7A, State-16, FMPC-3, Pallet Co, and WW-1 from the analyses (Table A.3). These five wells are located near the grid boundaries where limited information was available concerning ground water elevations. Ground water elevations at these boundaries were extrapolated from the closest wells and may be in error by several feet or more. Computed ground water elevations at nodes near the grid boundaries are more adversely impacted by errors in the assumed boundary conditions than nodes in the interior of the grid. Excluding

the above five wells gives an average difference between the observed and calculated values for the GEOFLOW model run of -0.14 feet, an average absolute difference of 1.24 feet, and a standard deviation of 1.47 feet. This is a highly satisfactory comparison, particularly since a majority of the remaining 40 wells are located in the primary areas of interest (near the FMPC plant and the collector wells).

It should be noted that the set of calibrated values presented in Table A.1 may not be the only set that gives a satisfactory calibration. Other combinations of aquifer hydraulic conductivity, river bed leakage, and recharge rates may give similar results. Determining what these possible combinations are requires extensive testing. Results for the calibration runs suggest that acceptable calibration can be obtained with hydraulic conductivities as much as 1.5 times higher than the values presented in Table A.1. The sensitivity of the model to modification of river bed leakage and recharge to the aquifer is discussed in the following section.

A.2.4 Sensitivity Analysis

The sensitivity of the GEOFLOW model to changes in the values of the input parameters was limited to two variables, river bed leakage and precipitation recharge after an acceptable model calibration was achieved. Of these, river bed leakage was of the most interest since it is the variable that is least well known and of greatest concern relative to the impact of the Great Miami River on the collector wells.

A summary of the seven sensitivity runs that were performed is presented in Table A.3. In two runs, recharge was varied while aquifer hydraulic conductivity and river bed leakage were held constant. In the other five runs, aquifer hydraulic conductivity and recharge were held constant while the river bed leakage was multiplied by a factor of 0.1, 0.5, 2, 10, and 100 in relation to the calibrated run.

The results, presented in Table A.3, show that changes in recharge produce proportional changes in the average difference between the observed and computed values. Increasing the recharge rate relative to the calibrated run results in a higher net negative difference between the observed and computed

values while lowering recharge gives a slightly positive net difference. In fact, the lower recharge rates give a slightly better calibrated model relative to two of the three statistical parameters provided all 45 wells are included in the analysis. However, the differences are minor and what is perhaps the key parameter, the average difference between observed and computed values divided by the number of observations for the subset of 40 wells, is closer to zero for the calibrated run than for Sensitivity Run No. 2.

Decreasing the river bed leakage by a factor of 10 (Sensitivity Run No. 3) resulted in a poorly calibrated model. Computed ground water elevations were lower than observed levels at most wells, with differences exceeding 10 feet near the SOWC Collector Wells. Using this river bed leakage and changing hydraulic conductivity and recharge input parameters within their ranges of acceptable values did not produce a calibrated model, which suggests that actual river bed leakage is more than 0.035 day^{-1}.

Mean differences between actual and computed ground water levels were less than ±1 foot when river bed leakage was reduced or increased by a factor of 2. Differences in this range may be compensated for by manipulation of other input parameters. This indicates that actual river bed leakage may fall in the range of 0.175 and 0.7 day^{-1}.

Further increasing river bed leakage by factors of 10 and 100 produced increasingly poorer results, with computed elevations exceeding observed elevations by an average of one foot or more. By changing the river bed leakage from 0.35 day^{-1} to 3.5 day^{-1} the mean difference between the observed and computed elevations declined from -0.39 to -1.10 feet. However, an additional order of magnitude change in river bed leakage (to 35 day^{-1}) caused the mean difference between the observed and computed values to decrease only from -1.10 to -1.17 feet.

A.2.5 Model Results

In order to evaluate the zone of influence for the SOWC pumping wells, plots of flow vectors were produced from the GEOFLOW model output. The flow vectors indicated that the zone of influence extended to the model boundaries east of Ross and to the northeast of Shandon. The calibration run was used to produce

a "best-fit" bound to the zone of influence. This is shown in Figure 3.2-4. River bed leakage was varied in several sensitivity runs of the GEOFLOW model. The model was sensitive to the river bed leakage parameter. The area of uncertainty for the zone of influence shown in Figure 3.2-4 was developed by using factors of 0.5 times and 10 times the calibrated river bed leakage as the lower and upper bounds of the parameter, respectively.

A.3.0 SWIFT III MODELING

A.3.1 Model Input Data and Assumptions

The physical layout of the SWIFT III grid and model conceptualization were similar to the GEOFLOW model. The grid configuration is shown in Figure A-1. SWIFT III accepts two levels of discretization, the larger more general level labeled "global system" and a finer subset called "local subsystems." The local subsystem is usually used in the representation of fractured media. For the water table aquifer case only the global system may be utilized. The global aquifer system was refined for the 2-D case by differentiating between the highly permeable sands and gravels of the buried valley aquifer and the less permeable bedrock.

Several boundary conditions were established for the SWIFT III flow model. It was assumed that no significant vertical recharge occurred through the base of the sand and gravel aquifer. The bedrock trough which defined the aquifer extent was assumed to be a no flow boundary. The amount of bedrock contributing ground water flow was considered insignificant relative to the large transmissivity of the aquifer. Areas along the model boundaries that were within the buried valley aquifer were given constant potentiometric heads which were based on April 1986 water level data. Specific values for grid boundary conditions are listed in Table A.4.

Recharge and discharge potential along the Great Miami River was accommodated by source/sinks located at each river cell and by designating a constant hydraulic head to each cell. The source/sinks were specified within the SWIFT III data input as boundary conditions equivalent to those used for wells. This equivalent well submodel for the river required setting a water level within the well bore equal to the river stage level and providing a well

index based upon the river bed leakage. The well submodel defined the recharge/discharge as equal to the product of the well index times difference between head in the cell (ground water table) and the head in the well bore. The well submodel is equivalent to the semiconfined river bed model used in GEOFLOW as discussed in Section A.2.2. The river bed leakage was assigned to be equal to that obtained from the GEOFLOW calibration. Leakage factors due to variances in effective river bed leakage, aquifer hydraulic conductivities, and the potential for either river recharge or discharge were accounted for by varying the well index.

Other variables that were assigned values in the model included hydraulic conductivity in the vertical and horizontal directions (aquifer and bedrock), aquifer thickness, precipitation recharge, and well pumping rates. Horizontal hydraulic conductivities in the aquifer were chosen as 400 feet per day (ft/day). A horizontal hydraulic conductivity of 0.003 ft/day was assigned to represent bedrock. Thicknesses of the aquifer material for each cell were estimated to the nearest 10 feet.

A.3.2 Model Calibration

To accomplish model calibration, boundary values and hydrogeologic parameters were varied across a range of known conditions until a high correlation between point source field measurements and model output was achieved. In this case, GEOFLOW was used to generate the optimum set of boundary and hydrogeologic parameters and this data set was transferred to SWIFT III. Two calibration runs were performed using the SWIFT III model. Input parameters in SWIFT III vary from GEOFLOW in one respect; GEOFLOW assigned three different horizontal hydraulic conductivity zones within the buried valley aquifer. For the SWIFT III model one zone was used. It should be noted that the selection of three discrete zones for the GEOFLOW model was based on interpretation of field data and the differences between the zones were minor. Consequently, it was generally accepted that initially restricting SWIFT III to one general hydraulic conductivity value for the buried valley aquifer does not detract to any degree from its validity.

Table A.4 summarizes the input data and Table A.5 the September 1987 state of calibration for the SWIFT III model. Ground water elevations computed by the

model were compared with actual water levels measured in 45 selected wells during April 1986. Ground water elevations generated by the model ranged from 4.9 feet below to 4.4 feet above the observed levels. The mean difference between the observed and calculated ground water levels was 0.07 feet, the average absolute difference was 1.69 feet and the standard deviation of the differences was 2.10 feet (Table A.5). Reviewing output differences between GEOFLOW and SWIFT III (Table A.6) shows a significant correlation (0.98) with a standard deviation of 1.04 feet. Differential values ranged from -2.1 feet to +3.0 feet between the two models.

A.3.3 Sensitivity Analysis

Obtaining an understanding of the sensitivity of a model to variable inputs is an important part of model development. Two separate tests were made with the 2-D version of SWIFT III. The initial test utilized the given input calibration parameters established by GEOFLOW. A second test was to run the model with decreased river bed leakage of one order of magnitude. The change resulted in a significant lowering of the aquifer ground water table for several thousand feet radially around the two SOWC collector wells.

This type of model sensitivity analysis will be expanded during the sitewide RI/FS to include inputs for which ranges of values have been published, i.e., hydraulic conductivity, surface recharge/discharge, and pumping rates. New hydrogeologic conditions such as the inclusion of the "blue clay" layer may affect the rates and direction of ground water flow and solute transport. Part of this effort will be the identification of sensitive, key input parameters. Sensitivity evaluations will also continue as the model is expanded to three dimensions. Continued refinement of the SWIFT III model will help quantify the rough estimations given in this report for the SOWC well field zone of influence (Figure 3.2-4).

TABLE A.1

SUMMARY OF INPUT DATA FOR THE CALIBRATED GEOFLOW MODEL (MODEL RUN 46)

I. Finite Element Grid System[a]

Length: (x-direction)	32,000 feet
Width: (y-direction)	25,000 feet
Number of elements:	1,553
Number of nodes:	1,688

II. Hydrogeologic Parameters

Base of aquifer:	From 350 to 550 feet MSL
Precipitation recharge:	
Zone 1 (river flood plain):	14 inches/year
Zone 2 (bedrock elements):	Not used
Zone 3 (aquifer covered by till):	6 inches/year
Zone 4 (top two rows of elements):	6 inches/year
Note: River elements lack precipitation recharge	
Hydraulic conductivities (K):	
Zone 1:	400 feet/day
Zone 2:	Not used
Zone 3:	300 feet/day
Zone 4:	150 feet/day
Note: Hydraulic conductivity is assumed isotropic within each zone	
Type of aquifer:	Unconfined
Flow regime:	Steady state

TABLE A.1
(Continued)

II. Hydrogeologic Parameters (cont'd)

Boundary conditions:

Grid lower west boundary:	492 feet MSL
Grid upper west boundary:	535 feet MSL
Grid north boundary:	540 feet MSL
Grid south boundary:	504 feet MSL
Grid east boundary:	530 feet MSL

Extraction wells production schedule:

Well Name	Pumping Rate
Collector 1 (SOWC)	1,644,000 $feet^3$/day
Collector 2 (SOWC)	822,000 $feet^3$/day
FMPC-P3	64,000 $feet^3$/day
Albright and Wilson	19,000 $feet^3$/day

River bed leakage factor: 0.35 day^{-1}

[a]Refer to Figure A-2 for grid element locations.

TABLE A.2

COMPARISON OF APRIL 1986 OBSERVED GROUND WATER LEVELS AND GEOFLOW COMPUTED VALUES (USING MODEL RUN 46)

WELL IDENTIFICATION	GEOFLOW ELEMENT NUMBER[a,b]	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFF. (ft)
12-7A	50	527.4	531.0	-3.6	3.6
STATE 16	86	526.3	531.0	-4.7	4.7
H-124	91	505.8	504.5	1.3	1.3
H-122	109	521.4	523.8	-2.4	2.4
RE	140	515.7	516.0	-0.3	0.3
H-115	101	518.7	516.5	2.2	2.2
7-8A	189	520.7	522.0	-1.3	1.3
H-105	196	523.4	525.0	-1.6	1.6
BPH	199	525.0	526.5	-1.5	1.5
FMPC-17	238	523.9	525.0	-1.1	1.1
H-129	256	507.7	505.0	2.7	2.7
H-126	260	512.6	511.0	1.6	1.6
HK-	278	521.5	523.5	-2.0	2.0
FMPC-16-S	283	524.8	525.5	-0.7	0.7
FMPC-9	288	526.4	527.0	-0.6	0.6
DE	309	519.9	517.0	2.9	2.9
FMPC-18-S	364	525.3	526.0	-0.7	0.7
PALLET CO	334	525.4	529.0	-3.6	3.6
16-1-S	296	504.3	504.0	0.3	0.3
FMPC-3	368	524.9	528.0	-3.1	3.1
FMPC-14-D	399	524.1	526.0	-1.9	1.9
IT-5	421	522.7	523.0	-0.3	0.3
IT-1	458	523.2	524.0	-0.8	0.8
FMPC-10	464	523.6	526.5	-2.9	2.9
BLK	547	522.5	522.0	0.5	0.5
IT-2	589	522.9	523.0	-0.1	0.1
FMPC-13-S	593	522.9	524.0	-1.1	1.1
02-E	615	522.2	522.0	0.2	0.2
IT-3	660	522.5	523.0	-0.5	0.5
H-127	727	522.3	522.0	0.3	0.3
IT-4	806	521.9	522.0	-0.1	0.1
B-3	841	520.2	522.0	-1.8	1.8
B-2	948	520.6	521.0	-0.4	0.4
SW-4A	978	519.1	521.0	-1.9	1.9
B-1	1015	521.3	521.0	0.3	0.3
SW-3A	1040	518.3	517.0	1.3	1.3
R-7	1158	520.7	519.0	1.7	1.7
B-4	1187	520.3	520.0	0.3	0.3
K-4	1277	520.6	522.0	-1.4	1.4
EL-1	1343	522.9	522.0	0.9	0.9
03	1351	526.5	524.0	2.5	2.5
ER-1	1375	525.9	524.0	1.9	1.9
LB-1	1449	522.3	524.0	-1.7	1.7

TABLE A.2
(Continued)

WELL IDENTIFICATION	GEOFLOW ELEMENT NUMBER[a,b]	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFF. (ft)
WK1	1463	525.5	524.0	1.5	1.5
WW-1	1473	528.2	525.5	2.7	2.7

SUM OF DIFFERENCES/NUMBER OF OBSERVATIONS	-0.39 feet
SUM OF ABSOLUTE DEVIATIONS/NUMBER OF OBSERVATIONS	1.50 feet
STANDARD DEVIATION OF DIFFERENCES	1.80 feet

[a]Wells are located in upper left corner of element.
[b]Refer to Figure A-2 for grid element locations.

TABLE A.3

SUMMARY OF GEOFLOW SENSITIVITY RUNS

	CALIBRATION RUN	SENSITIVITY RUN NUMBERS 1	2	3	4	5	6	7
Input Parameter								
Aquifer hydraulic conductivity (feet/day)								
Zone 1	400	400	400	400	400	400	400	400
Zone 2	-	-	-	-	-	-	-	-
Zone 3	300	300	300	300	300	300	300	300
Zone 4	150	150	150	150	150	150	150	150
Recharge from precipitation (inches/year)								
Zone 1	14	20	10	14	14	14	14	14
Zone 2	-	-	-	-	-	-	-	-
Zone 3	6	8	4	6	6	6	6	6
Zone 4	6	8	4	6	6	6	6	6
River bed leakage (factor) (day^{-1})	0.35(1.0)	0.35(1.0)	0.35(1.0)	0.035(0.1)	0.175(0.5)	0.70(2.0)	3.5(10.0)	35.0(100.0)
Comparison of observed versus computed results (Model Output) (feet)								
All 45 Wells:								
Mean difference[a]	-0.39	-0.89	+0.07	+3.52	+0.29	-0.76	-1.10	-1.17
Mean absolute difference[b]	1.50	1.81	1.42	3.87	1.66	1.73	2.03	2.10
Standard deviation of algebraic difference[c]	1.80	1.92	1.81	3.50	2.03	1.91	2.00	2.02

TABLE A.3
(Continued)

	CALIBRATION RUN	SENSITIVITY RUN NUMBERS 1	2	3	4	5	6	7
Wells 12-7A, State 16, PALLET CO, FMPC-3, and WW-1 excluded:								
Mean difference[a]	-0.14	-0.63	+0.28	+4.01	+0.63	-0.54	-0.89	-0.97
Mean absolute difference[b]	1.24	1.55	1.24	4.03	1.41	1.52	1.83	1.91
Standard deviation of algebraic difference[c]	1.47	1.64	1.60	3.23	1.63	1.70	1.82	1.85

[a]Sum of observed minus computed values divided by number of wells.

[b]Sum of absolute value of observed minus computed value divided by number of wells.

[c]Standard deviation of observed minus computed values.

TABLE A.4

SUMMARY OF INPUT DATA FOR THE
SWIFT III MODEL
SEPTEMBER 1987 (MODEL RUN 2)

I. Finite Difference Grid System[a]

Length: (i-direction)	32,000 feet
Width: (j-direction)	25,000 feet
Number of cells:	2,244
Number of layers:	1

II. Hydrogeologic Parameters

Base of aquifer:	From 350 to 600 feet MSL
Precipitation recharge:	
Zone 1 (river flood plain):	14 inches/year
Zone 2 (bedrock high):	0 inches/year
Zone 3 (aquifer covered by till)	6 inches/year
Horizontal hydraulic conductivities (K):	
Zone 1 and Zone 3:	400 feet/day
Zone 2:	0.003 feet/day
Porosities:	
Zone 1 and Zone 3:	0.25
Zone 2:	0.1
Type of aquifer:	Unconfined
Flow regime:	Steady state

TABLE A.4
(Continued)

II. Hydrogeologic Parameters (continued)

Boundary conditions:

Grid lower west boundary:	492 feet MSL
Grid upper west boundary:	535 feet MSL
Grid north boundary:	540 feet MSL
Grid south boundary:	504 feet MSL
Grid east boundary:	530 feet MSL

Extraction wells production schedule:

WELL	CELL i, j[a]	PUMPING RATE
COLL 1	32, 24	1.65×10^6 feet^3/day
COLL 2	36, 30	8.14×10^5 feet^3/day
P3	12, 36	6.44×10^4 feet^3/day
AW	6, 23	1.86×10^4 feet/^{3}/day

River bed leakage factor: 0.35 day^{-1}

[a]Refer to Figure A-1 grid cell locations.

TABLE A.5

COMPARISON OF APRIL 1986 OBSERVED GROUND WATER LEVELS AND SWIFT III COMPUTED VALUES (USING MODEL RUN 2)

WELL IDENTIFICATION	SWIFT III[a] COLUMN I	SWIFT III[a] ROW J	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFFERENCES (ft)
12-7A	2	32	527.4	531.8	-4.4	4.4
STATE 16	4	41	526.3	529.9	-3.6	3.6
H-124	5	8	505.8	506.8	-0.8	0.8
H-122	5	25	521.4	523.8	-2.4	2.4
RE	6	16	515.7	516.7	-1.0	1.0
H-115	5	17	518.7	517.6	1.1	1.1
7-8A	6	24	520.7	522.6	-1.9	1.9
H-105	6	31	523.4	525.3	-1.9	1.9
BPH	6	35	525.0	526.8	-1.8	1.8
FMPC-17-D	7	31	523.9	525.0	-1.1	1.1
H-129	8	6	507.7	504.7	3.0	3.0
H-126	8	10	512.6	511.4	1.2	1.2
HK-	8	28	521.5	523.8	-2.3	2.3
FMPC-16-S	8	34	524.8	525.9	-1.1	1.1
FMPC-9	9	38	526.4	526.9	-0.5	0.5
DE	10	16	519.9	518.4	1.5	1.5
FMPC-18-S	9	37	525.3	526.6	-1.3	1.3
PALLET CO	9	41	525.4	529.1	-3.7	3.7
16-1-S	9	3	504.3	503.6	0.7	0.7
FMPC-3	13	40	524.9	527.5	-2.6	2.6
FMPC-14-D	8	32	524.1	525.1	-1.0	1.0
IT-5	13	27	522.7	522.9	-0.2	0.2
IT-1	14	33	523.2	523.9	-0.7	0.7
FMPC-10	14	39	523.6	526.2	-2.6	2.6
BLK	16	24	522.5	522.2	0.3	0.3
IT-2	17	33	522.9	523.1	-0.2	0.2
FMPC-13-S	18	37	522.9	523.7	-0.8	0.8
02-E	18	26	522.2	521.9	0.3	0.3
IT-3	20	36	522.5	522.8	-0.3	0.3
H-127	21	29	522.3	521.2	1.1	1.1
IT-4	24	34	521.9	521.6	0.3	0.3
B-3	24	34	520.2	521.6	-1.4	1.4
B-2	27	32	520.6	520.5	0.1	0.1
SW-4A	28	25	519.1	518.1	1.0	1.0
B-1	29	31	521.3	519.6	1.7	1.7
SW-3A	30	24	518.3	513.4	4.9	4.9
R-7	34	26	520.7	516.0	4.7	4.7
B-4	32	28	520.3	518.1	2.2	2.2

See footnote at end of table.

TABLE A.5
(Continued)

WELL IDENTIFICATION	SWIFT III[a] COLUMN I	ROW J	OBSERVED GROUND WATER LEVEL (ft MSL)	COMPUTED GROUND WATER LEVEL (ft MSL)	DIFFERENCE OBS.-COMP. GWL (ft)	ABSOLUTE OF DIFFERENCES (ft)
K-4	40	27	520.6	521.1	-0.5	0.5
EL-1	42	30	522.9	521.5	1.4	1.4
03	42	38	526.5	522.9	3.6	3.6
ER-1	45	21	525.9	523.7	2.2	2.2
LB-1	47	30	522.3	523.8	-1.5	1.5
WK1	48	24	525.5	523.8	1.7	1.7
WW-1	48	35	528.2	524.8	3.4	3.4

SUM OF DIFFERENCES/NUMBER OF OBSERVATIONS	-0.07 feet
SUM OF ABSOLUTE DEVIATIONS/NUMBER OF OBSERVATIONS	1.69 feet
STANDARD DEVIATION OF DIFFERENCES	2.10 feet

[a]Refer to Figure A-1 for grid cell locations.

TABLE A.6

COMPARISON OF GEOFLOW (MODEL RUN 46)
AND SWIFT III (MODEL RUN 2) RESULTS

GEOFLOW ELEMENT NUMBER[a,b]	SWIFT III[c] COLUMN I	SWIFT III[c] ROW J	GEOFLOW GROUND WATER LEVEL	SWIFT III GROUND WATER LEVEL (ft MSL)	DIFFERENCE GEOFLOW-SWIFT (ft MSL)	ABSOLUTE DIFFERENCES (ft)
50	2	32	531	531.8	-0.8	0.8
86	4	41	531	529.9	1.1	1.1
91	5	8	504.5	506.6	-2.1	2.1
109	5	25	523.8	523.8	0.0	0.0
140	6	16	516.0	516.7	-0.7	0.7
101	5	17	516.5	517.6	-1.1	1.1
189	6	24	522.0	522.6	-0.6	0.6
196	6	31	525.0	525.3	-0.3	0.3
199	6	35	526.5	526.8	-0.3	0.3
238	7	31	525.0	525.0	0.0	0.0
256	8	6	505.0	504.7	0.3	0.3
260	8	10	511.0	511.4	-0.4	0.4
278	8	28	523.5	523.8	-0.3	0.3
283	8	34	525.5	525.9	-0.4	0.4
288	9	38	527.0	526.9	0.1	0.1
309	10	16	517.0	518.4	-1.4	1.4
364	9	37	526.0	526.6	-0.6	0.6
334	9	41	529.0	529.1	-0.1	0.1
296	9	3	504.0	503.6	0.4	0.4
368	13	40	528.0	527.5	0.5	0.5
399	8	32	526.0	525.1	0.9	0.9
421	13	27	523.0	522.9	0.1	0.1
458	14	33	524.0	523.9	0.1	0.1
464	14	39	526.5	526.2	0.3	0.3
547	16	24	522.0	522.2	-0.2	0.2
589	17	33	523.0	523.1	-0.1	0.1
593	18	37	524.0	523.7	0.3	0.3
615	18	26	522.0	521.9	0.1	0.1
660	20	36	523.0	522.8	0.2	0.2
727	21	29	522.0	521.2	0.8	0.8
806	24	34	522.0	521.6	0.4	0.4
841	24	34	522.0	521.6	0.4	0.4
948	27	32	521.0	520.5	0.5	0.5
978	28	25	521.0	518.1	2.9	2.9
1015	29	31	521.0	519.6	1.4	1.4
1040	30	24	517.0	513.4	3.6	3.6
1158	34	26	519.0	516.0	3.0	3.0
1187	32	28	520.0	518.1	1.9	1.9

See footnotes at end of table.

TABLE A.6
(Continued)

GEOFLOW ELEMENT NUMBER[a,b]	SWIFT III[c] COLUMN I	SWIFT III[c] ROW J	GEOFLOW GROUND WATER LEVEL	SWIFT III GROUND WATER LEVEL (ft MSL)	DIFFERENCE GEOFLOW-SWIFT (ft MSL)	ABSOLUTE DIFFERENCES (ft)
1277	40	27	522.0	521.1	0.9	0.9
1343	42	30	522.0	521.5	0.5	0.5
1351	42	38	524.0	522.9	1.1	1.1
1375	45	21	524.0	523.7	0.3	0.3
1449	47	30	524.0	523.8	0.2	0.2
1463	48	24	524.0	523.8	0.2	0.2
1473	48	35	525.5	524.8	0.7	0.7

SUM OF DIFFERENCES/NUMBER OF OBSERVATIONS	0.68 feet
SUM OF ABSOLUTE DIFFERENCES/NUMBER OF OBSERVATIONS	0.72 feet
STANDARD DEVIATION OF DIFFERENCES	1.04 feet
CORRELATION BETWEEN SWIFT II AND GEOFLOW RESULTS	0.98

[a]Wells are located in the upper left corner of the element.

[b]Refer to Figure A-2 for grid element locations.

[c]Refer to Figure A-1 for grid cell locations.

FIGURE A-1

SWIFT MODEL GRID FOR AREA OF INFLUENCE STUDY

PREPARED FOR

FERNALD RI/FS
U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS

IT ... Creating a Safer Tomorrow

DRAWN BY	B. KUMPF 15 SEPT 87	CHECKED BY	DJR 9/21/87	DRAWING NUMBER	303317-E2
		APPROVED BY	9/28/87		

21E	1E	DRAWN BY
21E	1E	
100% BLU	100% ORG.	

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"Do Not Scale This Drawing"

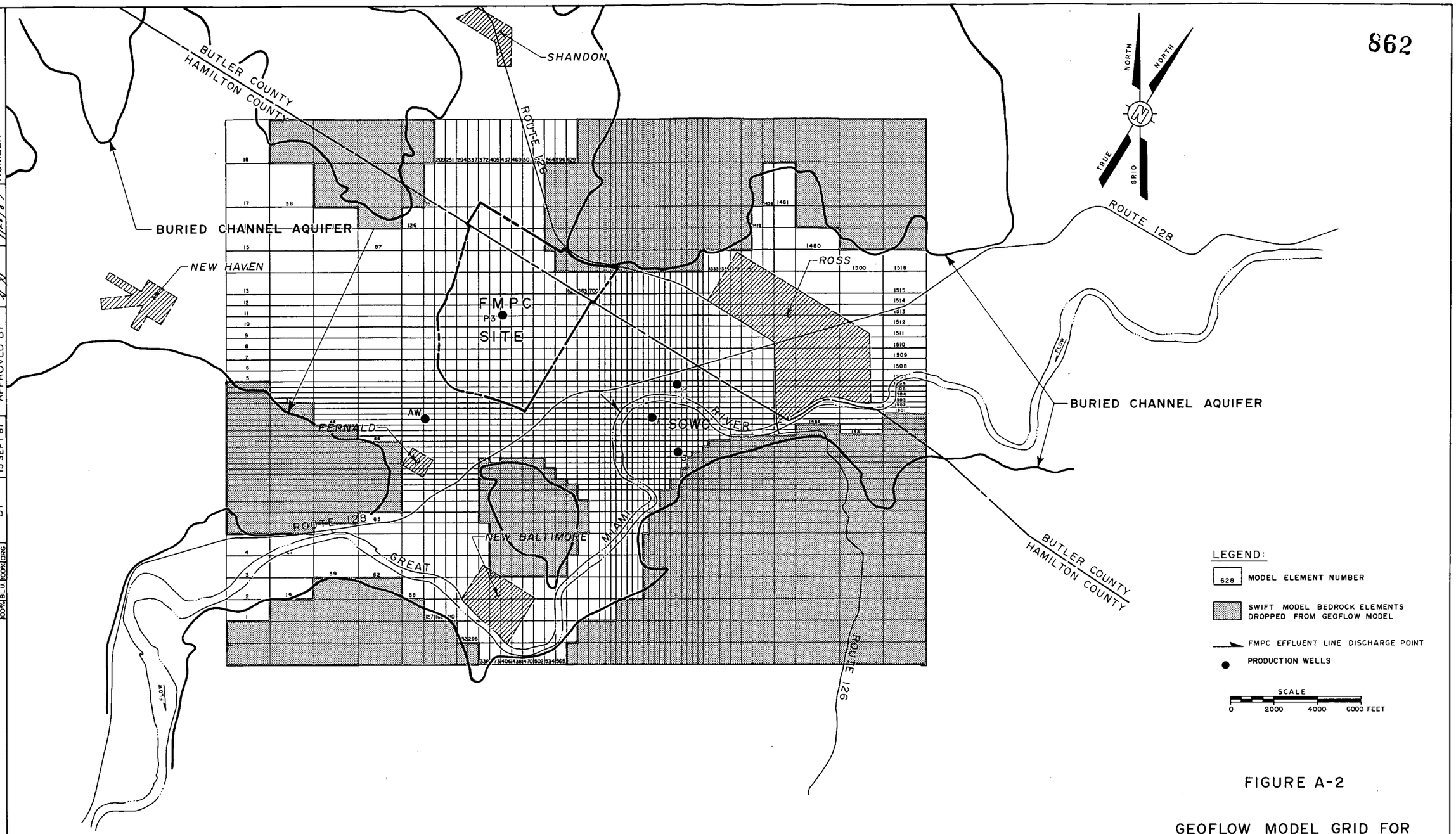

FIGURE A-2

GEOFLOW MODEL GRID FOR AREA OF INFLUENCE STUDY

PREPARED FOR

FERNALD RI/FS
U.S. DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS

DRAWING NUMBER	303317-E18		
CHECKED BY	VAW	9-22-87	
APPROVED BY		9/22/87	
DRAWN BY	B. KUMPF	15 SEPT 87	
20E	18E	18E	
20E	18E	ORG	
100%	BLU	100%	

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APPENDIX
B

APPENDIX B
LABORATORY DATA

RADIONUCLIDE ANALYSIS DATA
GREAT MIAMI RIVER WATER

Page 1 ITRSL Oak Ridge REPORT Work Order # R7-09-077
Received: 09/15/87 10/27/87 12:33:14

REPORT ASI
TO P. O. BOX 475
ROSS, OHIO 45061

ATTEN JOE YEASTED

CLIENT RI FS FERN SAMPLES 35
COMPANY ADVANCED SCIENCES, INC.
FACILITY

PREPARED IT/RADIOLOGICAL SCIENCES LAB.
BY 1550 BEAR CREEK ROAD
OAK RIDGE, TN 37831

James Harvey
CERTIFIED BY

ATTEN ERS
PHONE 615-482-9707 CONTACT J HARVEY

IT/RSL LAB #'S 15799-15833

WORK ID WATER SAMPLES
TAKEN
TRANS
TYPE
P.O. # PROJECT# 303317-09-03
INVOICE under separate cover

CC: Gary Gaillot

	SAMPLE IDENTIFICATION[a]	
01	01000	7-1
02	01001	7-2
03	01002	8-1
04	01003	8-2
05	01004	9-1
06	01005	9-2
07	01006	10-1
08	01007	10-2
09	01008	11-1
10	01009	11-2
11	01010	11-3
12	01011	BLANK-1
13	01012	1-1
14	01013	1-2
15	01014	2-1
16	01015	2-2
17	01016	3-1
18	01017	3-2
19	01018	4-1
20	01019	4-2
21	01020	5-1
22	01021	5-2
23	01022	6-1
24	01023	6-2
25	01024	BLANK-2
26	01025	6-1A

TEST CODES and NAMES used on this report

GS REQUESTED ANALYSES LISTED:

[a] Refer to Figure 4.1-1 for sample locations.

	SAMPLE IDENTIFICATION	
27	01026	6-1B
28	01027	6-1C
29	01028	6-1D
30	01029	6-1E
31	01030	6-2A
32	01031	6-2B
33	01032	6-2C
34	01033	6-2D
35	01034	6-2E

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01000 FRACTION 01A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15799

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	5	3
RU-106	<150		GROSS BETA	14	4
			U-TOTAL	2.9	1.2
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	1.0	0.6

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01001 FRACTION 02A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15800

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	5	3
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<5.3	
			SR-90	<5.0	
			U-TOTAL	2.4	1.2
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01002 FRACTION 03A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15801

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1	
			RA-228	<4.7	
			SR-90	<5.0	
			U-TOTAL	1.9	1.3
			U-ISOTOPIC:		
			U-234	1.3	0.6
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT
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Work Order # R7-09-077

862

SAMPLE ID 01003 FRACTION 04A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15802

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<5.6	
			SR-90	<5.0	
			U-TOTAL	<1.0	
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

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Received: 09/15/87

Results by Sample

862

SAMPLE ID 01004 FRACTION 05A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15803

UNITS pCi/l VERIFIED BY ERS

WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1	
			RA-228	4.2	2.2
			SR-90	<5.0	
			U-TOTAL	1.9	1.0
			U-ISOTOPIC:		
			U-234	1.5	0.6
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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Received: 09/15/87

Results by Sample

862

SAMPLE ID 01005 FRACTION 06A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15804

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1	
			RA-228	<4.5	
			SR-90	<5.0	
			U-TOTAL	1.7	1.0
			U-ISOTOPIC:		
			U-234	1.1	0.5
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

Received: 09/15/87

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SAMPLE ID 01006 FRACTION 07A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15805

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	5.3	2.5
			SR-90	<5.0	
			U-TOTAL	2.0	1.1
			U-ISOTOPIC:		
			U-234	1.2	0.5
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

Received: 09/15/87

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Results by Sample

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SAMPLE ID 01007 FRACTION 08A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15806

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<4.0	
			SR-90	<5.0	
			U-TOTAL	2.3	1.2
			U-ISOTOPIC:		
			U-234	1.0	0.5
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

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SAMPLE ID 01008 FRACTION 09A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15807

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<4.2	
			SR-90	<5.0	
			U-TOTAL	1.8	1.0
			U-ISOTOPIC:		
			U-234	1.0	0.5
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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Results by Sample

862

SAMPLE ID 01009 FRACTION 10A TEST CODE 6S NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/11/87 Category 15808

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<16	
			RA-226	<1.0	
			RA-228	<3.8	
			SR-90	<5.0	
			U-TOTAL	1.9	1.0
			U-ISOTOPIC:		
			U-234	1.1	0.5
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01010 FRACTION 11A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15809

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	5	3
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<4.5	
			SR-90	<5.0	
			U-TOTAL	1.8	1.1
			U-ISOTOPIC:		
			U-234	1.2	0.6
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

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SAMPLE ID 01011 FRACTION 12A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/11/87 Category 15810

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<1	
RU-106	<150		GROSS BETA	<7	
			RA-226	<1.0	
			RA-228	<3.8	
			SR-90	<5.0	
			U-TOTAL	1.3	0.9
			U-ISOTOPIC:		
			U-234	1.6	0.6
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01012 FRACTION 13A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15811

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	50	15
			RA-226	<1.0	
			RA-228	<4.8	
			SR-90	<5.0	
			U-TOTAL	3.8	1.5
			U-ISOTOPIC:		
			U-234	1.4	0.6
			U-235,236	<1.0	
			U-238	1.3	0.5

*U-TOTAL - ug/l

Received: 09/15/87

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SAMPLE ID 01013 FRACTION 14A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15812

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	70	18
			RA-226	<1.0	
			RA-228	<5.1	
			SR-90	<5.0	
			U-TOTAL	3.2	1.4
			U-ISOTOPIC:		
			U-234	2.3	0.8
			U-235,236	<1.0	
			U-238	1.1	0.5

*U-TOTAL - ug/l

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SAMPLE ID 01014 FRACTION 15A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15813

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	62	18
			RA-226	<1.0	
			RA-228	<4.3	
			SR-90	<5.0	
			U-TOTAL	2.0	0.9
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01015 FRACTION 16A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15814

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	59	18
			RA-226	<1.0	
			RA-228	<4.5	
			SR-90	<5.0	
			U-TOTAL	3.3	1.1
			U-ISOTOPIC:		
			U-234	1.1	0.4
			U-235,236	<1.0	
			U-238	1.1	0.4

*U-TOTAL - ug/l

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SAMPLE ID 01016 FRACTION 17A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15815

UNITS pCi/l *

VERIFIED BY ERS

WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	54	16
			RA-226	<1.0	
			RA-228	<3.8	
			SR-90	<5.0	
			U-TOTAL	3.4	1.2
			U-ISOTOPIC:		
			U-234	2.3	0.6
			U-235,236	<1.0	
			U-238	1.1	0.4

*U-TOTAL - ug/l

Received: 09/15/87

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Results by Sample

862

SAMPLE ID 01017 FRACTION 18A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15816

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	55	17
			RA-226	<1.0	
			RA-228	<4.3	
			SR-90	<5.0	
			U-TOTAL	3.4	1.1
			U-ISOTOPIC:		
			U-234	1.3	0.4
			U-235,236	<1.0	
			U-238	1.2	0.4

*U-TOTAL - ug/l

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SAMPLE ID 01018 FRACTION 19A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15817

UNITS pCi/l *
WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	46	14
			RA-226	<1.0	
			RA-228	<4.1	
			SR-90	<5.0	
			U-TOTAL	2.3	0.9
			U-ISOTOPIC:		
			U-234	1.2	0.4
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

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SAMPLE ID 01019 FRACTION 20A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15818

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	24	11
			RA-226	<1.0	
			RA-228	<4.1	
			SR-90	<5.0	
			U-TOTAL	2.2	0.9
			U-ISOTOPIC:		
			U-234	1.4	0.4
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01020 FRACTION 21A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15819

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/28/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	32	12
			RA-226	<1.0	
			RA-228	<4.4	
			U-TOTAL	1.9	0.9
			SR-90	<5.0	
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01021 FRACTION 22A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15820

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	5.0	2.4
			SR-90	<5.0	
			U-TOTAL	4.4	1.7
			U-ISOTOPIC:		
			U-234	1.6	0.6
			U-235,236	<1.0	
			U-238	1.5	0.6

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01022 FRACTION 23A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15821

UNITS pCi/l *

WRTN 10/27/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	51	14
			RA-226	<1.0	
			RA-228	<3.8	
			SR-90	<5.0	
			U-TOTAL	2.8	1.0
			U-ISOTOPIC:		
			U-234	1.5	0.5
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

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Received: 09/15/87

Results by Sample

SAMPLE ID 01023 FRACTION 24A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/12/87 Category 15822

UNITS pCi/l *

WRTN 10/26/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<5	
RU-106	<150		GROSS BETA	32	11
			RA-226	<1.0	
			RA-228	<4.2	
			SR-90	<5.0	
			U-TOTAL	4.8	1.9
			U-ISOTOPIC:		
			U-234	2.4	0.8
			U-235,236	<1.0	
			U-238	1.6	0.6
			*U-TOTAL	ug/l	

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SAMPLE ID 01024 FRACTION 25A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/12/87 Category 15823

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/26/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<2	
RU-106	<150		GROSS BETA	<9	
			RA-226	<1.0	
			RA-228	<4.7	
			SR-90	<5.0	
			U-TOTAL	<1.0	
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL	ug/l	

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SAMPLE ID 01025 FRACTION 26A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15824

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	71	19
			RA-226	<1.0	
			RA-228	<4.2	
			SR-90	<5.0	
			U-TOTAL	4.0	1.6
			U-ISOTOPIC:		
			U-234	2.3	0.7
			U-235,236	<1.0	
			U-238	1.4	0.6
			*U-TOTAL	ug/l	

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SAMPLE ID 01026 FRACTION 27A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15825

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	64	19
			RA-226	<1.0	
			RA-228	5.1	2.6
			SR-90	<5.0	
			U-TOTAL	4.5	1.8
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	1.5	0.6

*U-TOTAL - ug/l

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SAMPLE ID 01027 FRACTION 28A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15826

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	37	14
			RA-226	<1.0	
			RA-228	<4.1	
			SR-90	<5.0	
			U-TOTAL	2.9	1.4
			U-ISOTOPIC:		
			U-234	1.7	0.6
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

Received: 09/15/87 Results by Sample

SAMPLE ID 01028 FRACTION 29A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15827

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	23	12
			RA-226	<1.0	
			RA-228	4.0	2.0
			SR-90	<5.0	
			U-TOTAL	2.7	1.7
			U-ISOTOPIC:		
			U-234	1.5	0.8
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

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SAMPLE ID 01029 FRACTION 30A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15828

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	4	3
RU-106	<150		GROSS BETA	<19	
			RA-226	<1.0	
			RA-228	<3.7	
			SR-90	<5.0	
			U-TOTAL	3.2	1.6
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	1.1	0.5

*U-TOTAL - ug/l

Page 1 ITRSL Oak Ridge REPORT Work Order # R7-09-077
Received: 09/15/87 Results by Sample

SAMPLE ID 01030 FRACTION 31A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15829

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	67	20
			RA-226	<1.0	
			RA-228	5.6	2.5
			SR-90	<5.0	
			U-TOTAL	5.0	2.1
			U-ISOTOPIC:		
			U-234	2.4	0.8
			U-235,236	<1.0	
			U-238	1.7	0.7

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01031 FRACTION 32A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/14/87 Category 15830

UNITS pCi/l *

WRTN 10/27/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<4	
RU-106	<150		GROSS BETA	79	23
			RA-226	<1.0	
			RA-228	<4.9	
			SR-90	<5.0	
			U-TOTAL	3.8	1.6
			U-ISOTOPIC:		
			U-234	2.9	0.9
			U-235,236	<1.0	
			U-238	1.3	0.5

*U-TOTAL - ug/l

Received: 09/15/87

ITRSL Oak Ridge REPORT Work Order # R7-09-077

Results by Sample

862

SAMPLE ID 01032 FRACTION 33A TEST CODE GS NAME REQUESTED ANALYSES LISTED:

Date & Time Collected 09/14/87 Category 15831

UNITS pCi/l * VERIFIED BY ERS

WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	4	3
RU-106	<150		GROSS BETA	20	11
			RA-226	<1.0	
			RA-228	<4.6	
			SR-90	<5.0	
			U-TOTAL	2.5	1.2
			U-ISOTOPIC:		
			U-234	1.1	0.5
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

Received: 09/15/87

ITRSL Oak Ridge REPORT
Results by Sample

Work Order # R7-09-077

862

SAMPLE ID 01033 FRACTION 34A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15832

UNITS pCi/l *
WRTN 10/27/87

VERIFIED BY ERS

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<8	
RU-106	<150		GROSS BETA	<38	
			RA-226	<1.0	
			RA-228	<5.2	
			SR-90	<5.0	
			U-TOTAL	2.6	1.2
			U-ISOTOPIC:		
			U-234	1.1	0.5
			U-235,236	<1.0	
			U-238	<1.0	
			*U-TOTAL -	ug/l	

Page 1 ITRSL Oak Ridge REPORT Work Order # R7-09-077
Received: 09/15/87 Results by Sample

SAMPLE ID 01034 FRACTION 35A TEST CODE GS NAME REQUESTED ANALYSES LISTED:
Date & Time Collected 09/14/87 Category 15833

UNITS pCi/l * VERIFIED BY ERS
WRTN 10/27/87

GAMMA SPEC	RESULT	2-SIGMA	OTHER	RESULT	2-SIGMA
CS-137	<20		GROSS ALPHA	<3	
RU-106	<150		GROSS BETA	57	25
			RA-226	<1.0	
			RA-228	<4.1	
			SR-90	<5.0	
			U-TOTAL	2.9	1.4
			U-ISOTOPIC:		
			U-234	<1.0	
			U-235,236	<1.0	
			U-238	<1.0	

*U-TOTAL - ug/l

GRAIN-SIZE ANALYSIS DATA
GREAT MIAMI RIVER SEDIMENT

GRAIN SIZE ANALYSIS
GREAT MIAMI RIVER SEDIMENT
EXPLANATION OF SAMPLE NUMBERS IN LABORATORY REPORT

SAMPLE NUMBER AS REPORTED IN LABORATORY DATA SHEETS	SAMPLE LOCATION[a]
09000	2
09001	2
09002	2
03, 04, 05	3 Composite
06, 08	5 Composite
09, 10, 11	7 Composite
12, 13, 14	8 Composite
15, 16, 17	9 Composite

[a]Refer to Figure 4.1-1 for sample locations.

* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: X

SAMPLE NO.: 09000 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	100.0
0.375IN.	9.500	100.0
NO. 4	4.750	98.9
NO. 10	2.000	87.8
NO. 20	0.850	47.6
NO. 40	0.425	7.1
NO. 60	0.250	1.9
NO. 140	0.106	0.8
NO. 200	0.075	0.6

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 341.31

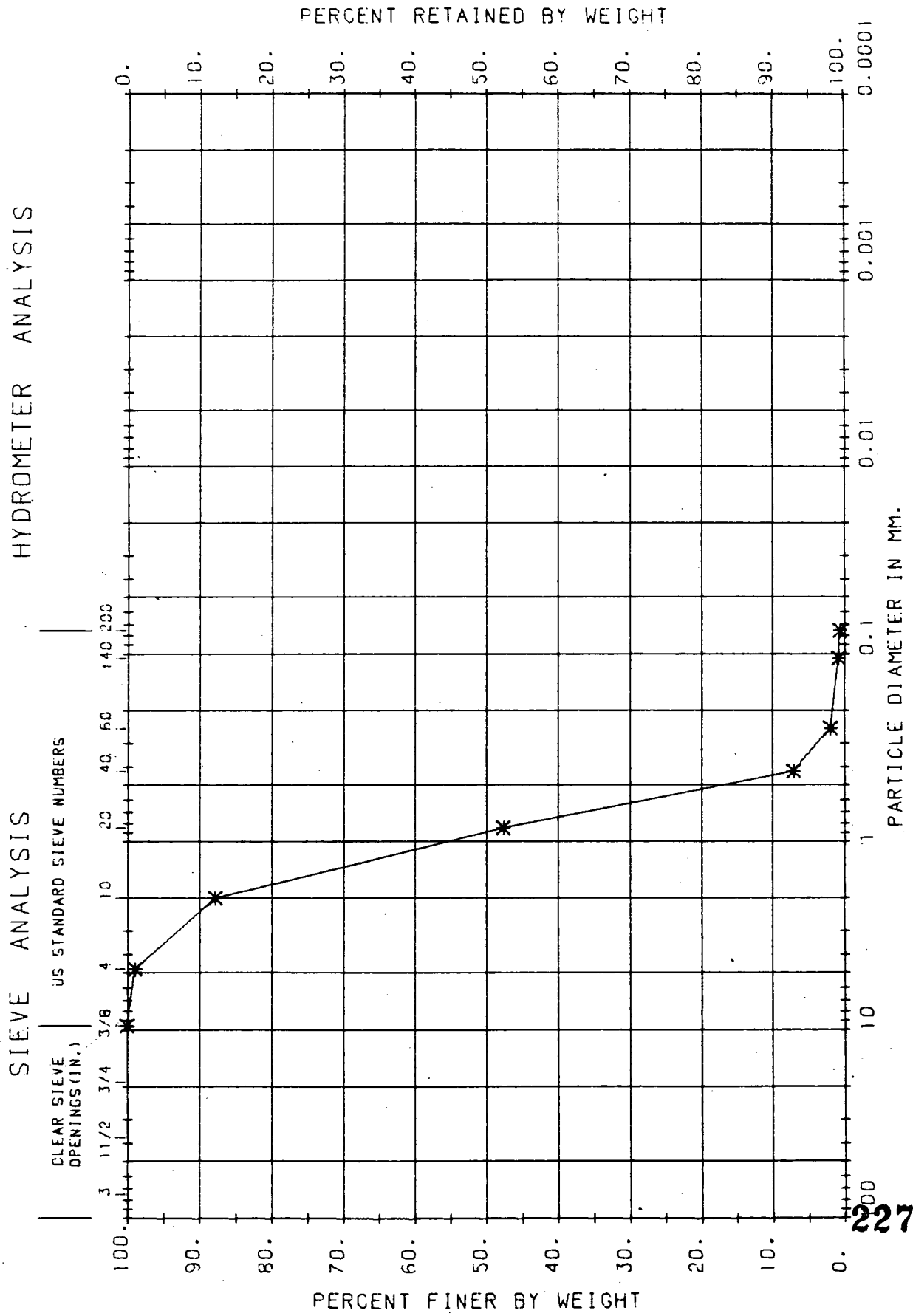
CU= 2.5 CZ= 0.8

D60= 1.1070 D30= 0.6293 D10= 0.4468

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317



* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: X

SAMPLE NO.: 09001 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	80.3
0.375IN.	9.500	74.6
NO. 4	4.750	71.3
NO. 10	2.000	65.1
NO. 20	0.850	56.8
NO. 40	0.425	42.6
NO. 60	0.250	35.2
NO. 140	0.106	32.7
NO. 200	0.075	32.3

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 378.71

CU=NA CZ=NA

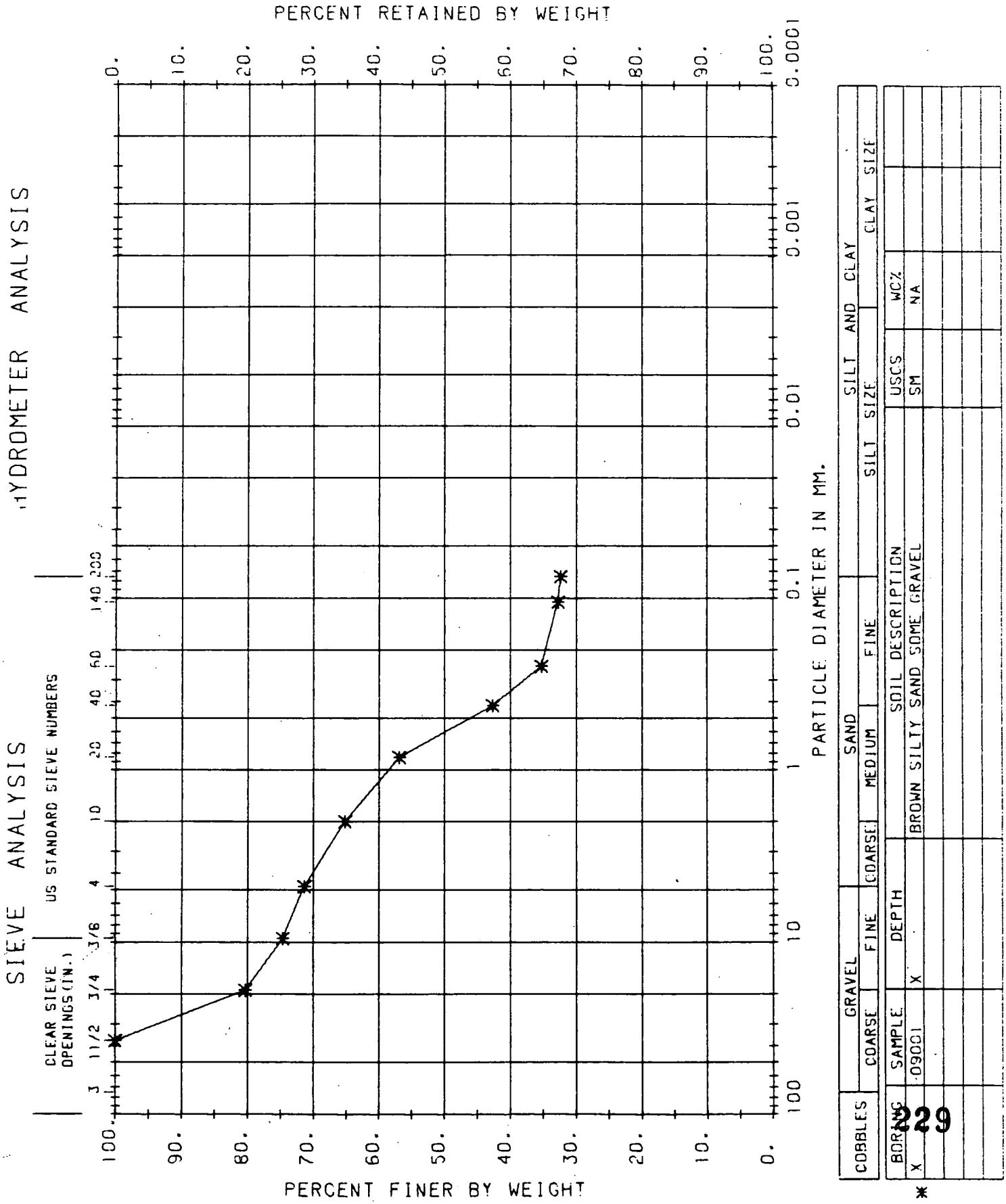
D60= 1.1833 D30=NA D10=NA

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



229

* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: X

SAMPLE NO.: 09002 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	44.9
0.375IN.	9.500	22.1
NO. 4	4.750	11.5
NO. 10	2.000	4.8
NO. 20	0.850	1.1
NO. 40	0.425	0.2
NO. 60	0.250	0.0
NO. 140	0.106	0.0
NO. 200	0.075	0.0

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 675.17

CU= 5.9 CZ= 1.6

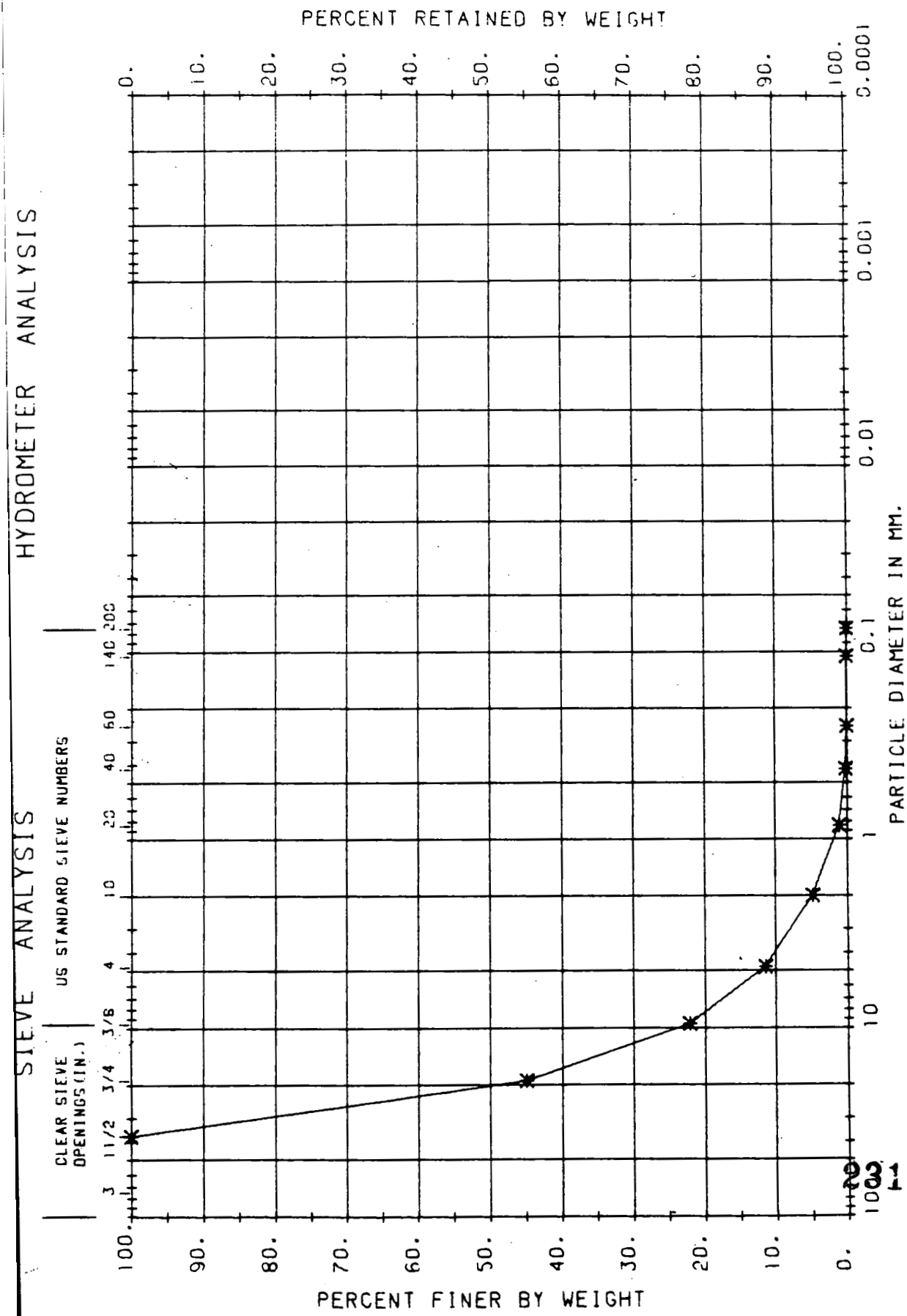
D60= 22.8951 D30= 12.0695 D10= 3.9086

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



BORING	SAMPLE	DEPTH	SOIL DESCRIPTION	USCS	WC%	CU	CZ
X	09002	X	FINE TO COARSE GRAVEL TRACE OF SAND	CP	NA	5.9	1.6

*

* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: COMPSITE

SAMPLE NO.: 03,04,05 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	82.6
0.375IN.	9.500	52.6
NO. 4	4.750	15.3
NO. 10	2.000	0.2
NO. 20	0.850	0.1
NO. 40	0.425	0.0
NO. 60	0.250	0.0
NO. 140	0.106	0.0
NO. 200	0.075	0.0

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 905.92

CU= 3.2 CZ= 1.0

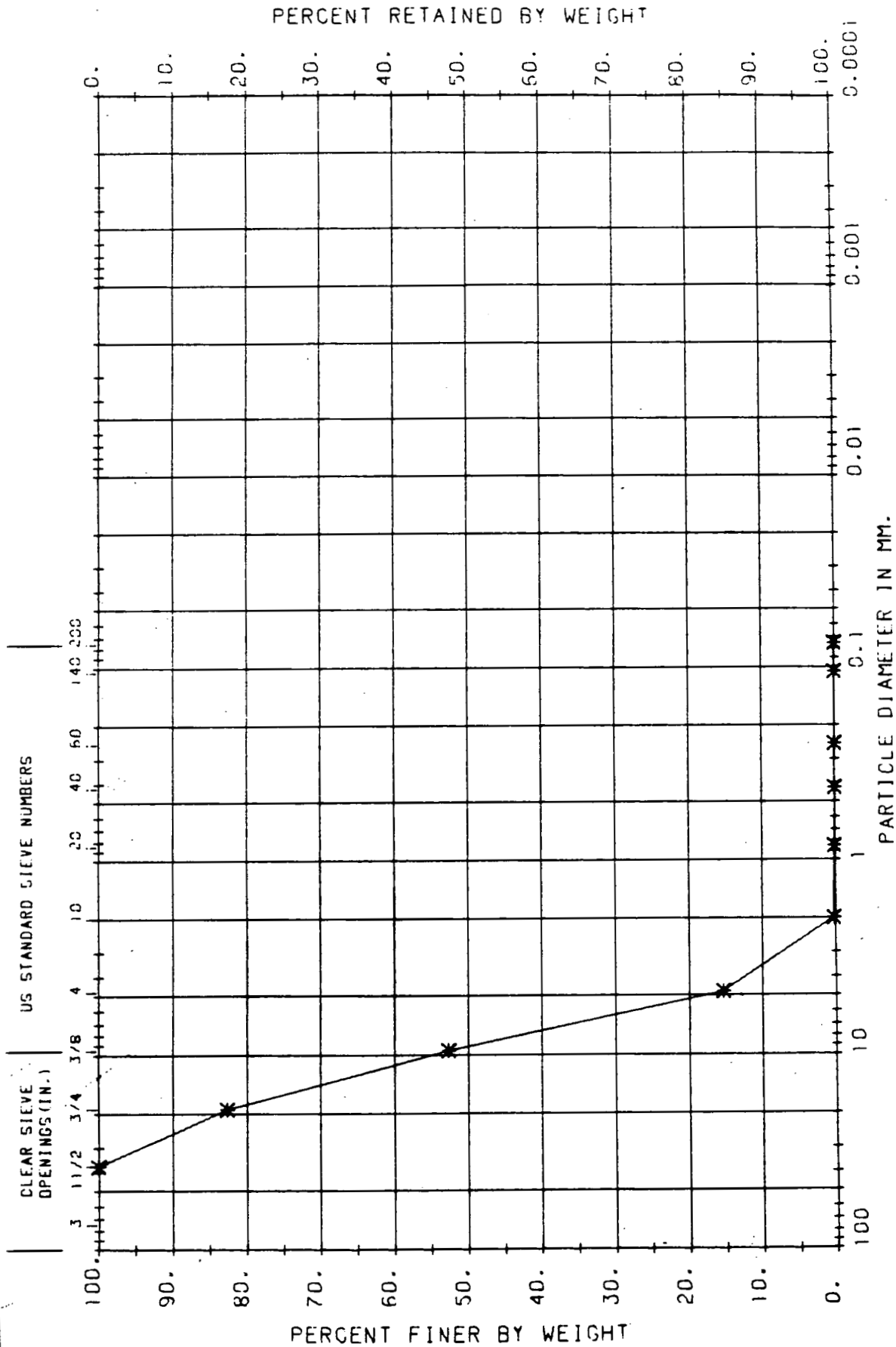
D60= 11.2777 D30= 6.2470 D10= 3.5101

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



* * * * GRAIN SIZE ANALYSIS * * * *

==-======REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: COMPSITE

SAMPLE NO.: 06,08 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	59.0
0.375IN.	9.500	48.4
NO. 4	4.750	41.2
NO. 10	2.000	34.7
NO. 20	0.850	22.0
NO. 40	0.425	6.1
NO. 60	0.250	4.0
NO. 140	0.106	2.9
NO. 200	0.075	2.9

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 921.59

CU= 38.3 CZ= 0.2

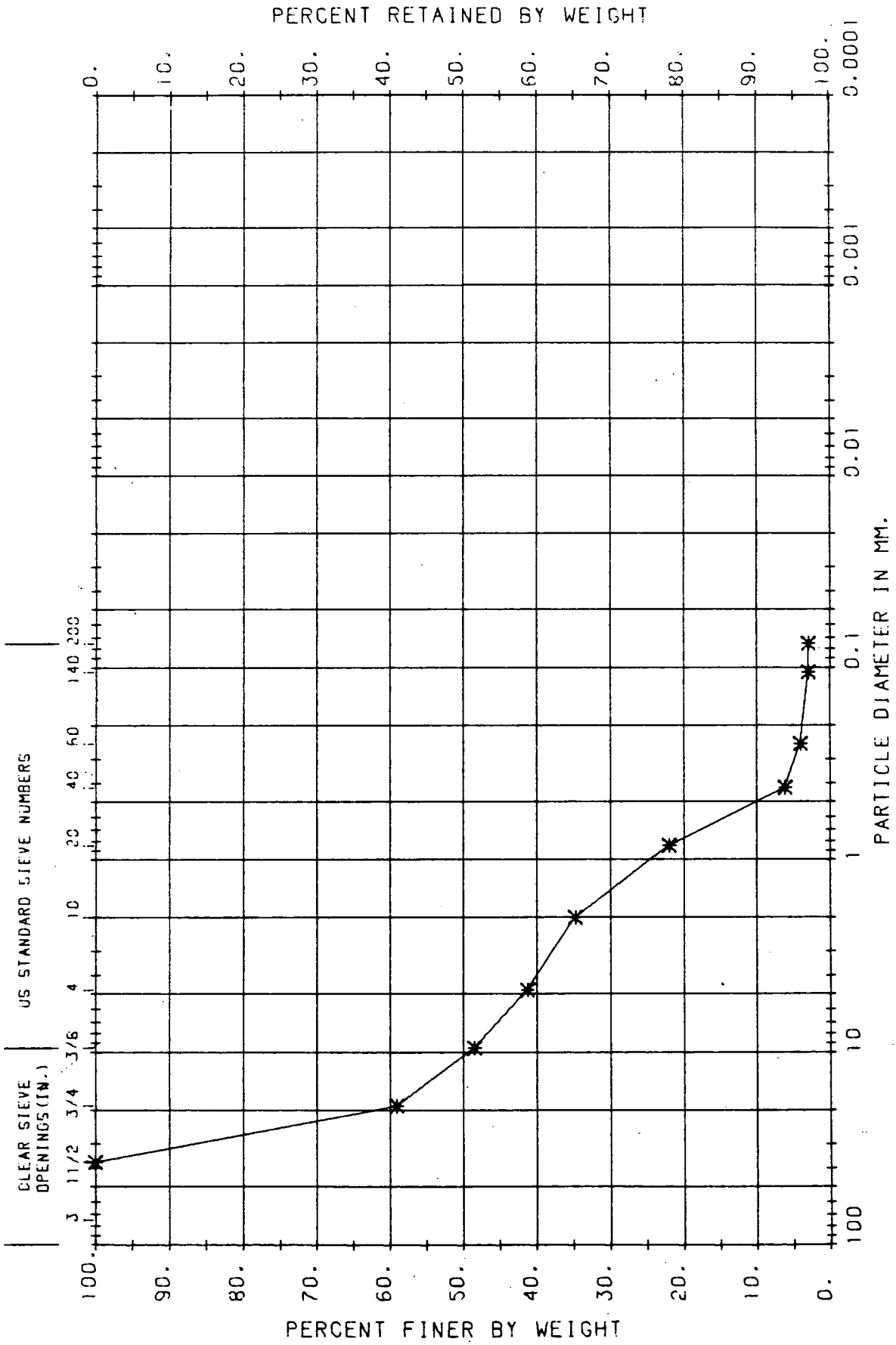
D60= 19.3084 D30= 1.4543 D10= 0.5038

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



COBBLES	GRAVEL		SAND			SILT AND CLAY	
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

BORING	SAMPLE	DEPTH	SOIL DESCRIPTION	USCS	WC%	CU	CZ
COMPSITE	06.08	X	SANDY GRAVEL	GP	NA	36.3	0.2

235

*

* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: COMPSITE

SAMPLE NO.: 09,10,11 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	100.0
0.375IN.	9.500	100.0
NO. 4	4.750	96.4
NO. 10	2.000	73.7
NO. 20	0.850	47.5
NO. 40	0.425	13.2
NO. 60	0.250	5.3
NO. 140	0.106	3.8
NO. 200	0.075	3.7

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 911.02

CU= 3.7 CZ= 0.8

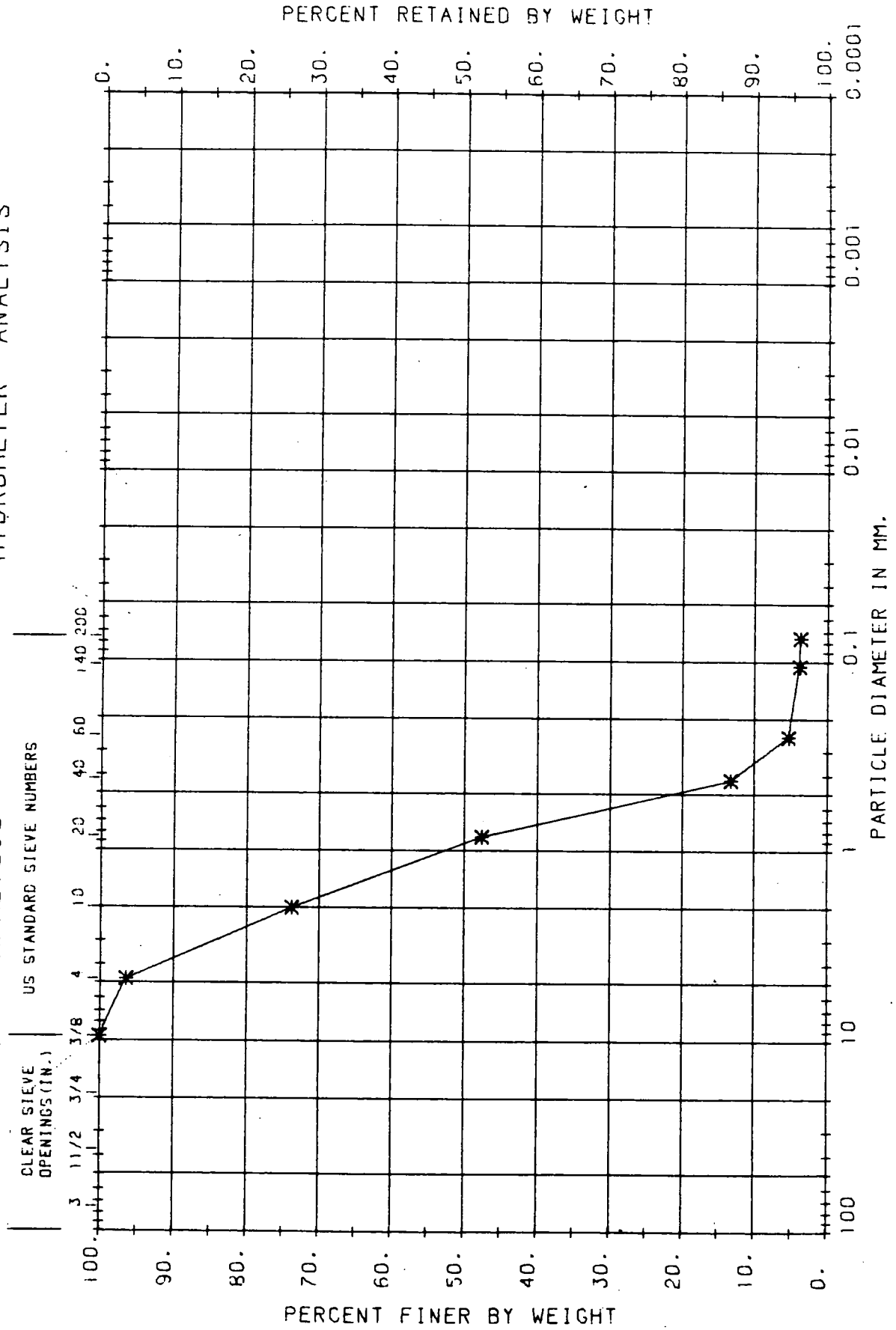
D60= 1.2786 D30= 0.5968 D10= 0.3425

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



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* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: COMPOSIT

SAMPLE NO.: 12,13,14 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	67.2
0.375IN.	9.500	44.2
NO. 4	4.750	26.1
NO. 10	2.000	14.6
NO. 20	0.850	5.8
NO. 40	0.425	1.9
NO. 60	0.250	1.4
NO. 140	0.106	1.1
NO. 200	0.075	1.0

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 1077.25

CU= 12.0 CZ= 1.6

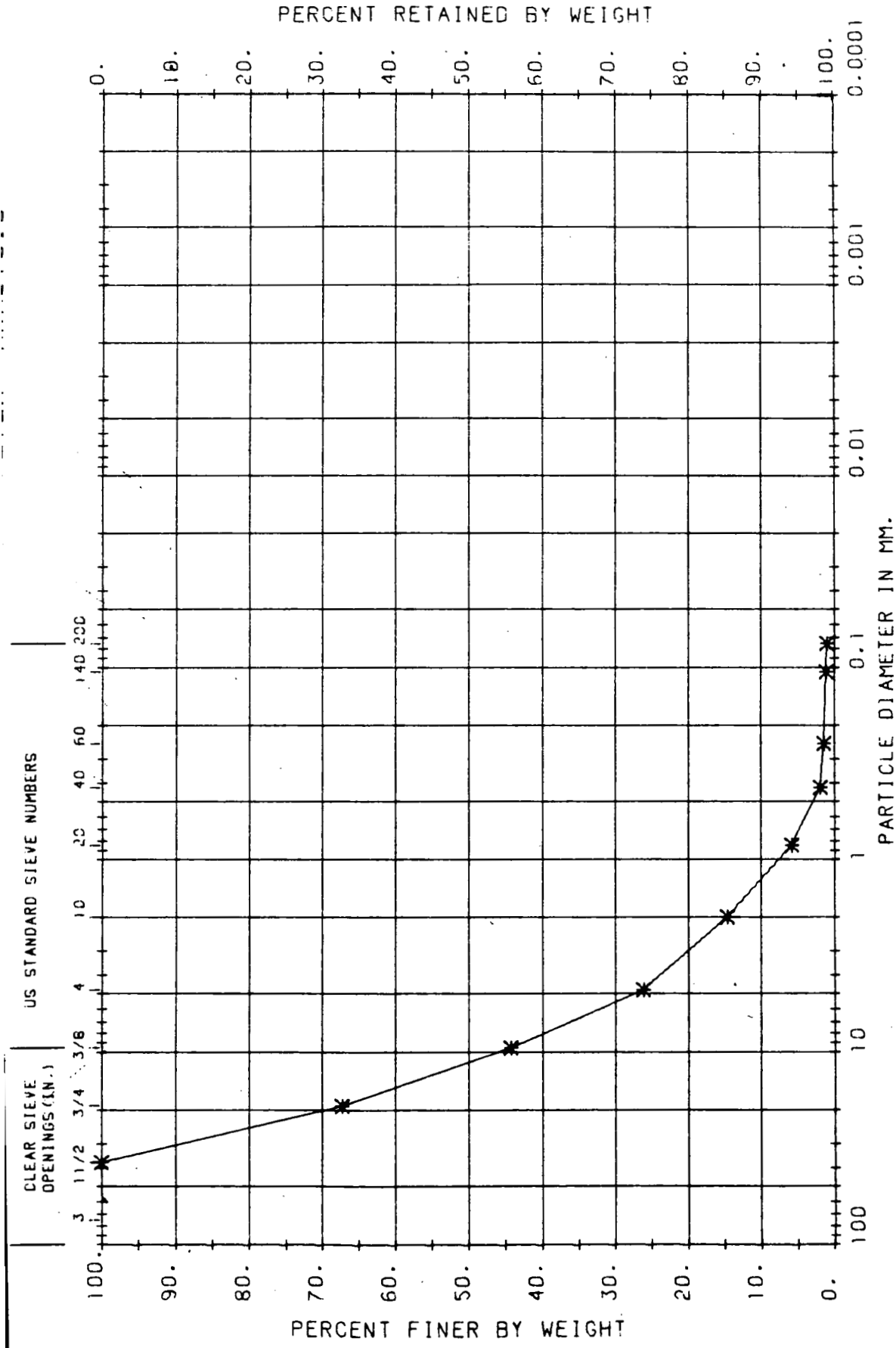
D60= 15.2942 D30= 5.5179 D10= 1.2769

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



COBBLES	GRAVEL		SAND			SILT AND CLAY	
	COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZE	CLAY SIZE

BORING	SAMPLE	DEPTH	SOIL DESCRIPTION	USCS	WC%	CU	CZ
COMPOSITE	12,13,14 X		COARSE TO FINE GRAVEL SOME BROWN SAND	CP	NA	12.0	1.6

239

* * * * GRAIN SIZE ANALYSIS * * * *

========REDUCED RESULTS========

PROJECT NAME: FERNALD

PROJECT NO.: 303317 BORING NO.: COMPSITE

SAMPLE NO.: 15,16,17 DEPTH: X

===SIEVE ANALYSIS===

SIEVE NO.	DIAMETER IN MM	PERCENT FINER
3.0 IN.	75.000	100.0
1.5 IN.	37.500	100.0
0.75 IN.	19.000	81.5
0.375IN.	9.500	70.8
NO. 4	4.750	67.0
NO. 10	2.000	56.1
NO. 20	0.850	41.2
NO. 40	0.425	22.6
NO. 60	0.250	18.6
NO. 140	0.106	16.4
NO. 200	0.075	15.9

WT. OF SOIL FOR SIEVE ANALYSIS (GM)= 710.00

CU=NA CZ=NA

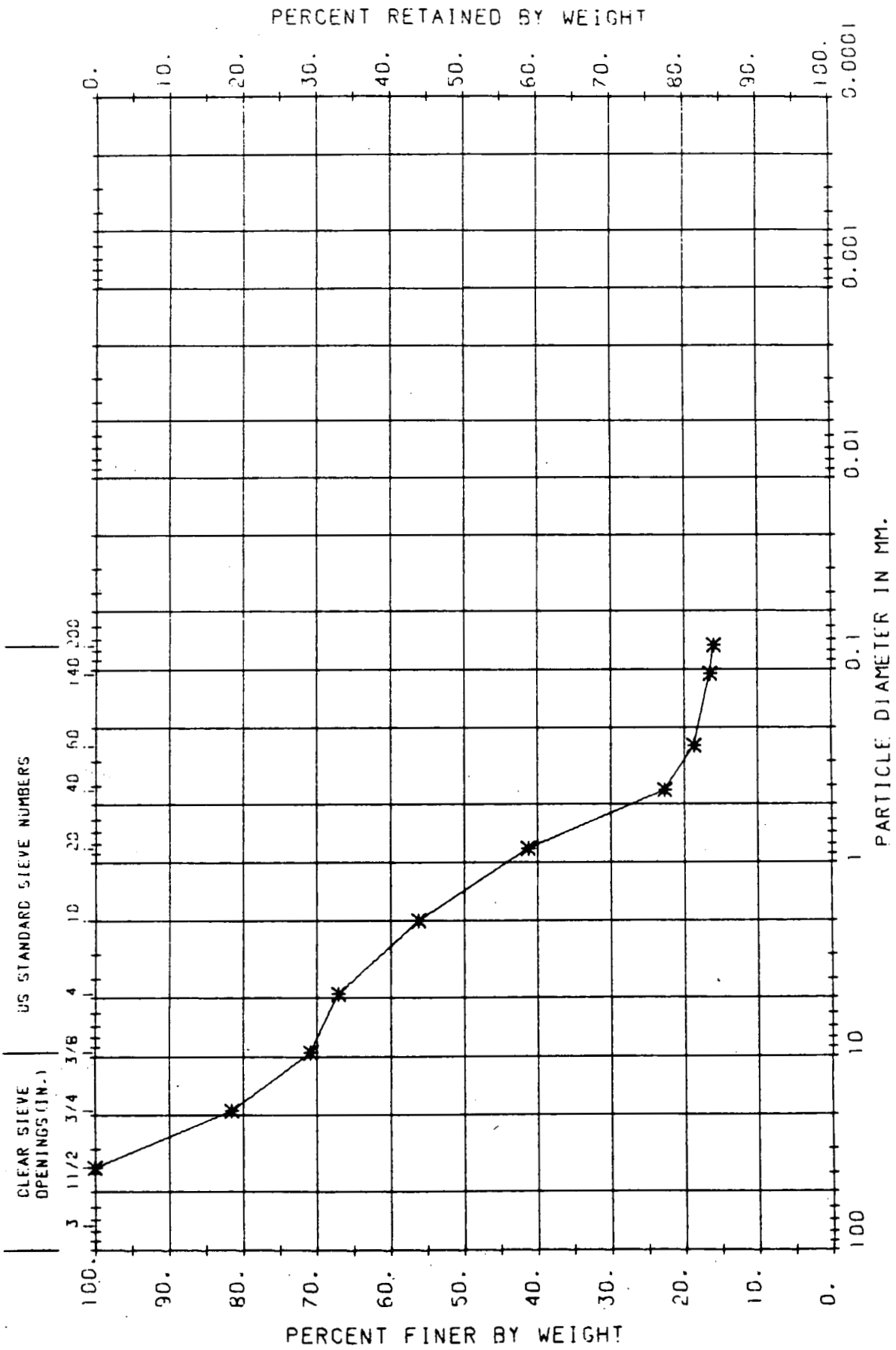
D60= 2.7190 D30= 0.5601 D10=NA

GRAIN SIZE ANALYSIS

PROJECT NAME: FERNALD

PROJECT NO.: 303317

862



HYDROMETER ANALYSIS

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