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# SOUTH PLUME REMOVAL ACTION GROUNDWATER MODELING REPORT APRIL 1992

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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT
FERNALD, OHIO

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U.S. DEPARTMENT OF ENERGY
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# 1.0 INTRODUCTION AND SCOPE OF WORK

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Operable Unit 5 (OU-5) - Environmental Media, which is a part of the Fernald Environmental Management Project (FEMP) Remedial Investigation/Feasibility Study (RI/FS), includes those environmental media that serve as migration pathways and/or environmental receptors of radiological or chemical releases from the FEMP (Figure 1). RI/FS findings have determined that a uranium contaminant plume exists in an area outside of FEMP property to the south. Because of the associated potential threats to human health and the environment, a Removal Action to address this plume outside of the FEMP boundary has been planned. The 1990 Consent Agreement between the Department of Energy (DOE) and the United States Environmental Protection Agency (U.S. EPA), Section IX, A.3, required the submission of a proposal for additional monitoring wells, an Engineering Evaluation/Cost Analysis (EE/CA), and a work plan for the South Plume Removal Action. This report details recent modifications made to the Removal Action based on additional information which has been obtained since issuance of the EE/CA. It also provides background information on pertinent FEMP site hydrogeology, Removal Action history, and previous groundwater modeling programs. The report is intended to provide background information on the Engineering Evaluation/Cost Analysis - South Plume (South Plume EE/CA) and the groundwater modeling program used during the study, and to present the results of the Removal Action well field relocation modeling work. It will not address in detail either the South Plume EE/CA modeling study or the construction, calibration, verification, and validation of the groundwater model; these have been described previously in other reports [South Plume EE/CA - (IT, 1990a - Appendix A) and the Groundwater Report (IT, 1990b - Part IV))].

The South Plume EE/CA was initially submitted in May 1990 and, after the public comment process (and resolution to the dispute between U.S. EPA and DOE), it was finalized in November 1990. The South Plume EE/CA selected an alternative which included groundwater pumping and discharge, an alternative water supply for two industrial users, installation of an interim advanced wastewater treatment system, and enhanced monitoring and institutional controls. The original location of recovery wells, based on groundwater modeling simulation, was along New Haven Road just west of its intersection with State Route 128 (Figure 2).

As a result of information obtained recently from a separate remedial investigation that is being performed by the Paddys Run Road Site (PRRS), additional concerns have been identified in the South Plume area. The PRRS consists of several industries (e.g., Mobil Mining, Albright & Wilson Americas Co. (A&W), and Rutgers and Nease) that, over the past years, have reportedly released both organics and inorganics into the environment which have now found their way to the Great Miami Aquifer. Some of these contaminants include cumene, toluene, benzene, arsenic, mercury, and others. The PRRS contaminants have been determined to extend near the original location of the proposed recovery well field as described in Appendix A of the November 1990 South Plume EE/CA (Figure 2). Therefore, operation of a uranium recovery well field at the location originally described

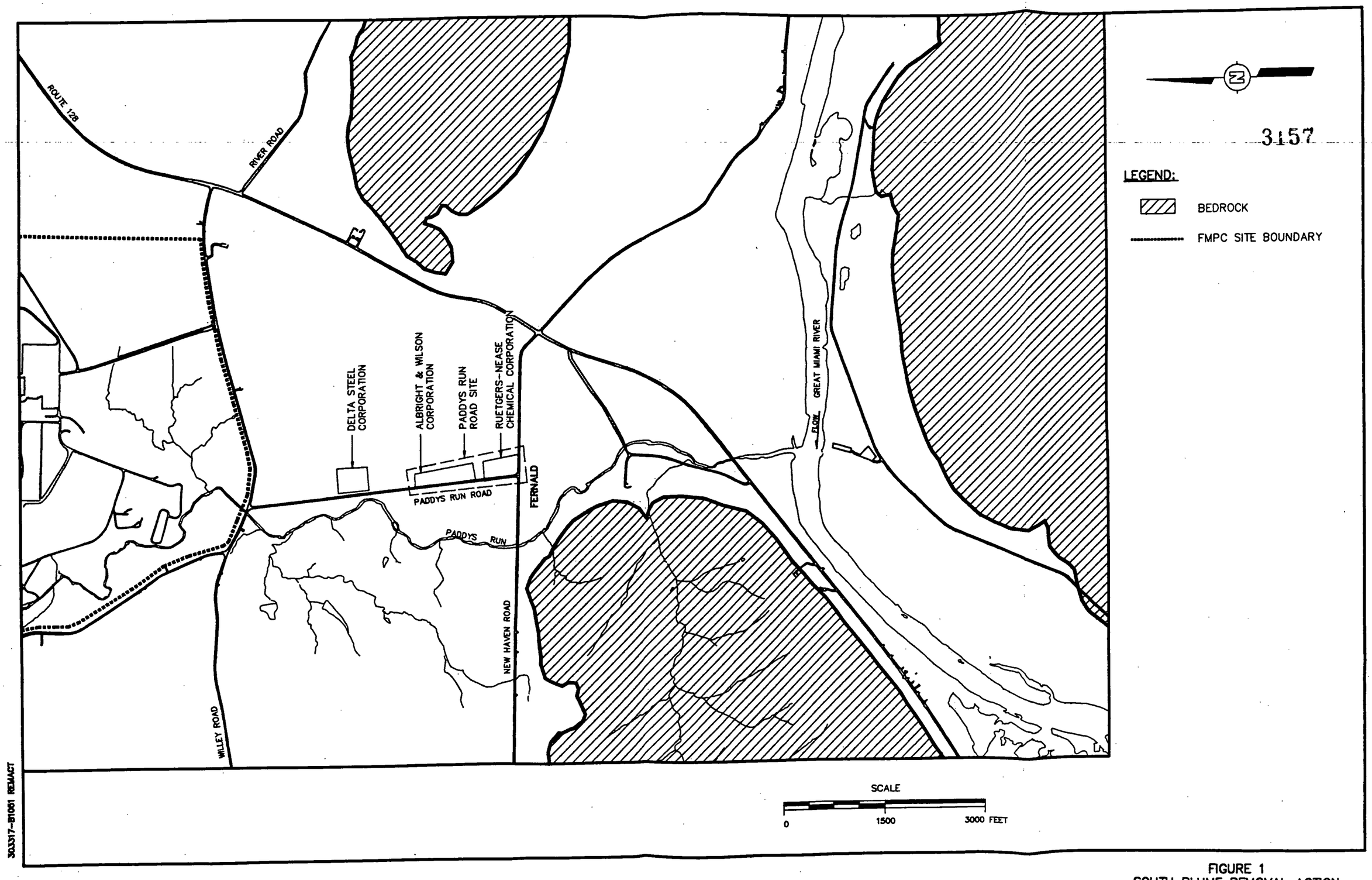


FIGURE 1
SOUTH PLUME REMOVAL ACTION
REMOVAL ACTION STUDY AREA
AND VICINITY

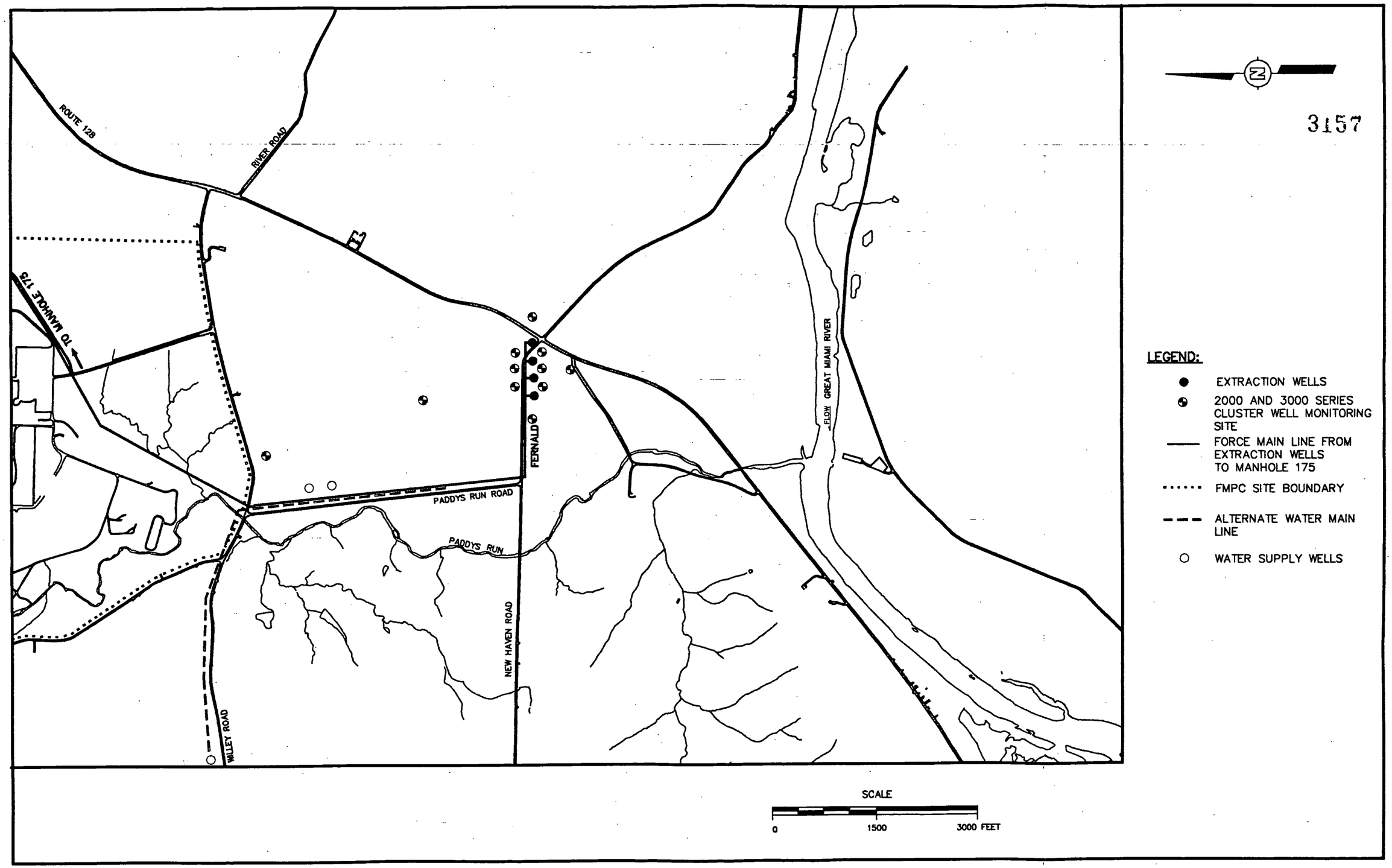


FIGURE 2
ORIGINAL LOCATION OF SOUTH PLUME EE/CA WELLS

could result in the extraction and discharge of PRRS contaminants to the Great Miami River (Interim Advanced Waste Water Treatment [IAWWT] system will only address uranium) and could result in the further spreading or shifting of the PRRS plumes.

As a result of these conditions, it has been deemed necessary to relocate the Part 2 well field to an area north of the PRRS. Groundwater flow and solute transport modeling has been performed to determine a location where pumping of the recovery well field will not significantly affect the PRRS plume and will not draw PRRS contaminants into the recovery wells. In addition, it was necessary to modify the November 1990 South Plume EE/CA with an addendum which restructured the EE/CA objectives to accommodate these conditions. This addendum was called the "Explanation of Significant Difference Document" (ESD). This document is a stand-alone document that justifies the changes in the South Plume EE/CA.

This relocation of the Part 2 well field has generated several additional requirements. The new location is in an area of higher uranium concentration which jeopardizes the equivalent mass treatment concept as described in the November 1990 EE/CA. Accordingly, the Part 3 IAWWT system has been expanded in size to provide the additional treatment necessary to meet the previously agreed upon equivalent mass concept, increasing its capacity to 1,700 pounds per year uranium removal.

In addition, the relocated well field is upgradient of an area of known 30 micrograms per liter (µg/L) uranium contamination. The computer model for the South Plume predicts that other areas could also exist where the level of uranium concentration is above 30 µg/l. Therefore, an additional investigation will be performed under a new Part 5 of the South Plume Removal Action. The Part 5 investigation will include hydropunching of the area south of the well field to New Haven Road. The investigation will identify the location of the 30 µg/l uranium isopleth. Because the U.S. EPA has recently issued a proposed revised limit of 20 µg/l for uranium in drinking water, the investigation will also identify the location of the 20 µg/l isopleth. The information obtained will be used to allow the FEMP to limit access to this water until additional response actions in this area are implemented.

Currently, it is envisioned that the remediation of the South Plume will be addressed by dividing the area into three zones. The purpose of the zones are to distinguish the areas of contamination for purposes of treatment. The zones are as follows:

- Zone 1 would be the area of the aquifer containing only uranium as the contaminant of concern. This will be the area addressed by the South Plume Removal Action project described in the ESD document, as mentioned above.

- Zone 2 would be the area of the aquifer containing uranium, inorganics, and organics as contaminants of concern.

- Zone 3 would include inorganics and organics as contaminants of concern. The area may also contain uranium contamination, but at a level below the planned cleanup level for the Operable Unit 5 Record of Decision (ROD).

This report addresses only those wells to be used in the extraction of Zone 1 contaminants.

## 2.0 HYDROGEOLOGY AND GROUNDWATER MODEL DEVELOPMENT

Within a hydrogeological context, two major types of geologic materials underlie the FEMP:

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

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

The portion of the Great Miami Aquifer that underlies the FEMP and South Plume areas consists primarily of glaciofluvial sand and gravel outwash deposited during the last two Pleistocene glaciations. Within the coarse-grained sediments of the Great Miami Aquifer lies an interbedded clay layer that underlies most of the FEMP and parts of the surrounding areas. The top of the clay interbed lies about 100 to 125 feet below the surface and generally about 60 to 80 feet below the water table. It ranges from 5 to 15 feet in thickness and consists of a low permeability homogeneous clay which acts as an aquitard within the Great Miami Aquifer. Because of this interbed, the aquifer is divided into upper and lower halves.

The generalized groundwater flow pattern in the Great Miami Aquifer underlying the FEMP study area is shown in Figure 3. Groundwater enters the study area from three directions. In the northeast, groundwater moves south-southwest from the Ross area into the portion of the New Haven Trough now occupied by the Great Miami River. The second source of groundwater is the Shandon Tributary which enters the New Haven Trough to the north of the FEMP. The majority of the groundwater from the Shandon Tributary flows under the FEMP plant and travels under the eastern boundary of the FEMP toward the Great Miami River. The third source of groundwater is from the west. The recharge from the Dry Fork area of the Whitewater River, located about two miles west of the FEMP, causes groundwater to move to the east toward the FEMP. This flow turns southward under the southern part of the FEMP and flows toward the Great Miami River in the glaciofluvial deposits under the southern part of Paddys Run, termed the Paddys Run Outlet. A portion of the groundwater from the Shandon Tributary also reaches the Great Miami River via Paddys Run Outlet.

The geomorphic setting of the Great Miami River and Paddys Run provides for interaction between the surface water and groundwater. Both surface water systems have eroded through the low permeability glacial overburden material to the Great Miami Aquifer. This contact allows for the direct exchange of water between the surface water and groundwater systems, which is important in

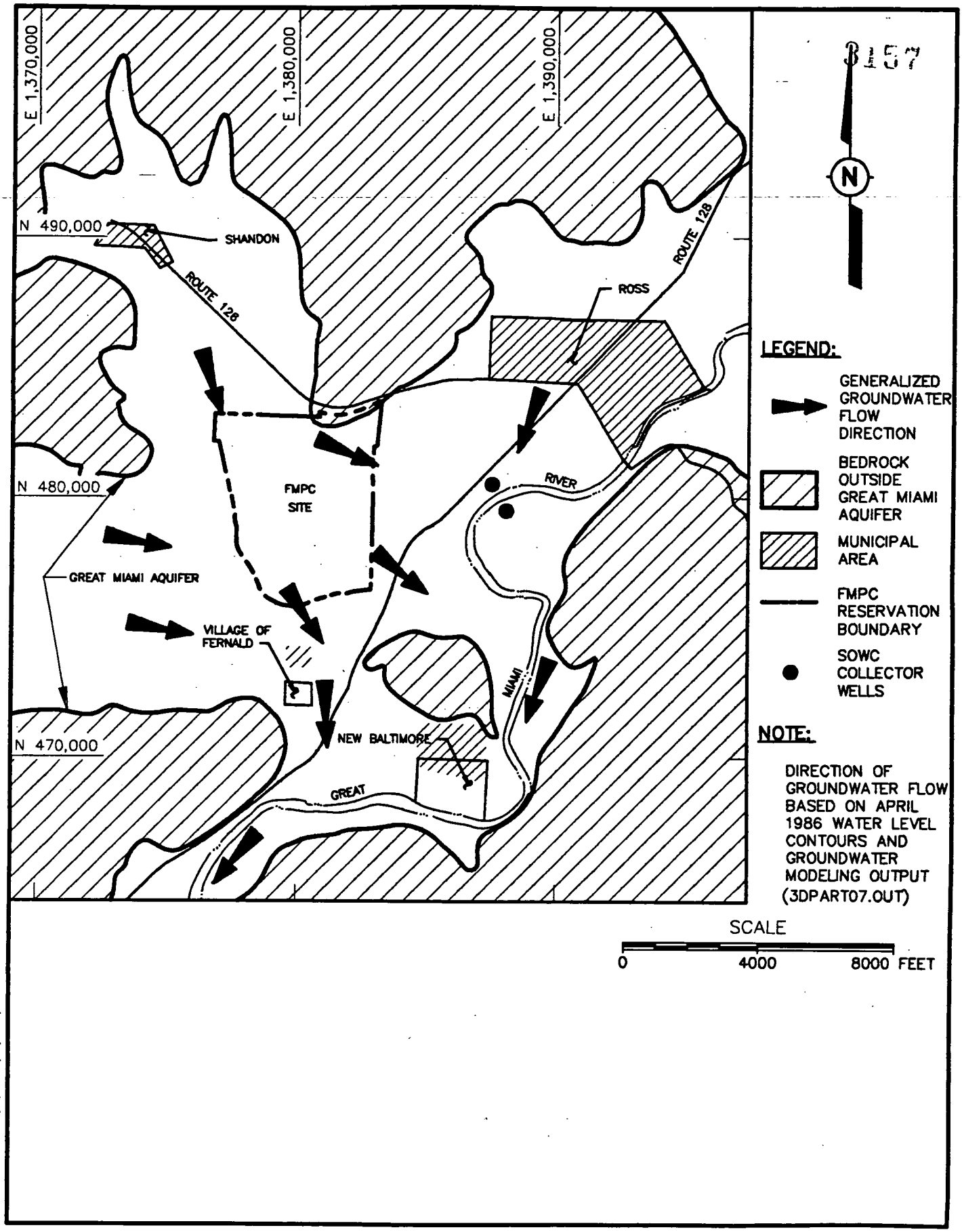


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FIGURE 3
GENERALIZED GROUNDWATER FLOW DIRECTIONS
IN THE VICINITY OF THE FEMP

relation to increased usage of the aquifer for water supplies and contaminant transport in the FEMP study area.

As the Great Miami River partially penetrates the water table, a portion of its flow originates from surface water while a portion also comes from the aquifer beneath the river. This relationship varies with changing river and groundwater elevations and is also affected by nearby pumping wells. At times when the groundwater elevation is above the river, flow is from the aquifer to the river. Conversely, when groundwater elevations are below the river elevations, flow is from the river to the aquifer and the river loses water. The natural groundwater flow is generally from the aquifer to the river; that is, groundwater discharges into the river. However, pumping of two large capacity collector wells owned by the Southwestern Ohio Water Company (SOWC), which are located close to the river (Figure 3), induces recharge to the aquifer by river infiltration. This occurs by creating a local hydraulic gradient, which causes flow from the river to the aquifer. This induced infiltration allows the collector wells to maintain a higher yield from the aquifer than could be achieved if the river was not present.

Paddys Run also interacts with the Great Miami Aquifer in several different ways that affect groundwater flow and discharge. The stream has eroded through the glacial overburden and into the Great Miami Aquifer from its confluence with the Great Miami River to approximately 15,000 feet upstream. It is directly connected with the Great Miami Aquifer in this reach. South of the FEMP, the elevation of the water table is close to or above the elevation of the stream bottom; consequently, as Paddys Run is normally dry during most of the year, the stream receives groundwater in this reach. In the vicinity of the FEMP, however, the stream is above the water table and loses water to the regional aquifer. Paddys Run is generally dry, except during runoff periods following rainfall and snow-melt events. These runoff periods have been found to cause transient groundwater fluctuations which may influence contaminant transport along the western side of the FEMP. Sustained flow has been reported in Paddys Run during the winter and spring by Dames and Moore (1985) and by stream gaging stations monitored during the RI. Relatively little recharge of the Great Miami Aquifer occurs where Paddys Run is on the clayey till 15,000 feet north of its confluence with the Great Miami River.

To evaluate contaminant transport in and around the FEMP, a groundwater modeling program was initiated to evaluate the site. The selection, verification, calibration, and results of the groundwater modeling are presented in two separate reports (IT, 1990 and 1991b). The groundwater model used in support of the Removal Action is a finite-difference computer model of groundwater flow and solute transport. The computer program is SWIFT III, Version 2.25. A detailed presentation of the model, its development, and the baseline input data were issued as part of the overall modeling report prepared under the RI/FS (IT, 1990b). Only the most pertinent information is provided here. A comprehensive verification study of the SWIFT III code has also been completed and a report issued (IT, 1990a).

Steps in the development of the model for application to the FEMP have included:

- Construction and calibration of a regional, two-dimensional, steady-state, groundwater flow model
- Construction and calibration of a regional, three-dimensional, steady-state, groundwater flow model
- Application of two-dimensional analytical solute transport models to help strategize the numerical solute transport model
- Construction of a local, two-dimensional, transient solute transport model
- Construction and calibration of a local, three-dimensional, transient solute transport model with uranium concentration data from the monitoring wells.

The local model covers a smaller area than the regional model, with model cells 125 feet on a side (Figure 4). The smaller area allows the use of a refined grid with a small cell size, which is necessary for solute transport modeling. The smaller grid area was established to include the area of the existing uranium plume. The grid size was selected based on the need to simulate a uranium dispersivity value of 100 feet longitudinally, which was the preferred value based on literature review (IT, 1990b). Using this value, the grid size used was set so as to be able to accommodate dispersivity values as low as 62.5 feet, or half the distance of the local area grid size of 125 feet. As the regional model did not contain a solute transport solution, its grid spacing was much larger, except in the area around the SOWC collector wells, where large groundwater gradients exist. The local model also covered the area for which uranium concentration data are available from monitoring wells. The interrelationship between the local and regional models is established by imposing the steady-state flow field predicted by the regional model on the solute transport model. Transient groundwater flow was not simulated; thus, transient flow effects such as mounding caused by Paddys Run were not included.

The regional and local models contain five layers. The uppermost two layers represent the upper and lower parts of the upper alluvial aquifer that underlies the area. The middle layer represents a clay interbed that is present in the immediate vicinity of the FEMP site, and the lowermost two layers represent the upper and lower parts of the lower alluvial aquifer. Where the clay interbed is not present, the middle layer is assigned the same characteristics as the uppermost two layers. The layers extend laterally into bedrock at the edges of a buried valley that contains the alluvium.

Pumping wells are located in the area spanned by the local model. These include an FEMP production well and three industrial wells located south of the FEMP site. Pumping from each of these wells was assigned to the proper cell and layer in the model. The three industrial wells are within the Removal Action study area.

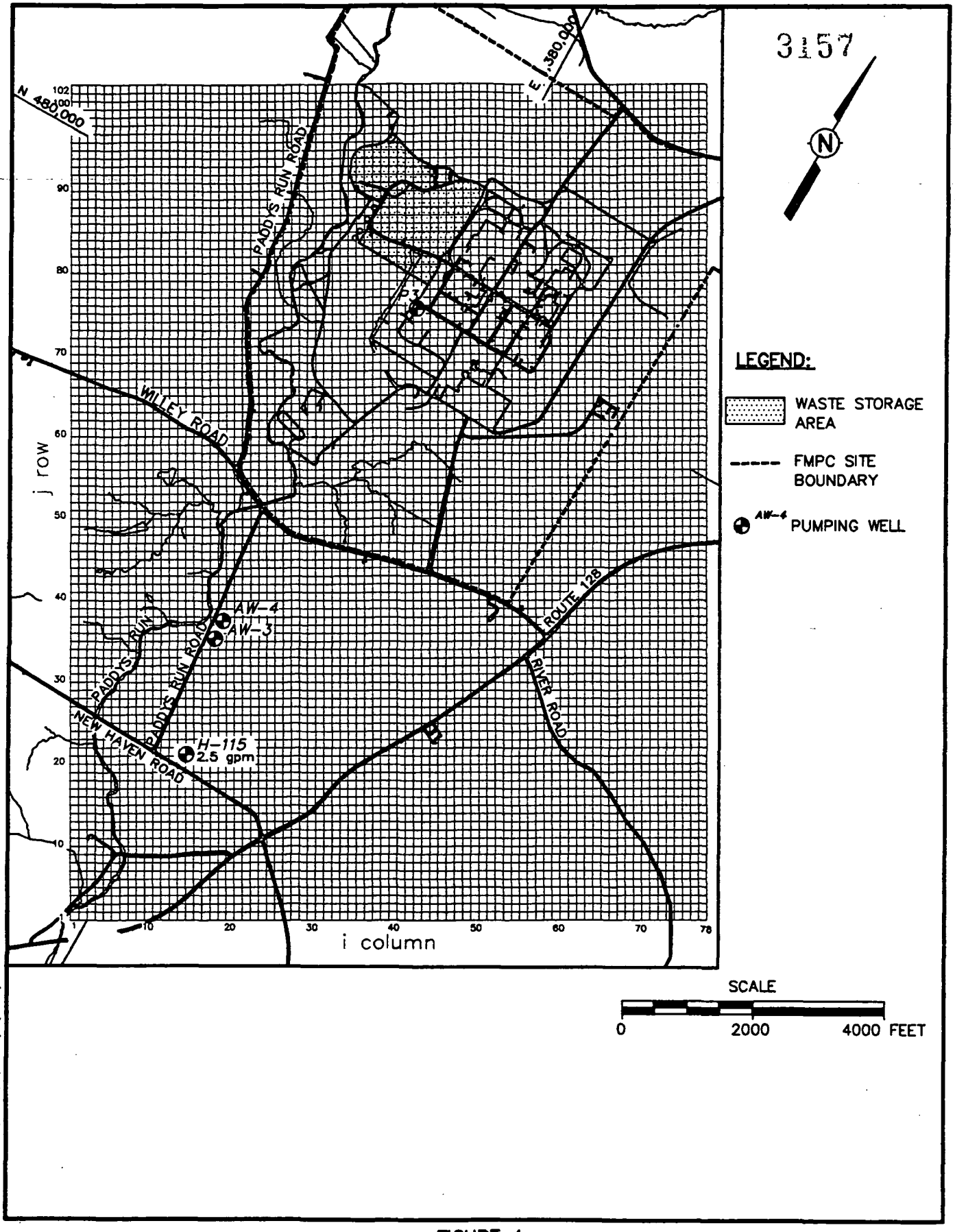


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FIGURE 4
LOCAL AREA MODEL GRID

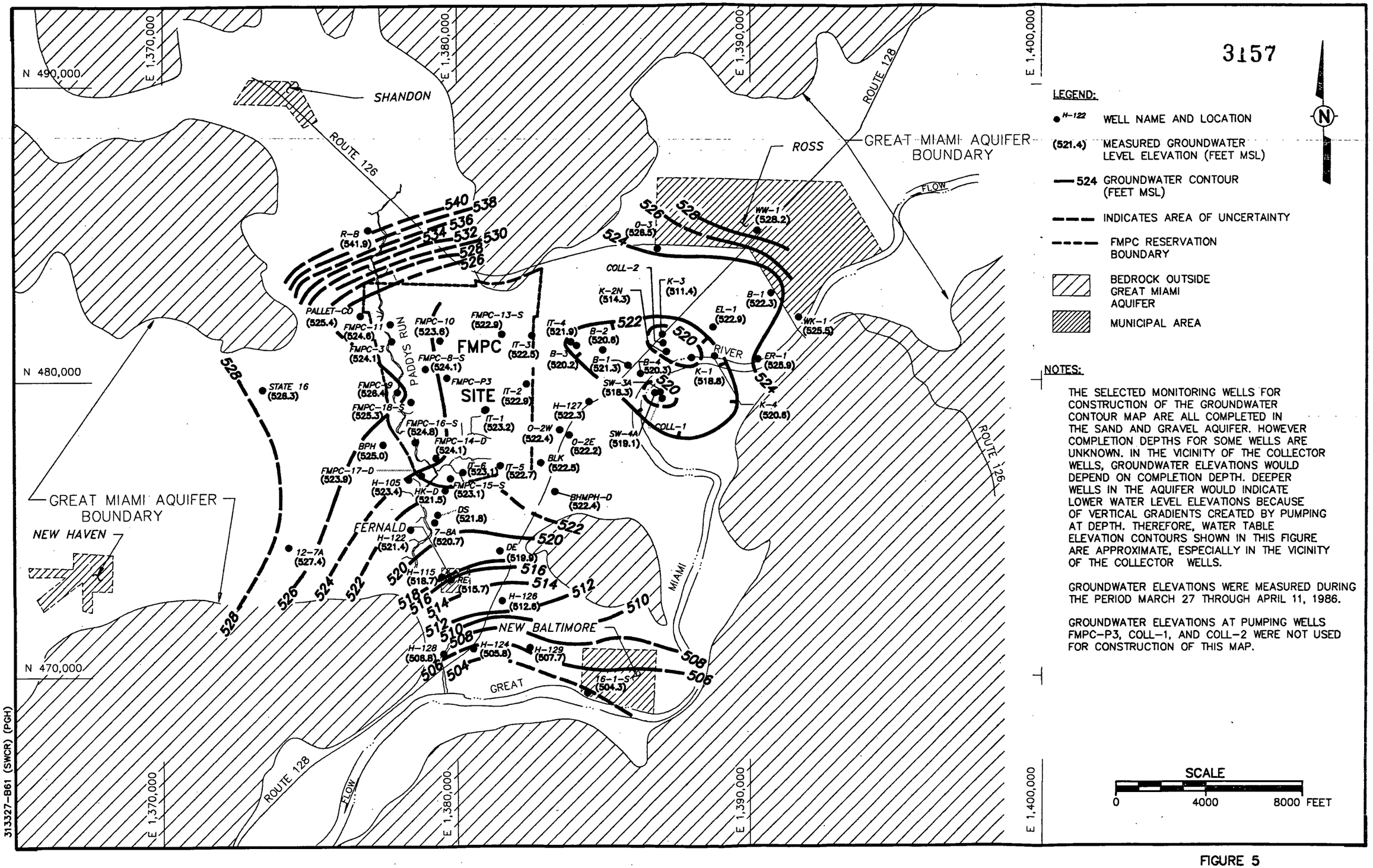
The calibration of the groundwater flow model was performed by comparing hydraulic heads calculated by the model against heads measured in numerous monitoring wells throughout the FEMP and surrounding areas. This calibration was performed using the regional flow model. Reasonable estimates of hydraulic conductivity and recharge were initially input to the model and then varied within an acceptable range to adjust model-computed heads to agree with observed monitoring well heads. The monitoring well heads used for calibration were measured in 1986 and are shown in Figure 5.

Groundwater flow conditions simulated by the model were successfully made to reproduce the observed flow conditions throughout the study area. Based on water levels from 55 wells, the arithmetic mean residual (observed head minus calculated head at the monitoring well) for the calibrated flow model was 0.21 foot. The match of field data portrayed by this residual value is realized when compared to a total change in hydraulic head of approximately 20 feet over the South Plume area. The mean of the absolute values of the residuals was 1.08 feet. When the local model was constructed, a computer program was used to check, cell by cell, the correspondence of heads in the local model with heads in the regional model. The correspondence verified that the flow model calibration was preserved in the solute transport model; thus, no new flow calibration was necessary. This resulting potentiometric surface from the local model is shown in Figure 6.

The calibration of the solute transport model involved the following steps:

- Based on the current understanding of historic patterns of uranium release, designating appropriate cells as source cells where uranium may enter the groundwater system
- Dividing the model time into source loading periods corresponding to intervals during which source loading was probably significantly different from in other periods
- Introducing reasonable initial estimates of uranium source loading for each source cell
- Establishing the best initial values of longitudinal and transverse dispersivity, as well as a distribution coefficient for uranium
- Adjusting source loading, source loading periods, dispersivities, and the distribution coefficient until concentrations calculated by the model are close to concentrations measured in the field.

The distribution coefficient was set at 0.022 cubic feet per pound, which corresponds to a retardation factor of 12. After attempting calibrations with distribution coefficients corresponding to retardation factors of 1, 6, and 9, a retardation factor of 12 was selected as the most representative, based on results of geochemical studies (IT, 1989) and the goals of the solute transport calibrations. These goals were to keep the dispersivities as close to 100 feet as possible and to keep the distribution coefficient as low as possible. The preference for a dispersivity of 100 feet was based on information




LEGEND:

- ● H-122 WELL NAME AND LOCATION
- (521.4) MEASURED GROUNDWATER LEVEL ELEVATION (FEET MSL)
- 524 GROUNDWATER CONTOUR (FEET MSL)
- INDICATES AREA OF UNCERTAINTY
- FMPC RESERVATION BOUNDARY
- BEDROCK OUTSIDE GREAT MIAMI AQUIFER
- MUNICIPAL AREA

NOTES:

THE SELECTED MONITORING WELLS FOR CONSTRUCTION OF THE GROUNDWATER CONTOUR MAP ARE ALL COMPLETED IN THE SAND AND GRAVEL AQUIFER. HOWEVER COMPLETION DEPTHS FOR SOME WELLS ARE UNKNOWN. IN THE VICINITY OF THE COLLECTOR WELLS, GROUNDWATER ELEVATIONS WOULD DEPEND ON COMPLETION DEPTH. DEEPER WELLS IN THE AQUIFER WOULD INDICATE LOWER WATER LEVEL ELEVATIONS BECAUSE OF VERTICAL GRADIENTS CREATED BY PUMPING AT DEPTH. THEREFORE, WATER TABLE ELEVATION CONTOURS SHOWN IN THIS FIGURE ARE APPROXIMATE, ESPECIALLY IN THE VICINITY OF THE COLLECTOR WELLS.

GROUNDWATER ELEVATIONS WERE MEASURED DURING THE PERIOD MARCH 27 THROUGH APRIL 11, 1986.

GROUNDWATER ELEVATIONS AT PUMPING WELLS FMPC-P3, COLL-1, AND COLL-2 WERE NOT USED FOR CONSTRUCTION OF THIS MAP.

SCALE

0 4000 8000 FEET

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FIGURE 5

APRIL 1986 GROUNDWATER ELEVATIONS USED FOR CALIBRATION

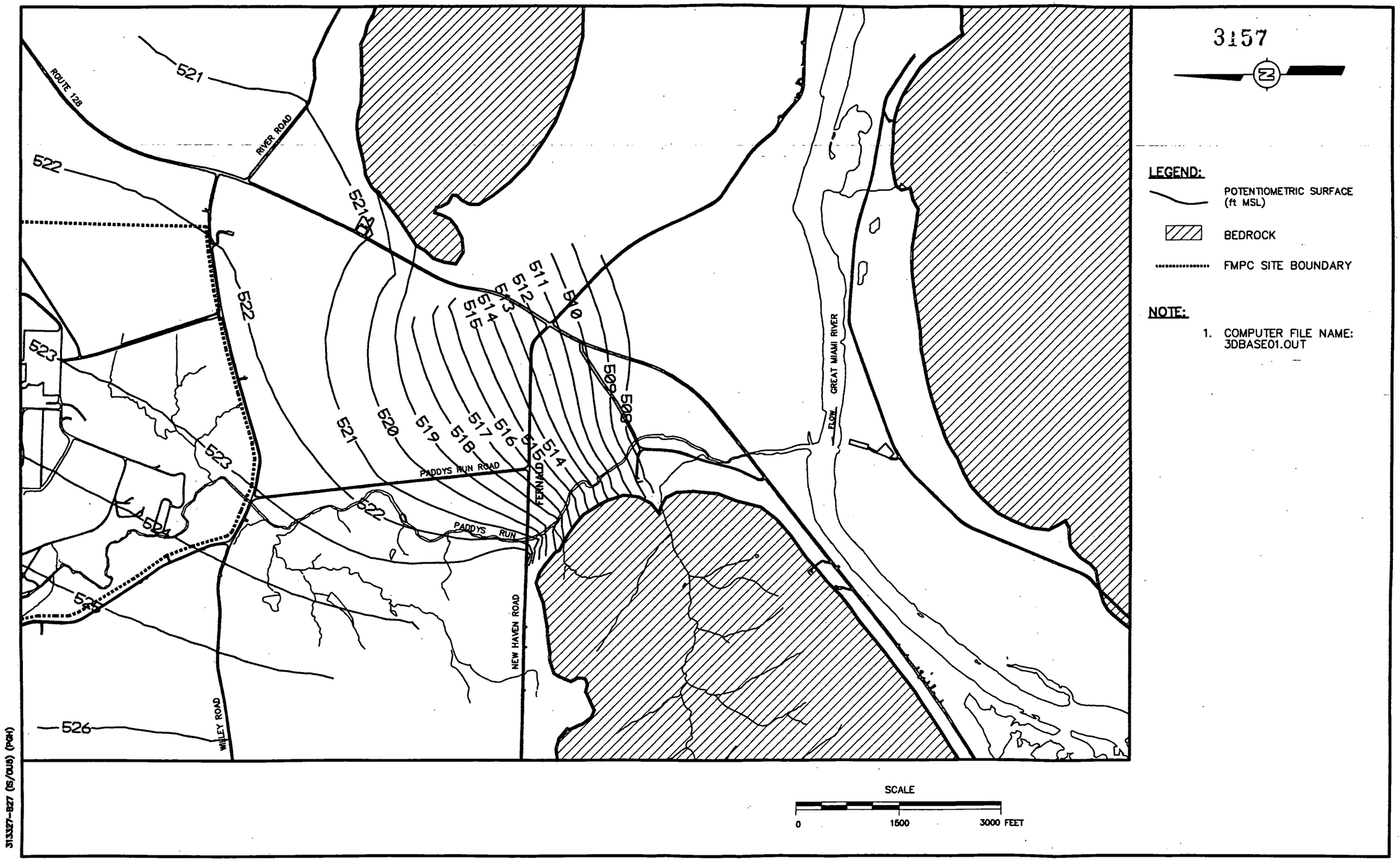



FIGURE 6
SOUTH PLUME REMOVAL ACTION
PREDICTED POTENTIOMETRIC
SURFACE

in the scientific literature. Walton (1985, Figure 2.16) presents a graph of mean travel distance versus longitudinal dispersivity from field studies. Assuming a mean travel distance in the South Plume of 2,500 feet, Walton's graph yields a longitudinal dispersivity slightly over 100 feet. Walton also shows representative longitudinal dispersivities for areal models of alluvial sediments and glacial deposits to be between 39 and 200 feet. The desire to keep the distribution coefficient low was based on results of the geochemical investigation, which found that the uranium is in complexes which have neutral or negative charges; such charges imply low retardation. The geochemical investigation is discussed in detail in a previous report (IT, 1989) and is based on site-specific investigations using analytical data and geochemical speciation models.

Because the plume is narrow and has high concentration gradients away from the center, the concentration patterns could be matched by having either a sufficiently high retardation factor or a sufficiently low dispersivity. Calibration with a retardation factor of 12 yielded the preferred longitudinal dispersivity of 100 feet and transverse dispersivity of 10 feet. The model uses transverse dispersivity for vertical dispersivity, so the calibrated transverse dispersivity tends to be low.

Statistics used to characterize the degree of calibration were based on monitoring data from wells that yielded detectable uranium in all samples. The object of the calibration was to produce a representative simulated plume. Calibration was performed by comparing calculated concentrations to the mean values of concentrations measured at the individual wells. The monitoring well data were obtained from multiple quarterly sampling rounds, with each well having from 2 to 93 sampling rounds, but most with 4 or 5 rounds. The majority of these wells used data from the 1988 and 1989 RCRA sampling rounds collected over a 2-year period. The calibration aimed at reducing the difference between the uranium concentration calculated by the model at each well and the mean concentration of the actual population at each well. Consequently, an appropriate goal for calibration is to attempt to put as many calculated concentrations as possible within the 95 percent confidence interval of the true mean. Calculation of confidence intervals for the mean is described in Mood and Graybill (1963, pp. 251-253). This test is a more restrictive one than the outlier test used in preliminary calibrations. Consequently, its application to the final calibration resulted in a more refined model. Hereafter, the 95 percent confidence interval for the true mean concentration at the well will be called the "range."

The result of the calibration with data collected up to April, 1990 was that all of the calculated concentrations in Layer 1 were brought into range, except the concentration at one well and the concentrations at a few wells upgradient from any known sources, upgradient of Paddys Run, south of the FEMP. Several concentrations at wells screened in lower layers also could not be brought into range. Uranium data from domestic wells with unknown screen depths were not included in this analysis. However, they have been inspected to verify that they contain no concentrations that were inconsistent with the solute transport modeling results.

The calibrated solute transport model (Figure 7) yielded a predicted uranium plume centered approximately 500 feet south of the FEMP with a peak concentration above 400 µg/l. The model shows the majority of contamination is located within the upper half of the Great Miami Aquifer, with most of the uranium residing in the upper three model layers. The plume's 10 µg/l boundary extends from the FEMP's production area in the north to New Haven Road in the south and from just west of Paddys Run to approximately 1,500 feet east of Paddys Run Road. This 10 µg/l line is the outer contour shown in this report and is defined to be the plume's boundary for predictive purposes.

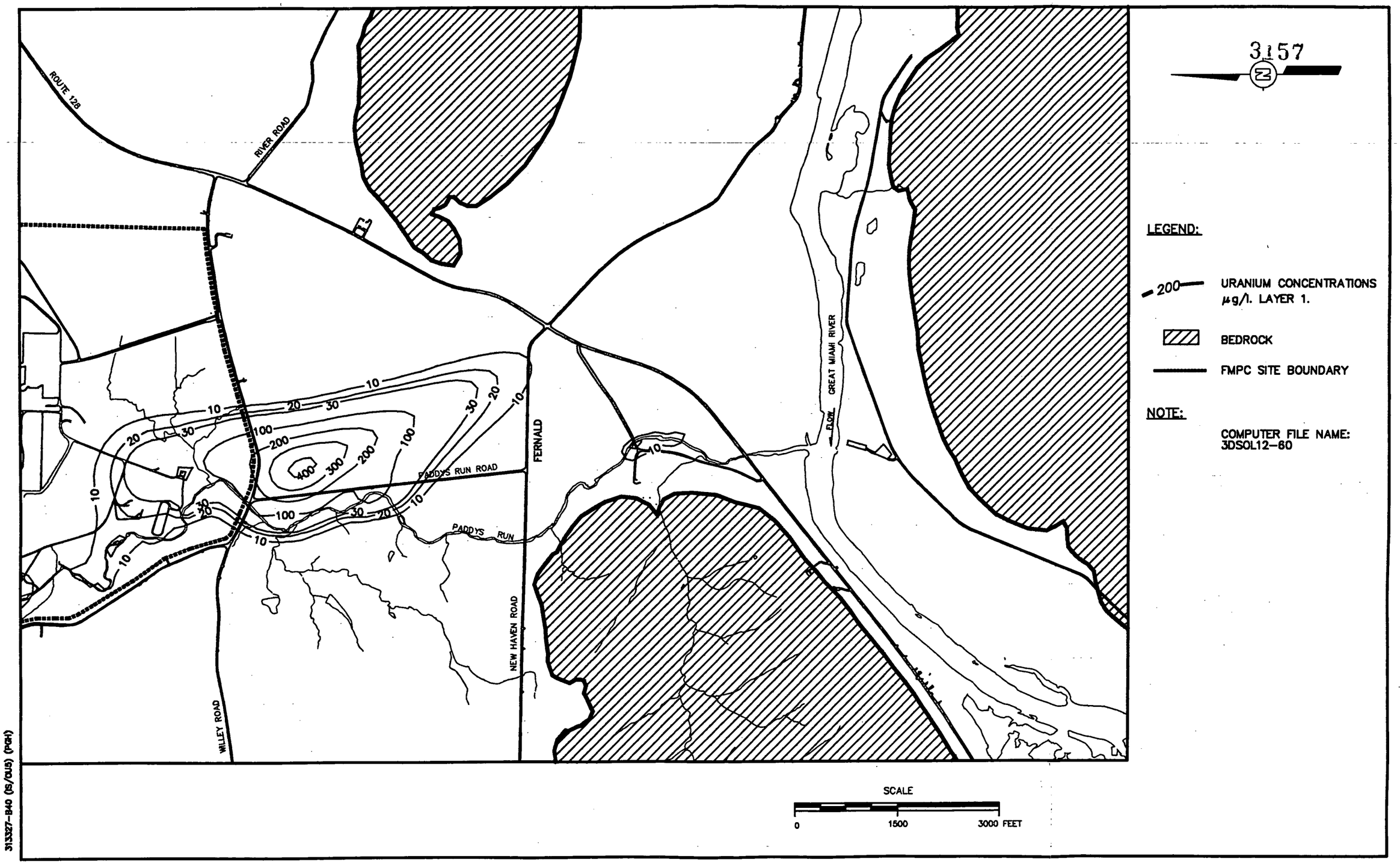



FIGURE 7
SOUTH PLUME REMOVAL ACTION
MODELED PRESENT DAY URANIUM CONCENTRATIONS

## 3.0 PREVIOUS South Plume EE/CA MODELING INVESTIGATION

The South Plume EE/CA identified one primary and two secondary objectives for the South Plume Removal Action:

- Primary Goal: Protection of public health by limiting access to and use of groundwater with uranium concentrations exceeding the derived concentration limit of 30 µg/l for uranium in drinking water, as well as other appropriate, risk-based levels for various potential exposure scenarios.

- Secondary Goal:

  - Protection of the groundwater environment which, in this case, is represented by a sensitive, sole-source aquifer

  - Control of plume migration toward additional receptors further south.

To meet these goals, a groundwater modeling investigation was undertaken to determine number, placement, and pumping rates of interceptor wells for the South Plume EE/CA. The modeling work used an interim calibration of the solute transport model which used a retardation factor of 9 to simulate the uranium plume. This calibration, although not completely refined, was able to simulate large changes in the solute transport system such as would be caused by pumping wells.

The solute transport model representing the current distribution of uranium in the South Plume shows the highest observed uranium values were from the uppermost layer of the aquifer. The maximum concentration in the plume was predicted to be approximately twice the maximum observed value and to lie northeast of the well with the highest observed level. The maximum concentration is also some distance downgradient from the source locations. This result indicates that the plume is affected by source loadings that were greater in the past than they are now.

The South Plume EE/CA groundwater modeling tested several possible scenarios for dealing with uranium-contaminated groundwater. These included a no-action alternative, an alternative water supply alternative, and a pumping alternative with a goal of plume interception. Modeling future concentrations under the no-action alternative was completed by extending the estimates of present source loadings five years into the future. The crest of the plume moves south about 1,100 feet and the maximum concentration declines approximately 25 percent, due to plume dispersion.

Additional modeling was conducted to determine the effect of providing an alternate water supply to several industries located within or near the South Plume. The proposed source of the alternate water supply is from a well located near Willey Road, 1,750 feet west of the FEMP boundary. Particle tracking was used in conjunction with the groundwater flow model to investigate whether operation of this well at a 500 gallons per minute (gpm) flow rate would pull water from the plume. These results

show that the particle trajectories in the plume are not distorted by the simulated production well; therefore, the well would not draw water from the plume. To verify this, these particle tracks were compared with the no-action scenario, again showing that the simulated production well has little effect on the particle tracks.

Particle tracking is a technique for determining and depicting the three-dimensional movement of the groundwater in a finite-difference flow model. In the present investigation it involved processing output from the local SWIFT III model via a computer program named STLINE (GeoTrans 1987). STLINE computes the positions of particles moving in the direction of flow and at the interstitial velocity of water in each model cell in the porous material. The STLINE program accepts particle initial positions supplied by the user and computes the positions of the particles at the ends of specified time periods. The STLINE output describes the tracks of the particles as they move through the system.

The location and pumping rates for interceptor wells that will produce a hydraulic control to the southward movement of contaminated water in the South Plume were selected by introducing a line of wells with various spacings and pumping rates into the model. Particle tracking was used to determine whether water upgradient from the wells and within the lateral and vertical boundaries of the plume would be drawn into them.

Initial positions of particles were placed within the plume, along the lateral and vertical boundaries of the plume upgradient from the general location of future pumping, and along Paddys Run. Figure 8 shows the particle tracking if no action is taken (i.e., no pumping). The plume is shown to migrate in a south-southeasterly direction. The focusing of flow lines from all along Paddys Run into the narrow trough of the aquifer is also demonstrated by particle tracking.

The particles were then strategically placed in a sufficient number of locations to determine whether all water in the plume upgradient from any pumping wells would be intercepted. Particles were placed in both the upper and lower halves of the aquifer as well as along the boundary of the uranium plume. The results of the particle tracking for the recommended interceptor well system are shown in Figure 9. The interceptor well system shown in this figure was selected after trying and rejecting several other possibilities. The system selected used four wells spaced 280 feet apart, with each well pumping at 500 gpm. This case was subjected to detailed particle tracking analysis and captured all particles seeded in the plume north of the wells.

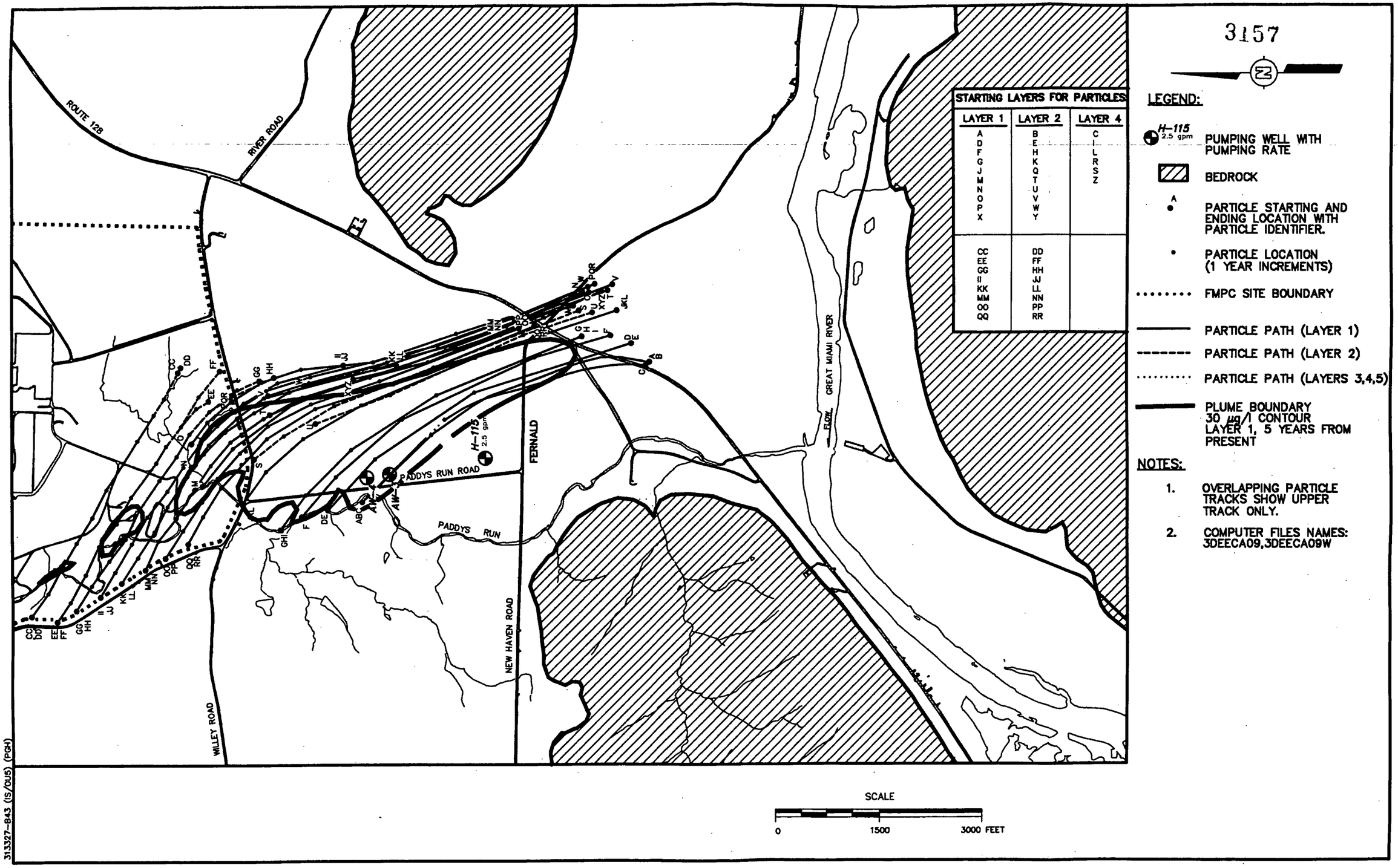



FIGURE 8
PARTICLE TRACKING
NO-ACTION ALTERNATE

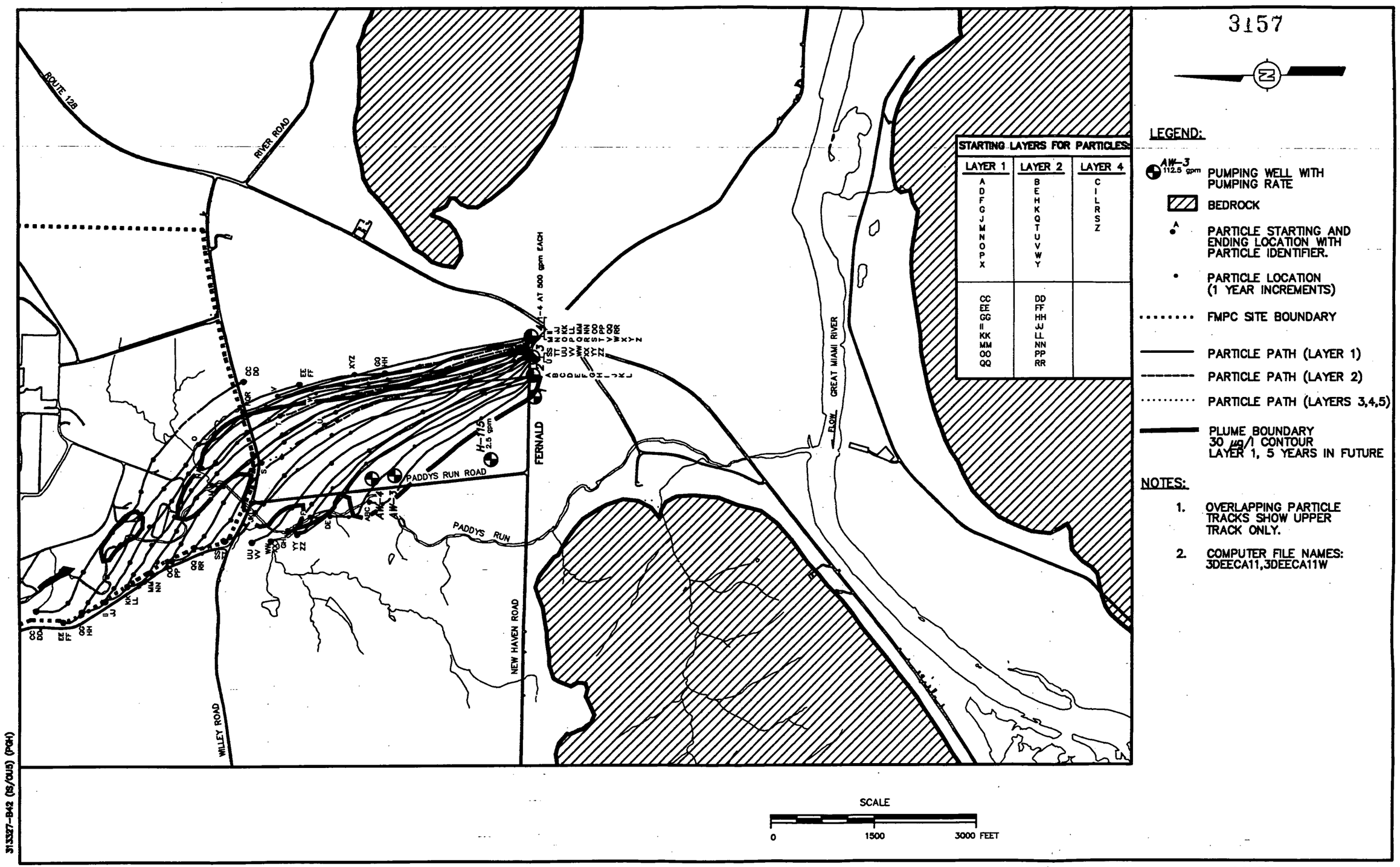



FIGURE 9

PARTICLE TRACKING
SOUTH PLUME EE/CA
INTERCEPTION ALTERNATIVE

The maximum concentration in the plume after five years of operation is predicted to be reduced relative to the no-action alternative. This minor reduction in the maximum concentration is due to the fact that the wells are placed at the leading edge of the plume and high concentrations of uranium are not removed by the wells within the first few years of operation. The placement of the wells near the southern leading edge of the plume was intended to protect groundwater users at downgradient locations.

To meet the goals of the pumping and discharge system portion of the Removal Action, the primary and secondary goals had to be restated and expanded to take into account the impact of the PRRS and to clarify the specific performance criteria for evaluation of the system. The groundwater recovery system needs to meet, to the extent possible, the following four objectives:

- Objective 1: The groundwater extraction wells need to be pumped at the sufficient rate to create a hydraulic barrier along a line running perpendicular to the longitudinal axis of the South Plume in the Great Miami Aquifer, creating an elongated groundwater trough. This hydraulic barrier needs to extend sufficiently outward from the centerline of the South Plume to intercept uranium above the 20 µg/l level.

- Objective 2: The magnitude of the hydraulic trough needs to be minimized while still meeting Objective 1, in order to minimize the impact on the overall hydrogeologic system. If extensive capture zones are created, then the PRRS plumes may be pulled toward the extraction wells. Also, minimal disturbance to the local hydrologic system is desired to prevent impacts on groundwater users in the area, to minimize the possible velocity increases to movement of additional on-site plumes, and to not significantly deflect the PRRS contaminant flow trajectory. The extraction wells, therefore, need to create a hydraulic sink to prevent plume movement by the wells and to minimize capture zones and large-scale reversals of groundwater flow.

- Objective 3: Contamination within the aquifer needs to be removed as soon as feasible to prevent further plume and degradation of the groundwater environment. Removal of contaminants near the source or in the shallow portion of the aquifer is more efficient and prevents further damage. The recovery system should be operated to prevent further spread of contamination.

- Objective 4: The operation of the Removal Action recovery system needs to be consistent with the final site remediation. This standard is difficult because the final site remediation systems are unknown at the present time. However, probably the most relevant issue regarding the impact of a pump-and-treat system is the possible expansion of other plumes caused by increased hydraulic slope, thus increasing potential spread of contamination. This issue is the basis of Objective 2, which requires minimizing the impact of the natural system.

To meet the multiple objectives requires that the system balances the two opposing factors of creating sufficient drawdown to prevent migration around, between, or beneath the pumping wells and of

minimizing drawdown to prevent gradient changes over a large area. Therefore, the system must be evaluated in relation to balancing these objectives. The primary objective (Objective 1) will carry more weight. However, any recommended change to the operation or design of the system needs to evaluate its impact on all the objectives.

## 4.0 MODELING TO DETERMINE REMOVAL ACTION WELL FIELD LOCATION

To determine the placement and pumping of a well field capable of meeting the objectives of the Removal Action, additional groundwater modeling was conducted. The calibrated local three-dimensional solute transport model of the FEMP site was used, with a retardation factor of 12, in order to utilize the most accurate calibration.

Evaluated during this modeling study were the possibilities of:

- Reducing the pumping rates of the wells to create a smaller capture zone while maintaining hydraulic control of the South Plume
- Modifying the pumping center of the well field to pump more from the east side of the uranium plume and less from the west
- Moving the well field location north, away from the organic and inorganic groundwater plumes, to avoid capture and limit influence of nonuranium-containing groundwater
- Pumping with variable numbers of wells in the well field.

The local model was applied using two methods to evaluate the effectiveness and the zone of influence of the well field. Particle tracking was first done to determine the capture zone of the well field. Particle tracking established the capture zone of the wells and their effects on the South Plume. Following this was an evaluation of the effects of the well field on the organic and inorganic groundwater plumes by tracking particles from wells found to be contaminated by these plumes. Comparisons of particle tracks before and after installation of the interceptor wells allowed the effects of the wells to be quantified.

Particles were initially seeded along the outer boundary (10 µg/l contour) of the South Plume in the region around the Removal Action wells. This was done to test the hydraulic control of the well field. Particles were then placed in lines directly upgradient of the wells, to determine if any flowpaths existed between the wells in the well field. In both of these initial seeding locations, particles were seeded in model Layers 1, 2, and 4, representing the top, middle, and lower portions of the Great Miami Aquifer, in all regions where uranium is known to be present in the South Plume.

Based on the results of the particle sets used to test the hydraulic control of the well field, additional particle tracking was done using particle locations identical to wells containing contaminated groundwater for the PRRS. Monitoring wells from 10 locations were chosen as being contaminated by the PRRS plumes, based on results of groundwater sampling and analysis as reported by the PRRS. Three of these wells are located within the inorganics plume by Albright & Wilson Americas Co., and the remaining seven wells were within the organics plume by Ruetgers and Nease. These locations

were used to test the Removal Action well field's influence on the PRRS plumes. For the purposes of clarity, only six of the ten particle locations are shown on maps detailing particle tracking.

Based on the results of the particle tracking, and once a successful capture zone was established, solute transport modeling simulation was done to predict the effects of the well field on the South Plume for a period of five years after its installation. A graphical depiction of the effects of the well field capture of the uranium plume was produced, which also determined if hydraulic control of the South Plume could be achieved.

## 4.1 REDUCED WELL FIELD PUMPING RATES

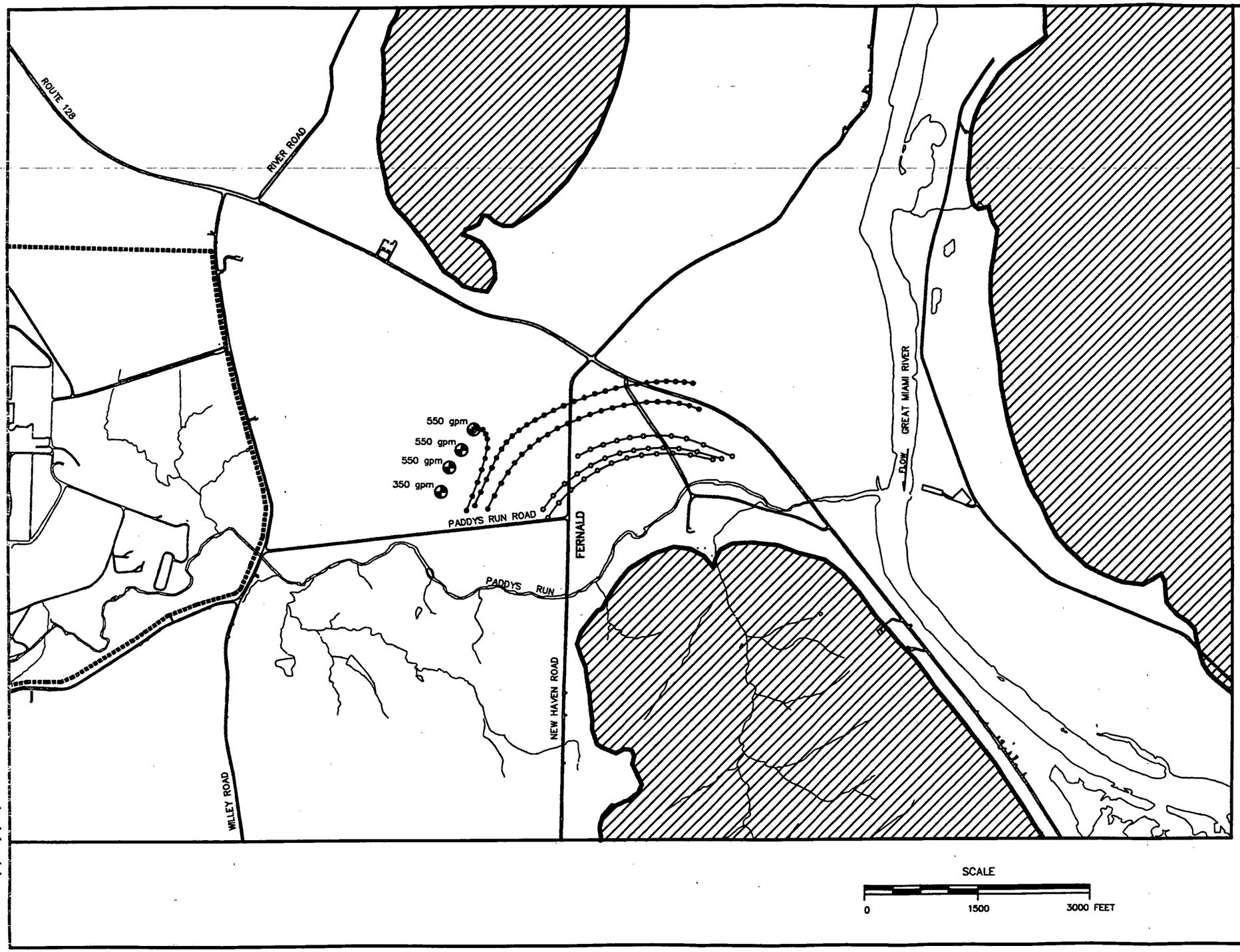
Initial modeling runs were made with the interceptor wells which were left in their previously proposed locations (Figure 2) but with reduced pumping rates to minimize the capture of the organics plume located adjacent to Ruetgers-Nease. Several simulations were made during which the pumping rates of all the wells were reduced and during which the westernmost wells in the field were moved to the east or turned off.

All of these runs proved unsuccessful. Due to the location of the interceptor well field, the pumping was predicted to have significant influence on the contaminant plumes. The inorganics plume and an eastern portion of the organics plume were captured by the wells, and the remainder of the organics plume was spread to the east. This resulted in a greater impact to the organic and inorganic plumes, due to their spreading, and indicated that the interceptor wells must be moved to increase their distance from these plumes.

## 4.2 MODIFYING THE PUMPING CENTER OF THE WELL FIELD

The next series of simulations located the wells further to the north and adjusted the rates of the individual interceptor wells to pump more from the east side of the plume and less from the west. The well field remained unchanged from its previous 2,000 gpm pumping rate and 280 feet well spacing. The wells were located in the area east of the A&W plant, along a line proposed by DOE and Westinghouse Environmental Management Company of Ohio (WEMCO). This alignment ran east from Paddys Run in the area just north of the A&W plant for approximately 750 feet before turning southeast for another 750 feet (Figure 10). This contained the well field within the alluvial terrace within which Paddys Run flows and allowed the wells to remain near the proposed force main. Several simulations were performed in this general area, by varying well pumping rates and shifting the alignment of the well field.

One such simulation is shown in Figure 10. The westernmost well in the well field was pumped at a reduced pumping rate of 350 gpm, while the remaining three wells were pumped at 550 gpm each to maintain the 2,000 gpm well field pumping rate. This well field was able to successfully contain the uranium plume to the north of the well field but not without influencing the PRRS plumes. The




LEGEND:

- PREDICTED PARTICLE PATHS FOR INORGANIC AND ORGANIC GROUNDWATER CONTAMINANT PLUMES WITH PUMPING
- PARTICLE LOCATION – INORGANICS PLUME (30 DAY INTERVALS)
- PARTICLE LOCATION – ORGANICS PLUME (30 DAY INTERVALS)
- BEDROCK
- FMPC SITE BOUNDARY
- 550 gpm TESTED REMOVAL ACTION EXTRACTION WELL WITH PUMPING RATE

NOTES:

1. COMPUTER FILE NAMES: REMOVAL05.OUT
2. PARTICLES START IN GROUNDWATER PLUMES

313327-B35 (IS/OU5) (PGI)

FIGURE 10
SOUTH PLUME REMOVAL ACTION
PREDICTED EFFECT OF MODIFYING THE PUMPING CENTER ON INORGANIC AND ORGANIC GROUNDWATER PLUMES

organics plume was basically unaffected by the wells, but the inorganics plume was both partially captured and shifted by the well fields. Even though the well field's pumping center was shifted to the east, the well field still drew particles from the west into the wells.

## 4.3 MOVING THE WELL FIELD NORTH

An additional series of runs were made using the 4-well, 2000 gpm well field by moving the well field north, away from the PRRS groundwater plumes. It was found during these simulations that moving the well field north did improve the capture zone of the wells, but that to accomplish the Removal Action objectives, the well field must be located approximately 650 feet north (upgradient) of the PRRS plumes. Simulations which located the well field just upgradient of the inorganics plume (Figure 11) resulted in significant shifts of the trajectories of the inorganics plume. Although not captured, the particle tracking indicated the inorganics plume would be shifted due to the influence of the well field. This was deemed unacceptable.

Further well field locations were tested to attempt to minimize the effects of the wells on the inorganics plume. The well field was moved further north in 250-foot increments until its influence on the inorganics plume was minimized. This occurred at a location approximately 2,500 feet north of the location proposed in the South Plume EE/CA.

## 4.4 FINAL Removal Action WELL FIELD LOCATION

The final series of simulations which resulted in the desired performance for the interceptor wells under the new constraints (Section 1.0) were achieved by moving the well field further to the north, adjacent to Delta Steel Corporation's property (Figure 1). The 4-well, 2000 gpm well field was moved north to pump from an area slightly south of the highest predicted concentrations of the South Plume. The wells were able to contain the plume and successfully captured contaminated groundwater moving south, away from the FEMP (Figure 7). The portion of the South Plume located south of the well field was not captured by this Removal Action.

Analysis of the wells showed them to have only minimal impact on the inorganics groundwater plume located by A&W. Groundwater modeling simulations using particle tracking predicted a maximum plume deflection of 20 feet to the east away from its present path. The predicted effect on the organics groundwater plume located by Ruetgers-Nease was less than 1 foot of deflection. Figure 12 shows the predicted flowpaths from wells contaminated by both the organic and inorganic groundwater plumes. These flowpaths are shown with the Removal Action wells pumping.

Particle tracking also predicts another effect of the Removal Action wells, namely the slowing of the transport of the PRRS plumes because of the location of the wells to the north of these plumes. The Removal Action wells are pumping upgradient of these groundwater plumes, causing reduced

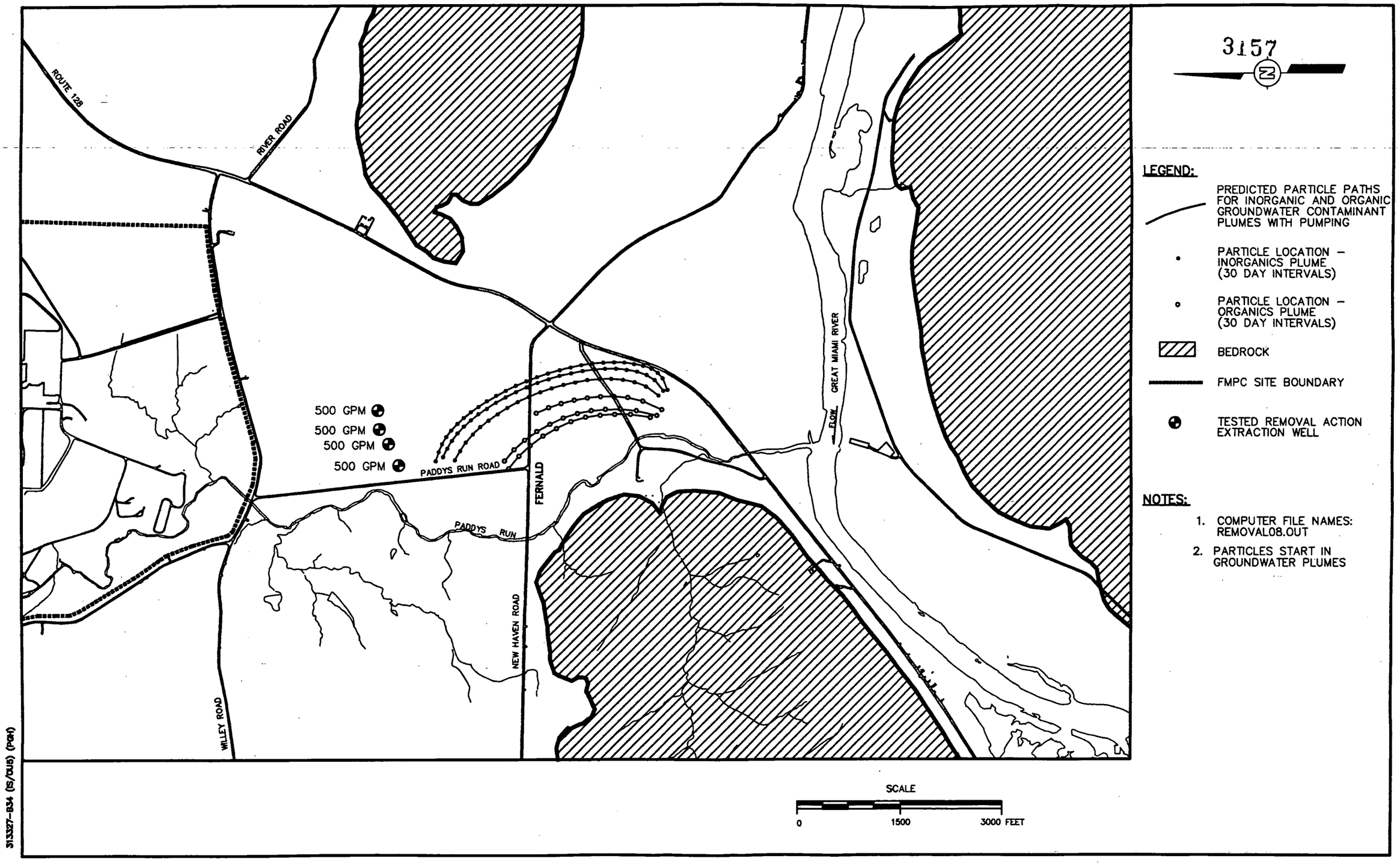



FIGURE 11
SOUTH PLUME REMOVAL ACTION
PREDICTED EFFECT OF MOVING THE WELL FIELD
NORTH ON INORGANIC AND
ORGANIC GROUNDWATER PLUMES

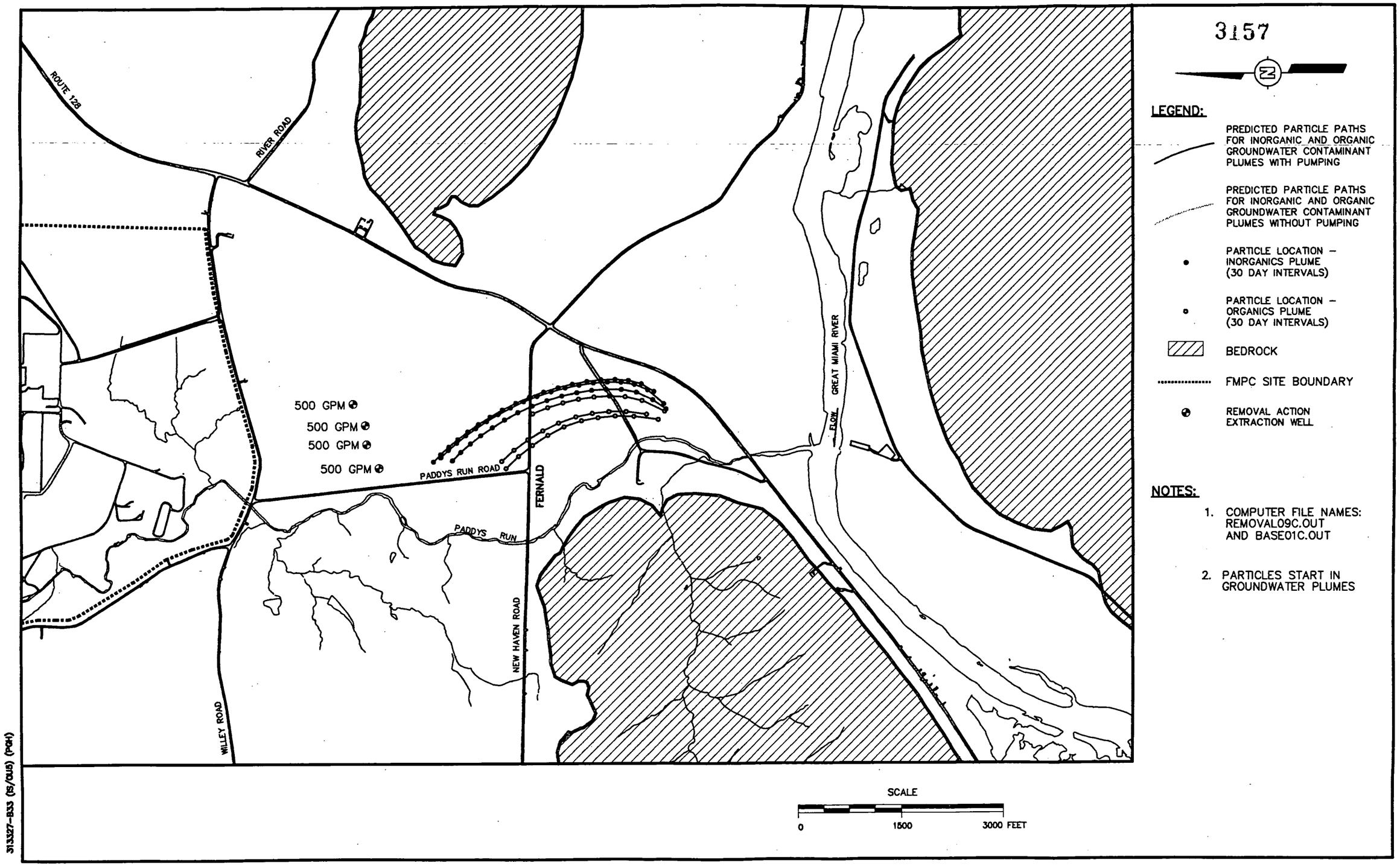



FIGURE 12
SOUTH PLUME REMOVAL ACTION
PREDICTED EFFECT OF REMOVAL
ACTION WELLS ON INORGANIC AND
ORGANIC GROUNDWATER PLUMES

groundwater gradients in this area. This, in turn, slows groundwater velocities and thus the transport rate of the PRRS plumes. Although this effect is small, it will influence the transport of the plumes.

Additional well configurations were also tested in the same area to determine alternate well fields which could be successful. The alternate well field configurations were created by adding or deleting wells in the middle of the well field as necessary. Outside wells in the well field remained at the same locations except for the 2 well configuration. In this case, the wells were placed in the same location as the 4-well field, but were spaced 640 feet apart from each other. The resulting well capture zones were tested using particle tracking sets identical to those used to test the recommended 4-well configuration. Table 1 shows the alternate configurations. The recommended 4-well configuration maintains a low pumping rate without an excessive number of wells. Although additional well field configurations do exist, they are not as efficient as the proposed well field in their operational potential. To be considered operationally efficient, a design was selected which minimized both total well field pumping and the number of pumping wells. This condition was met by the 4-well field, which requires less pumping than the 2-and 3-well configurations, but which matches the pumping rate of the 5-well configuration. It should be noted that if a well becomes nonoperational during its use, the well field can maintain its operation by increasing the pumping rate in the other wells to 750 gpm each. This was tested during the analysis of alternate well fields and was found to function adequately. Well field integrity was maintained with only three wells pumping provided the well pumping rates were increased to 750 gpm each. This was true regardless of the positioning of the last well in the well field. This 3-well configuration should only be maintained for as long as is necessary to effect repairs or replace the fourth well. This will maintain hydraulic control over the South Plume while repairs are effected.

The sensitivity of this well field to model input parameters was examined and found to have little effect as far as the placement of the wells is concerned. Previous sensitivity analysis tests have shown that the model is only very slightly sensitive to recharge and hydraulic conductivity values. These values do not affect the placement of the well field although they do influence the time necessary for steady state to be reached. The flow model is sensitive to the river leakage factor; however, as the solute transport model in general and the Removal Action wells specifically are located away from the Great Miami River, this does not influence their placement. Additionally, the solute transport model was also determined to be sensitive to the dispersivities used during its initial calibration. This sensitivity may affect the predictive capabilities of the model with respect to the well field and the uranium plume, but does not affect the placement of the well field itself, which was based solely on the use of the local flow model.

Based on the proposed Removal Action well field location, the effect on the South Plume was evaluated using the local solute transport model. The predicted uranium contaminant plume is shown after five years of operation in Figure 13. The plume has begun to pinch in the area of the Removal

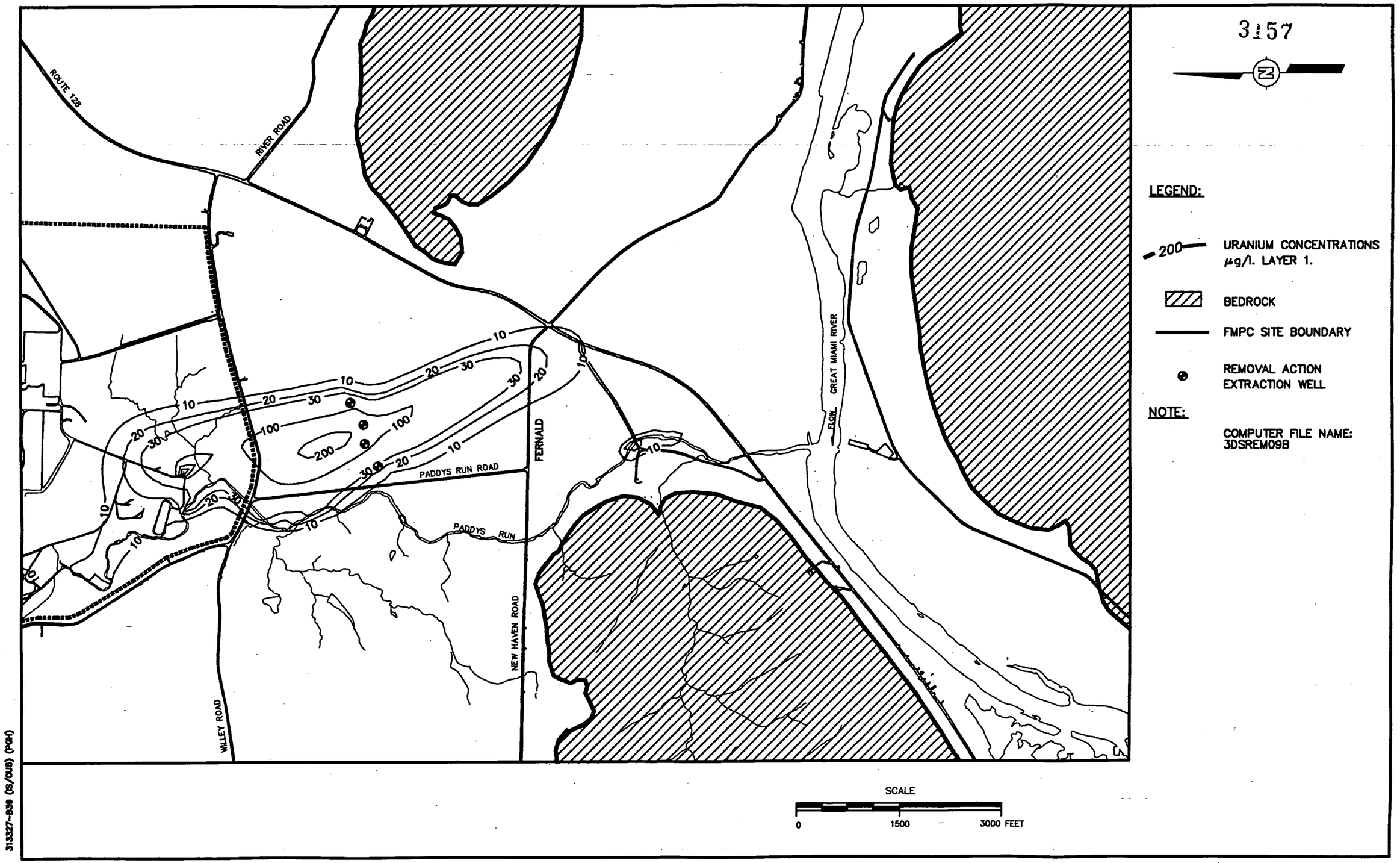



FIGURE 13
SOUTH PLUME REMOVAL ACTION
PREDICTED EFFECT OF REMOVAL ACTION WELLS
MODELED URANIUM CONCENTRATIONS
5 YEARS IN FUTURE

Action well field as the northern plume half is drawn into the wells and the southern half continues its movement. This southern half will continue its migration and will need to be addressed in future actions.

The predicted drawdown and the potentiometric surface with the influence of the Removal Action well field is shown in Figures 14 and 15, respectively. The maximum steady-state drawdown forms an ellipse around the Removal Action wells and spreads out throughout Paddys Run Outlet until bedrock is reached. As can be seen, the wells do have an influence throughout the entire valley, but due to the high groundwater velocities in the area (on the order of 0.1 to 0.3 feet/day) they only capture a small area to the north of their proposed locations.

To further evaluate the extraction efficiency of the proposed Removal Action wells, the solute transport model results were used to derive uranium extraction curves based on the predicted uranium concentration and the wells' pumping rates. During the 5-year period of their operation, the predicted average concentration removed by the well field will decline, as shown in Figure 16. This decline in concentrations results in a declining uranium removal rate as shown in Figure 17. This decline in removal is due to the wells' proximity to the South Plume's predicted center. Initially, the wells are extracting groundwater with the highest uranium concentrations. As time passes, the uranium plume begins to contract in this area and the highest concentrations of uranium-contaminated groundwater are removed. At this point, only the central interceptor wells are extracting uranium at high concentrations because of the narrowing of the plume, resulting in lower removal rates. This effect can also be seen in the predicted cumulative well field removal (Figure 18), which begins to stabilize after three years of pumping.

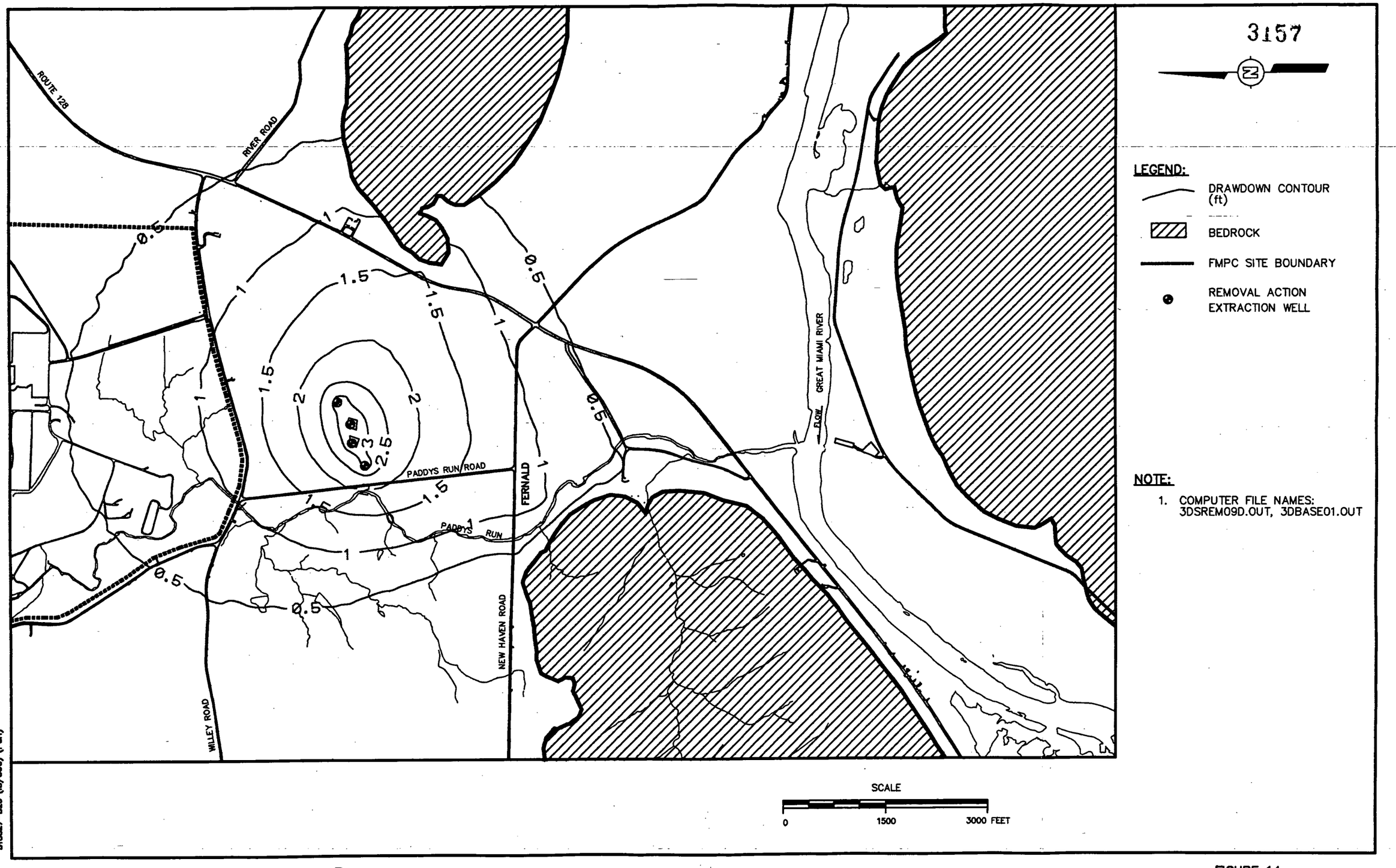



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FIGURE 14
SOUTH PLUME REMOVAL ACTION
PREDICTED DRAWDOWN DUE TO REMOVAL
ACTION WELL FIELD

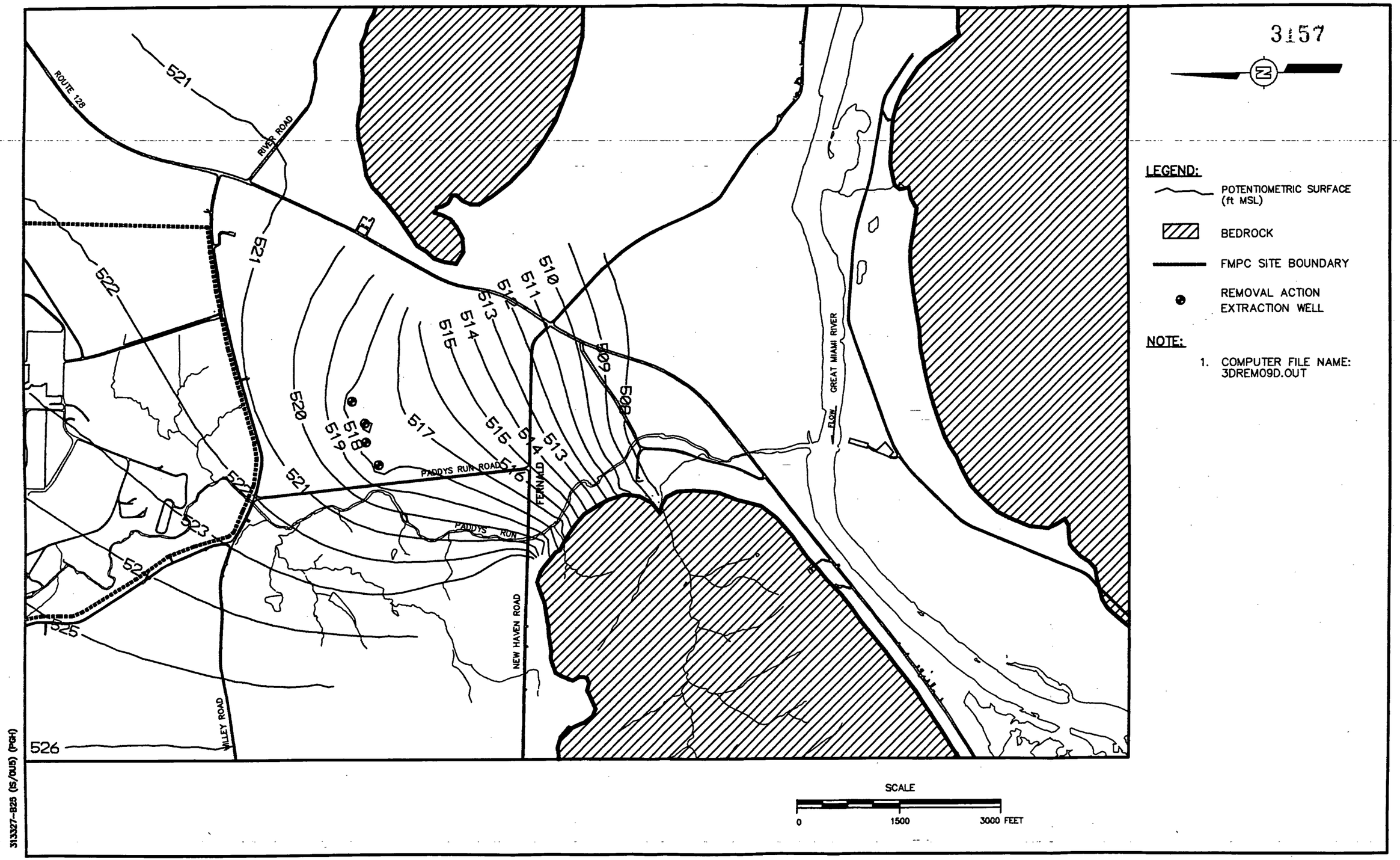
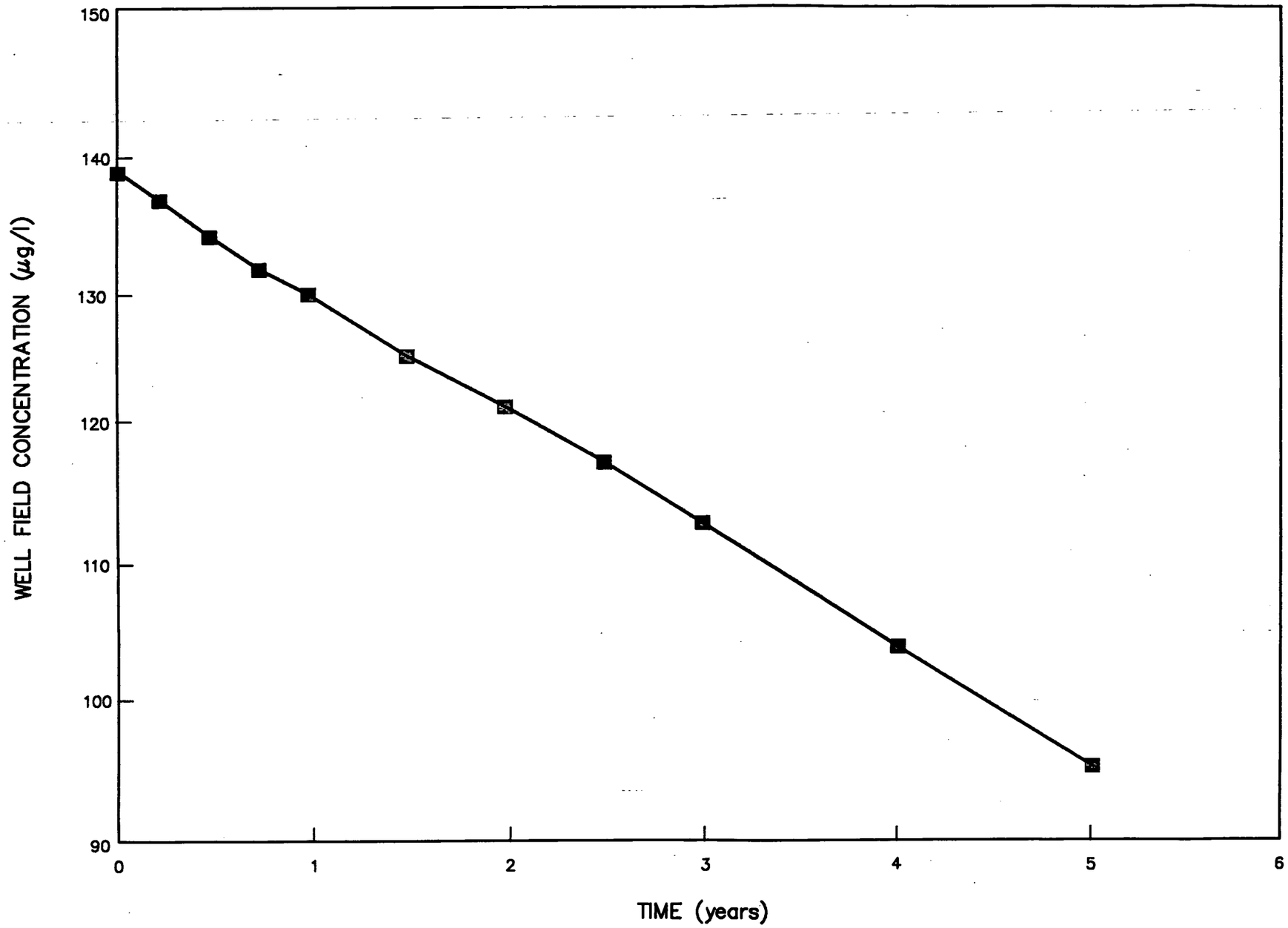



FIGURE 15
SOUTH PLUME REMOVAL ACTION
PREDICTED POTENTIOMETRIC
SURFACE WITH PUMPING

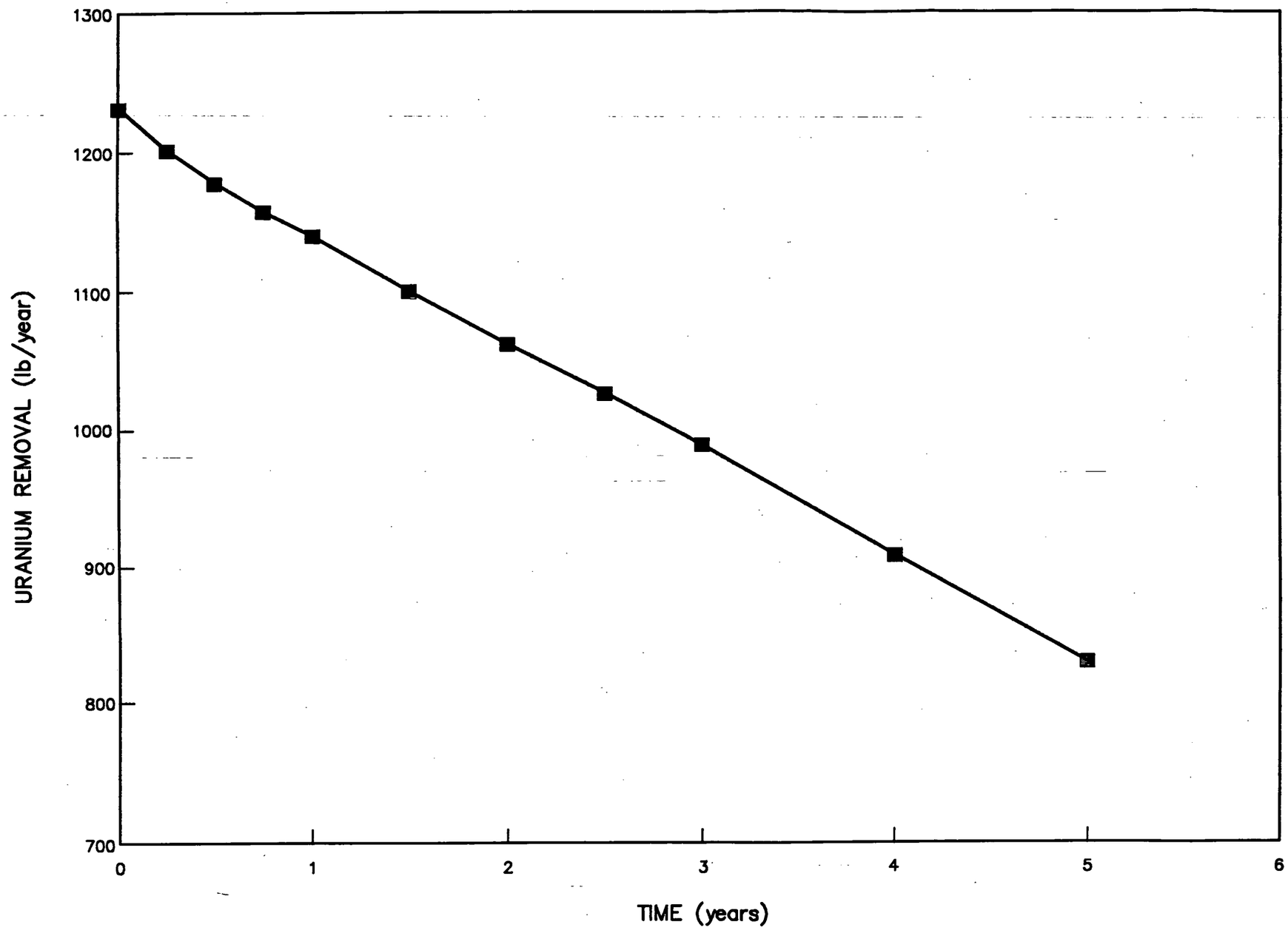



NOTES:

1. TAKEN FROM 3DSREM09E.OUT
2. SEE FIGURE 12 FOR REMOVAL ACTION WELL FIELD LOCATION

313327-B36 (IS/OU5) (PGH)

FIGURE 16
SOUTH PLUME REMOVAL ACTION
AVERAGE WELL FIELD CONCENTRATION

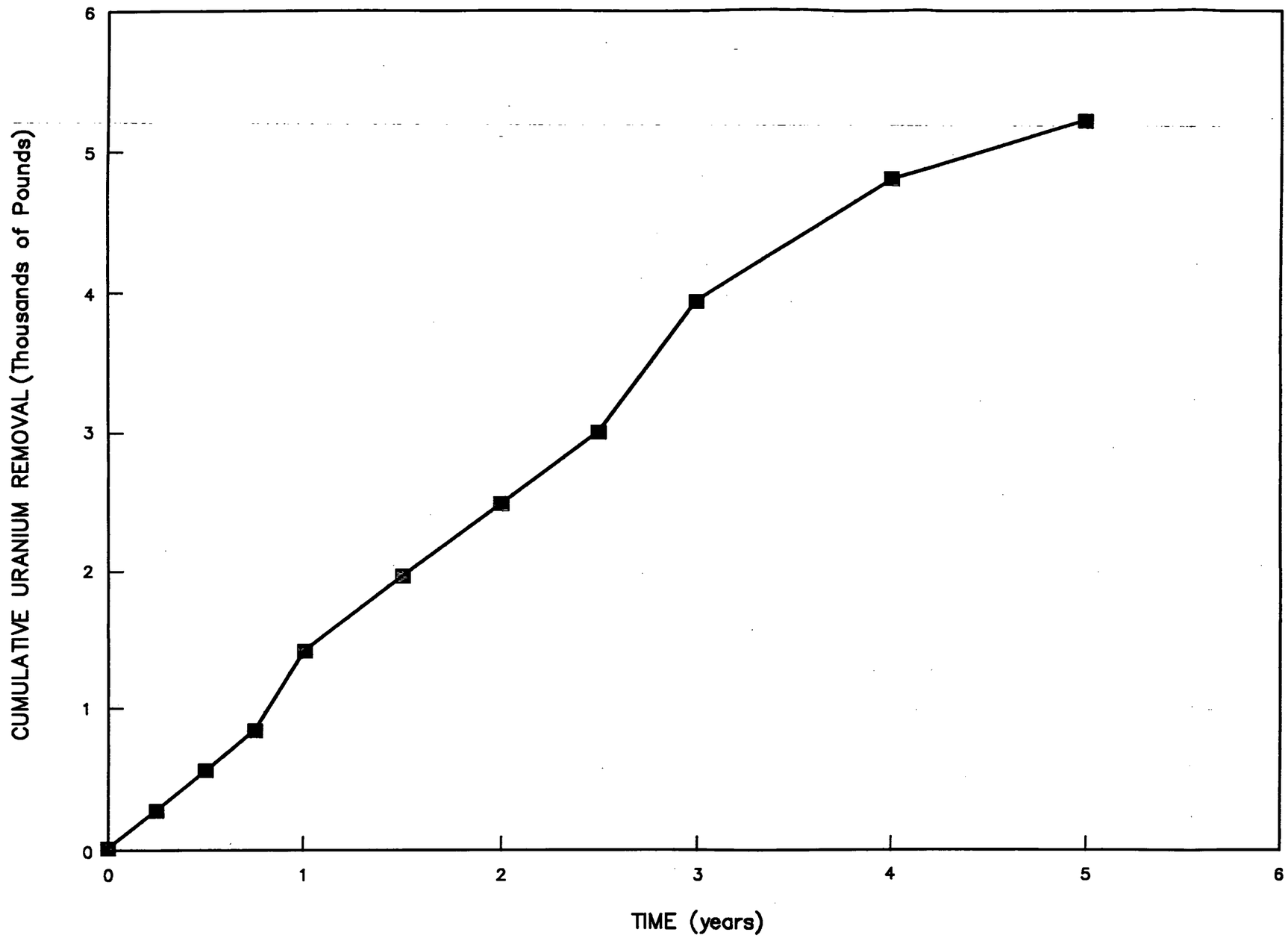



NOTES:

1. TAKEN FROM 3DSREMO9E.OUT
2. SEE FIGURE 12 FOR REMOVAL ACTION WELL FIELD LOCATION

313327-B38 (IS/OU5) (PGH)

FIGURE 17
SOUTH PLUME REMOVAL ACTION
WELL FIELD URANIUM REMOVAL RATE




NOTES:

1. TAKEN FROM 3DSREM09E.OUT
2. SEE FIGURE 12 FOR REMOVAL ACTION WELL FIELD LOCATION

313327-B37 (IS/OU5) (PGH)

FIGURE 18
SOUTH PLUME REMOVAL ACTION
CUMULATIVE WELL FIELD URANIUM REMOVAL

**TABLE 1**

**ALTERNATE REMOVAL ACTION WELL FIELD CONFIGURATION**

| Number of Wells | Pumping Rate | Spacing |
|---|---|---|
| 2 | 1,500 gpm each | 640 feet |
| 3 | 750 gpm each | 375 feet |
| 4 | 500 gpm each | 280 feet |
| 5 | 400 gpm each | 250 feet |

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

The modeling techniques used to simulate the relocation of the Removal Action wells were successful in achieving the goals of the Removal Action as discussed in Chapter 3.0. The well field was shifted to the north where it is still able to intercept the highest concentrations of the South Plume, while at the same time has minimal impact on the PRRS groundwater plume. Due to the proximity of the South Plume to the PRRS plumes, it is impossible to meet all of the goals of the Removal Action without having some influence on the PRRS plumes. However, the currently proposed well field is predicted to deflect the inorganics plume by less than 20 feet and the organics plume by less than 1 foot.

This well design is predicted to contain the 20 µg/l contour line of the South Plume to the north of the Removal Action wells. The location of the 20 µg/l line should be field verified prior to well installation to ensure proper well field placement and operation. It has minimal impact on the PRRS inorganics and organics plume and meets the objectives of the Removal Action. Enough flexibility has been built into its design to allow it to operate with only three wells and with variable pumping rates (Appendix A). This well field only addresses the portion of the South Plume which is free of the PRRS plumes. Uranium contamination south of the wells will need to be addressed in a separate design. Appendix A contains the design criteria for the Removal Action well field and recommendations on its installation and operation.

APPENDIX
A

# APPENDIX A
# REMOVAL ACTION WELL FIELD DESIGN CRITERIA

3157

## A.1 Well Field Design Parameters

The basic criteria established by the groundwater modeling effort for the Removal Action well field include well placement, spacing, and pumping rates. Initial work was done to define the upper and lower bounds for these parameters, based on keeping the well field design as flexible as possible.

The recommended design parameters for the Removal Action well field are specified in Table A.1. These parameters are based on utilization of the 4-well, 2000 gpm well field with the option of using a 3-well, 2250 gpm well field in case of the failure of one of the wells. If two or more wells fail, the well field integrity will not be able to be maintained because of the large gaps in the hydraulic barrier which will arise. Some flexibility in the placement and spacings of the wells is shown to account for model discretization limits and the possible need to site wells away from buildings and other geographical features.

## A.2 Well Field Installation

Due to the complexity of the Removal Action well field's operation, it is recommended that its installation occur in a phased approach to gather data which will support its placement and operational design. This phasing should consist of six tasks, at a minimum:

- Collection of hydropunch samples in the region in which the well field is to be installed, to define the South Plume's boundaries and structure and to verify the placement of the wells.

- Installation of one of the Removal Action pumping wells using design specifications and collection of geologic and groundwater samples from the well to confirm aquifer properties and the results of the hydropunch samples.

- Performance of an aquifer pumping test in the first Removal Action pumping well. This test should consist of a step-drawdown test to determine well efficiency and specific capacity and a long-term, constant-rate test to determine the aquifer properties of transmissivity and storativity.

- Comparison of the results of the aquifer pumping test to the groundwater flow model to validate the model and to determine if the model accurately simulates transient aquifer pumping.

- Installation of the remaining Removal Action pumping wells pending validation of the model with the results of the aquifer pumping test.

- Sampling and analysis of groundwater samples from the pumping wells prior to their

operation to collect information on the starting concentration of the wells for uranium, inorganics, and organics.

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## A.3 Well Field Operation and Monitoring

Following installation of the well field, an operational and performance monitoring program should be instigated to verify the proper functioning of the Removal Action well field. This program should contain the following elements:

- Collection and analysis of groundwater samples on a regular basis from local groundwater monitoring wells for uranium and inorganic constituents. Monitoring wells should be placed flanking the pumping wells (east and west) and in the downgradient direction (south) to monitor that a proper capture zone is being maintained. In addition, wells should be placed between the inorganics plume and the pumping wells to act as an early warning system in case inorganics are drawn toward the pumping wells.

- Collection and analysis of groundwater samples from the pumping wells on regular intervals for uranium, inorganic, and organic constituents to monitor the extraction rate for uranium and possible unknown contaminants by the pumping wells.

- Periodic monitoring of well efficiencies and structural conditions to determine the maintenance needs of the well field.

## TABLE A.1
## REMOVAL ACTION INTERCEPTOR WELL SPECIFICATIONS

3157

| | |
|---|---|
| Number of Wells: | 4 |
| Pumping Rate: | 500 gpm each maximum[a]<br>800 gpm each maximum[b] |
| Well Diameter: | 12-inch I.D. |
| Screen Length: | 40 feet |
| Screen Diameter: | 12-inch I.D. |
| Screen Size: | 0.020-inch slots (approximate; determine during drilling) |
| Screen Placement: | From surface of static water table to 40 feet below static water table |

| Well Locations: | State Coordinator[c] | |
|---|---|---|
| Well: | East | North |
| 1 | 1379841 | 474259 |
| 2 | 1380165 | 474448 |
| 3 | 1380444 | 474466 |
| 4 | 1380768 | 474654 |
| Well Spacing: | 280 feet[d] | |

[a] Based on well capture design.
[b] Based on well size.
[c] Coordinates of wells are ± 50 feet any direction.
[d] Well spacing is ± 25 feet.

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