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A Ground Water Flow Model for the A/M Area of the SRS (U)

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EXECUTIVE SUMMARY

In 1984 and 1985, a quasi three-dimensional groundwater flow model was developed for the A/M Area (Savannah River Laboratory Complex) of the Savannah River Site to assist in the design of a groundwater recovery well network to remediate groundwater contaminated with chlorinated hydrocarbon solvents. In 1986, the existing groundwater flow model was used to evaluate the effectiveness of groundwater remediation systems. Since the original model was developed, additional monitoring wells have been installed, the understanding of the hydrogeologic system has improved and the horizontal and vertical extent of the contamination in the groundwater systems has been better defined.

The objective of this study is to update and improve the existing A/M Area groundwater flow model by incorporating recent hydrologic information. The new model is calibrated to 1989-1990 groundwater levels and surface water flows. The model area is approximately 31 square miles and encompasses a manufacturing and processing area designated the A/M Area, a previous waste effluent disposal basin and overflow to a natural depression (Lost Lake), and several surface water features. The simulations are run on a 80386-based personal computer using the public-domain groundwater flow code MODFLOW.

This calibrated coarse-grid model is a base model. Specific areas of interest can be further discritized to provide more detailed and accurate water level elevations for use in particle tracking and capture analysis. The particle tracking and capture analysis are used to evaluate the groundwater contamination capture and removal capacity of proposed recovery wells.

1.0 INTRODUCTION

1.1 PURPOSE AND OBJECTIVES

The purpose of this study is to develop a groundwater flow model for the A/M Area within the Savannah River Site (SRS) so that the effectiveness of groundwater remediation systems can be simulated. This report describes the set-up and calibration of a coarse-grid model for the area. The coarse-grid model can be subsequently refined within an area of interest so that a capture zone analysis of contaminated groundwater can be simulated. The objective of this project is to update and improve the existing A/M Area model by incorporating recent hydrologic information.

1.2 DESCRIPTION OF MODELING SITE

The Savannah River Site, operated by Westinghouse Savannah River Company (WSRC), is located in South Carolina along the banks of the Savannah River. The location of the SRS and the area modeled by Schreuder & Davis, Inc. (SDI) are indicated in Figure 1. The model encompasses a manufacturing and processing area called the A/M Area, a previous waste effluent disposal basin and overflow to a natural depression (Lost Lake), and several surface water features. The modeled area is a rectangle 25,000 ft from east to west and 35,000 ft from north to south. SRS plant coordinates from the southwest corner of N77,000 and E33,500 ft to the northeast corner of N112,000 and E58,500 ft are included. Plant north is 36° to the west of true north. The total modeled area is 20,087 acres (31.4 square miles). The nodal spacing of the model is 1,000 x 1,000 feet (ft) spaced on a regular basis (Figure 2).

1.3 HISTORICAL DEVELOPMENT OF THE MODEL

The first quasi three-dimensional groundwater flow model for the A/M Area was prepared by S.S. Papadopulos & Associates (SSP&A) in 1986 to evaluate the effectiveness of the A/M Area recovery well network (Figure 3) and to simulate chemical transport from the M-Area settling basin and Lost Lake (Papadopulos, 1986 and 1987). That model was used to develop a groundwater recovery well network for the SRL Area (Schreuder et al., 1990). Since the original three-dimensional model was developed, additional monitoring wells have been installed and the understanding of the hydrogeologic system has improved. This provides the motivation for updating the original model.

2.0 HYDROGEOLOGICAL SETTING

The SRS is located on the Aiken Plateau in the Upper Atlantic Coastal Plain of South Carolina. The unconsolidated and semi-consolidated sediments underlying the model area are part of a Tertiary to late Cretaceous-age wedge that dips and thickens toward the Atlantic Ocean. The land surface is deeply incised by surface water drainage features. The topography in the model area ranges from 380 feet mean sea level (MSL) in the A/M Area to 120 feet MSL along Upper Three Runs Creek (Figure 4).

The major drainage divide in the model area is along the north-south (directions referenced to true north) trending ridge on which the A/M Area is located (Figure 4). Surface water on the east side of the ridge drains into Tim's Branch which flows south into Upper Three Runs Creek. Upper Three Runs Creek flows southwest into the Savannah River. Surface water on the west side of the ridge drains into a series of wetlands to the southwest.

Surface water southwest of the A/M Area also drains into a depressional area called Lost Lake. It has been suggested that Lost Lake is a Carolina Bay feature. These features typically form temporary wetlands which fill and drain with the cycles of rainfall. In the past, Lost Lake received overflow from the M-Area settling basin. Lost Lake was dry during the time period used for calibration and is, therefore, not a source of recharge in the model.

2.1 GENERAL GEOLOGY

Fallaw and Sargent (1986) proposed a detailed description of the general geology. Their stratigraphic descriptions are summarized in Figure 5. The relationship of the hydrostratigraphic units to geologic formations is also shown in Figure 5. These hydrostratigraphic units are, in descending order, the water table, Upper Congaree, Lower Congaree, Ellenton, and Black Creek. A northwest-southeast cross-section of the hydrostratigraphy in the model area and its relationship to the hydrogeologic layers used in the groundwater model is shown in Figure 6 (Aadland and Bledsoe, 1990). Four water-bearing zones in the SRL area are included in the model.

In the A/M Area, the upper most geologic formation is the Upland Unit followed in descending order by the Tobacco Road, Dry Branch and the McBean. The water table unit is the saturated portion of the McBean Formation which consists of clayey sand and calcareous clayey sand. The top of the water table unit is over 100 feet below land surface. The stratigraphic units above the McBean contain clay and silty sand lenses that may act as local confining or semi-confining layers. The McBean and the underlying Congaree Formation are separated by a clay layer informally referred to as the "Green Clay."

The Congaree consists of sand with clay lenses and is approximately ten times more permeable than the McBean. The Congaree is divided into an upper and lower unit in the A/M Area by a clay layer. This clay layer thins and becomes discontinuous to the south.

The Ellenton consists of dark lignitic clay with some coarse sand units and is separated from the Congaree by an unconformity. The Ellenton is considered to be the principle confining bed that separates the water table and the Congaree from the deeper hydrologic system. However, it is known to thin and disappear in the northern portion of the model area (Aadland and Bledsoe, 1990).

The deepest aquifer system at the SRS is in Cretaceous-age sediments that were previously denoted the Black Creek and Middendorf Formations (e.g., Papadopulos, 1986). This group of sediments has been recently designated Aquifer System I (Aadland and Bledsoe, 1990). This aquifer system produces large quantities of high-quality water. For this modeling effort, only the upper portion of Aquifer System I is considered and is designated as the Black Creek to remain consistent with previous reports for the A/M Area.

2.2 GROUNDWATER FLOW

Groundwater in the Upper Congaree and Lower Congaree generally flows south to southeast towards Upper Three Runs Creek. Groundwater flow along the northwest side of the model area is southwest towards a low wetland area that drains into the Savannah River approximately three miles to the southwest. Groundwater in the Black Creek flows south towards the Savannah River (Christensen & Gordon, 1983). In the SRS area, the Ellenton is an aquitard so the groundwater flow in this unit is nearly vertical. Vertical flow in the Ellenton is downward in the A/M Area where hydraulic heads in the Black Creek are less than in the hydrostratigraphic unit above the Ellenton. Vertical flow is upward in the Ellenton around Upper Three Runs Creek where hydraulic heads in the Black Creek are greater than those in the unit above the Ellenton.

2.3 SURFACE WATER FLOW

The deeply incised streams in the region dissect the McBean Formation and divide the hydrogeologic unit into separated subunits, each having its own recharge and discharge area. The regional hydrostratigraphic cross-section in Figure 6 (hereafter referred to as the regional cross-section) shows Tim's Branch and Upper Three Runs Creek to be incised into the Upper Congaree. The Upper Congaree also crops out in the southwest wetlands. Groundwater in the water table and Upper and Lower Congaree discharge into the streams and wetlands.

2.4 RAINFALL RECHARGE

The average annual rainfall at the SRS is approximately 47 inches per year (in/yr). Studies by the U.S. Geological Survey (Cahill, 1982) and Savannah River Laboratories (Hubbard and Emslie, 1984 and Hubbard, 1986) indicate the average annual recharge rate is approximately 15 in/yr. Recharge rates may vary in areas of steep topography.

3.0 FIELD DATA COMPILATION AND ANALYSIS

Synchronous water level data were provided by SRL to calibrate this model. In accordance with SDI's quality assurance/quality control plan, all data were checked during compilation and analysis and discrepancies were noted to SRL in writing.

3.1 RAINFALL DATA

Daily rainfall data from a rain gauge in the A/M Area for 1967 to 1987 were provided by SRL. Rainfall in the A/M Area for the years 1967 through 1987 ranged from 37 to 68 inches (in) and averaged 47 in/yr.

3.2 STREAM FLOW DATA

Stream flow data were used to estimate the magnitude of surface water recharge or discharge to/from Tim's Branch and Upper Three Runs Creek to the model. Stream flow data from U.S.G.S. gauging stations on Tim's Branch at Road C and Upper Three Runs Creek at Road C and Road A, for water year (WY) 1987, were provided by SRL (U.S.G.S., 1987). The locations of the gauging stations on Tim's Branch at Road C and Upper Three Runs Creek at Road C are shown on Figure 4. The gauging station on Upper Three Runs Creek at Road A is just west of the model area. Daily stream flow data for Upper Three Runs Creek for WY 1974 through 1988 were provided on floppy disk. The drainage area for Tim's Branch is 17.5 square miles (mi^2) of which the model area is estimated to encompass the lower 7.6 mi^2 (43%). The mean discharge for WY 1987 was 6.71 cubic feet per second (cfs). The average base flow is estimated to range from 3 to 5 cfs. Theoretically, approximately 1.3 to 2.2 cfs of the base flow should be contributed by the model area. However, Lockwood Greene Engineers (1983) indicate that flow in the upper portion of Tim's Branch is seasonal. Therefore, a larger percentage of the base flow may be contributed by the modeled area.

The elevation of the stream bottom in the upper portion of Tim's Branch, northeast of the A/M Area, is above the water table. Thus, this part of Tim's Branch is a losing stream. The stream is incised into the water table southeast of the A/M Area and base flow is sustained by discharge from the water table. Base flow in the lower portion of the stream is sustained by discharge from the Upper Congaree.

The discharge through the gauging station at Road C and Upper Three Runs Creek does not include discharge from the entire model area. Data from the gauging station at Road A and Upper Three Runs Creek were used for calibration. The total drainage area for Upper Three Runs Creek above Road A is 203 mi^2. Upper Three Runs Creek and Road A intersect 1.25 miles west of the model area. Approximately two-thirds of the model area east of the drainage divide makes up approximately 10% of the Upper Three Runs Creek drainage area above Road A. The mean discharge at the Road A gauging station for WY 1987 was 239 cfs. The average base flow is estimated to range from 120 to 200 cfs. Thus the base flow contribution from the model area to Upper three Runs Creek is estimated to be 12 to 20 cfs. Base flow in Upper Three Runs Creek within the model area is sustained by the discharge of groundwater from the Upper and Lower Congaree.

3.3 WATER LEVEL DATA

As part of the groundwater remediation program, an extensive monitoring well network in the A/M Area is used to measure groundwater levels and to collect samples for analysis to determine groundwater quality on a quarterly basis. Data from the last three quarters of 1989 and the first quarter of 1990 were provided to SDI to use as model calibration data. Water level data for the water table, Upper Congaree, Lower Congaree and Black Creek were averaged and contoured to produce the average observed water level maps in Figures 7 through 10. The list of the wells used in contouring these maps is provided in Appendix A. For the purpose of clarity, not all data points are posted on the maps. The data is concentrated in the northeast portion of the model. Topography and surface water elevations were used as a guide to approximate the groundwater level contours in areas of insufficient data (Department of Energy, 1989). Water levels southeast of Upper Three Runs Creek are from Duffield, et al., 1989.

As part of SDI's quality assurance plan, the water level data were checked during analysis. A list of wells with questionable data was compiled and sent to SRL (SDI, 1990a). A number of wells were not used for reasons such as: improper well construction, abandoned or dry wells, or perched water table. A list of the wells not used in contouring the observed water level maps is provided in Appendix A as Table A-5. The observed water level maps for each layer were approved by SRL for calibration of this model.

3.4 AQUIFER TEST DATA

Aquifer pumping tests were performed by Geraghty & Miller (1985) on recovery wells RW-3 through RW-11 in the central A/M Area. Unfortunately, these tests provide little information on specific hydrostratigraphic units because the pumping wells are screened across the water table, Upper Congaree and Lower Congaree. Many of the monitoring wells, used as observation wells during these tests, are only screened in one layer. However, in several of the recovery well pumping tests, other recovery wells (also screened in water table and Upper and Lower Congaree) were used as observation wells. The total transmissivity for the water table and Upper and Lower Congaree calculated for these wells ranged from 2,390 feet squared per day (ft^2/day) to 5,940 ft^2/day (Papadopulos, 1986).

Values of hydraulic conductivity used in this study were selected from previous models and are assumed to be reasonable numbers for the types of sedimentary deposits found in the water bearing zones. Unit thicknesses used are from the regional cross-section (Figure 6). A specific capacity of about 4 gallons per minute per foot (gpm/ft) of drawdown recently measured in recovery well RW-16 (Figure 3) suggests there is an area of lower transmissivity south of the A/M Area (southern sector). RW-16 is screened in the Upper and Lower Congaree. Using Walton's (1970) method, this specific capacity is equivalent to a transmissivity of 1,340 ft^2/day. This lower transmissivity is consistent with data by Fallaw (1990) which indicates a depression or trough in the Upper and Lower Congaree south of the A/M Area.

An aquifer pumping test was performed on production well PW-20A which is screened in both the Black Creek and the Middendorf (Geraghty & Miller, 1985). A summary of the aquifer test data in Papadopulos, 1986, shows the total transmissivity to range from 10,400 to 14,200 ft^2/day. The hydraulic conductivity in the Black Creek is estimated as half of the hydraulic conductivity of the underlying hydrologic unit. Using this hydraulic conductivity ratio and the thicknesses from the regional cross-section, the range in transmissivity for the Black Creek in the A/M Area is 3,185 to 5,060 ft^2/day.

3.5 AQUIFER AND AQUITARD THICKNESS DATA

The sources of the aquifer thickness data used in this coarse grid model are the regional hydrostratigraphic cross-section (Aadland and Bledsoe, 1990; Figure 6) and data from Fallaw, 1990. The cross-section has a north-south orientation through the model area. The Fallaw data is confined to the A/M Area. The source of the aquitard data used in this calibration is data from Fallaw and Sargent (1986), and from the 1987 Papadopulos model report.

3.6 WATER QUALITY DATA

Water quality data and contour maps of the trichloroethylene (TCE) concentrations in the water table, Upper Congaree, Lower Congaree and Black Creek from fourth quarter, 1990 (4Q90), were provided by SRL (WSRC, 1990). The water quality data are in parts per billion (ppb). The water quality data will be used in the zone of capture modeling. The contours are shown in Figures 11 through 14. As part of SDI's QA/QC plan, data points were checked and discrepancies were noted in writing to SRL (SDI, 1990b).

An alternative interpretation of the same TCE concentration data for the Lower Congaree in the southern sector was provided by SDI for SRL's consideration as shown in Appendix B. These contours were generated using the 4Q90 data points and the direction of groundwater flow indicated by the observed average water level contour maps as a guide (SDI, 1991).

4.0 GROUNDWATER MODEL SET-UP

4.1 SELECTION OF MODEL CODE

The public-domain groundwater flow code MODFLOW was chosen for this model. The code is widely used and accepted by regulatory agencies. MODFLOW operates on 80386-based personal computers (PC), and MODFLOW files can be easily used with a number of particle tracking programs.

The version of MODFLOW used in this study is run by a FORTRAN compiler (FTN77) developed at the University of Salford, England to allow for the use of extended and virtual memory. The code was modified to provide the data input files for the particle tracking program. These changes are documented in the report by Schreuder et al., 1990. Copies of the codes with changes have been provided to SRL on floppy disk.

The MODFLOW input files for this calibrated model are provided both on disk and hard copy (Appendix C) in this report.

4.2 MODEL SIMULATION OF HYDROGEOLOGIC SETTING

The 25,000-ft by 35,000-ft area in this study has the same dimensions as in the previous SSP&A and SDI models. Four hydrogeological layers are simulated and an evenly-spaced coarse grid of 1,000 ft x 1,000 ft cells is used over the entire area (Figure 2). Each layer is made up of 25 by 35 cells (875) for a total of 3,500 cells in the model. A model-simulated hydrogeological layer consists of an aquifer and underlying aquitard. The layers are in descending order; the water table, Upper Congaree, Lower

Congaree and Black Creek. In previous models, the Ellenton was modeled as a separate layer. In this simulation, the Ellenton is modeled as the aquitard underlying the Lower Congaree in layer 3. The model layers and their relationship to the stratigraphy are shown on Figure 6.

4.2.1 Boundary Conditions

The water table unit is only present at the higher elevations in the northeast portion of the model and is therefore not simulated over the entire area. The areal extent of the water table was determined by comparing water levels between the Upper Congaree and the units above. Based on the regional cross-section in Figure 6, the Upper Congaree, Lower Congaree and Black Creek are simulated over the entire model area. Constant-head boundary conditions are used in all layers where the observed water level contours indicate flow into or out of the modeled area. The discharge of groundwater to streams and wetlands is simulated in this model by nodes with head-dependent discharge (general-head boundary nodes).

To simulate groundwater flow in the water table, constant-head nodes are placed on the northern, western, and part of the southern boundaries of layer 1 (Figure 15). A report by Lockwood Greene Engineers, Inc. (1983) on the stream flow of Tim's Branch indicates that the upper portion of Tim's Branch has only seasonal flow. Because much of the stream in layer 1 is not a constant source of water, that portion is not simulated in the model with general-head boundary (GHB) nodes.

To simulate groundwater flow out of model layer 2 (Upper Congaree), constant-head nodes are used in the northeast as shown in Figure 16. The regional cross-section shows Tim's Branch and Upper Three Runs Creek to be incised into the Upper

Congaree. Constant-head nodes are used in the southeast corner of the model to simulate water levels in the Upper and Lower Congaree south of Upper Three Runs Creek (Duffield et al., 1989). This area is included in the model to aid in the surface water flow calibration. GHB nodes are used to simulate both streams and the wetlands to the southwest.

It is likely that some of the groundwater in the Lower Congaree and discharges into the wetlands. No-flow boundary conditions were used along the southwestern edge of layer 3 (Lower Congaree) to induce upward flow into layer 2 and simulate discharge to the wetlands. These boundary conditions result in model-predicted water levels and gradients in layers 2 and 3 that satisfactorily reproduce the observed average water levels. There is insufficient data in this area to estimate the amount of discharge to the wetlands from the Upper and Lower Congaree.

To simulate groundwater flowing out of layer 3 (Lower Congaree), constant-head nodes are used along the northern boundary. As in layer 2, constant heads are also used to simulate groundwater flowing into the model in the southeast corner as shown in Figure 17.

The regional groundwater flow in the Black Creek is to the southwest. Constant-head nodes were used on the northeast, east and west boundaries to simulate the observed regional groundwater flow (Figure 18).

4.2.2 Aquifer Parameters

A total transmissivity of 2,805 ft^2/day is used for the upper three layers in the northern half of the model. As in the SSP&A and previous SDI models, layer 1 is modeled as a confined layer with a transmissivity of 175 ft^2/day (Figure 15). There is insufficient data to accurately model the water table as an unconfined layer, especially along the edges where the unit pinches out. The output from this calibrated model will be used for particle tracking to model the zone of capture for recovery wells. Modeling the water table unit as confined or unconfined makes no difference in the particle track because only the water levels and the hydraulic conductivity are utilized in the program.

The total transmissivity for the Upper and Lower Congaree is 2,630 ft^2/day in the northern half of the model. The distribution of transmissivity in the Upper Congaree is shown in Figure 16. The distribution of transmissivity in the Lower Congaree is shown in Figure 17. A hydraulic conductivity of 44 ft/day is used for both layers (Papadopulos, 1987). In layer 2, a transmissivity of 1,750 ft^2/day is used in the north and a value of 3,100 ft^2/day is used in the south. In layer 3, a transmissivity of 880 ft^2/day is used in the north and a value of 2,400 ft^2/day is used in the south. A block of lower transmissivity southeast of the A/M Area is present in both layers 2 and 3. A transmissivity of 4,000 ft^2/day was calculated for the Black Creek (Figure 18).

The leakance values for layer 1 are very similar to the values used by Papadopulos (1987; Figure 19). Leakance coefficients range from 0.00018 to 0.002 day^{-1}. The lowest leakance value is in the A/M Area, and the highest leakance value is northeast and east of the A/M Area. Leakance values for layer 2 range from 0.000403 to 0.22 day^{-1} (Figure 20). Leakance is higher in the south than in the north. The range in leakance values for layer 3 is 0.000002 to 0.00055 (Figure 21). The lowest values are in the A/M Area and southeast of the A/M area.

4.2.3 Recharge

An uneven distribution of rainfall recharge is chosen for this model. A recharge rate of 15 in/yr is used over the top of the ridge and a lower rate of 10 in/yr is used in areas of steeper topography (Figure 22).

4.3 MODEL SIMULATION OF GROUNDWATER WITHDRAWALS

Present production and recovery well pumpages in the A/M Area are included in this model. Appendix D is a table of the well positions and withdrawal rates provided by SRL for the period to which the model was calibrated. The recovery wells and four of the production wells located in the A/M Area are shown in Figure 3. Production well PW-67B is located in the southern portion of the model southeast of the intersection of Roads C and 2. Wells PW-112G and PW-113G are located east of Tim's Branch and the A/M Area. The seven production wells pump from Aquifer System I. Because this model does not simulate the groundwater flow system below the Black Creek, pumpages were pro-rated according to transmissivity. Therefore, the anticipated amount of pumpage contributed from the Black Creek assumed to be one-third of the total pumpage.

The recovery wells are screened in the water table, Upper Congaree and Lower Congaree and pumpage is proportional to transmissivity in the three layers. The water table contributes 5% of the total pumpage while the Upper and Lower Congaree contribute 63% and 32%, respectively. The withdrawal rate from each layer for each recovery well is shown in the table in Appendix D.

5.0 MODEL CALIBRATION

The model was considered to be calibrated when: 1) the predicted water levels in each layer approximately matched the averaged observed water levels and gradients; 2) the discharges calculated from the GHB nodes were within the range of observed base flow discharges; and 3) aquifer parameters were within reported ranges. The model was run under steady-state conditions. It is assumed that the drawdown from the present day recovery system has reached equilibrium. The model was also run under transient conditions for periods of one and two years. Model-predicted groundwater level elevations approached steady-state levels. Recharge and well pumpage do not change throughout the simulation. The following section is a brief description of the steps taken in the calibration of this model. A more detailed description of the calibration process is provided in Appendix E.

5.1 DESCRIPTION OF CALIBRATION PROCESS

SDI started with the model parameters used in the 1987 SSP&A calibration; the only deviation from the SSP&A model was combining the Ellenton and Lower Congaree layers into one model layer and utilizing a leakance coefficient to simulate the Ellenton as a confining unit below the Upper Congaree. The water levels predicted by the SSP&A model were reproduced in the water table, Upper Congaree, Lower Congaree and Black Creek.

The 1989-1990 observed water levels differ from the model-predicted water levels produced by the SSP&A, 1987 calibrations. This may be attributed to the effects of several years of recovery well pumpage and differences in rainfall rates. The 1987 model-predicted water levels were higher than the 1989-1990 observed water levels.

Additional monitoring wells have been installed since the SSP&A calibration and understanding of the hydrogeologic system has improved. SDI analyzed the available data and recalibrated the model to 1989-1990 observed water levels, surface water flow, and aquifer test data. Model parameters were adjusted to the final configurations of transmissivity, leakance, recharge and boundary conditions presented in the previous section. A detailed description of the calibration process is presented in Appendix E.

5.2 CALIBRATION TO OBSERVED WATER LEVELS

The resulting model-predicted water levels for each layer are shown in Figures 23, 24, 25 and 26. For ease of comparison, the observed water level contours for each layer are shown in red while the model-predicted contours are shown in blue.

5.2.1 Predicted Water Levels, Water Table

As shown in Figure 23, the highest water levels are in the vicinity of the A/M Area for both calculated and observed water levels. Although the model-predicted water levels are higher in the A Area than the observed data, the water level gradient agrees well with the observed gradient within the southern sector. The general direction of horizontal flow is to the south and west as well as southeast into Tim's Branch. The predominant direction of groundwater flow in the water table is downward into the Upper Congaree. The absence of data points east of Tim's Branch made calibration along the northeast boundary of layer difficult.

5.2.2 Predicted Water Levels, Upper Congaree

The model-predicted water levels are a few feet lower than the observed water levels north of the A Area (Figure 24). The general direction of groundwater flow is to the southeast towards Upper Three Runs Creek and to the southwest towards the wetlands. Overall, the agreement between the model-predicted water levels and the observed water levels is good.

5.2.3 Predicted Water Levels, Lower Congaree

As shown in Figure 25, the calculated water levels are slightly higher in the area south of Lost Lake. The northward inflection in the 220-foot contour line is not as pronounced in the model-predicted water levels as it is in the observed water levels. This may be an artifact of model discritization due to a change in aquifer parameters or the use of averaged pumpage rates. Overall, the agreement between the model-predicted water levels and the observed water levels is good in layer 3.

5.2.4 Predicted Water Levels, Black Creek

As shown in Figure 26, calculated water levels agree well with observed water levels in the northern half of the model. Calculated water levels are about 3 feet lower in the vicinity of the only southern data point (well P-29). Because there is little water level data in the southern half of the model area, the observed contours were taken from a regional water level map of the Black Creek. The data used in contouring the regional map are too coarse to show any detail in the Upper Three Runs Creek area.

The model indicates that there is some upward flow of groundwater from the Black Creek into the Lower Congaree in the southern half of the model due to lower hydraulic heads along Upper Three Runs Creek.

5.3 CALIBRATION TO SURFACE WATER FLOW

In order to calibrate the model to surface water flow, stream discharge data were used to estimate the base flow in Tim's Branch and Upper three Run's Creek. Groundwater flow out of the GHB nodes was adjusted until it was within the range of base flow estimated for each stream reach.

Discharge data for Tim's Branch in WY 1987 indicates the base flow averages 3 to 5 cfs. Because approximately 43% of the Tim's Branch drainage basin is within the model area, 1.3 to 2.2 cfs of the base flow is assumed to be contributed by the model area. The discharge through the GHB nodes simulating Tim's Branch in the model is 3.4 cfs. This is slightly higher than the estimated contribution for the model area. However, the flow in the upper portion of Tim's Branch is reported to be seasonal so a larger percentage of the base flow may be contributed by lower Tim's Branch.

The gauging station at Road A and Upper Three Runs Creek had an estimated base flow of 120-200 cfs in WY 1987. The model area east of the drainage divide is approximately 10% of the total drainage basin area above the gauging station, thus approximately 12 to 20 cfs of discharge is assumed to be contributed by the model area. The flow through the GHB nodes simulating Upper Three Runs Creek in the model is 15.2 cfs.

5.4 WATER BALANCE

In Table 1, the water balance calculated by MODFLOW for this calibrated model is presented. Water enters the model from rainfall recharge, flow into GHB nodes simulating streams, and flow from constant-head nodes simulating water that enters the model area at the boundaries. The total amount of water flowing into the model is 2,880,000 ft^3/day. Of this total, rainfall recharge accounts for 78%, while constant-head nodes contribute 17% and GHB nodes on the upper portion of Tim's Branch account for 5%.

Table 1. Volumetric Budget for Entire Model at End of Time Step 1 in Stress Period 1.

CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T[1]
IN:		IN:	
STORAGE =	0.00000E+00	STORAGE =	0.00000E+00
CONSTANT HEAD =	5.04475E+05	CONSTANT HEAD =	5.04475E+05
WELLS =	0.00000E+00	WELLS =	0.00000E+00
RECHARGE =	2.23668E+06	RECHARGE =	2.23668E+06
HEAD DEP BOUNDS =	1.38656E+05	HEAD DEP BOUNDS =	1.38656E+05
TOTAL IN =	2.87981E+06	TOTAL IN =	2.87981E+06
OUT:		OUT:	
STORAGE =	0.00000E+00	STORAGE =	0.00000E+00
CONSTANT HEAD =	4.10471E+05	CONSTANT HEAD =	4.10471E+05
WELLS =	1.91608E+05	WELLS =	1.91608E+05
RECHARGE =	0.00000E+00	RECHARGE =	0.00000E+00
HEAD DEP BOUNDS =	2.27767E+06	HEAD DEP BOUNDS =	2.27767E+06
TOTAL OUT =	2.87974E+06	TOTAL OUT =	2.87974E+06
IN - OUT =	67.750	IN - OUT =	67.750
PERCENT DISCREPANCY =	0.00	PERCENT DISCREPANCY =	0.00

1 Units are in feet and days.

Groundwater exits the model through surface water runoff, groundwater discharge to streams, groundwater flow out of model area boundaries, and well pumpage. The total amount of water flowing out of the model is 2,880,000 ft^3/day. Of this total, 79% exits the model through the GHB nodes simulating surface water runoff. This is an average discharge from the model of 26.4 cfs. The amount of groundwater flowing out of the model through boundaries is 14% and the total pumpage from the recovery and production wells is 7%.

Table 2 is the MODFLOW calculated breakdown of the movement of water into and out of the model by layers. The model output indicates that there is both upward and downward vertical flow between the model layers. The net vertical flow between layers is downward. The largest amount of water moving between layers is downward from layer 1 to layer 2.

Constant-head boundary nodes allow the simulation of groundwater flowing horizontally into and out of the model. Table 2 indicates that the largest amount of horizontal flow into and out of the model is in layer 4. With the exception of layer 4, the net flow at the constant-head boundaries is into the model. Groundwater enters all 4 layers through the northeastern corner of the model.

Of the total amount of water flowing out of the model, 7% is from well pumpage. Production wells in the Black Creek extract approximately 57% of the total pumpage. The recovery wells pump 2% from the water table, 27% from the Upper Congaree and 14% from the Lower Congaree.

The total amount of rainfall recharge entering the model is 2,237,000 ft^3/day which averages 11.2 in/yr over the model area. Layer 1 receives 31% of the total recharge and layer 2 receives the other 69%.

Table 2. **Volumetric Flow Budget for Each Model Layer for Time Step 1 in Stress Period 1.**

VERTICAL FLOW SUMMARY, BY LAYER INTERFACE (L**3)[1]

TOP LAYER	BOT. LAYER	UPWARD	DOWNWARD	NET (+ = DOWN)
1	2	46999.2	713865.	666865.
2	3	879466.	1.008670E+06	129205.
3	4	216119.	338492.	122372.

CONSTANT HEAD FLOW SUMMARY, BY LAYER (L**3)

LAYER	INTO DOMAIN	OUT OF DOMAIN	NET (+ = IN)
1	100417.	77718.4	22699.0
2	120838.	55801.3	65037.2
3	52334.1	8774.70	43559.4
4	230885.	268176.	-37291.1

WELL FLOW SUMMARY, BY LAYER (L**3)

LAYER	INJECTION	EXTRACTION	NET (+ = IN)
1	0.000000E+00	4110.00	-4110.00
2	0.000000E+00	52061.0	-52061.0
3	0.000000E+00	26029.0	-26029.0
4	0.000000E+00	109408.	-109408.

RECHARGE FLOW SUMMARY, BY LAYER (L**3)

LAYER	RECHARGE IN	RECHARGE OUT	NET (+ = IN)
1	695400.	0.000000E+00	695400.
2	1.541280E+06	0.000000E+00	1.541280E+06
3	0.000000E+00	0.000000E+00	0.000000E+00
4	0.000000E+00	0.000000E+00	0.000000E+00

[1] Units are in feet and days.

The coarse grid groundwater flow model has been calibrated to the available data. The predicted water levels in each layer agree favorably well with the observed water level data. The discharge from GHB nodes simulating Tim's Branch and Upper Three Runs Creek are within the ranges of base flow estimated from stream discharge data. Aquifer parameters used in the model are within reported values.

6.0 FUTURE USE

The purpose in constructing this model is to evaluate groundwater remediation options and assess recovery systems in the vicinity of the A/M Area of the SRS. This calibrated coarse-grid model is a base model. Specific areas of interest can be fine gridded to provide more accurate water level elevations that can be used for particle tracking and capture zone analysis. Copies of the MODFLOW code and input data have been furnished to WSRC on floppy disk. SDI will use this model to investigate groundwater recovery options for the "southern sector" south of Lost Lake and the A/M Area.

7.0 REFERENCES

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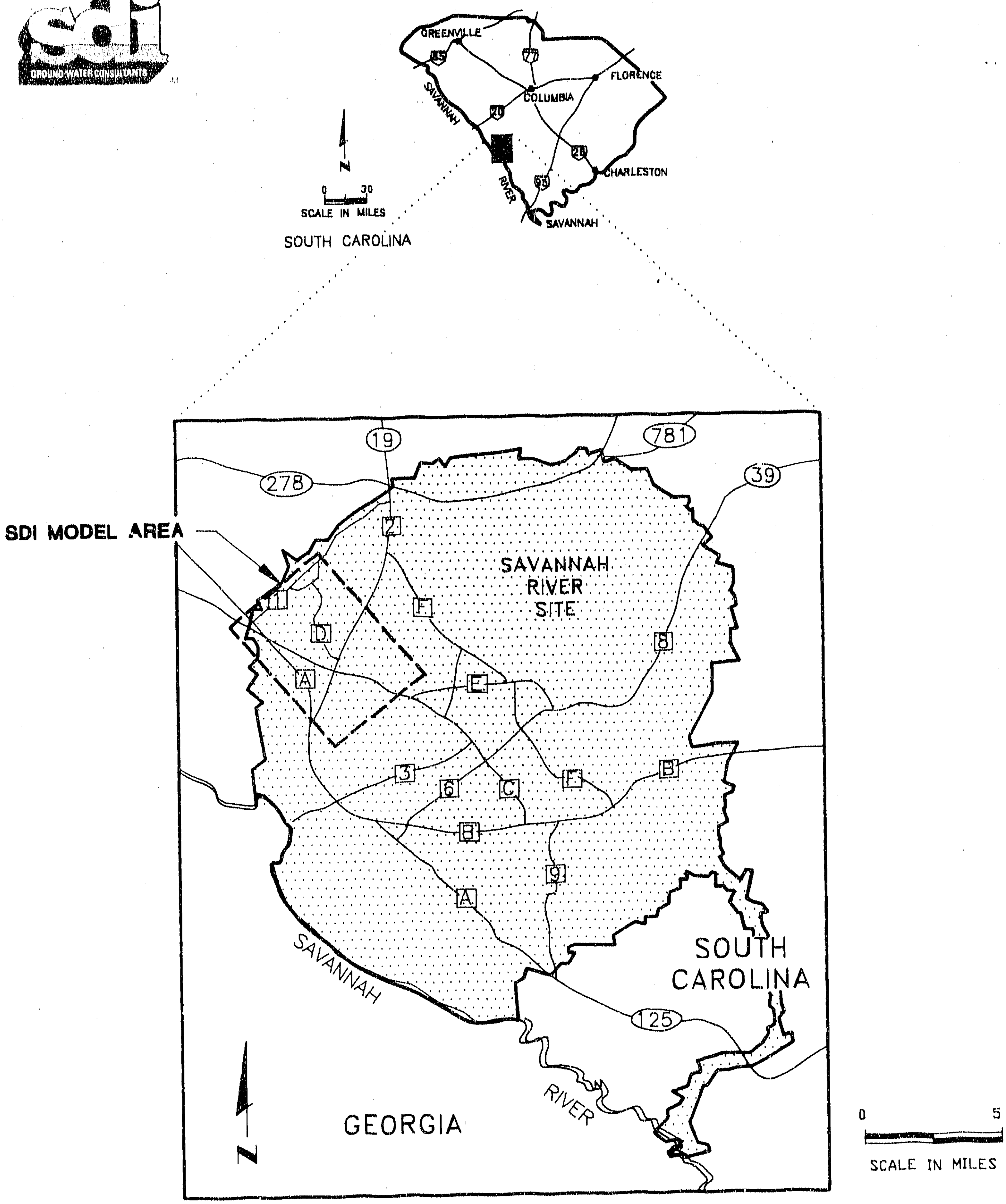

Figure 1. Location of the Savannah River Site and Modeled Area.

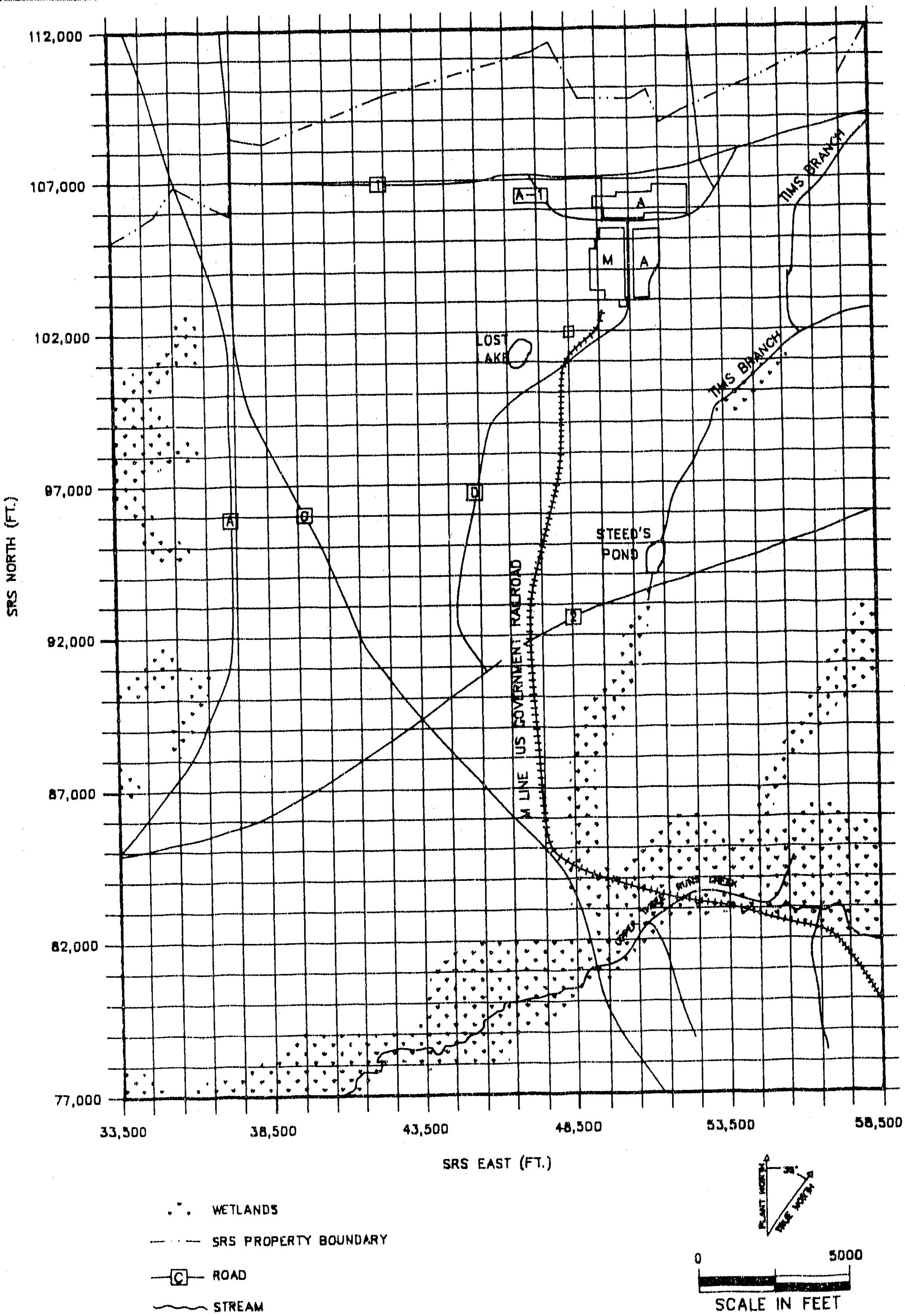

Figure 2. Model Area and Nodal Grid.

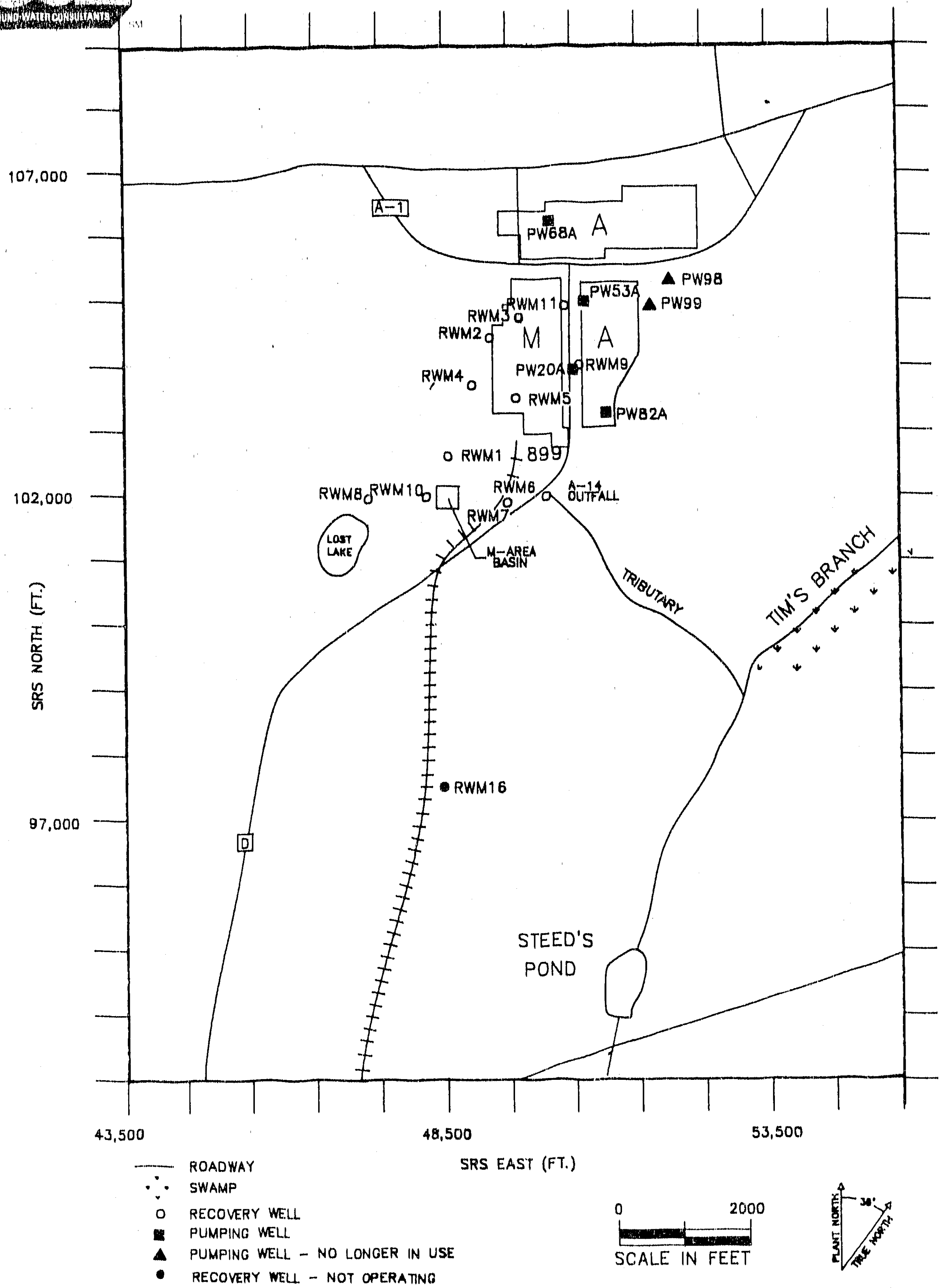

Figure 3. Location of Recovery Wells and Production Wells.

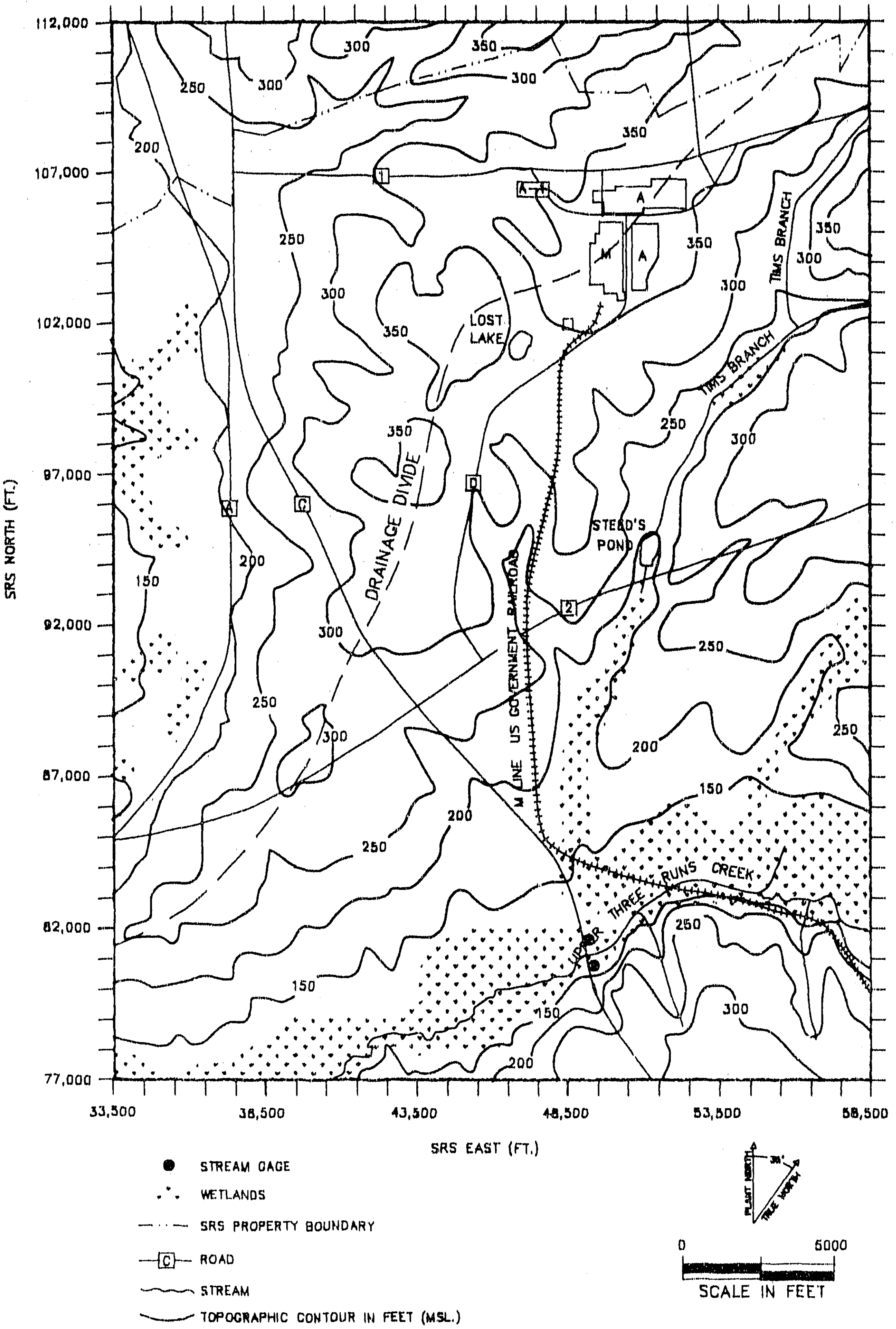

Figure 4. Topography, Watershed Boundary and Surface Water Features.

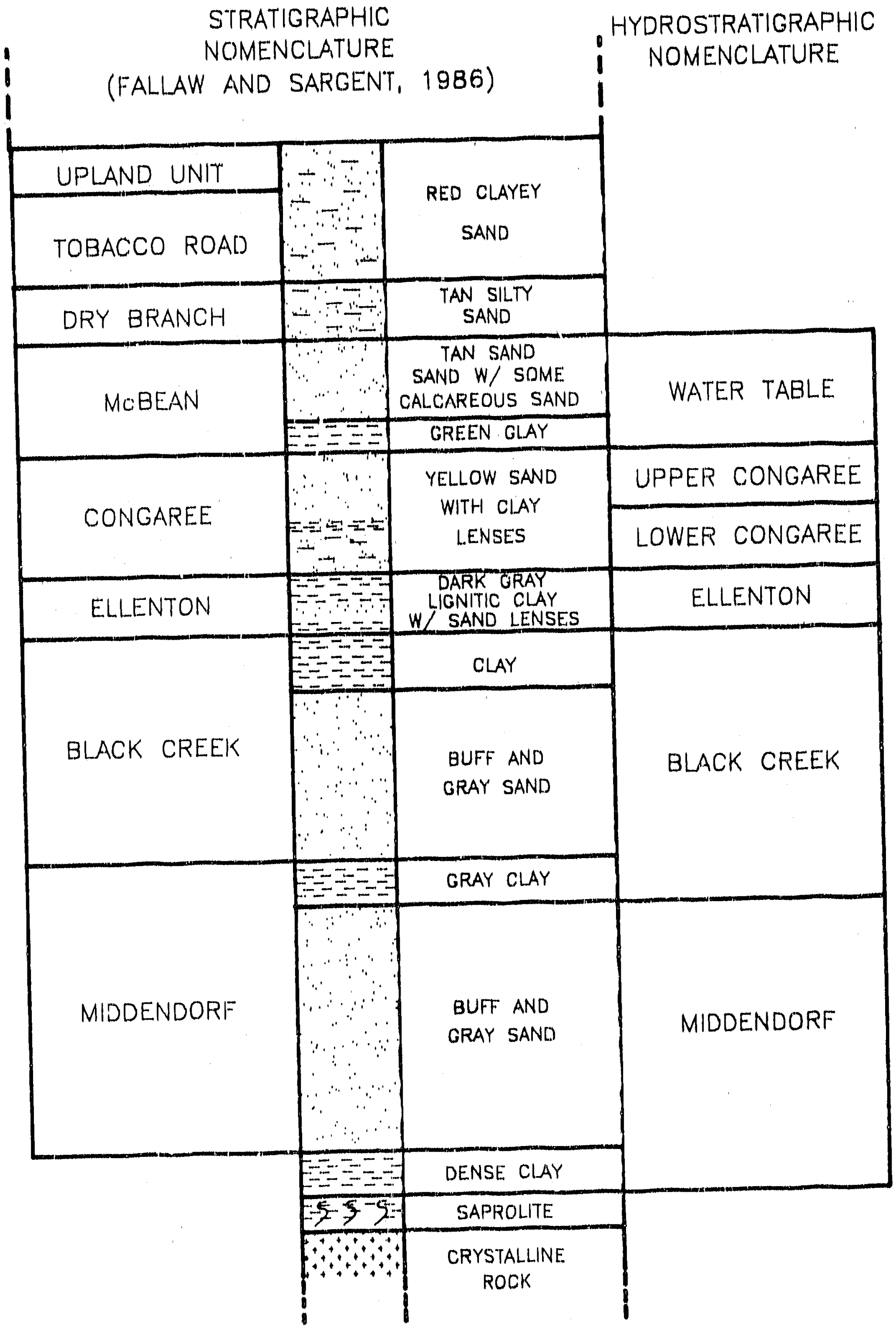

Figure 5. **Lithology and Relationship Between Hydrostratigraphic and Stratigraphic Nomenclature.**

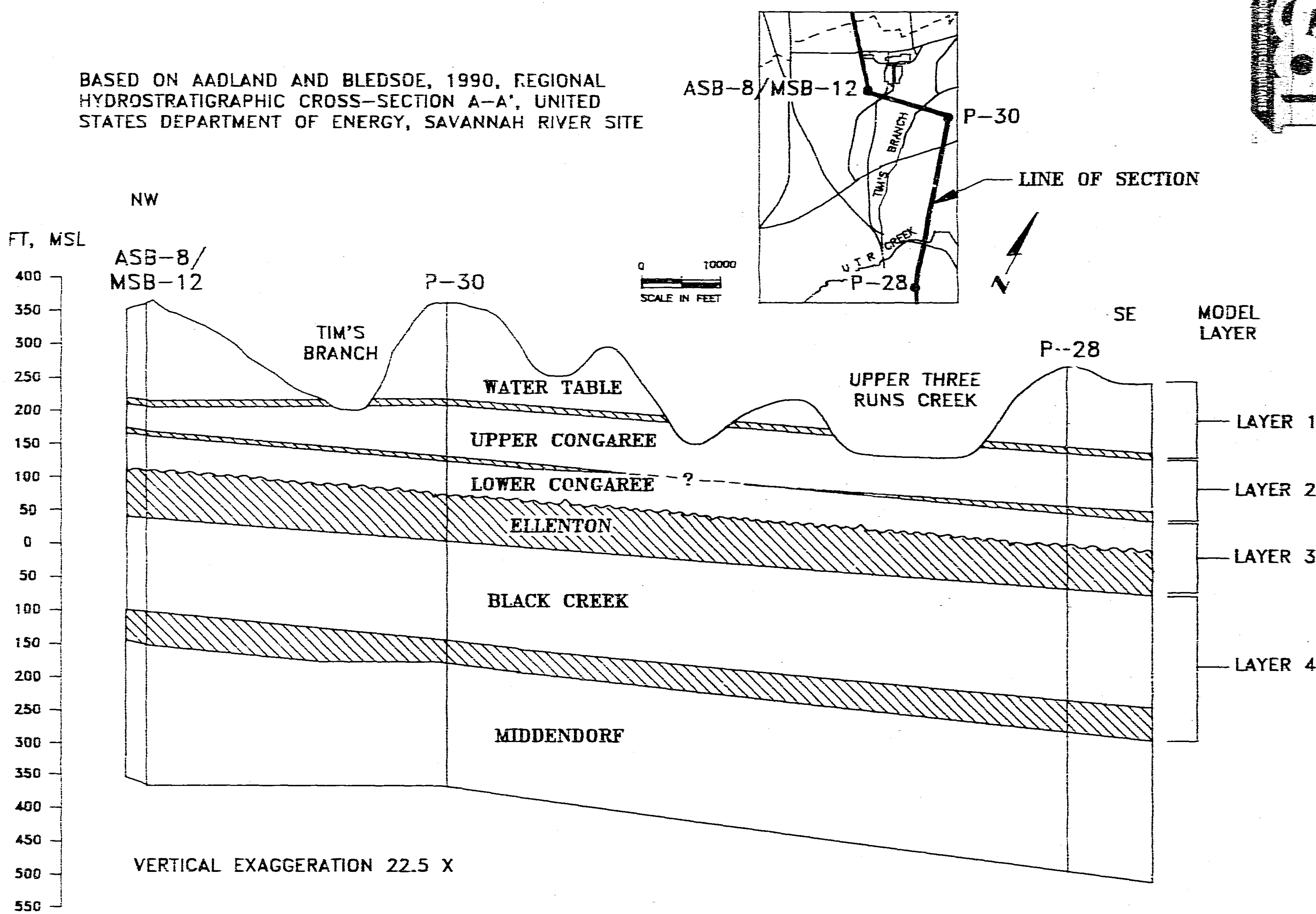

Figure 6. **Hydrostratigraphic Cross-Section and Model Layer Definitions.**

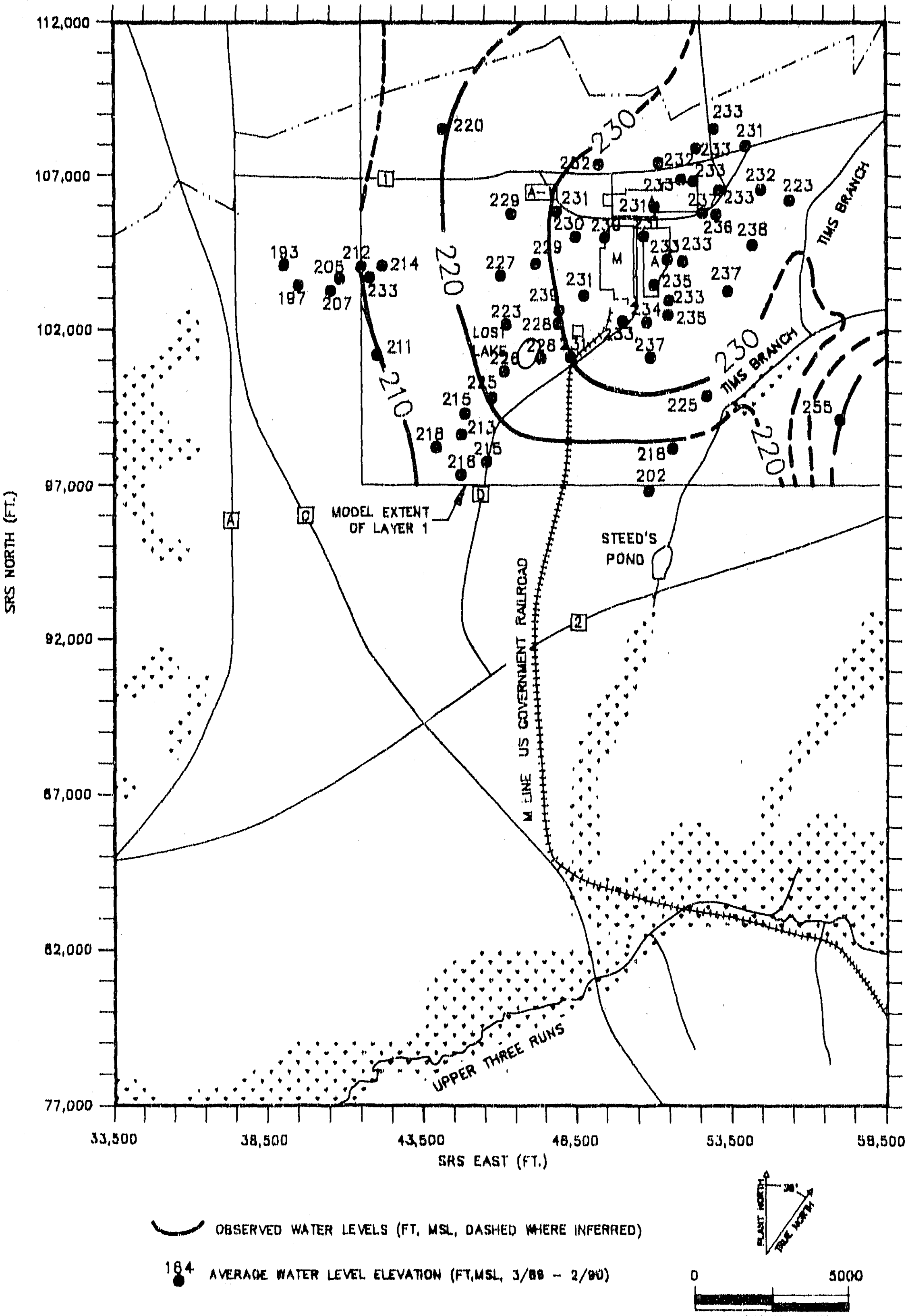

Figure 7. Observed Water Levels in the Water Table.

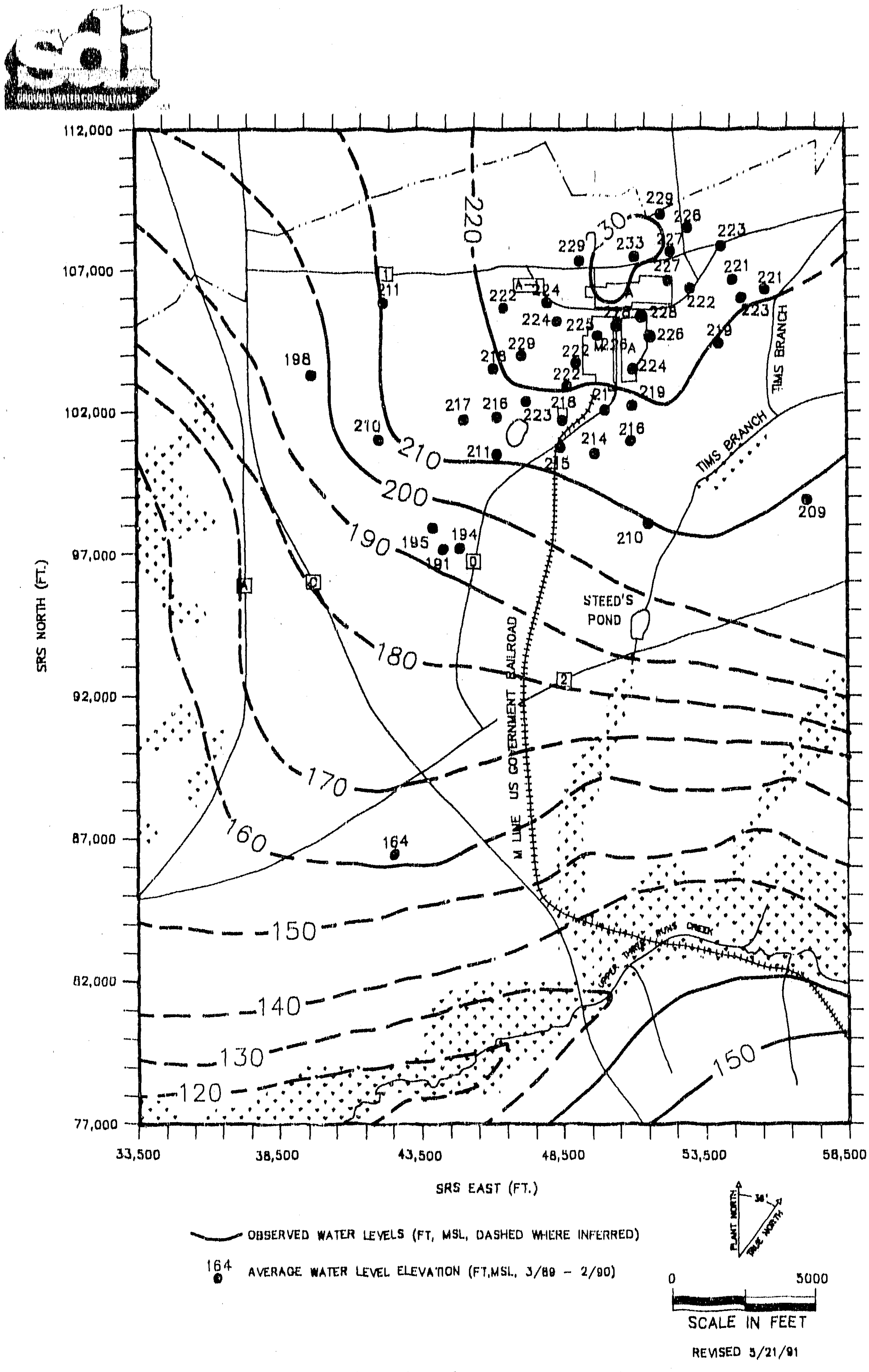

Figure 8. Observed Water Levels in the Upper Congaree.

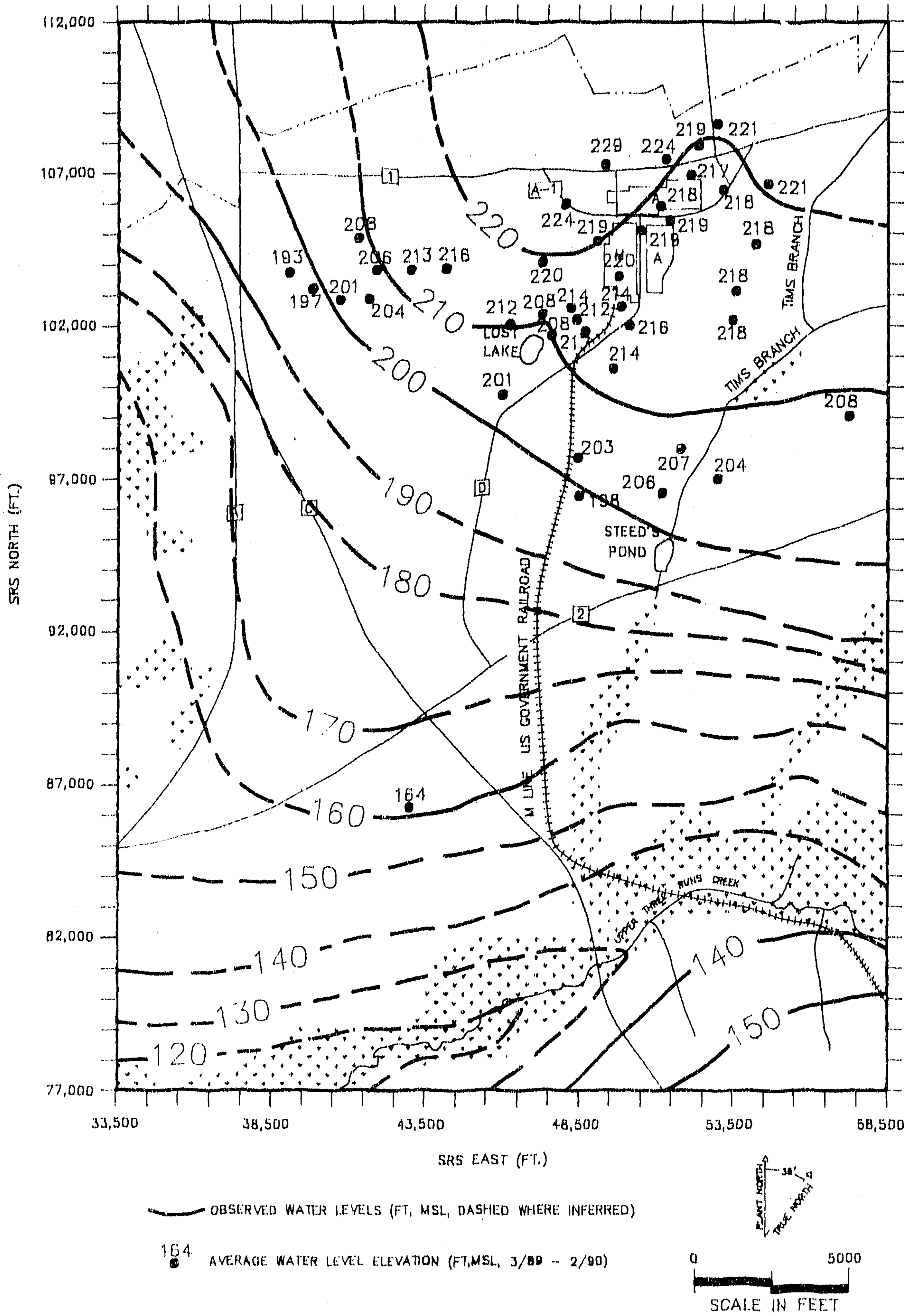

Figure 9. Observed Water Levels in the Lower Congaree.

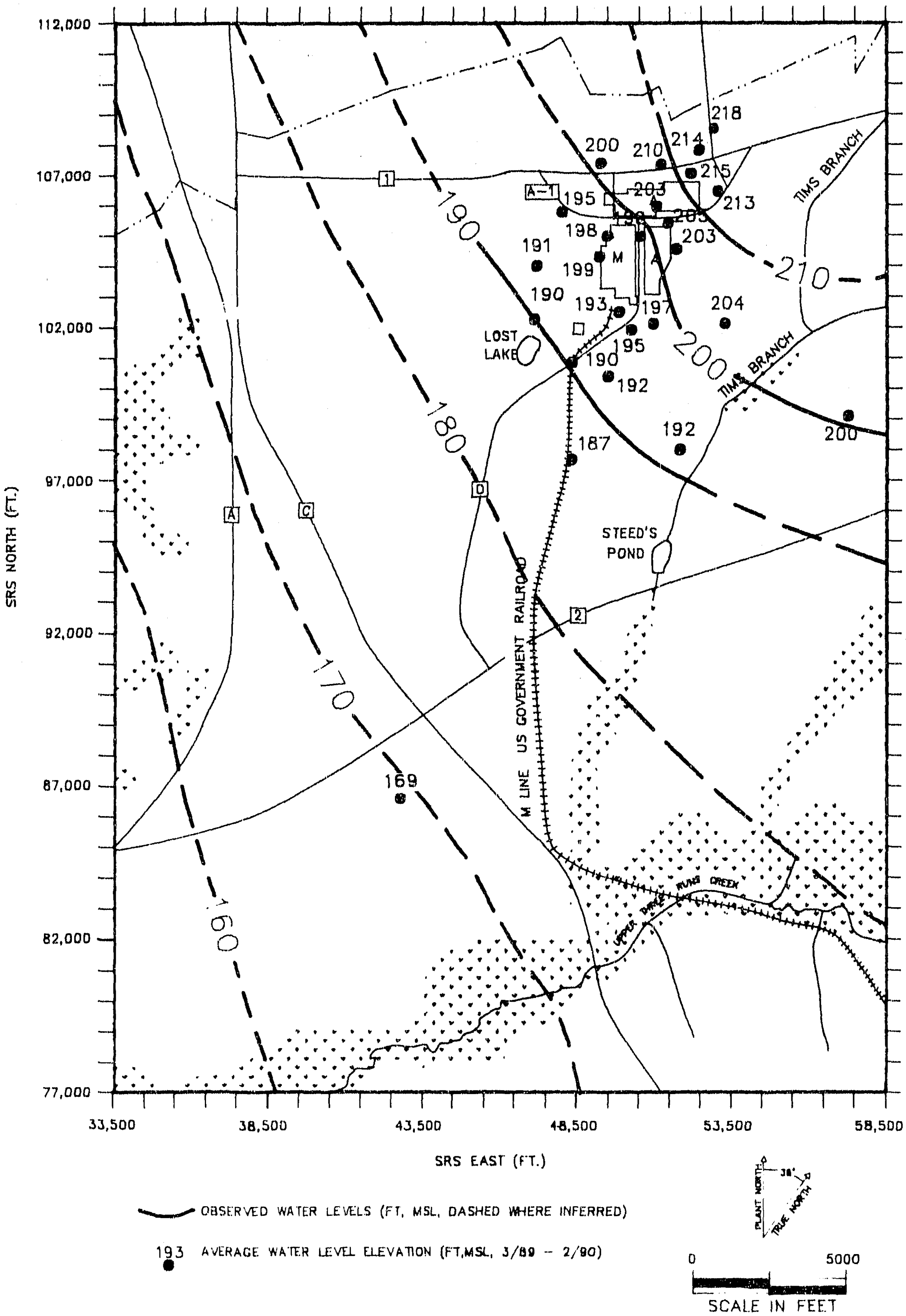

Figure 10. Observed Water Levels in the Black Creek.

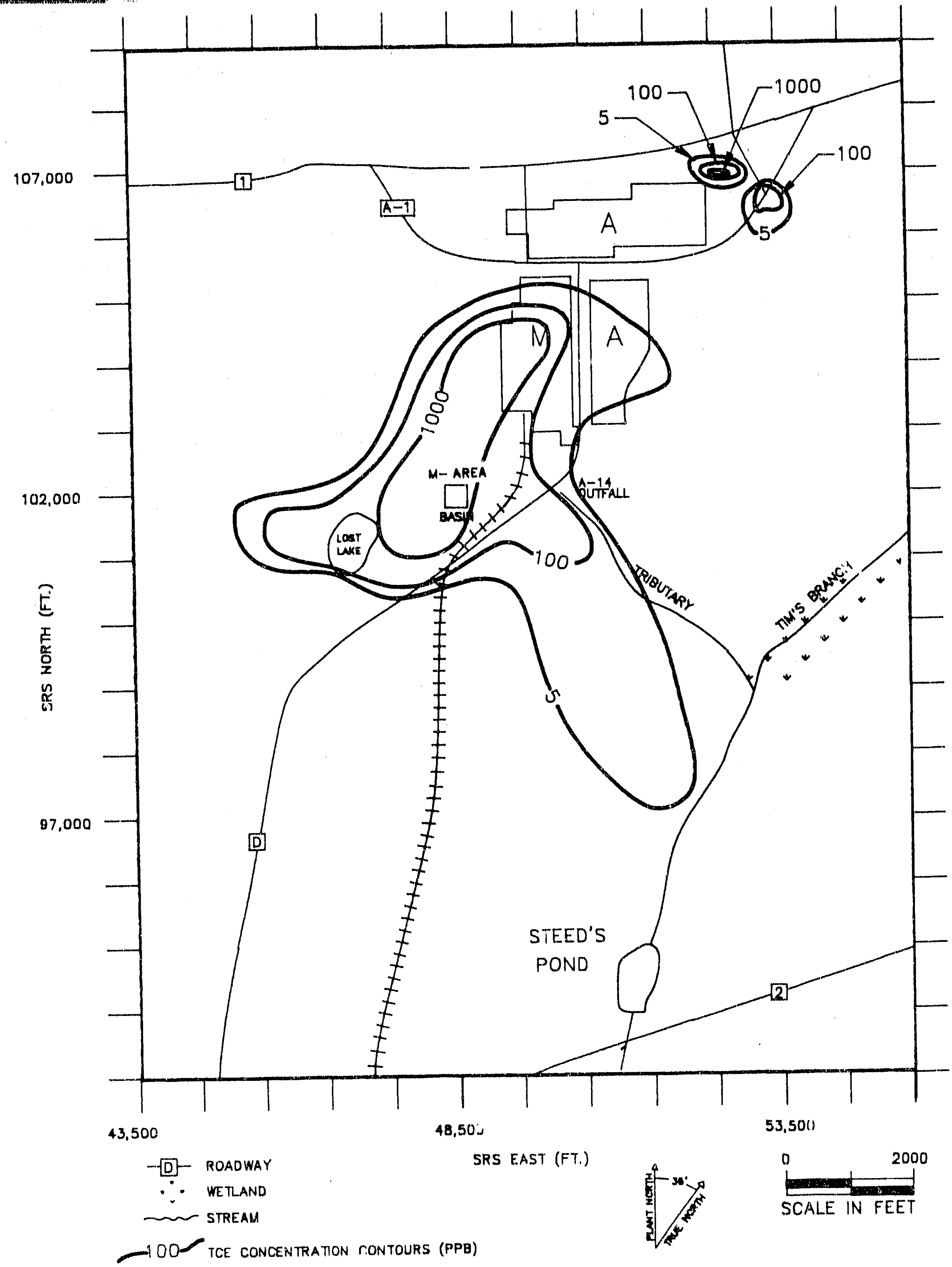

Figure 11. Observed TCE Concentration in Water Table. After Westinghouse Savannah River Company, 1990.

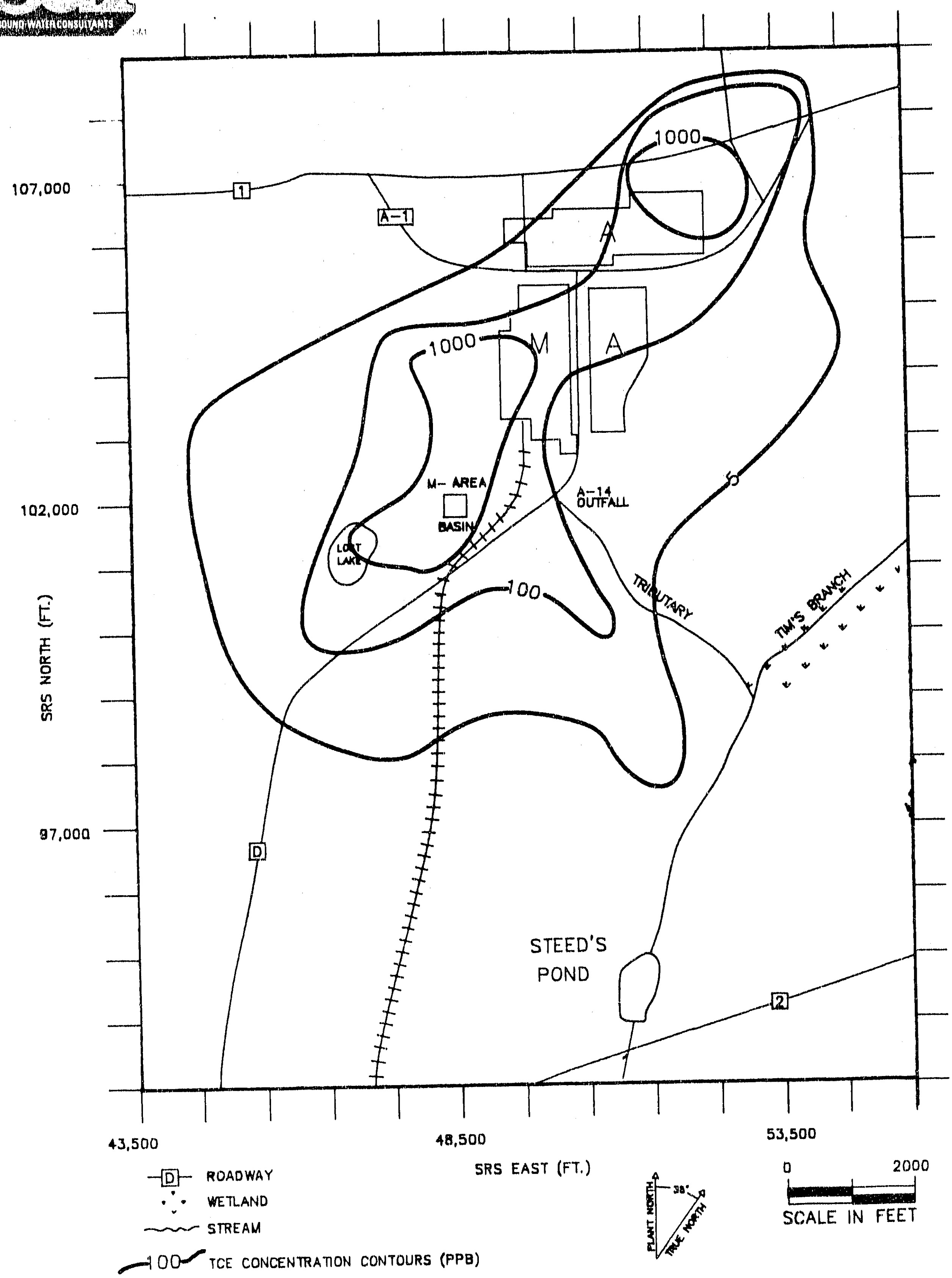

Figure 12. Observed TCE Concentration in Upper Congaree. After Westinghouse Savannah River Company, 1990.

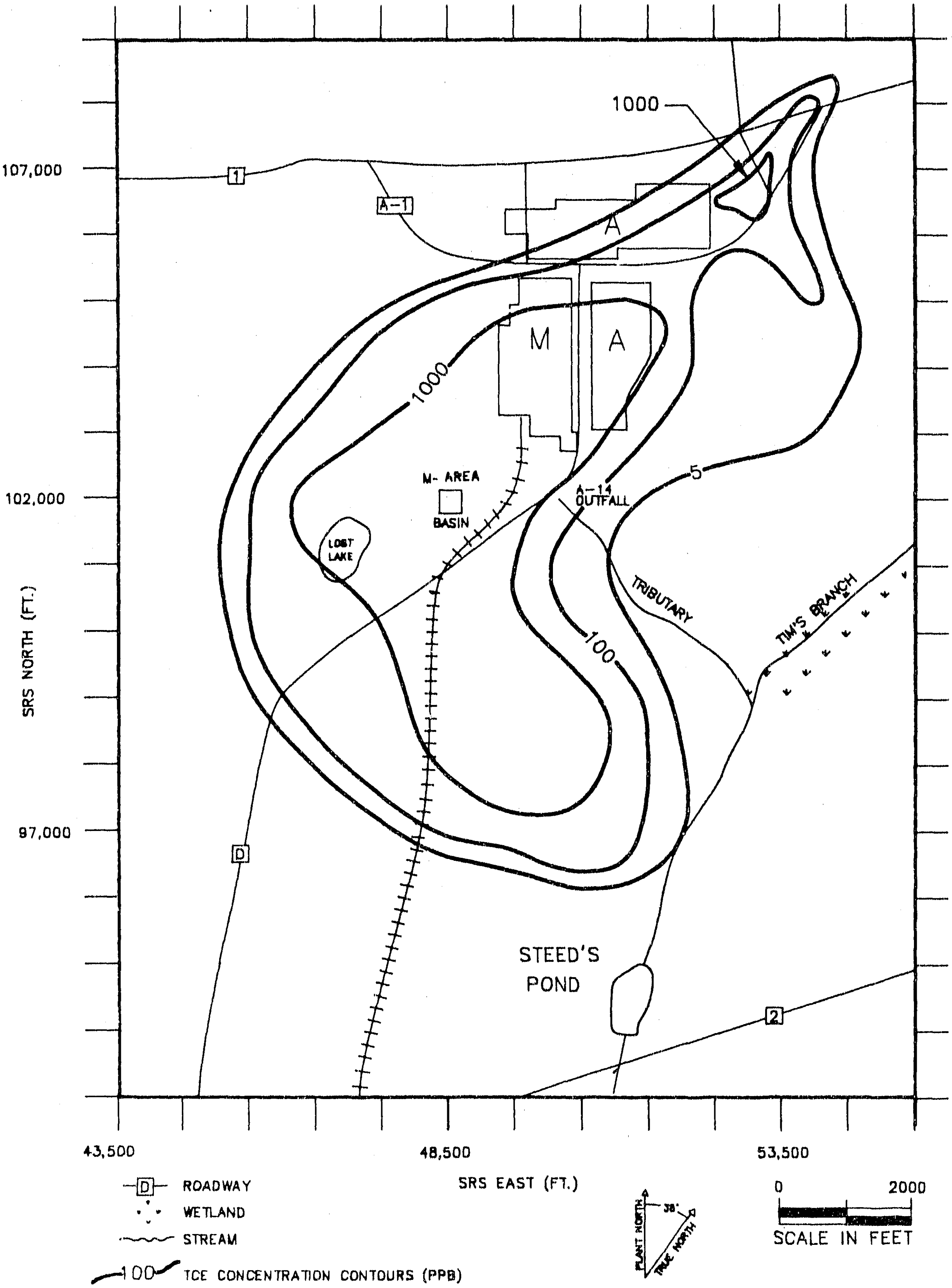

Figure 13. **Observed TCE Concentration in the Lower Congaree. After Westinghouse Savannah River Company, 1990.**

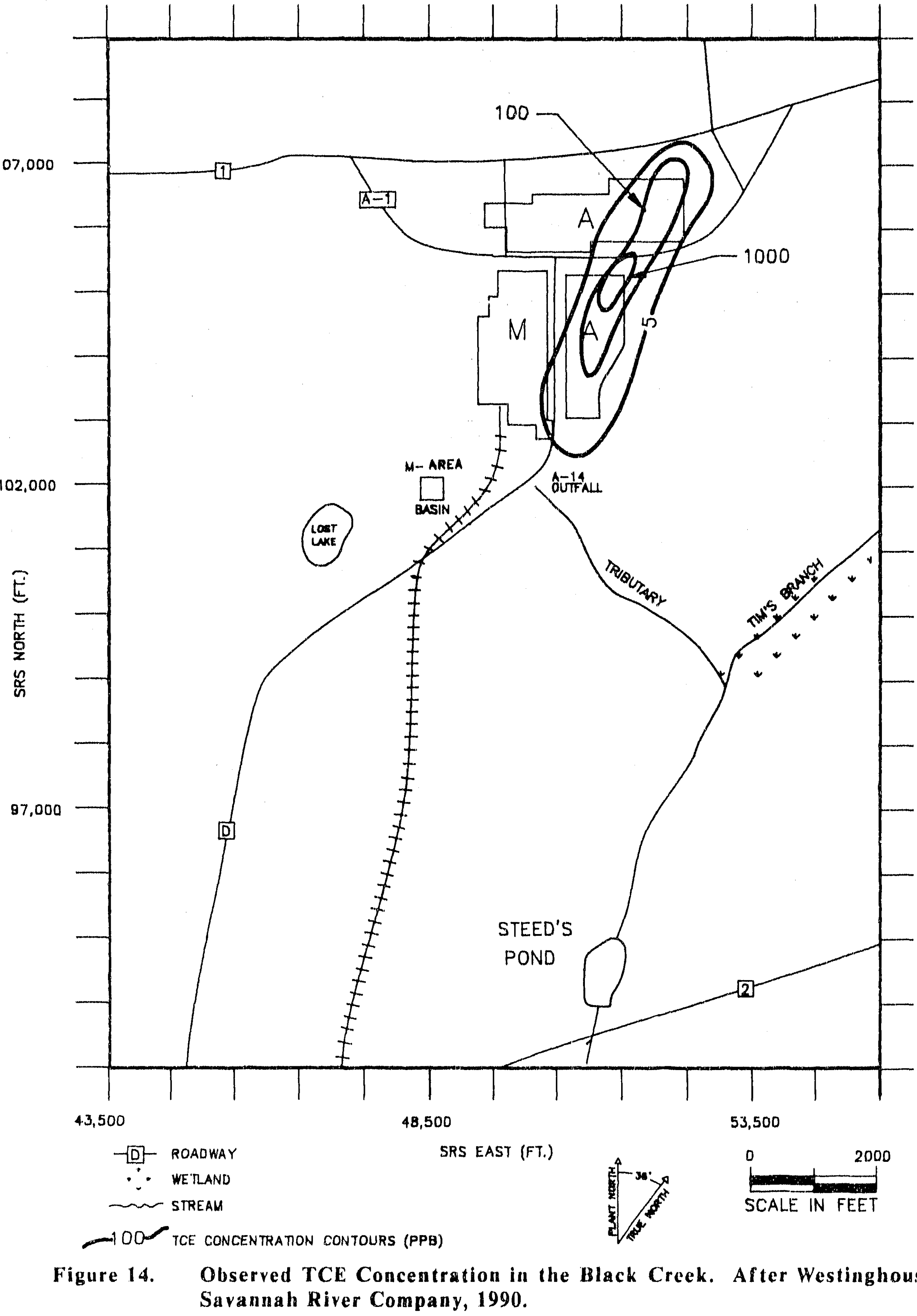

Figure 14. **Observed TCE Concentration in the Black Creek. After Westinghouse Savannah River Company, 1990.**

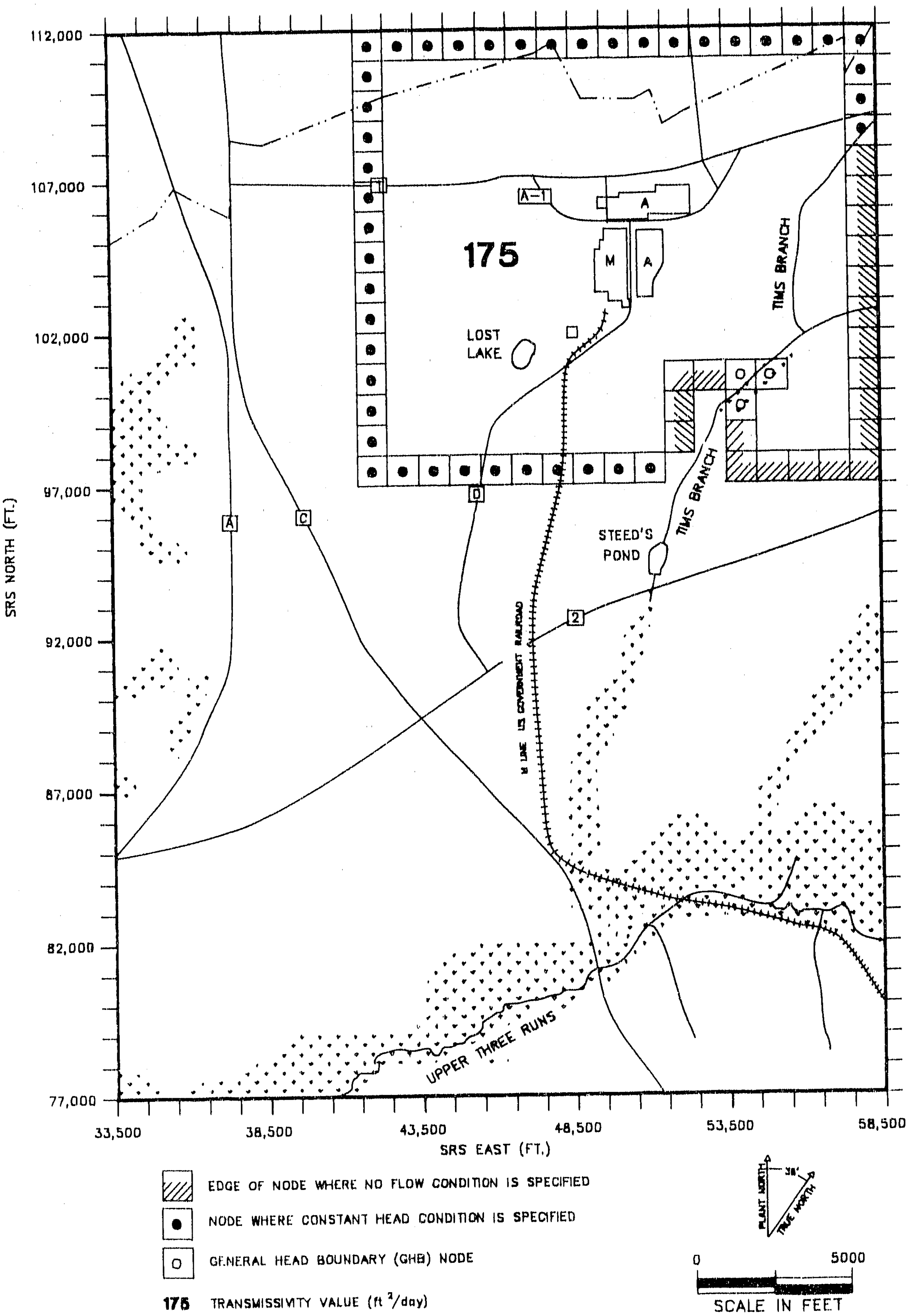

Figure 15. **Boundary Conditions and Transmissivity in Model Layer 1.**

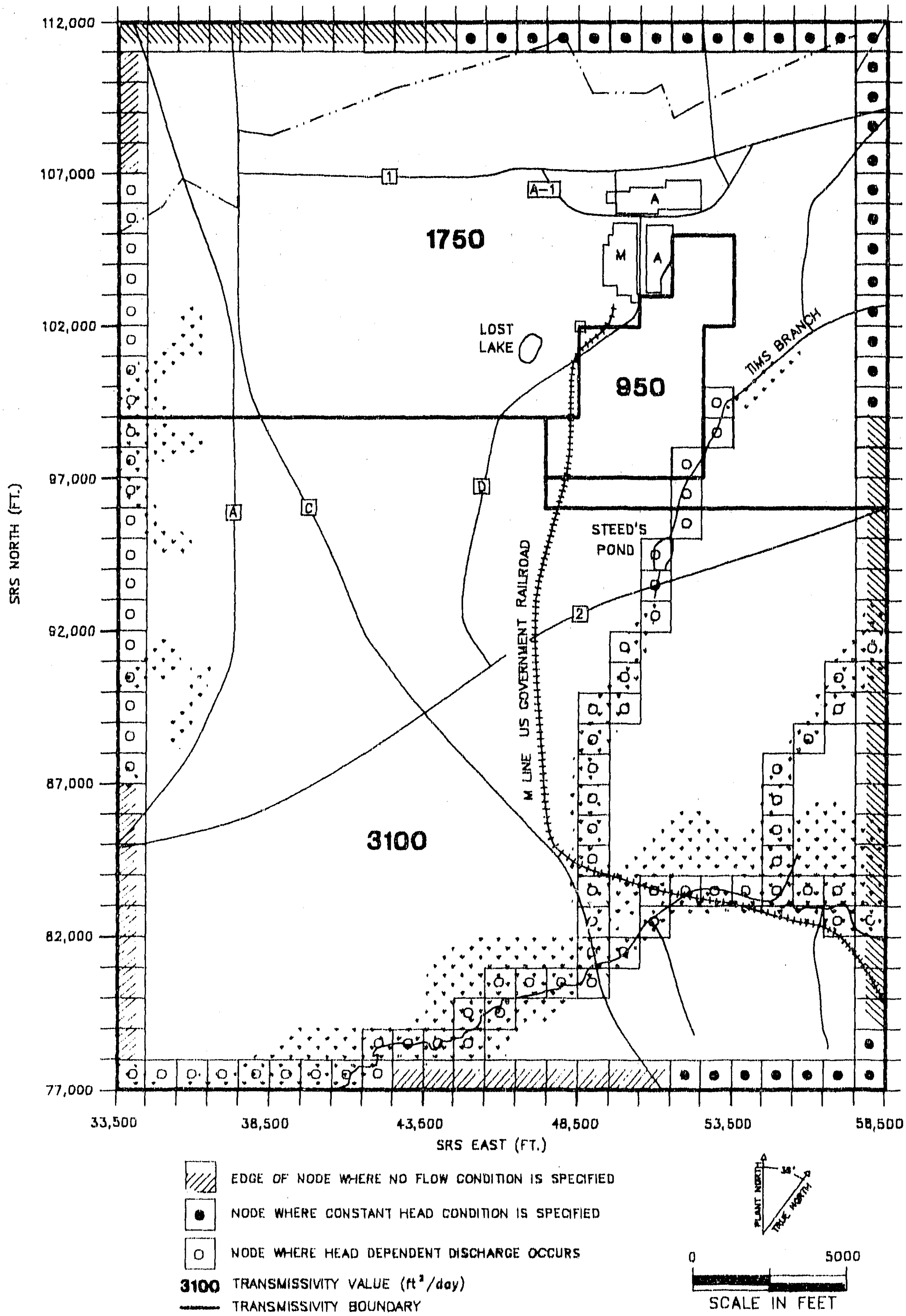

Figure 16. Boundary Conditions and Transmissivity in Model Layer 2.

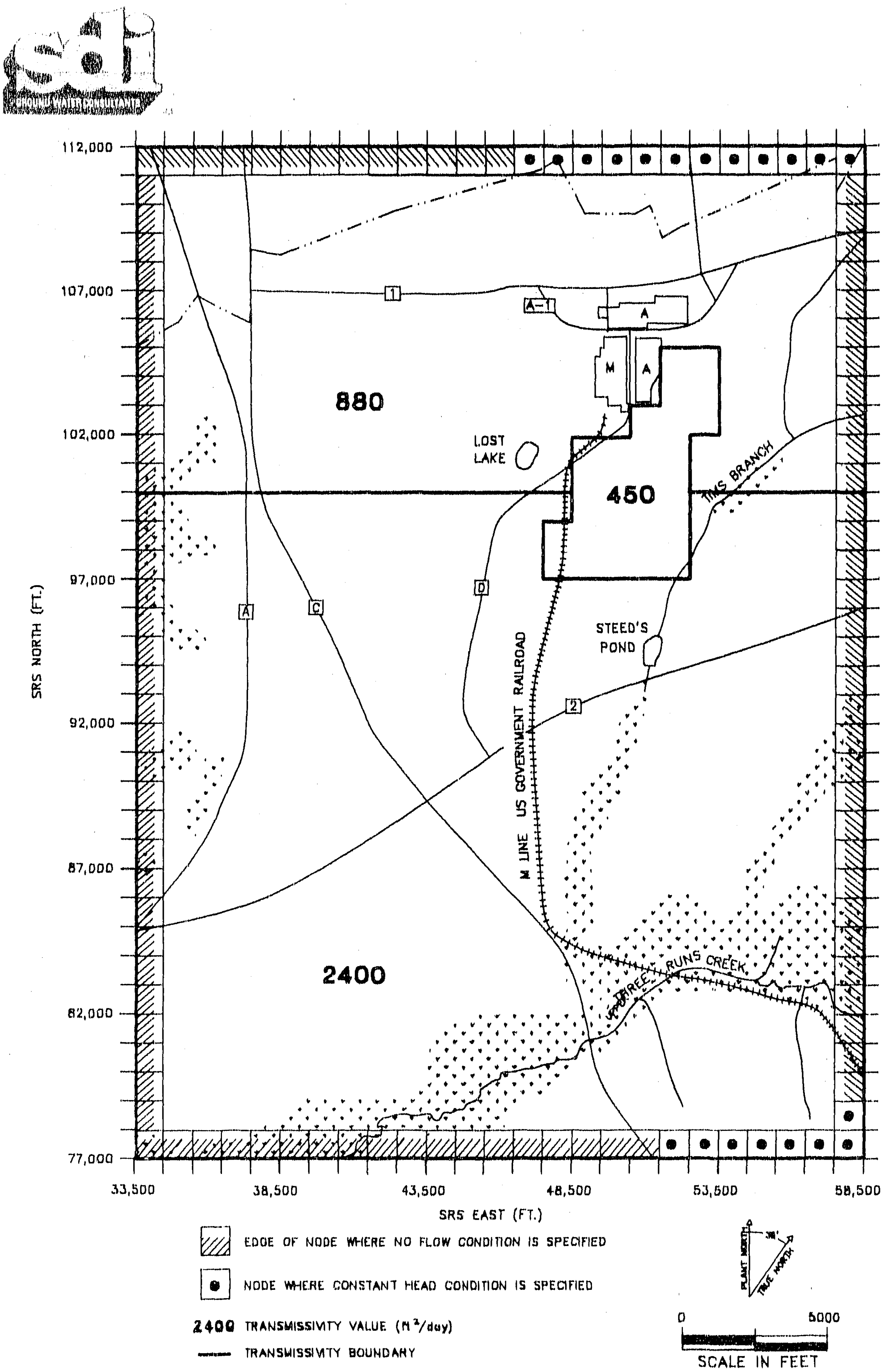

Figure 17. Boundary Conditions and Transmissivity in Model Layer 3.

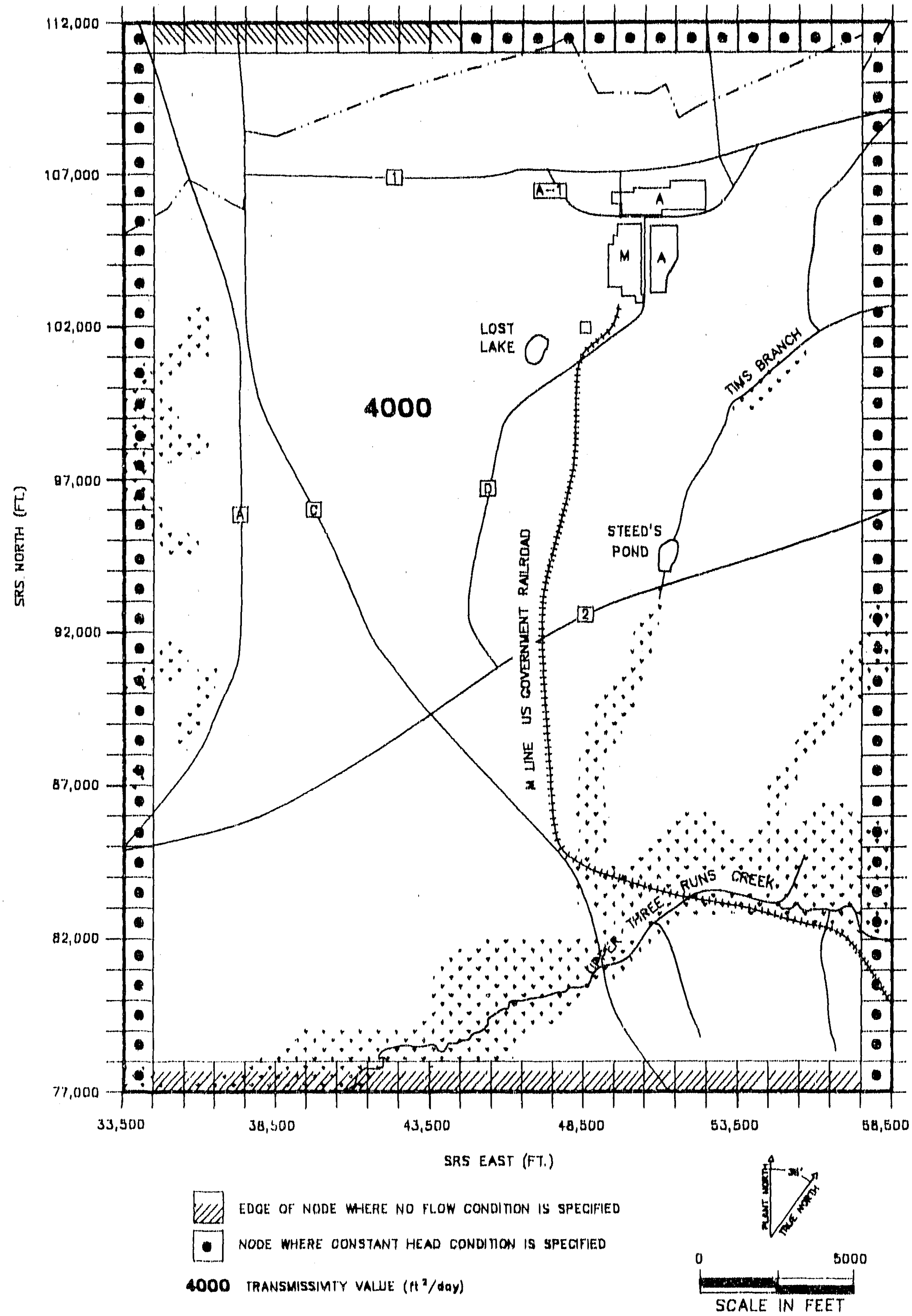

Figure 18. Boundary Conditions and Transmissivity in Model Layer 4.

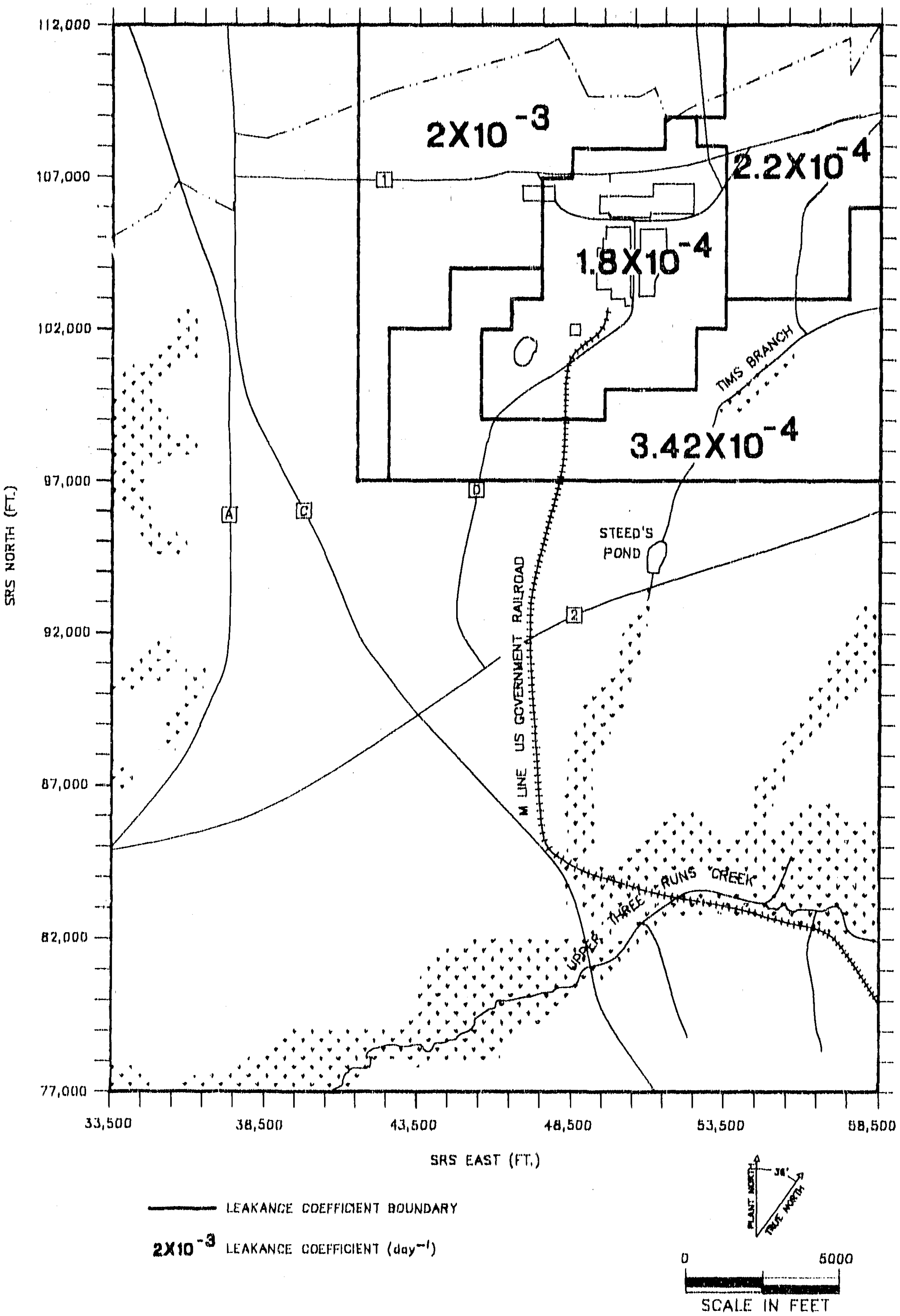

Figure 19. Calibrated Leakance Map for Model Layer 1.

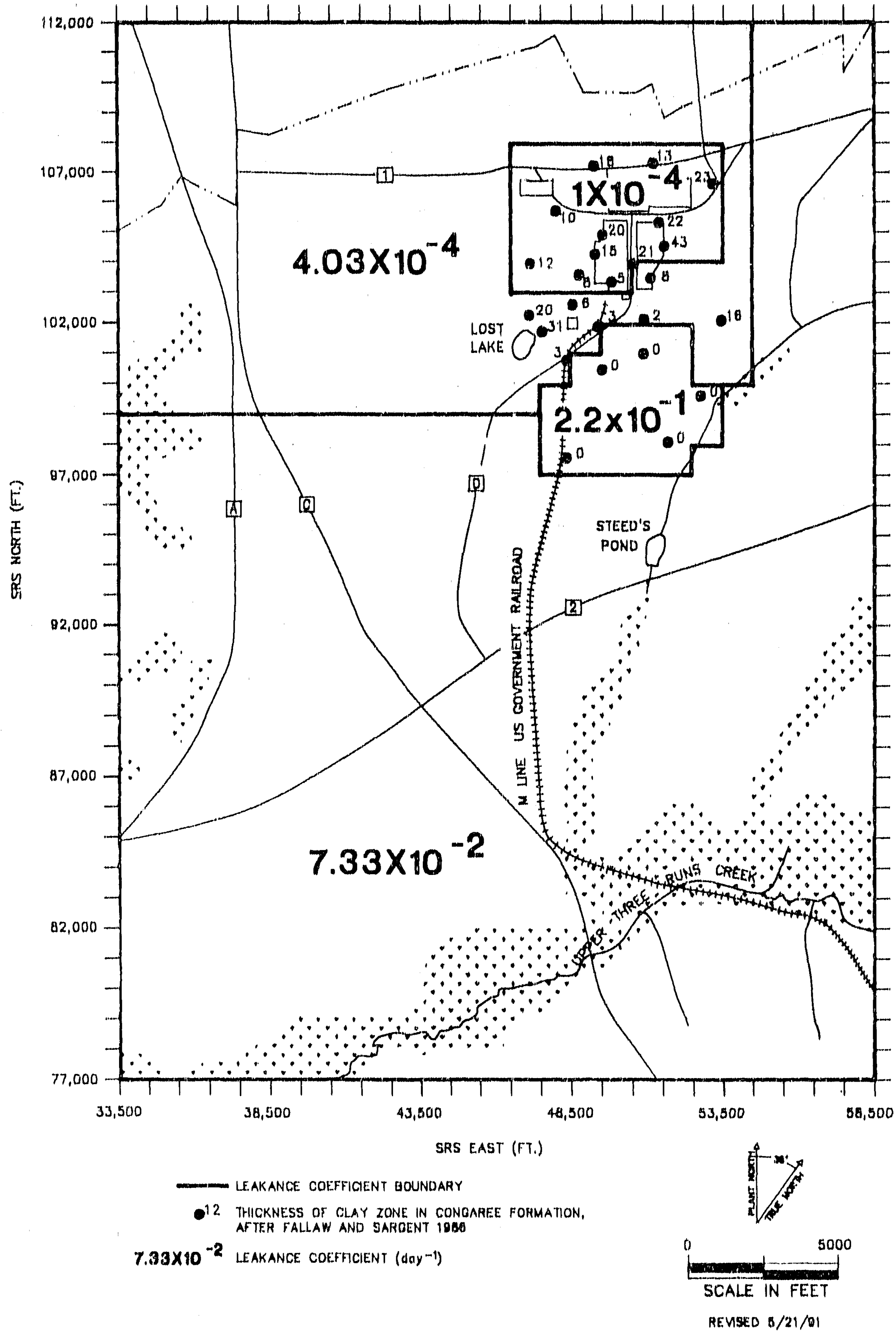

Figure 20. Calibrated Leakance Map for Model Layer 2.

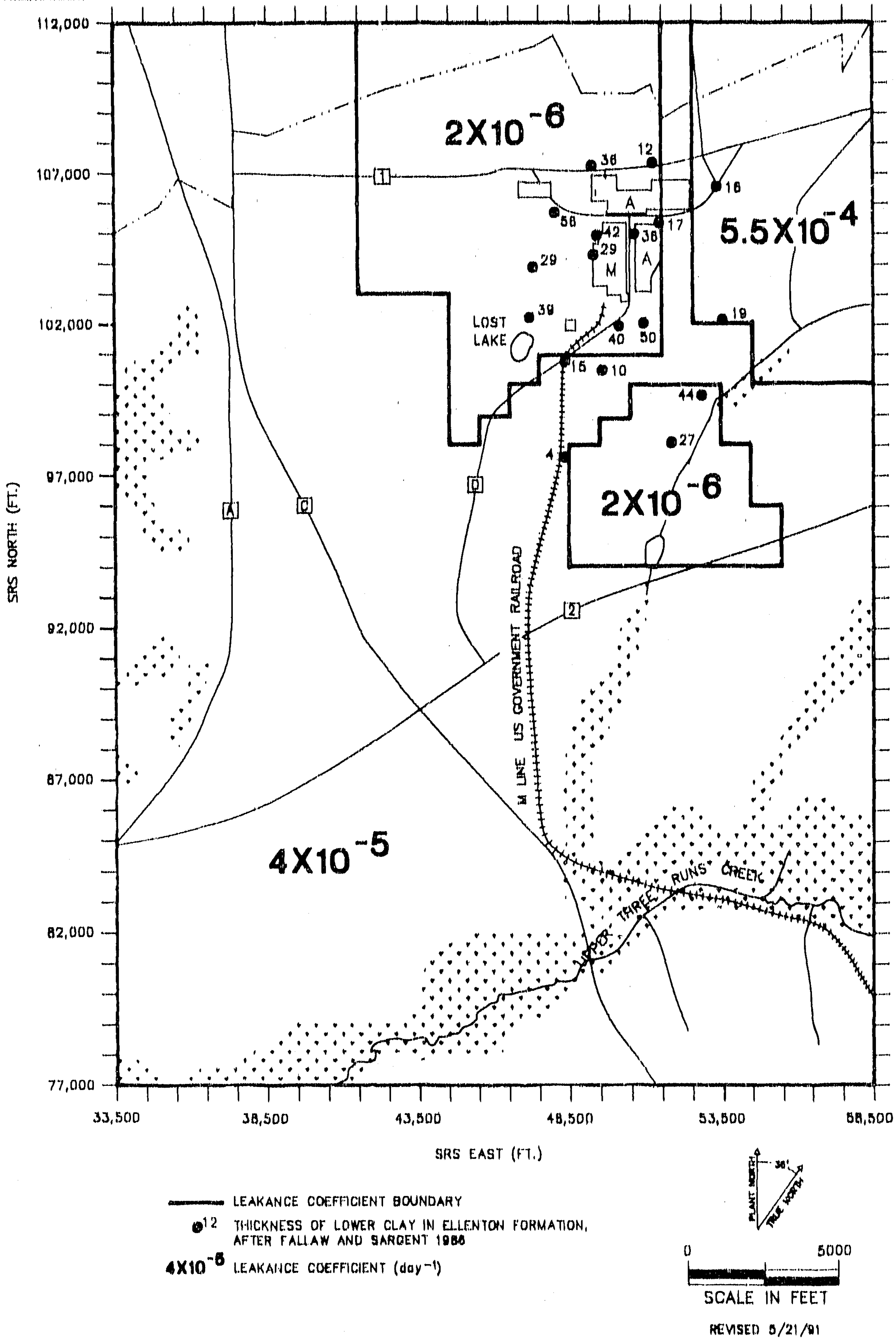

Figure 21. Calibrated Leakance Map for Model Layer 3.

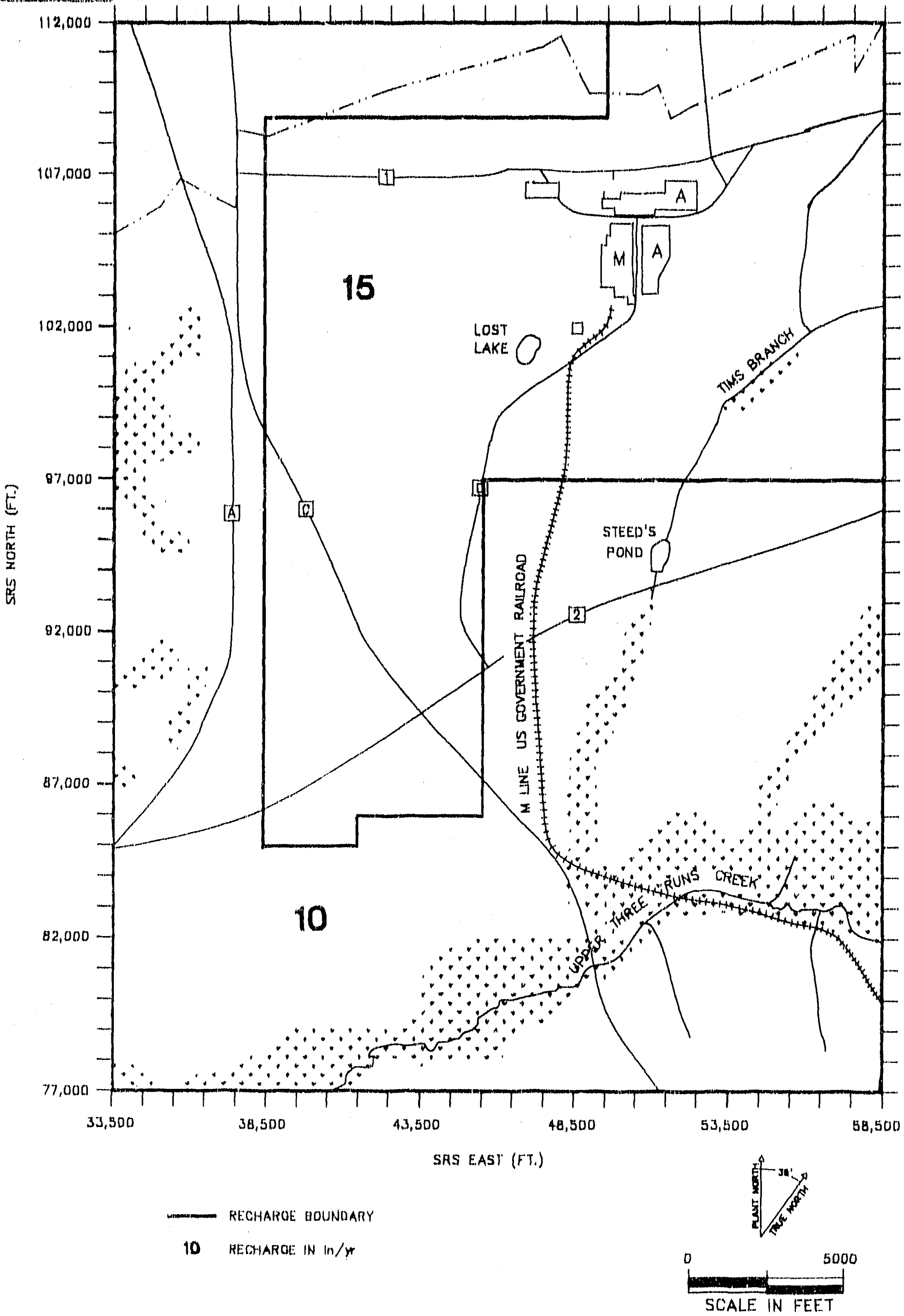

Figure 22. Modeled Rainfall Recharge.

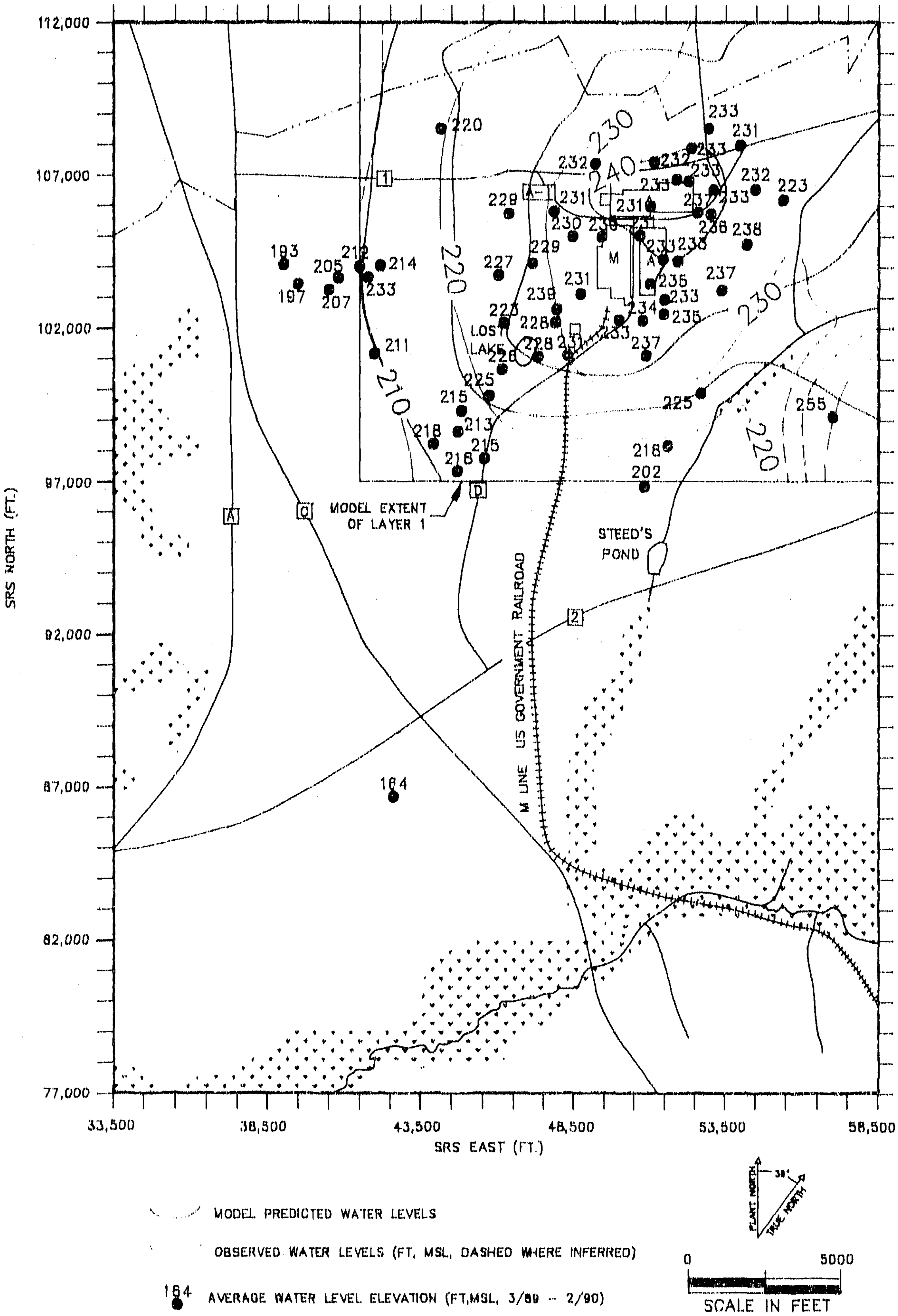

Figure 23. Observed and Model-Predicted Water Levels in Layer 1.

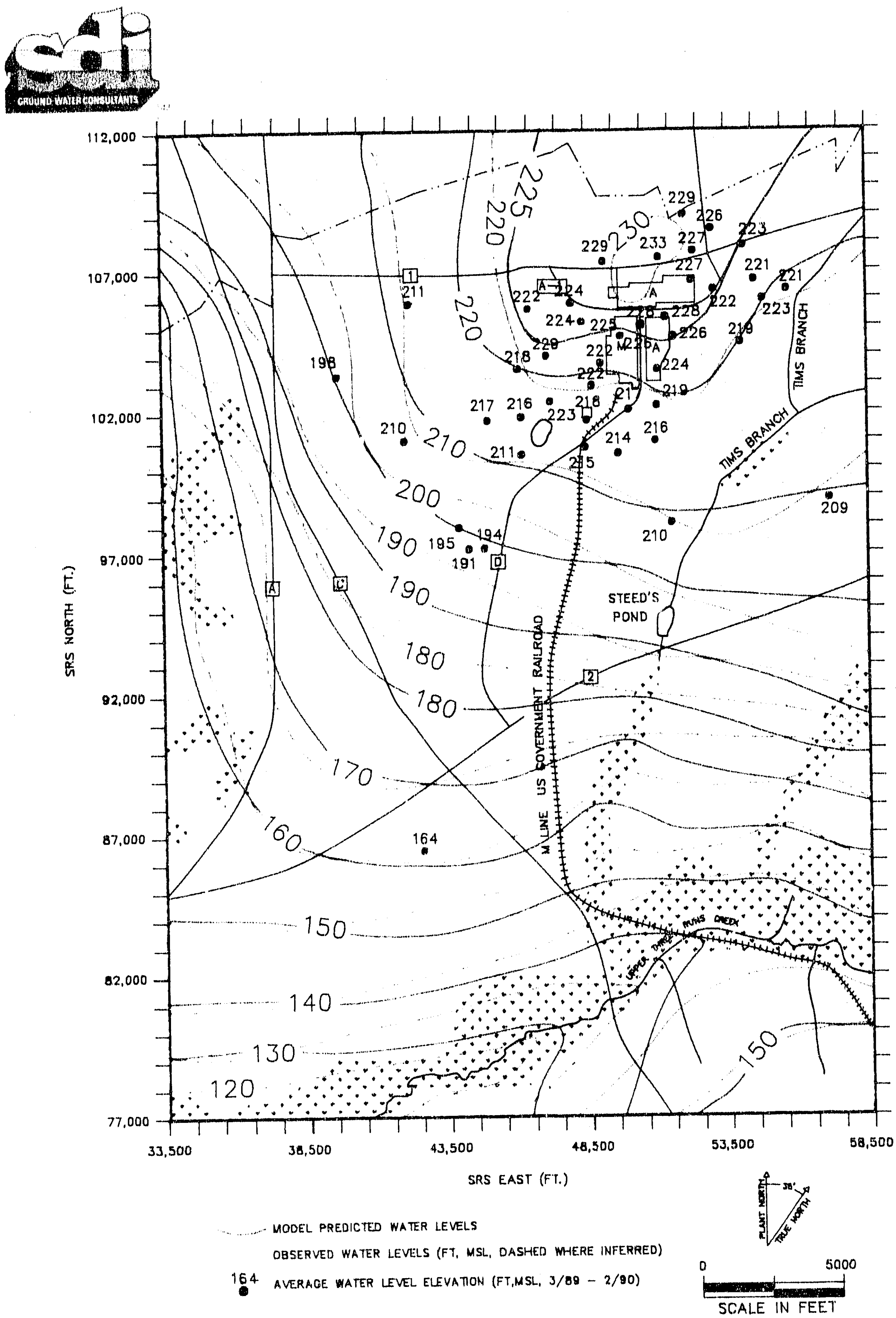

Figure 24. Observed and Model-Predicted Water Levels in Layer 2.

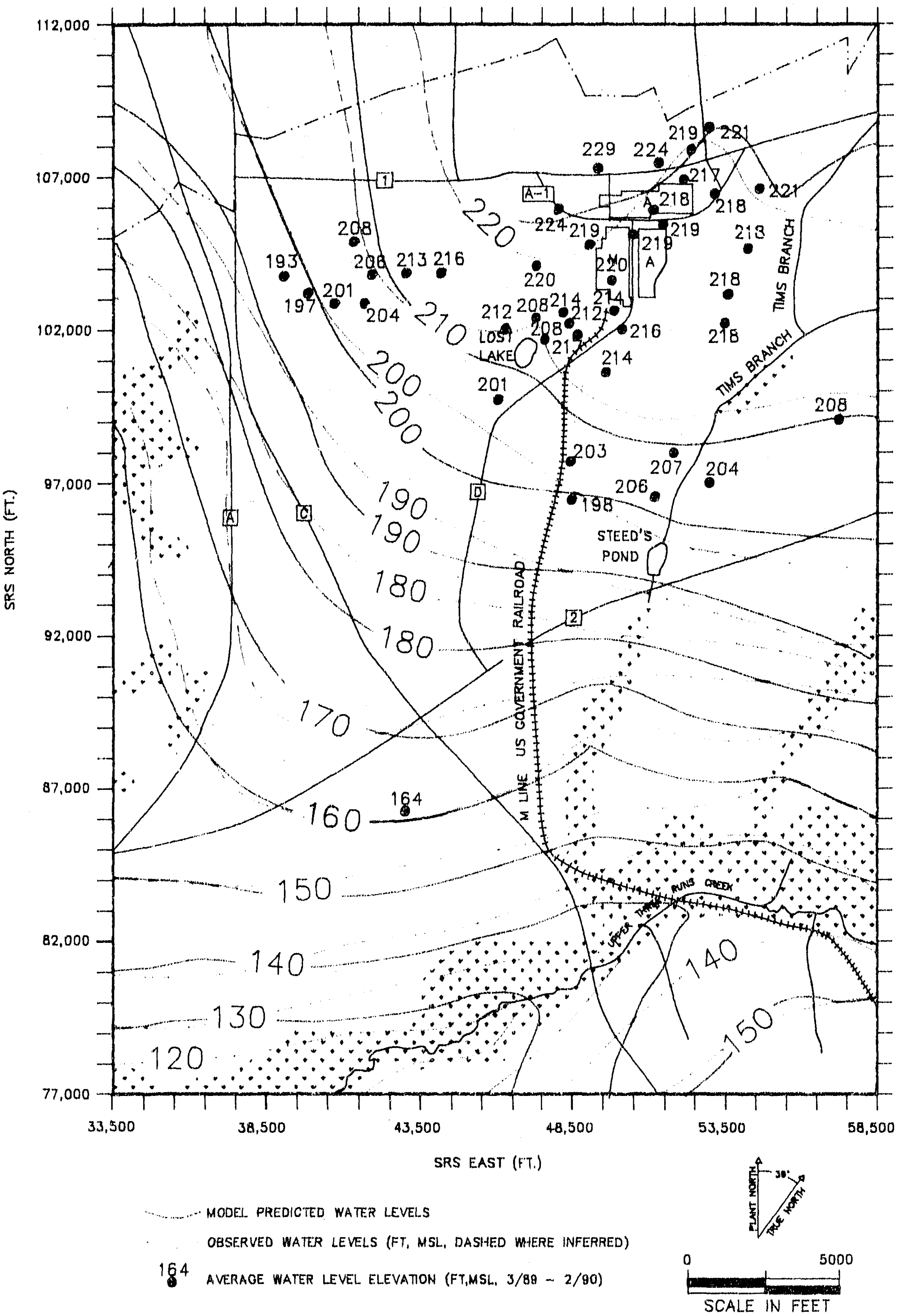

Figure 25. Observed and Model-Predicted Water Levels in Layer 3.

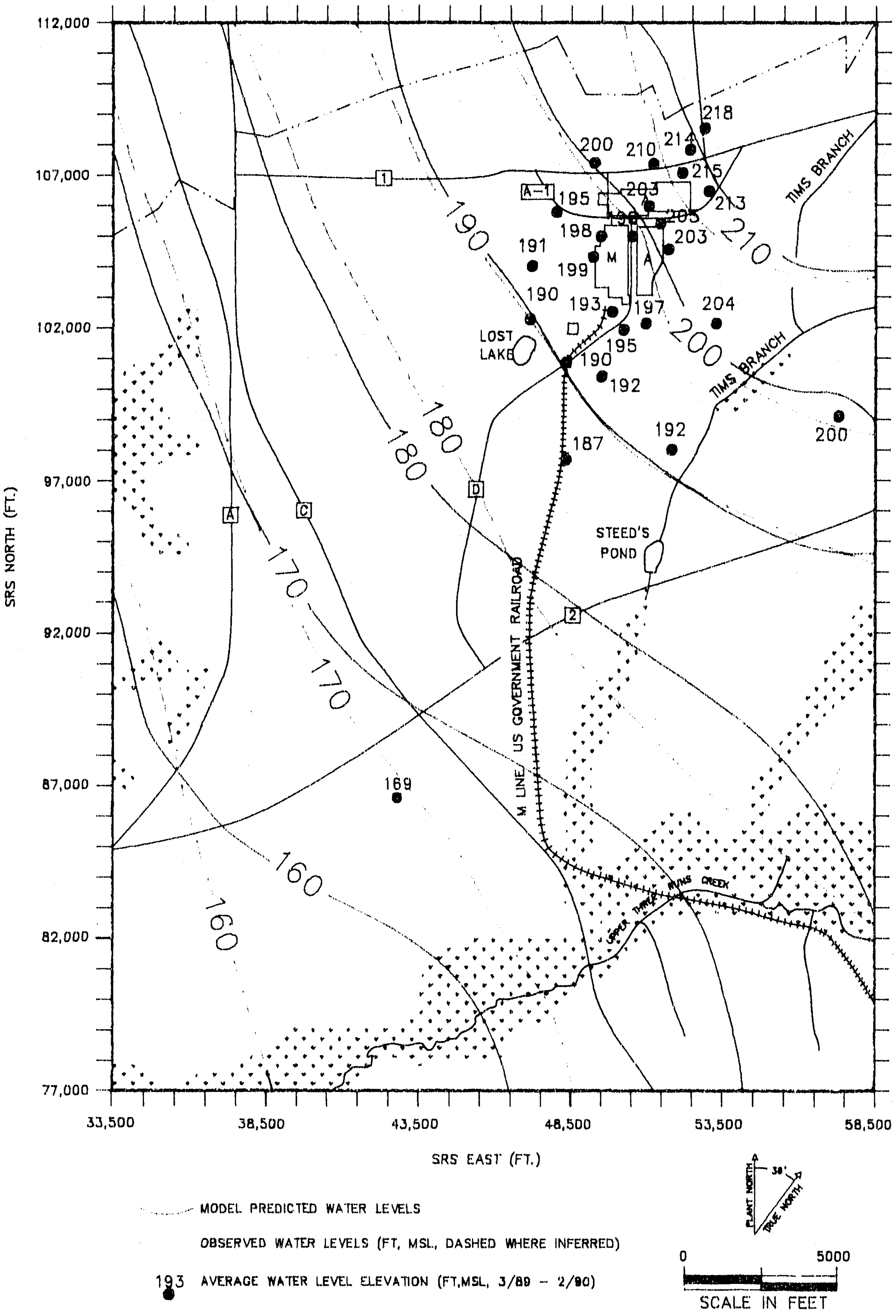

Figure 26. Observed and Model-Predicted Water Levels in Layer 4.

APPENDIX A

Water Level Data

APPENDIX A

Table A-1. Water Table Observed Water Level Data.

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
ABP 1A	97501	44425	219.02
ABP 1DD	97511	44434	219.36
ABP 2A	97764	44119	217.47
ABP 2DD	97754	44127	217.11
ABP 3	97794	44509	219.93
ABP 4	97481	44096	216.74
ABP 4DD	97496	44101	217.59
ABP 6D	97890	44101	217.34
ABP 7D	97450	43930	217.65
ABP 8D	97855	43984	217.08
AC 2B	105649	46445	228.71
AC 3B	100997	42114	211.35
ACB 1A	102624	51360	235.88
ACB 2A	102349	51559	236.77
ACB 3A	102162	51332	236.85
ACB4 A	102324	51113	237.50
AMB 4	104126	51480	232.95
AMB 5	104083	51467	232.87
AMB 6	104034	51466	232.93
AMB 7	103920	51625	233.24
AOB 1	101918	50486	235.12
AOB 2	102010	50725	235.35
ARP 2	99120	44876	214.99
ARP 3	98638	44904	216.66
ARP 4	98568	44375	213.13
ASB 2A	105615	52855	237.07
ASB 3A	105664	53150	237.43
ASB 4	105942	53175	236.38
ASB 5A	105892	52863	236.17
ASB 6A	105722	52674	235.46
ASB 7	105777	52625	234.04
ASB 8	106390	53132	232.71
ASB 9	104589	54226	238.39
MCB 2	97017	45129	218.40
MCB 4	97532	44705	219.82
MCB 5	97336	44864	219.65
MCB 6	97426	45214	215.25
MCB 8D	97181	44770	220.04

Table A-1. Water Table Observed Water Level Data (Continued).

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
MCB 9D	97606	44859	217.91
MSB 6A	101105	46328	224.80
MSB 7A	100564	46737	226.17
MSB 8A	100796	47303	227.72
MSB 9B	102466	47951	229.77
MSB 10C	102466	47951	229.34
MSB 11D	102670	48580	230.02
MSB 13C	101746	47522	228.38
MSB 15D	102971	48827	231.14
MSB 17B	101995	46238	225.20
MSB 17D	102057	46226	226.76
MSB 18B	100431	46121	220.01
MSB 18C	100431	46121	225.62
MSB 19C	100992	50942	236.94
MSB 20C	103556	46089	226.51
MSB 21C	103973	47237	229.38
MSB 24	104614	49843	237.03
MSB 27	104973	49488	239.05
MSB 28	104942	48517	230.40
MSB 29D	107323	51227	232.26
MSB 29DD	107311	51191	232.37
MSB 30C	105731	48014	230.65
MSB 31C	101980	50090	233.79
MSB 32	99656	52734	225.10
MSB 33	98031	51736	217.75
MSB 34C	104934	50536	230.57
MSB 39D	100859	48396	231.23
MSB 43D	107274	49322	231.44
MSB 43DD	107273	49341	231.63
MSB 44C	103296	51107	235.11
MSB 47D	106960	52184	233.25
MSB 48D	107914	54056	231.41
MSB 49D	99725	45856	224.94
MSB 50D	96617	51044	202.02
MSB 51D	97016	52816	209.05
MSB 52D	103063	53417	236.52
MSB 53D	106448	54553	231.61
MSB 54D	108462	52985	232.69
MSB 56D	108464	44208	220.31
MSB 61D	106095	55391	223.32

Table A-1. Water Table Observed Water Level Data (Continued).

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
MSB 65D	101916	49414	233.08
MSB 66D	105842	51044	231.23
MSB 67D	106831	51972	232.86
MSB 68D	106741	52294	233.44
MSB 69D	107784	52462	232.78
SRW 2	103722	41627	212.23
SRW 3A	103516	41851	211.05
SRW 4	103360	41612	211.83
SRW 5	103418	41240	209.56
SRW 6	103603	41244	210.10
SRW 7	103541	40926	208.71
SRW 8	103470	40456	206.48
SRW 9	103260	39688	196.65
SRW 11	103693	40874	208.49
SRW 12C	103712	39023	193.33
SRW 13C	102987	40682	207.28
SRW 15C	104775	41245	210.81
SRW 16C	103772	42842	213.71

*Average of Quarters II, III, & IV (1989), and Quarter I (1990).

Table A-2. Upper Congaree Observed Water Level Data.

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
ABP 3C	97778	44506	194.04
ABP 8C	97856	44059	194.73
ABW 1	105954	55013	223.15
AC 1A	105865	42239	211.46
AC 2A	105636	46428	221.97
AC 3A	100989	42120	209.74
ASB 8C	106354	53101	221.99
ASB 9C	104568	54201	218.65
MCB 5C	97315	44863	195.05
MCB 6C	97413	45207	195.16
MCB 7C	97140	44871	191.21
MSB 11B	102649	48579	219.94
MSB 11C	102649	48579	221.81
MSB 12B	102252	47140	217.29
MSB 12C	102252	47140	222.76
MSB 13B	101736	47524	196.69
MSB 14B	101639	48519	217.82
MSB 15A	102984	48827	221.62
MSB 16A	103694	48965	222.19
MSB 17A	101977	46246	215.59
MSB 18A	100416	46110	210.70
MSB 19B	100999	50935	216.10
MSB 20A	103545	46061	217.94
MSB 21A	103967	47217	220.61
MSB 23B	104337	49287	223.79
MSB 24A	104685	49845	226.22
MSB 26A	104602	48941	224.72
MSB 27B	104940	49486	225.81
MSB 28A	104948	48522	223.83
MSB 29C	107315	51207	232.72
MSB 30CC	105724	47993	224.43
MSB 31CC	101983	50068	215.61
MSB 33C	97985	51747	209.98
MSB 34B	104945	50535	227.78
MSB 35B	102111	50948	219.14
MSB 36C	100518	49537	213.58
MSB 37C	105283	51440	228.18
MSB 38C	102373	49762	216.86
MSB 39C	100852	48387	214.58
MSB 42B	104570	51583	225.63

Table A-2. Upper Congaree Observed Water Level Data (Continued).

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
MSB 42C	104582	51583	231.03
MSB 43B	107275	49312	229.43
MSB 44B	103296	51096	224.30
MSB 45B	103988	50555	225.94
MSB 47B	106975	52207	226.67
MSB 47C	106975	52207	232.27
MSB 48C	107917	54076	223.10
MSB 53C	106456	54541	221.39
MSB 54C	108447	52956	225.53
MSB 55C	108326	52030	228.74
MSB 61C	106091	55407	221.39
MSB 66C	103967	47217	228.61
MSB 67C	106731	52305	227.39
MSB 68C	106731	52305	226.56
MSB 69C	107780	52448	227.36
MSB 70C	101785	45012	216.79
MSB 82C	107522	51949	228.38
MSB 83C	108405	52385	227.38
MSB 84C	108968	51974	229.08
MSB 85C	107835	53151	223.92
SRW 9B	103242	39697	197.59
SRW 12B	103703	39020	187.50

* Average of Quarters II, III, & IV (1989), and Quarter I (1990).

Table A-3. Lower Congaree Observed Water Level Data.

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
ASB 8B	106362	53110	218.33
ASB 9B	104565	54215	218.13
MSB 9A	102239	48252	211.98
MSB 10B	102488	47943	213.60
MSB 12A	102252	47140	208.46
MSB 13A	101727	47525	207.94
MSB 14A	101630	48522	216.99
MSB 17BB	102009	46221	211.61
MSB 21B	104000	47272	220.12
MSB 25A	103505	49658	220.32
MSB 26B	104647	48945	219.48
MSB 29B	107319	51218	223.51
MSB 30B	105720	47982	224.14
MSB 31B	101981	50079	215.83
MSB 33B	97996	51742	207.37
MSB 34A	104955	50535	318.60
MSB 36B	100515	49526	213.53
MSB 37B	105290	51450	218.64
MSB 38B	102361	49746	213.65
MSB 39B	100845	48377	211.12
MSB 40B	97685	48282	202.56
MSB 41C	102177	53411	216.09
MSB 42A	102204	53411	217.95
MSB 43A	107276	49294	229.08
MSB 49B	99738	45868	201.24
MSB 50B	96433	51054	207.77
MSB 51B	96993	52818	203.51
MSB 52B	103078	53418	217.50
MSB 53B	106444	54574	220.66
MSB 54B	108447	52971	220.71
MSB 66B	105842	51065	218.19
MSB 67B	106842	51990	217.81
MSB 68B	106842	51990	217.44
MSB 69B	107776	52433	219.41
MSB 71B	103802	44055	216.46
MSB 72B	96388	48350	198.26
MSB 73B	107523	51949	200.12
SRW 2B	103730	41632	205.93
SRW 9A	103251	39693	196.98
SRW 12A	103710	39013	192.59

Table A-3. Lower Congaree Observed Water Level Data (Continued).

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
SRW 13B	102994	40676	201.48
SRW 14B	102836	41548	203.54
SRW 15B	104773	41252	207.95
SRW 16B	103772	42826	212.99

* Average of Quarters II, III, & IV (1989), and Quarter I (1990).

Table A-4. **Black Creek Observed Water Level Data.**

Well No.	North SRP (ft)	East SRP (ft)	Water Level* (ft, msl)
ASB 8TA	106375	53125	213.24
MSB 12TA	102260	47133	189.87
MSB 12TB	102260	47133	190.26
MSB 21TA	103980	47218	191.13
MSB 23TA	104299	49226	198.69
MSB 27TA	104951	49487	197.61
MSB 29TA	107330	51246	209.98
MSB 30A	105727	48004	195.35
MSB 31A	101979	50100	195.34
MSB 33TA	98018	51734	192.39
MSB 34TA	104892	50538	195.30
MSB 34TB	104892	50538	198.87
MSB 35TA	102102	50920	197.14
MSB 36TA	100508	49503	192.13
MSB 37A	105295	51440	205.15
MSB 37TA	105295	51440	205.00
MSB 38TA	102435	49810	192.77
MSB 39TA	100831	48358	190.01
MSB 40TA	97660	48277	187.04
MSB 41TA	102177	53430	203.89
MSB 42TA	104546	51583	203.46
MSB 43TA	107276	49282	200.27
MSB 47TA	106988	52219	214.74
MSB 54TA	108446	52986	217.73
MSB 66TA	105843	51097	202.90
MSB 69TA	107772	52418	213.76

* Average of Quarters II, III, & IV (1989), and Quarter I (1990).

Table A-5. Wells Not Used in Contouring Observed Water Level Maps.

Well No.	Unit
AC-1B	Water Table
AMB 10DD	Water Table
ARP 1A	Water Table
ASB 1A	Water Table
MSB 1A	Water Table
MSB 2A	Water Table
MSB 3A	Water Table
MSB 4A	Water Table
MSB 5A	Water Table
MSB 9C	Water Table
MSB 10D	Water Table
MSB 11E	Water Table
MSB 11F	Water Table
MSB 12D	Water Table
MSB 14C	Water Table
MSB 15C	Water Table
MSB 16C	Water Table
MSB 17C	Water Table
MSB 22	Water Table
MSB 23	Water Table
MSB 25	Water Table
MSB 26	Water Table
MSB 35D	Water Table
MSB 36D	Water Table
MSB 37D	Water Table
MSB 38D	Water Table
MSB 40D	Water Table
MSB 41D	Water Table
MSB 42D	Water Table
MSB 45C	Water Table
MSB 46C	Water Table
MSB 51DD	Water Table
MSB 55D	Water Table
SRW 1	Water Table
SRW 10	Water Table
SRW 14C	Water Table
MSB 27A	Upper Congaree
MSB 40C	Upper Congaree
MSB 46B	Upper Congaree

APPENDIX B

An Alternative Interpretation of the TCE Data in the Southern Sector of the Lower Congaree

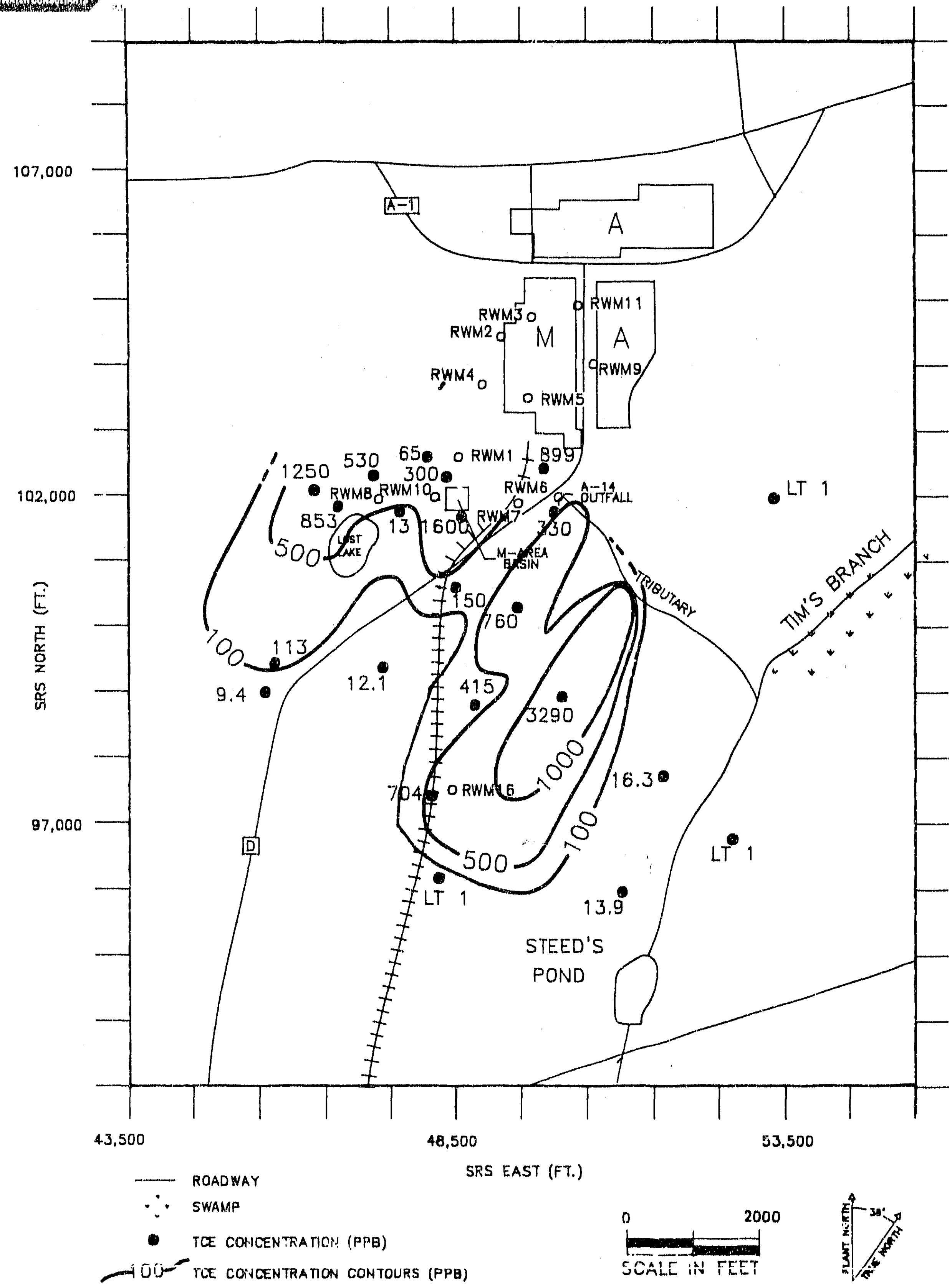

Figure B-1. An Alternative Interpretation of the TCE Data in the Southern Sector of the Lower Congaree.

APPENDIX C

Hardcopy of Model Input
(Units in Feet and Days)

APPENDIX C1

Basic Package - Boundary Conditions and Starting Heads

WSSC.BAS

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COARSE GRID SIMULATION - WESTINGHOUSE SAVANAH RIVER COMPANY
GROUND WATER FLOW MODEL IN THE A/M AREA OF THE SRS
         4        35        25         1         4
11 12  0  0  0  0 17 18 19  0  0 22
         0         0
         6         1(40I2)                      2
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 0 0 0 0 0 0 0 0-1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1-1
 0 0 0 0 0 0 0 0-1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1-1
 0 0 0 0 0 0 0 0-1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1-1
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  202.1   207.4   211.5   214.5   216.3   220.0   221.2
  223.2   225.0   224.9   226.0   227.0   228.0   230.0
  231.0   232.0   233.0   234.0
  170.5   171.6   174.6   179.9   185.6   191.5   197.0
  202.6   207.5   212.0   214.9   217.4   219.7   222.0
  224.2   225.8   226.2   227.4   228.3   232.0   235.8
  237.7   240.1   230.0   233.0
  169.2   169.9   173.2   179.6   185.8   191.6   197.6
  203.2   207.6   212.3   232.0   219.3   221.0   223.2
  225.2   226.6   227.7   228.8   229.7   232.2   235.0
  237.0   239.7   242.8   232.0
  169.8   171.4   175.0   180.3   186.4   192.4   198.4
  203.6   208.0   213.0   217.1   220.5   222.4   224.6
  226.5   227.7   229.2   231.0   231.0   232.5   233.5
  235.4   239.3   243.6   231.0
  171.4   173.7   177.3   182.4   187.8   193.5   199.2
  204.4   208.5   213.6   217.8   221.3   223.7   226.0
  228.0   229.6   230.6   231.4   232.1   232.7   231.9
  233.2   238.5   245.3   230.0
  173.0   175.8   179.4   184.2   189.0   194.2   199.4
  204.8   209.1   214.1   218.0   221.7   224.6   227.2
  229.2   230.7   232.0   232.1   232.5   233.2   231.9
  231.7   237.1   250.1   233.2
  174.9   177.7   181.4   185.7   189.9   194.5   199.6
  205.5   210.1   214.4   218.1   221.6   225.2   228.4
  229.9   231.7   233.7   232.2   231.9   233.7   234.9
  231.1   231.3   259.3   258.3
  175.8   179.6   183.1   186.9   190.2   193.9   199.1
  206.0   211.4   214.3   217.7   221.4   225.2   228.2
  229.7   230.6   238.8   231.0   232.0   235.2   236.9
  237.0   244.1   255.3   257.4
  177.1   180.4   185.2   188.5   190.5   192.6   197.4
  206.0   211.6   213.4   216.7   220.8   224.7   227.8
```

229.7	231.7	234.9	234.0	233.0	235.2	237.2
240.2	246.4	252.3	254.0			
175.5	180.1	186.1	189.9	190.8	192.4	196.1
205.7	210.6	213.1	216.5	220.0	224.0	227.3
229.1	230.4	233.2	235.0	235.4	235.6	236.5
239.1	243.9	248.2	250.2			
172.4	178.7	183.3	187.9	189.9	192.7	197.6
203.8	209.1	213.0	216.3	219.0	223.0	226.6
228.5	230.8	233.1	235.1	236.6	235.0	234.6
236.2	239.0	243.6	248.2			
170.9	172.4	176.6	182.4	186.9	191.5	196.1
202.2	207.9	212.5	215.2	217.8	221.7	225.3
228.4	231.4	232.7	235.2	235.1	232.1	230.7
232.3	237.6	244.0	248.9			
167.7	168.2	171.9	177.0	182.4	188.3	194.6
200.7	206.1	210.7	213.2	216.2	221.9	224.8
226.6	228.0	229.0	230.2	229.6	227.4	224.8
229.1	237.4	246.5	251.7			
165.6	165.8	170.0	172.3	179.1	186.0	192.8
199.1	204.1	209.2	212.2	214.0	219.4	222.4
222.5	222.6	223.0	223.4	223.2	221.3	220.3
226.9	236.5	248.0	254.0			
165.0	165.2	163.3	169.5	177.0	184.3	191.1
197.1	203.3	209.5	214.3	218.1	217.1	218.3
218.4	217.9	216.9	216.0	216.8	214.8	217.1
223.7	232.6	241.7	246.7			
164.8	170.0	168.0	171.1	177.0	183.6	190.3
195.9	202.3	207.8	213.9	218.4	216.1	213.6
212.2	211.3	209.7	207.2	206.6	208.0	212.6
219.2	226.5	233.3	238.0			
161.5	165.4	168.5	172.3	177.3	183.1	188.6
193.2	199.0	204.3	208.3	211.9	211.2	209.5
207.5	205.5	203.9	201.8	201.8	204.5	208.5
213.8	219.8	225.4	229.7			
157.6	161.3	167.3	172.4	177.3	181.5	186.3
191.3	195.6	199.5	202.8	205.5	204.3	203.3
201.8	200.8	199.5	199.0	200.0	201.0	203.9
208.4	213.4	218.2	222.3			
154.1	160.1	167.0	172.1	176.4	180.6	184.8
188.8	191.7	194.7	196.8	198.7	197.7	197.4
196.7	195.4	195.0	195.0	195.0	195.6	198.5
201.9	206.2	210.8	214.8			
150.0	160.8	168.3	172.4	175.8	179.3	182.9
185.4	188.0	190.0	191.5	193.5	191.8	191.9
190.6	189.4	188.9	190.0	188.9	189.4	191.1
194.3	198.1	202.9	207.4			
154.6	163.8	170.0	172.0	174.8	177.7	180.7

182.4	184.3	185.6	186.3	188.2	185.6	185.7
184.0	182.4	181.3	180.0	181.1	182.0	183.9
185.6	188.5	193.1	199.4			
155.9	160.8	165.9	170.0	173.4	175.9	178.1
180.3	182.0	182.6	182.7	183.4	181.4	180.1
177.6	175.7	174.0	173.3	173.8	174.6	176.2
176.9	177.6	179.0	185.2			
156.5	159.8	164.7	169.4	172.1	173.8	176.1
177.3	177.9	178.4	177.7	177.5	176.4	174.3
171.7	169.1	167.0	166.8	167.3	168.7	168.9
168.4	168.1	168.3	173.5			
157.3	161.6	166.9	170.0	170.1	170.1	172.9
173.6	174.3	174.7	173.7	172.7	171.3	169.3
166.2	163.2	160.0	161.0	162.2	163.0	162.7
161.9	161.4	162.4	165.8			
157.4	161.9	164.7	166.5	166.9	167.0	167.2
167.8	170.3	170.3	169.8	168.4	166.0	164.4
161.8	159.3	157.5	157.4	157.8	158.0	157.7
156.1	155.2	156.2	158.9			
153.4	157.9	160.2	161.8	162.7	163.2	163.8
164.2	164.6	165.6	164.5	162.4	160.2	158.6
157.3	155.9	154.5	153.6	153.5	154.2	153.8
151.4	149.4	149.9	152.3			
148.2	151.9	154.8	156.5	157.4	158.4	159.0
159.5	160.0	160.8	159.4	157.3	155.7	154.4
153.4	152.4	152.0	149.5	147.6	150.0	149.9
148.6	144.5	143.7	145.8			
144.7	147.1	149.6	151.0	152.4	153.1	152.9
153.2	153.9	153.8	152.7	151.0	149.9	148.0
147.5	148.2	150.0	144.2	139.7	137.3	141.2
141.3	138.1	137.8	139.4			
140.9	142.6	144.3	145.5	146.8	146.6	147.0
147.1	147.4	147.0	145.8	144.3	142.4	141.6
141.5	141.6	140.8	137.3	133.3	131.9	131.8
131.8	132.2	134.8	137.4			
137.4	138.0	138.9	139.9	140.5	140.7	141.3
141.2	141.1	140.3	138.9	136.8	135.8	135.2
135.3	135.2	134.8	133.7	130.0	133.5	130.0
132.6	134.3	140.0	145.8			
133.3	133.9	134.5	135.2	135.2	135.3	135.4
134.9	134.9	134.7	133.1	130.0	129.3	129.1
130.0	130.4	131.8	137.9	144.6	150.3	152.7
154.1	157.2	162.8	166.1			
129.7	129.9	130.3	130.6	130.3	129.6	129.5
129.4	129.5	129.2	130.0	126.3	124.4	124.0
124.2	123.1	130.0	148.5	165.1	176.6	182.1
183.5	185.3	189.4	189.7			

126.1	125.7	126.0	126.1	125.6	125.0	124.5
124.5	124.4	124.0	123.8	122.0	120.6	121.2
124.5	127.5	142.4	164.5	188.3	204.9	212.7
210.6	209.1	210.0	204.4			
122.9	122.5	122.5	123.0	122.4	121.4	120.0
120.9	121.0	120.0	120.2	119.3	118.7	120.0
131.4	142.1	158.4	180.1	203.2	220.7	230.0
228.7	225.2	218.6	212.6			
120.0	120.0	120.7	120.7	120.3	119.7	119.3
119.8	119.8	119.8	120.0	119.9	120.0	130.0
140.1	154.2	171.4	192.2	213.2	228.6	236.3
238.2	237.7	226.9	219.6			
	6 0.100E+01(7G11.4)			12		
197.8	200.3	202.1	203.6	205.4	207.7	208.8
211.0	213.1	216.8	218.9	221.1	222.5	223.5
227.9	228.0	228.2	228.4	227.7	227.1	226.1
225.2	224.4	223.8	223.4			
196.6	199.0	201.1	203.1	204.8	207.3	208.6
211.1	212.6	216.1	218.3	220.9	222.5	223.8
227.8	228.4	228.8	229.0	228.1	227.0	225.7
224.6	223.9	223.3	222.8			
195.9	197.9	200.6	202.1	203.9	206.2	208.1
210.4	212.7	215.5	218.0	220.6	222.4	224.2
227.8	228.8	229.9	229.8	228.7	226.6	224.9
223.9	223.2	222.7	222.3			
193.9	196.0	199.3	201.4	203.1	205.2	207.3
209.7	212.1	215.6	217.7	219.9	222.0	224.3
227.5	229.1	230.5	230.7	228.8	225.5	223.8
223.0	222.5	222.0	221.7			
191.8	194.7	196.9	200.0	202.2	204.1	206.8
209.0	211.6	214.7	217.2	219.6	221.6	223.9
226.8	228.9	230.8	232.2	228.5	224.7	222.6
222.1	221.8	221.4	219.5			
190.2	193.2	195.6	197.9	200.4	202.6	205.4
208.1	211.0	214.0	216.5	218.9	221.3	223.6
225.6	227.6	229.6	230.5	227.9	222.8	221.6
221.9	221.2	220.9	218.6			
188.4	191.2	194.2	196.5	198.8	201.2	203.9
207.2	210.3	213.1	215.8	218.2	220.8	223.1
224.2	225.8	227.8	228.7	226.8	222.8	220.9
221.6	220.5	218.5	217.5			
186.4	189.6	192.8	195.1	197.0	199.1	202.1
205.9	209.6	212.6	215.0	217.4	220.0	223.5
224.1	224.4	226.0	227.7	226.6	222.6	219.2
219.2	218.1	217.1	216.3			
183.5	187.5	191.2	193.4	195.0	196.7	199.7
204.8	209.1	212.2	215.0	216.6	217.8	222.5

223.2	222.0	222.8	224.9	224.0	221.9	219.9
218.0	216.9	216.0	215.2			
179.7	183.9	190.0	190.9	192.6	194.9	198.8
204.2	209.1	212.1	214.7	216.7	217.1	220.2
220.9	219.5	217.9	220.6	221.4	220.9	219.3
217.8	216.6	215.4	214.4			
174.6	177.7	182.5	186.3	189.4	193.1	197.6
203.5	209.2	211.4	213.3	215.3	214.7	216.2
217.2	216.3	215.1	217.4	219.3	219.8	218.9
217.2	215.5	214.1	213.1			
169.8	170.0	176.4	181.3	185.9	190.2	195.3
200.8	206.3	208.4	209.4	210.2	211.0	212.1
213.1	213.6	213.8	215.4	217.6	219.3	218.6
216.6	214.4	212.6	212.1			
166.9	168.7	172.5	177.0	182.2	187.2	191.8
196.3	200.3	202.7	204.1	204.8	206.2	207.8
209.2	210.2	211.3	213.3	216.1	219.2	217.8
215.1	212.5	210.5	210.5			
165.3	163.6	166.0	173.3	179.0	184.1	188.5
192.0	195.1	196.9	198.3	199.3	201.5	203.7
205.1	206.7	208.2	210.2	212.7	214.7	214.7
212.8	210.9	209.2	209.6			
166.6	166.5	167.2	172.1	177.1	181.6	185.5
188.2	190.6	192.2	192.9	195.3	197.1	199.2
201.1	203.4	205.2	207.2	209.0	210.6	210.9
210.5	209.7	209.5	209.7			
166.0	168.3	169.5	172.6	176.2	179.8	183.1
185.7	187.2	188.0	188.5	190.7	193.2	195.4
197.5	199.9	202.0	204.2	205.7	206.9	207.7
208.2	208.6	209.3	210.0			
161.5	165.6	169.9	172.6	175.3	177.9	180.3
183.8	185.7	184.3	184.3	187.3	189.1	191.4
193.6	196.2	198.6	200.9	202.3	203.2	204.0
205.4	207.0	208.9	210.0			
157.5	162.7	168.4	171.8	174.4	176.8	178.6
180.3	181.1	181.0	181.6	184.2	185.6	187.1
189.4	192.1	195.1	197.1	198.0	198.7	199.6
202.2	204.8	207.8	209.9			
154.3	160.4	166.2	170.5	173.4	175.6	177.3
178.0	178.5	178.8	178.5	179.7	182.3	183.3
185.9	188.2	190.9	192.5	192.6	193.2	194.8
197.4	200.8	205.2	209.3			
153.4	159.6	165.5	170.0	172.8	174.6	175.6
176.6	176.3	177.1	176.7	177.6	178.8	179.8
181.5	182.4	184.2	185.4	185.7	186.7	188.1
190.4	194.3	200.1	204.9			
154.9	160.0	166.3	170.9	173.2	174.6	175.8

175.9	176.3	176.2	176.2	175.8	176.2	176.3
175.8	176.2	176.4	177.3	178.6	179.5	180.4
181.6	184.1	190.3	194.4			
156.6	160.0	167.2	171.2	172.8	173.7	174.1
174.9	174.7	175.3	173.4	172.8	172.2	171.7
170.7	170.0	170.0	170.6	171.6	172.2	172.5
172.6	172.3	175.2	181.6			
158.8	163.5	168.9	170.9	171.7	172.1	172.5
173.1	173.4	172.5	171.3	170.2	169.1	167.6
165.7	163.8	163.5	164.8	165.6	165.6	165.3
164.8	164.8	167.2	171.7			
160.0	164.2	168.1	169.0	169.3	169.6	170.0
170.3	170.6	169.8	168.6	166.2	165.2	163.4
161.5	159.4	158.8	159.6	160.4	160.3	159.4
158.5	158.8	161.0	164.1			
160.0	161.7	163.7	165.0	165.3	165.9	166.4
167.0	167.5	167.0	165.4	163.0	161.4	159.9
158.0	156.6	155.7	155.5	156.1	155.9	154.5
152.5	153.3	155.2	157.7			
152.6	156.4	158.6	159.8	160.5	161.2	161.7
162.5	163.2	163.7	161.0	158.9	157.3	155.9
154.8	153.9	152.6	151.2	151.4	152.1	151.4
149.3	149.1	150.1	151.8			
148.0	150.9	153.1	154.3	155.2	156.0	156.5
157.1	157.4	157.0	155.2	153.4	152.3	151.4
151.2	151.3	149.2	145.2	142.4	144.1	150.0
146.6	145.5	145.5	146.0			
144.0	146.0	147.5	148.7	149.7	150.2	150.8
150.6	150.6	150.0	148.5	147.1	146.4	146.2
146.2	146.6	144.3	139.4	137.0	137.7	140.1
140.6	141.3	141.8	140.9			
140.0	141.1	142.3	143.3	143.9	144.3	144.7
144.3	144.0	142.9	141.5	140.3	140.0	140.1
140.3	140.2	138.6	136.0	133.8	132.7	132.8
133.5	137.8	140.2	139.7			
135.8	136.6	137.4	137.9	138.2	138.5	138.6
138.2	137.9	136.8	134.7	133.3	133.5	133.9
134.4	134.7	134.3	132.8	131.1	129.6	129.1
129.9	134.9	138.1	138.5			
131.8	132.2	132.6	132.9	132.9	132.8	132.5
132.5	132.4	132.0	129.9	127.8	127.9	128.5
128.6	129.6	131.2	130.4	129.3	128.4	128.3
129.7	132.6	135.2	136.5			
127.9	128.2	128.4	128.3	128.0	127.5	127.1
127.1	127.0	127.1	125.8	123.6	123.4	125.4
123.7	123.6	128.1	128.4	128.0	127.8	128.0
129.2	131.1	133.2	135.3			

124.4	124.6	124.7	124.5	123.8	122.7	122.3
122.7	122.3	122.1	121.6	120.6	121.7	127.1
127.6	125.4	126.5	127.2	127.3	127.3	127.8
128.8	130.2	132.0	133.6			
121.2	121.6	122.0	121.8	121.0	119.9	119.7
120.2	119.8	119.5	119.5	119.7	124.2	129.2
129.0	127.2	126.6	126.8	126.9	127.1	127.5
128.2	129.5	130.8	152.6			
119.4	120.0	120.4	120.0	119.5	118.9	119.0
119.6	119.6	119.1	119.2	120.1	124.7	128.8
128.3	127.3	126.6	126.8	150.0	151.5	152.2
154.8	155.9	157.1	158.4			
6 0.100E+01(7G11.4)				12		
191.2	197.6	198.1	198.8	200.6	203.0	205.1
211.1	213.0	215.0	220.1	220.2	225.3	228.3
228.3	227.4	226.8	226.1	225.5	224.6	223.9
223.4	223.1	221.9	221.8			
195.0	196.1	196.9	199.0	201.1	202.9	206.3
210.4	212.6	214.7	220.2	221.6	221.9	228.4
228.5	228.2	227.0	226.1	225.1	224.1	223.3
222.9	221.8	221.7	221.6			
193.3	194.3	196.4	198.2	200.5	202.4	204.4
207.8	212.0	214.4	219.7	221.2	222.6	228.2
228.7	228.5	227.3	226.1	224.7	223.3	222.5
221.6	221.5	221.5	221.4			
191.9	193.7	195.5	197.4	199.7	201.7	203.9
207.4	210.3	212.7	217.7	220.9	222.4	226.5
228.4	228.8	227.9	226.3	223.9	222.1	221.2
221.2	221.2	221.2	221.1			
191.0	192.7	194.4	196.4	198.6	200.9	203.4
206.8	210.0	212.7	217.3	221.1	222.4	225.2
228.1	228.8	228.4	226.0	222.9	220.0	220.2
220.7	220.9	220.9	220.8			
189.9	191.6	193.5	195.3	197.4	199.7	202.5
205.4	209.7	212.7	215.3	220.3	222.4	225.2
226.9	227.6	227.4	224.2	220.5	218.0	219.2
220.5	220.7	220.5	220.4			
187.8	190.5	192.3	193.9	195.9	198.0	201.2
205.1	209.2	212.5	216.3	219.0	220.9	223.4
224.6	224.5	223.1	220.6	218.2	217.8	218.7
219.9	220.2	220.3	220.3			
186.0	188.6	191.0	192.9	194.1	195.7	199.1
204.1	209.0	212.4	215.9	218.1	219.9	221.2
222.2	221.3	220.2	218.7	218.5	217.9	218.4
218.7	219.2	219.7	219.8			
183.9	186.7	189.8	191.7	192.4	193.0	196.4
202.0	206.4	211.5	215.2	216.9	217.8	218.5

219.8	219.2	219.8	219.0	218.3	218.3	217.9
218.1	218.5	216.4	215.6			
181.2	184.1	188.3	190.7	190.9	191.9	195.7
200.6	203.8	208.6	212.5	214.0	214.5	214.1
214.6	216.1	217.2	217.5	217.5	217.5	217.5
217.7	215.9	215.1	214.3			
177.3	179.6	183.8	187.4	188.9	189.7	193.1
198.9	202.2	205.6	208.7	210.0	211.1	210.3
208.9	214.5	214.7	216.1	216.5	216.7	216.8
215.7	214.6	213.9	213.4			
172.9	173.3	176.3	180.9	184.9	188.0	190.0
194.2	200.6	203.0	205.5	206.0	206.8	206.5
208.2	212.5	214.4	215.0	214.3	214.3	214.1
213.4	212.7	212.1	211.7			
169.4	169.1	171.6	175.8	180.1	184.3	187.2
190.7	199.1	200.8	202.8	202.8	202.4	203.5
205.9	209.0	211.5	211.9	212.2	212.0	211.3
210.8	210.3	209.9	209.9			
166.8	166.5	170.0	171.8	175.7	180.2	184.2
187.7	190.9	200.0	201.3	200.2	200.6	201.7
203.9	206.3	208.3	209.3	209.8	209.4	208.7
208.4	208.3	208.1	208.4			
166.1	165.8	163.3	168.7	173.5	176.9	181.8
186.2	187.6	191.2	198.8	199.6	199.7	200.4
201.6	203.7	205.9	207.4	207.6	206.7	206.2
206.5	206.8	207.2	207.9			
165.8	170.0	167.9	169.3	171.7	174.1	180.4
184.2	187.6	188.4	197.8	198.8	198.6	198.8
199.4	200.8	203.8	206.5	206.8	204.4	204.2
204.9	205.6	206.6	207.8			
162.4	165.7	168.4	170.6	172.3	173.9	175.3
182.8	185.4	187.6	189.3	198.0	197.9	198.1
198.0	198.8	202.1	205.2	206.0	204.2	203.0
203.2	204.3	206.1	207.9			
158.1	161.2	167.1	170.7	172.0	173.5	174.7
182.2	183.7	185.7	186.8	197.7	188.2	189.4
190.9	193.0	195.4	197.5	198.4	200.0	200.1
200.9	202.8	205.4	208.1			
154.2	158.4	164.3	168.9	171.6	173.4	174.6
175.6	184.4	182.6	179.3	183.3	184.4	185.3
186.4	188.0	189.7	191.0	192.2	192.8	195.8
197.2	199.6	203.3	207.3			
150.0	156.5	162.8	168.0	171.2	173.3	174.6
172.0	179.7	178.0	178.3	178.0	180.2	180.7
181.5	182.7	183.6	184.9	185.9	186.7	188.0
191.4	194.4	199.2	205.3			
152.2	156.8	162.8	168.1	171.4	171.5	171.6

171.4	175.8	176.5	175.4	175.4	176.5	177.6
177.6	178.0	178.2	178.3	179.1	179.9	180.9
182.7	186.6	192.0	199.3			
154.0	157.7	163.4	170.0	171.4	171.9	171.9
171.7	174.2	173.9	173.9	174.1	174.3	173.7
173.1	172.6	172.1	172.5	173.4	174.4	170.0
171.9	175.7	178.6	185.6			
155.7	159.4	164.9	169.7	171.2	171.3	171.0
170.9	170.8	172.8	172.4	171.9	171.1	170.0
168.2	167.0	166.0	166.3	162.6	164.2	164.9
165.1	167.2	168.3	173.9			
157.3	161.7	167.0	170.2	170.3	170.1	169.9
169.5	168.8	167.9	167.1	169.0	167.9	166.0
164.3	162.4	160.0	159.6	159.5	159.5	160.0
160.5	161.0	162.7	166.1			
157.4	161.9	165.3	167.6	167.0	167.8	167.6
167.5	166.9	166.6	165.3	163.3	161.7	160.5
159.3	158.7	157.4	157.1	157.0	156.9	155.7
155.1	155.4	157.0	159.2			
153.5	158.2	160.4	162.0	162.7	163.2	163.4
163.5	164.2	164.8	163.3	161.0	159.3	157.6
157.0	155.8	154.7	154.0	153.3	153.8	153.4
151.3	150.7	152.1	153.3			
148.4	152.1	154.9	156.7	158.0	158.0	158.5
159.1	159.9	160.6	159.5	157.0	155.3	153.8
153.5	151.2	151.9	149.8	147.5	150.0	149.8
149.9	148.4	148.4	148.6			
144.6	146.6	148.9	150.5	151.6	152.8	153.2
153.5	154.2	153.3	152.7	150.9	150.0	149.3
149.0	148.2	150.0	144.5	140.3	138.8	143.0
144.8	144.3	144.8	144.4			
140.8	142.4	143.8	145.1	146.1	146.0	147.0
147.3	147.7	146.5	146.0	144.3	143.1	142.8
140.4	142.5	142.7	139.9	136.6	135.1	135.8
136.8	138.6	141.1	141.2			
137.2	137.6	139.0	139.1	139.7	140.2	140.8
142.0	140.2	139.9	138.8	136.8	136.5	134.1
135.6	137.1	137.3	135.8	133.5	131.4	130.0
130.4	133.0	140.0	139.6			
133.3	133.3	132.9	132.8	133.9	133.8	133.5
134.1	134.6	134.4	133.2	130.0	128.7	129.7
130.7	131.9	133.2	132.3	130.6	129.1	128.2
129.1	131.7	135.6	137.3			
129.7	129.2	129.0	128.8	127.5	128.5	128.7
129.0	129.2	129.5	130.0	127.3	125.5	125.8
126.0	124.6	130.0	130.5	128.8	127.6	127.5
129.1	131.0	133.4	135.1			

126.1	125.7	125.6	124.9	124.3	121.5	121.7
122.2	124.4	123.8	124.5	123.3	121.2	123.9
126.4	123.5	126.1	128.3	127.6	128.1	128.4
128.3	130.3	131.7	133.7			
122.9	122.5	122.5	122.4	120.6	120.4	120.0
120.5	120.6	120.0	121.0	120.5	121.1	125.9
129.7	128.2	126.8	127.6	128.8	129.1	128.3
127.6	128.8	131.1	152.7			
120.0	120.0	120.7	120.7	120.0	119.8	119.7
119.8	119.8	119.6	119.8	119.8	120.0	130.0
130.0	129.4	128.7	128.5	150.0	151.5	152.2
154.3	155.2	156.2	158.4			

6 0.100E+01(7G11.4)   12

174.7	176.2	177.7	179.5	181.6	183.8	186.1
188.4	190.7	192.9	195.2	197.4	199.6	201.7
203.9	206.4	208.9	210.9	212.2	213.3	214.0
214.4	214.7	214.8	214.6			
173.5	175.0	176.7	178.6	180.7	182.8	185.1
187.5	189.8	192.1	194.3	196.4	198.4	200.4
202.8	205.5	208.3	210.6	212.3	213.4	214.2
214.6	214.8	214.9	214.8			
172.2	173.8	175.6	177.6	179.6	181.8	184.1
186.5	188.9	191.2	193.2	195.2	197.1	199.1
201.4	204.3	207.3	210.2	212.2	213.4	214.2
214.7	214.8	214.8	214.7			
170.9	172.7	174.6	176.6	178.6	180.9	183.2
185.5	187.9	190.2	192.2	194.0	195.9	197.7
199.9	202.6	205.9	209.3	211.8	213.3	214.1
214.5	214.6	214.6	214.4			
170.1	171.8	173.7	175.7	177.8	180.1	182.2
184.4	186.7	188.9	191.0	192.8	194.5	196.3
198.1	200.4	203.7	207.7	211.1	212.8	213.7
214.1	214.2	214.2	214.0			
169.5	171.1	172.8	174.8	176.9	179.0	181.1
183.1	185.3	187.5	189.6	191.5	193.2	194.8
196.4	198.3	200.9	205.0	209.5	211.9	212.9
213.3	213.5	213.4	213.3			
169.0	170.3	172.0	173.9	175.8	177.8	179.7
181.7	183.7	185.9	188.1	190.2	191.8	193.3
194.9	196.6	198.4	201.4	206.4	209.9	211.5
212.1	212.4	212.5	212.4			
168.3	169.6	171.2	173.0	174.8	176.6	178.4
180.1	182.1	184.2	186.4	188.6	190.3	191.9
193.6	195.3	197.1	199.4	203.5	207.3	209.4
210.4	211.0	211.2	211.2			
167.8	169.0	170.5	172.2	173.9	175.5	177.1
178.7	180.5	182.5	184.7	186.8	188.7	190.6

192.5	194.4	196.4	198.8	201.9	204.8	207.0
208.4	209.2	209.6	209.7			
167.2	168.4	169.9	171.4	173.0	174.6	176.1
177.6	179.1	180.9	183.0	185.2	187.4	189.6
191.6	193.5	195.6	198.0	200.6	202.8	204.7
206.1	207.0	207.5	207.8			
166.5	167.8	169.3	170.8	172.3	173.7	175.2
176.6	178.0	179.6	181.5	183.8	186.2	188.5
190.5	192.5	194.5	196.7	198.9	200.9	202.5
203.7	204.7	205.3	205.7			
165.9	167.2	168.6	170.1	171.6	173.0	174.4
175.8	177.2	178.7	180.5	182.6	184.9	187.2
189.4	191.3	193.2	195.1	196.9	198.7	200.1
201.4	202.4	203.1	203.6			
165.1	166.4	167.9	169.5	171.0	172.4	173.8
175.2	176.6	178.0	179.6	181.6	183.8	185.9
188.0	189.9	191.6	193.3	194.9	196.3	197.7
198.9	200.0	200.9	201.4			
164.3	165.6	167.2	168.8	170.4	171.8	173.3
174.6	176.0	177.4	178.9	180.7	182.8	184.7
186.6	188.4	190.0	191.4	192.7	194.0	195.2
196.4	197.4	198.4	199.0			
163.4	164.8	166.4	168.1	169.8	171.3	172.8
174.2	175.5	176.9	178.5	180.1	181.9	183.6
185.4	187.0	188.4	189.6	190.6	191.7	192.8
193.9	194.9	195.8	196.5			
162.4	163.9	165.6	167.4	169.3	170.9	172.3
173.7	175.1	176.5	177.9	179.5	181.0	182.6
184.2	185.6	186.9	187.9	188.8	189.7	190.6
191.5	192.4	193.3	194.1			
161.3	162.9	164.8	166.7	168.7	170.4	171.9
173.3	174.6	176.0	177.4	178.8	180.2	181.7
183.1	184.4	185.5	186.5	187.3	188.1	188.8
189.4	190.2	191.0	191.8			
160.4	162.1	164.0	166.0	167.9	169.8	171.4
172.8	174.1	175.5	176.8	178.1	179.5	180.8
182.2	183.3	184.4	185.3	186.0	186.7	187.4
188.0	188.6	189.2	189.9			
159.9	161.4	163.3	165.3	167.3	169.2	170.8
172.3	173.6	174.9	176.2	177.5	178.8	180.1
181.3	182.4	183.3	184.2	184.9	185.6	186.2
186.8	187.4	188.0	188.6			
159.5	160.9	162.7	164.6	166.6	168.6	170.3
171.8	173.1	174.3	175.6	176.8	178.1	179.4
180.6	181.6	182.4	183.2	183.9	184.5	185.1
185.7	186.3	187.0	187.7			
159.2	160.4	162.1	164.0	166.0	167.9	169.8

171.2	172.5	173.7	174.9	176.1	177.4	178.6
179.8	180.7	181.5	182.3	183.0	183.6	184.2
184.8	185.4	186.1	186.7			
159.0	160.1	161.6	163.4	165.3	167.2	169.0
170.5	171.7	172.9	174.1	175.3	176.5	177.7
178.8	179.8	180.6	181.4	182.1	182.7	183.4
184.0	184.6	185.2	185.9			
158.9	159.8	161.2	162.9	164.6	166.4	168.1
169.6	170.9	172.1	173.3	174.4	175.6	176.7
177.8	178.8	179.7	180.5	181.2	181.9	182.5
183.1	183.8	184.4	185.1			
158.7	159.6	160.8	162.3	164.0	165.6	167.2
168.7	170.0	171.2	172.4	173.5	174.7	175.8
176.8	177.8	178.7	179.6	180.4	181.1	181.7
182.3	183.0	183.6	184.3			
158.6	159.4	160.5	161.8	163.4	164.9	166.4
167.8	169.1	170.3	171.4	172.6	173.7	174.8
175.9	176.9	177.8	178.7	179.5	180.3	180.9
181.6	182.2	182.8	183.5			
158.5	159.2	160.2	161.4	162.8	164.3	165.7
167.0	168.3	169.4	170.6	171.7	172.8	173.9
174.9	175.9	176.9	177.8	178.6	179.4	180.1
180.8	181.4	182.0	182.7			
158.4	159.1	160.0	161.1	162.4	163.7	165.1
166.3	167.5	168.6	169.7	170.8	171.9	173.0
174.1	175.0	176.0	176.9	177.7	178.5	179.3
180.0	180.6	181.3	181.9			
158.4	159.1	159.9	160.9	162.1	163.3	164.5
165.7	166.9	168.0	169.0	170.1	171.1	172.2
173.2	174.2	175.2	176.1	176.9	177.7	178.5
179.2	179.8	180.5	181.1			
158.4	159.0	159.8	160.7	161.8	162.9	164.0
165.2	166.3	167.3	168.4	169.4	170.4	171.4
172.4	173.4	174.4	175.3	176.1	176.9	177.7
178.4	179.1	179.7	180.3			
158.4	159.0	159.7	160.6	161.6	162.6	163.6
164.7	165.7	166.8	167.8	168.8	169.8	170.7
171.7	172.7	173.6	174.6	175.4	176.2	177.0
177.7	178.4	179.0	179.6			
158.4	159.0	159.7	160.5	161.4	162.3	163.3
164.3	165.3	166.4	167.3	168.3	169.2	170.1
171.1	172.0	173.0	173.9	174.7	175.5	176.3
177.0	177.7	178.3	179.0			
158.5	159.0	159.6	160.4	161.3	162.1	163.1
164.0	165.0	165.9	166.9	167.8	168.7	169.6
170.4	171.4	172.4	173.3	174.1	174.9	175.7
176.4	177.1	177.7	178.4			

158.5	159.0	159.6	160.3	161.1	162.0	162.9
163.8	164.7	165.6	166.6	167.5	168.3	169.1
170.0	170.9	171.9	172.8	173.6	174.4	175.1
175.8	176.5	177.1	177.8			
158.6	159.0	159.6	160.2	161.0	161.8	162.7
163.6	164.5	165.4	166.3	167.2	168.0	168.9
169.7	170.6	171.5	172.3	173.1	173.9	174.6
175.2	175.9	176.6	177.2			
158.8	159.1	159.6	160.2	160.9	161.8	162.6
163.5	164.3	165.2	166.0	166.9	167.8	168.7
169.6	170.4	171.2	172.0	172.7	173.4	174.1
174.7	175.4	176.0	176.7			

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APPENDIX C2

Block Centered Flow Package - Nodal Spacing, Transmissivity, and Leakance

WSSC.BCF

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 0 0 0 0
        0 0.100E+01
        0 0.100E+04
        0 0.100E+04
        0 0.175E+03
       11 0.100E+01(7G11.4)              12
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 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2200E-03
 0.2200E-03 0.2200E-03 0.2200E-03 0.2200E-03
 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02
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 0.2000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.1800E-03 0.2200E-03 0.2200E-03
 0.2200E-03 0.2200E-03 0.2200E-03 0.2200E-03
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0.4000E-04 0.4000E-04 0.4000E-04 0.4000E-04
     0 0.400E+04
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APPENDIX C3

Well Package

WSSC.WEL

33	0	
33		
4	8	17-.4493E+05
4	9	17-.2566E+05
4	26	10-4813.
1	10	16-260.0
2	10	16-3292.
3	10	16-1646.
1	8	16-231.0
2	8	16-2926.
3	8	16-1463.
1	8	17-1502.
2	8	17-.1902E+05
3	8	17-9509.
1	9	16-404.0
2	9	16-5121.
3	9	16-2560.
1	9	17-48.00
2	9	17-610.0
3	9	17-305.0
1	11	17-481.0
2	11	17-6096.
3	11	17-3048.
1	11	16-279.0
2	11	16-3536.
3	11	16-1768.
1	11	14-327.0
2	11	14-4145.
3	11	14-2072.
1	11	15-578.0
2	11	15-7315.
3	11	15-3658.
4	13	25-.3209E+05
4	13	24-.3208E+05
4	6	17-1925.

APPENDIX C4

General Head Boundary Package

WSSC.GHB

82	-1			
82				
2	6	1	0.150E+03	0.500E+04
2	7	1	0.150E+03	0.500E+04
2	8	1	0.150E+03	0.500E+04
2	9	1	0.150E+03	0.500E+04
2	10	1	0.150E+03	0.500E+04
2	11	1	0.150E+03	0.500E+04
2	21	25	0.195E+03	0.100E+05
2	22	24	0.190E+03	0.100E+05
2	13	20	0.213E+03	0.100E+05
2	14	20	0.211E+03	0.100E+05
2	15	19	0.206E+03	0.100E+05
2	16	19	0.204E+03	0.100E+05
2	17	19	0.201E+03	0.100E+05
2	18	18	0.195E+03	0.100E+05
2	19	18	0.188E+03	0.100E+05
2	20	18	0.182E+03	0.100E+05
2	21	17	0.175E+03	0.100E+05
2	22	17	0.168E+03	0.100E+05
2	12	1	0.150E+03	0.500E+04
2	13	1	0.150E+03	0.500E+04
2	14	1	0.150E+03	0.500E+04
2	15	1	0.150E+03	0.500E+04
2	16	1	0.150E+03	0.500E+04
2	17	1	0.150E+03	0.500E+04
2	18	1	0.150E+03	0.500E+04
2	19	1	0.150E+03	0.500E+04
2	20	1	0.150E+03	0.500E+04
2	21	1	0.150E+03	0.500E+04
2	22	1	0.150E+03	0.500E+04
2	23	1	0.150E+03	0.500E+04
2	24	1	0.150E+03	0.500E+04
2	25	1	0.150E+03	0.500E+04
2	26	1	0.150E+03	0.500E+04
2	35	1	0.106E+03	0.500E+04
2	35	2	0.107E+03	0.500E+04
2	35	3	0.108E+03	0.500E+04
2	35	4	0.109E+03	0.500E+04
2	35	5	0.110E+03	0.500E+04
2	35	6	0.111E+03	0.500E+04
2	35	7	0.112E+03	0.500E+04
2	35	8	0.113E+03	0.500E+04
2	35	9	0.114E+03	0.500E+04

2	34	10	0.115E+03	0.500E+04
2	34	11	0.116E+03	0.500E+04
2	33	13	0.119E+03	0.500E+04
2	32	14	0.121E+03	0.500E+04
2	34	12	0.117E+03	0.500E+04
2	33	12	0.118E+03	0.500E+04
2	32	15	0.122E+03	0.500E+04
2	32	16	0.125E+03	0.500E+04
2	31	16	0.127E+03	0.100E+05
2	30	16	0.133E+03	0.100E+05
2	29	16	0.138E+03	0.100E+05
2	28	16	0.145E+03	0.100E+05
2	27	16	0.150E+03	0.100E+05
2	26	16	0.152E+03	0.100E+05
2	25	16	0.154E+03	0.100E+05
2	24	16	0.156E+03	0.100E+05
2	23	16	0.158E+03	0.100E+05
2	23	17	0.160E+03	0.100E+05
2	27	22	0.146E+03	0.500E+04
2	26	22	0.150E+03	0.500E+04
2	25	22	0.155E+03	0.500E+04
2	24	23	0.160E+03	0.500E+04
2	23	24	0.167E+03	0.500E+04
2	31	17	0.127E+03	0.500E+04
2	30	18	0.128E+03	0.500E+04
2	29	19	0.131E+03	0.500E+04
2	29	20	0.132E+03	0.500E+04
2	29	22	0.135E+03	0.500E+04
2	29	23	0.136E+03	0.500E+04
2	29	24	0.137E+03	0.500E+04
2	30	24	0.138E+03	0.500E+04
2	30	25	0.140E+03	0.500E+04
2	34	9	0.115E+03	0.500E+04
2	29	21	0.133E+03	0.500E+04
2	28	22	0.140E+03	0.500E+04
2	32	13	0.120E+03	0.500E+04
2	29	18	0.130E+03	0.500E+04
1	13	21	0.214E+03	0.100E+05
1	12	21	0.215E+03	0.100E+05
1	12	22	0.215E+03	0.100E+05

APPENDIX C5

Output Control Package

WSSC.OPC

-1	0	0	0
0	1	1	1
1	0	0	0

APPENDIX C6

Recharge Package

WSSC.RCH

```
         3         0
         0         0
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APPENDIX C7

Sip Solution Package

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APPENDIX D

Location and Pumpage Rates of Production and Recovery Wells Used in Groundwater Model

APPENDIX D

LOCATION OF WELLS AND PUMPING RATES USED IN GROUNDWATER MODEL

Well No.	North SRP (ft)	East SRP (ft)	Total Pumping Rate (gpm)	Pumpage From Model Layer (gpm)*			
				1	2	3	4
PW-53A	105011	50757	350				116.7
PW-20A	104000	50615	350				116.7
PW-82A	103330	51100	400				133.3
PW-112G	99388	58023	500				116.7
PW-113G	99961	57023	500				116.7
PW-67B	86693	42622	75				25
PW-68A	106266	50266	30				10
RWM-1	102608	48581	27	1.4	17.1	8.5	
RWM-2	104434	49206	24	1.2	15	7.8	
RWM-3	104730	49680	57	2.9	36.1	18	
RWM-4	103719	48948	42	2.1	26.6	13.3	
RWM-5	103502	49628	5	0.3	3.2	1.5	
RWM-6	102002	50107	50	2.5	31.7	15.8	
RWM-7	101905	49450	29	1.5	18.4	9.1	
RWM-8	101948	47353	34	1.7	21.5	10.8	
RWM-9	104100	50400	34	1.7	21.5	10.8	
RWM-10	102001	48244	60	3	38	19	
RWM-11	104875	50400	65	3.3	41.2	20.5	

*Production wells in layer 4 are also pumping from the Middendorf (lower portion of Aquifer System I) which is not simulated in this model.

APPENDIX E

Description of Calibration Process

APPENDIX E

Summary of Runs Made During Coarse Grid Model Calibration

SDI started with the parameters used in the coarse grid model calibrated by S.S. Papadopulos & Associates (SSP&A) in 1987. The only deviation from the Papadopulos model was combining the Ellenton and the Lower Congaree layers into one model layer and utilizing a leakance coefficient to simulate the Ellenton as a confining unit below the Upper Congaree. SDI reproduced the predicted water levels reported by Papadopulos (1987).

The 1989-1990 observed water levels differ from the model-predicted water levels produced by the SSP&A calibration. This may be attributed to the effect of several years of recovery well pumpage and a decline in rainfall rates. Model-predicted water levels were higher than observed water levels. Additional monitoring wells have been installed since the SSP&A calibration and understanding of the hydrogeologic system has improved. SDI analyzed the available data and recalibrated the model to 1989-1990 observed water levels, surface water flow, and aquifer test data. The following text describes the steps taken in the recalibration.

The groundwater flow direction and water levels did not match observed data in layer 4 (Black Creek). A number of runs changing boundary conditions in layer 4 and leakance values in layer 3 were made in an effort to reduce the amount of water entering layer 4. None of the runs satisfactorily improved the calibration in this layer. Boundary conditions and leakance were returned to the SSP&A parameters.

The SSP&A model had a ring of inactive nodes around each layer. These nodes are not necessary in MODFLOW to simulate boundary conditions. The outer ring of inactive nodes were converted to active nodes in all layers. After reviewing available data, the layer boundaries were further extended in layers 1 through 3. Layer 1 was extended 2 nodes to the west to incorporate new well data and layer 2 was expanded to the south to match the boundary of layer 3. In the SSP&A model, layer 3 stopped just north of Upper Three Runs Creek. The expanded layer boundaries improved calibration along the edges of the model in layers 1 through 3.

The well package was updated by including the new pumpage rates for the production and recovery wells provided by SRL. Pumpage rates for the recovery wells were prorated between layers 1, 2 and 3 according to the transmissivity of the layers (Appendix D).

A number of runs were devoted to assessing the model's sensitivity to recharge. A recharge rate of 15 in/yr was used over the entire model area in the SSP&A calibration. A run using 12 in/yr and a run using 18 in/yr were done. The simulation using 12 in/yr resulted in a good calibration for the southern half of the model, but did not provide enough water in the A/M Area. The simulation using 18 in/yr resulted in a good calibration in the A/M Area but too much water in the southern portion of the model. The model was found to be quite sensitive to recharge. Recharge was returned to 15 in/yr.

After these adjustments, water levels in all layers of the model were still too high in the southern two-thirds of the model. The reasons for the high groundwater levels was thought to be due to one or more of three factors: 1) too much recharge; 2) too little downward leakage; and/or 3) transmissivity values that are too low. The analyses showed that the high water levels in layers 2 and 3 caused most of the water entering layer 4 through constant head nodes in the upper part of the modeled area to flow upward into layer 3 along Upper Three Runs Creek.

After reviewing the regional hydrostratigraphic cross-section (hereafter referred to as the regional cross-section) sent by SRL (Figure 6) it was observed that both the Upper and Lower Congaree thicken to the south. A series of model runs were made to investigate the effects of the transmissivity distribution and value on the calibration. The model was found to be less sensitive to changes in transmissivity than recharge and leakance.

As in the SSP&A model, the total transmissivity for the Upper and Lower Congaree is 2,630 ft^2/day in the northern half of the model. A hydraulic conductivity of 44 ft/day is used for both layers (Papadopulos, 1987). The thicknesses of the Upper and Lower Congaree in the A/M Area are 40 feet and 20 feet, respectively. The transmissivity of both the Upper and Lower Congaree was increased to the south to account for the thickening of strata shown in the regional cross-section. These distributions of transmissivity resulted in a marked improvement of the calibration over the entire model.

At this point in the calibration, layer 4, which had a transmissivity of 12,500 ft^2/day, still had too much water. The total transmissivity for the Black Creek and the Middendorf has been calculated to range from 10,400 to 14,200 ft^2/day based on an aquifer pumping test on production well PW-20A. The hydraulic conductivity in the Black Creek is estimated as half of the hydraulic conductivity of the Middendorf. Using a hydraulic conductivity of 23.5 ft/day for the Black Creek and a thickness of 170 ft from the regional cross-section, the transmissivity of the Black Creek in the SRL is approximately 4,000 ft^2/day. The value of transmissivity for the Black Creek (layer 4) was reduced from 12,500 ft^2/day to 4,000 ft^2/day (Figure 18). This change improved the calibration of the water level elevations and gradient in layer 4 and reduced the upward flow to layer 3 beneath Upper Three Runs Creek.

The boundaries of both layers 2 and 3 were extended over the entire model area as a result of information from the regional cross-section and the Duffield et al. (1989) report on the F and H areas. Based on the regional cross-section and conversations with SRL, the Upper and Lower Congaree are modeled as a continuous unit in the southern half of the model. The leakance in layer 2 was raised in the southern half of the model to simulate the absence of a confining unit between the Upper and Lower Congaree.

As in the SSP&A model, the discharge of groundwater to streams and wetlands was simulated in this model by nodes with head-dependent discharge (general-head boundary nodes). Extending the Upper and Lower Congaree layer boundaries made it necessary to relocate the general-head boundary (GHB) nodes directly over Upper Three Runs Creek. The GHB nodes were previously along the southern boundaries of layers 2 and 3 just north of Upper Three Runs Creek. The regional cross-section as well as cross-sections in Christensen and Gordon (1983) indicate that Upper Three Runs Creek is incised into the Upper Congaree. Therefore, all GHB nodes that were in layer 3 were raised to layer 2.

The flow through general head boundary nodes is regulated by the assigned head at the node and a conductance term that simulates the hydraulic properties of the stream bottom. Heads in each node were chosen from a topographic map (Department of Energy, 1987). The conductance terms were calculated then adjusted during calibration. The flow into and out of the GHB nodes was calibrated to the stream flow data SDI received for Tim's Branch and Upper Three Runs Creek. The Lockwood Greene Engineers, Inc. (1983) report on the stream flow of Tim's Branch indicates that the upper portion of Tim's Branch has only seasonal flow. Because this portion of the stream is not a constant source of water, some of the GHB nodes were eliminated from the upper reach of Tim's Branch in layer 1 (Figure 15). This improved the calibration in the water table.

As mentioned previously, the model was found to be sensitive to recharge rates. Quite a few runs were made in an effort to use one recharge rate and balance the deficiency of water in the north with the abundance of water in the south using leakance, transmissivity and GHB nodes. These simulations were not able to match the observed water levels without using unrealistic values for one or more parameters. A range in recharge rates of 8 to 15 in/yr have been used in past models in the area. To achieve the desired water levels in the southern half of the model recharge was cut from 15 in/yr to 10 in/yr. The resulting water levels were too low in the northeast portion of the model. More water was needed in the A/M Area and along the ridge between Tim's Branch and the southwest wetlands. Recharge was increased to 15 in/yr over the top of the ridge and left at 10 in/yr over the areas of steeper topography. Figure 22 illustrates the final recharge distribution for the entire model area. After this adjustment, the only area remaining deficient in water level elevation was the A/M Area in layers 1 and 2.

The variable recharge distribution resulted in the correct range of water levels in each layer. However, the flow directions and gradients did not match the observed water level contours in all areas of the model. It was found that boundary conditions needed to be changed in some places to simulate the flow indicated by the observed water levels. Constant-heads were added to the north and west sides of layer 1 to simulate flow from the ridge toward areas of lower elevation. Constant-heads were also added to layer 2 and layer 3, where observed water levels also suggest flow out of the northeast corner. The final boundary conditions used in this calibration are in Figure 15 through 18.

To further improve the calibration of the coarse grid model calibration, leakance values in each layer were adjusted. Some of the final leakance zones configurations are similar to those in the SSP&A calibration. The model is sensitive to leakance rates in the A/M Area where hydraulic head differences between the layers are the largest. A series of runs were necessary to balance leakance rates between the layers and to adjust the leakance zones to match the observed water level contours in each layer.

In layer 1, a slightly lower leakance was necessary in the A/M Area to match the observed water levels (Figure 19). The leakance value in layer 2 is determined by the thickness of the clay layer between the Upper and Lower Congaree. The clay appears to be the thickest in the A/M Area and thins and becomes discontinuous to the south. Leakance is highest in the southern sector where the Congaree is thinnest and data points from Fallaw and Sargent (1986) show the clay layer to be absent (Figure 20). Leakance in layer 3 is determined by the thickness of the clays in the Ellenton (Figure 21). Data from Fallaw and Sargent (1986) indicates that the clay is thickest in the A/M Area and to the southeast beneath Tim's Branch.

At this point the coarse grid model was calibrated and sent to SRL for review. SDI was advised of a specific capacity test run on a new recovery well, RW-16, in the southern sector. The specific capacity of 4 gpm/ft suggested a lower transmissivity in the Upper and Lower Congaree than was modeled. Further investigation revealed that the Upper and Lower Congaree may be thinner southeast of the A/M Area (Fallaw, 1990). A block of lower transmissivity was added to layers 2 and 3. The shape of the block was determined by isopach data of the Upper and Lower Congaree in Fallaw (1990). The final distribution of transmissivity in the Upper Congaree is shown in Figure 16. The final distribution of transmissivity in the Lower Congaree is shown in Figure 17. Leakance rates in layer 2 and layer 3 were adjusted to recalibrate to the observed water levels.

END

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