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Recharge to the North Richland Well Field

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Assistant Secretary for Environment, Safety and Health

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April 3, 1989

8900601B R2

Ms. Elizabeth A. Bracken, Acting Director
Environmental Restoration Division
U.S. Department of Energy
Richland Operations Office
Richland, Washington 99352

Dear Ms. Bracken:

RECHARGE TO THE NORTH RICHLAND WELL FIELD

References: (1) Letter, E. A. Bracken to President, WHC, "Recharge to the North Richland Well Field", 8900601B, dated February 6, 1989.

(2) Letter, R. E. Lerch to E. A. Bracken, "Recharge to the North Richland Well Field", 8950380, dated January 19, 1989.

This letter transmits the attached letter report, prepared by Pacific Northwest Laboratory and Westinghouse Hanford Company, which contains the results of the ground-water modeling effort outlined in the Statement of Work contained in reference 2 and authorized by reference 1.

The objective of the task was to investigate the potential for any contamination that might migrate to ground water from 1100 Area disposal sites to reach the City of Richland well field. This work consisted of steady-state and transient simulations of ground-water flow conditions in an area encompassing the North Richland well field and recharge basins of the City of Richland.

Modeling made use of the monthly recharge and well field pumpage data supplied by the City of Richland for the period January 1983 through June 1988. Since water level measurements were not initiated until January 1989, it was not possible to compare the simulated water table conditions with the field measurements. Due to this condition and the limited geohydrologic information in the area, the results may best be described as a "sensitivity analysis".

The results of both the steady-state and transient models of the 1100 Area and North Richland show that recharge to the North Richland well field has a significant impact on ground-water flow. During periods of high net recharge (net recharge equals recharge minus pumpage), a ground-water mound develops causing flow from upgradient to be diverted around the well field. When operation of the well field and recharge basin produces no net

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The results of both the steady-state and transient models of the 1100 Area and North Richland show that recharge to the North Richland well field has a significant impact on ground-water flow. During periods of high net recharge (net recharge equals recharge minus pumpage), a ground-water mound develops causing flow from upgradient to be diverted around the well field. When operation of the well field and recharge basin produces no net recharge, ground water from the 1100 Area can move toward the well field, although a small mound does form near the well field. Steady-state treatment of the no recharge condition results in a predicted travel time from the disposal areas to the well field of about three years. Noting the seasonal nature of recharge to the well field, the condition of flow toward the well field is unlikely to be sustained long enough for significant movement of any contaminants into the well field.

Therefore the modeling suggests that past operation of the recharge/well field may have kept most of the ground water from the 1100 Area away from the well field. Additional work could be undertaken if more realistic model results are desired. With recharge and pumpage data from the city for the period since June 1988 the transient modeling could be continued to allow for comparison with the monthly water level measurements initiated in January 1989. Hydrologic characterization of the aquifer would also contribute to the calibration of the model. The transient model could be expanded so that the upgradient boundary is not affected by operation of the recharge/well field. With this additional work the uncertainties associated with the modeling process would be reduced.

Questions pertaining to this letter report may be addressed to A. G. Law on 376-9028 or to M. P. Bergeron on 376-8410.

Very truly yours,

R E Lerch

R. E. Lerch, Manager
Environmental Division

Attachment

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	R. K. Stewart	
	K. M. Thompson	
IT	- D. A. Myers	(w/o attachment)
PNL	- M. P. Bergeron	
	R. W. Bryce	(w/o attachment)
	P. S. Long	(w/o attachment)
	M. D. Freshley	
HEHF	- L. J. Maas	(w/o attachment)

GROUND-WATER MODELING INVESTIGATION OF NORTH RICHLAND WELL FIELD AND THE 1100 AREA

Letter Report

M. D. Freshley
M. P. Bergeron
N. J. Aimo

March 1989

Pacific Northwest Laboratory
Richland, Washington

A. G. Law
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This report summarizes the 1100 Area modeling investigation, including the approach used to generate results for the regional and 1100 Area VTT models, the approach used in the transient MODFLOW model, results from some initial steady-state and transient simulations with the submodel and the MODFLOW models, and resulting conclusions and recommendations. Because local data were lacking to develop and calibrate the models, the investigation described in this report can best be described as a "sensitivity analysis" of ground-water flow in the 1100 Area.

SITE DESCRIPTION

The 1100 Area of the Hanford Site is located approximately one-half mile west of the North Richland well field (Figure 1). The 1100 Area is the location of vehicle maintenance operations and warehouse facilities, which support activities at the Hanford Site.

Specific information on the hydrogeology in the vicinity of the 1100 Area is limited. The existing information is based on regional data and data extrapolated from other areas of the Hanford Site. The 1100 Area is underlain by the Columbia River Basalt Group at a depth of approximately 170 to 200 ft. The uppermost basalt flows are overlain by the Ringold Formation, a fluvial sedimentary unit, and the Hanford formation, consisting primarily of glaciofluvial deposits known as the Pasco Gravels. Ground water in the vicinity of the 1100 Area occurs in both confined aquifers within the basalt sequence, and in an unconfined aquifer system, consisting of the Ringold Formation and Pasco Gravels. The unconfined aquifer is the focus of this modeling study.

The unconfined aquifer in the area exhibits relatively high permeability, particularly in the Pasco Gravels. The hydraulic gradient is from west to east, and the primary source of recharge for the unconfined aquifer in the 1100 Area is the Yakima River. The unconfined aquifer discharges to the Columbia River. This west-to-east flow system is complicated by recharge to the unconfined aquifer by operation of the North Richland well field and other infiltration resulting from irrigation or discharges from industrial operations such as the Lamb-Weston potato processing plant and Advanced Nuclear Fuels.

The North Richland well field is recharged by water from the Columbia River. The city pumps water from the river into recharge ponds that allow for percolation to the ground water. Water is then pumped from the ground for municipal use during peak demand periods through a series of wells around the recharge ponds. Review of the historical data indicates that the ratio of recharge to pumpage has ranged from about 4:1 to about 2:1. The city has now reduced the ratio to about 1:1 for the period of low demand and is planning on increasing this to a maximum of about 2:1 when the demand increases. This reduction of recharge to the basins represents a change in the existing ground-water system and provides the impetus for this modeling investigation.

APPROACH

Regional Steady-State Model

The regional steady-state model of the unconfined aquifer at the Hanford Site and the steady-state model of the 1100 Area are both based on the VTT code. The VTT code solves the Boussinesq equation for unconfined ground water flow in two dimensions. A finite difference numerical scheme is used in the code, with capabilities for handling heterogeneous distributions of aquifer properties such as hydraulic conductivity and storage coefficient.

A regional model of ground-water flow in the unconfined aquifer at the Hanford Site based on the VTT code was developed in the mid-1970s and calibrated with an iterative scheme called the Transmissivity Iterative Routine (Cearlock, Kipp, and Friedrichs 1975). This calibration resulted in the distribution of transmissivity (the product of hydraulic conductivity and aquifer thickness) currently used in the model.

The regional model of the unconfined aquifer is based on no-flow boundary conditions at basalt outcrops along Rattlesnake Mountain, Umtanum Ridge, Gable Butte, and Gable Mountain, prescribed head boundary conditions for the Columbia and Yakima rivers, and prescribed flux along the Cold Creek and Dry Creek valleys and at spring discharges along the front of Rattlesnake Mountain. The base of the unconfined aquifer is either the top surface of the Columbia River Basalt Group or the top of the Lower Ringold clays. A 2000-ft grid spacing is used to represent conditions in the unconfined aquifer (Figure 2).

The VTT model of the unconfined aquifer was applied to simulate average conditions for 1987. The steady-state solution is based on average Columbia River elevations and average discharges from operations at the Hanford Site.

1100 Area Steady-State Model

The 1100 Area model was designed to meet the level of detail needed to investigate local conditions. This design considered appropriate boundary conditions and the grid resolution necessary to approximate the physical location of facilities such as the North Richland well field/recharge basin, major waste facilities in the 1100 Area, and major geographic features such as the Columbia and Yakima rivers.

The boundaries of the submodel were located so that they would be unaffected by the North Richland well field (Figure 3). The 1100 Area model extends from the Columbia River on the east to the Yakima River on the west. The northern boundary is located one-half mile north of Horn Rapids Road, and the southern boundary is located approximately half-way between McMurray and Van Giesen Streets in Richland. The submodel is based on a 400-ft grid spacing.

Information from the regional model was interpolated directly to the 1100 Area model. The distribution of hydraulic conductivity and information on the aquifer bottom were extrapolated directly from the regional model. Boundary conditions for the 1100 Area model are based on a potential solution with the regional model for average conditions during 1987. Although model results based on information extrapolated from the regional solution are acceptable, it must be recognized that the information may only approximate the detailed aquifer geometry and heterogeneity in aquifer properties present in the 1100 Area.

In this study, the 1100 Area model was not calibrated, and no local information was incorporated in the model simulations. The model was not calibrated because local data on hydraulic properties and water levels were not available. However, results from the steady-state 1100 Area model were qualitatively compared with the limited local water level measurements, which are available to determine if they reasonably reproduced local conditions.

Initial plans were to simulate up to six steady-state scenarios that would represent an appropriate range of hydrologic conditions anticipated at the North Richland well field/recharge basin and the Columbia River. Preliminary scenarios included a minimum recharge to pumpage scenario (1:1 ratio), a maximum recharge to pumpage scenario (3 to 4:1 ratio), and an average recharge to pumpage scenario. The latter ratios were derived from recent historical information provided by the city. Plans also included variation of the Columbia River level.

Two scenarios were considered to evaluate the effects of the North Richland well field on ground-water flow in the 1100 Area and North Richland. These scenarios were defined to bracket possible conditions resulting from operation of the well field and recharge basins. The first scenario consisted of no recharge to the basins and no pumpage from the well field. The second scenario consisted of recharge to pumping at a ratio of 3.3:1. For each scenario, a streamline and travel-time analysis was performed. The streamlines were initiated from near locations of various waste facilities in the 1100 Area and continued to points of ground-water discharge.

<u>1100 Area Transient Model</u>

A transient, or time-dependent, ground-water flow model was used to evaluate the dynamic nature of the water table in the 1100 Area and North Richland, resulting from operation of the North Richland well field and recharge basin. The submodel is based on MODFLOW, a two-dimensional, finite difference code developed by the U.S. Geological Survey (USGS). The results of this model provide a check on the VTT modeling results.

The model is based on a 500-ft grid for an area extending from Newcomer Street in Richland north to Horn Rapids Road and from the Columbia River to approximately the western boundary of the 1100 Area, forming a 35 by 17 grid. The Columbia River was treated as a constant head boundary of 340 ft. The Columbia River elevation of 340 ft was established after several model simulations and inspection of the river stages published by the USGS, which indicate a monthly mean stage of the Columbia River at Pasco of about 339 to 340 ft for 1983 through 1988. The upgradient boundary was simulated as a constant head boundary of 354 ft based on an inspection of a historical water table map .

The bottom of the aquifer was assigned a constant 300-ft elevation based on geologic and driller's logs and the regional steady-state VTT model. The hydraulic conductivity of the aquifer was selected to be a constant of 690 ft/day, which was consistent with the hydraulic conductivity interpolated from the regional steady-state VTT model. A specific yield of 0.3 was selected based on the geologic materials described in the driller's logs and adjustment after several initial model simulations. The MODFLOW code is capable of simulating the variable distributions of aquifer thickness, hydraulic conductivity, and specific yield, but no local information exists on which to base this refinement.

The MODFLOW transient model was applied with monthly recharge and pumping data at the North Richland well field for January 1983 through June 1988. These data, supplied by the city of Richland, are illustrated as net recharge (recharge minus pumpage) in Figure 4. As with the steady-state submodel, the transient model was not calibrated. The water levels predicted by the model were compared with water-level measurements in about 15 wells for January and February 1989 and recorder charts from two wells for November 1988 to February 1989.

RESULTS

Regional Steady-State Model

The results of the steady-state solution for the regional model are illustrated in Figure 5. The solution is representative of average 1987 conditions and compared favorably with the water-table measurements for June 1987 (Schatz, Ammerman, and Serkowski 1987).

1100 Area Steady-State Model

The recharge and pumpage at the North Richland well field are dynamic. Therefore, the results of steady-state simulations with the 1100 Area model should be considered simplistic representations of the ground-water system behavior in the 1100 Area and North Richland. The steady-state results reflect equilibrium conditions for the scenario being considered. More realistic simulations of the dynamic nature of the stresses should be conducted in a transient mode with, at a minimum, monthly time steps that could evaluate the monthly fluctuations of recharge and pumpage at the North Richland well field and the Columbia River.

The results of the two steady-state simulations with the VTT submodel are illustrated in Figures 6 and 7. Figure 6 illustrates the solution for no recharge and no pumping at the well field and Figure 7 illustrates the solution for high recharge to the well field. Ground water in both scenarios flows from west to east. Operation of the recharge basin and well field results in a substantial mound that diverts ground water from the 1100 Area around the well field. Streamlines from starting locations near waste sites are also included in the figures to illustrate the impacts on the flow direction. The travel times associated with streamlines in Figures 6 and 7 are listed in Tables 1 and 2, respectively. The predicted travel time from the waste sites to the well field for conditions of no recharge based on review of streamline data was estimated to be about three years. As can be seen in Figure 7, depicting high recharge conditions, the streamlines are altered by the recharge mound present under the North Richland well field.

<u>1100 Area Transient Model</u>

Results of the transient simulations are displayed as hydrographs at specific locations and as contours at specific times. Simulated hydrographs for four nodes are illustrated in Figure 8. The locations of the four nodes are represented by asterisks in Figures 9 and 10. Figure 9 illustrates the predicted water table during a period of low recharge (Month 25, January 1985), and Figure 10 shows the water table predicted for a period of high recharge (Month 43, July 1986).

The results of transient modeling indicate that wells near the well field may fluctuate as much as 12 ft over the course of a year (Figure 10), and the dynamic nature of the water table correlates well with the net recharge in Figure 4. The results indicate that during periods of high recharge, ground water flow is away from the well field (Figure 10). During

TABLE 1. Predicted Times and Distances Travelled by Streamlines Originating from the 1100 Waste Sites to the Columbia River for Conditions of No Recharge.

Streamline	Time (Years)	Distance (Feet)
1	8.55	6960
2	8.60	6960
3	9.15	7320
4	9.02	7320
5	8.93	7320
6	8.81	7320
7	8.69	7320
8	8.64	7320
9	7.90	6840
10	7.65	6840
11	7.54	6840
12	7.43	6840
13	7.25	6840
14	7.09	6840
15	7.09	6840

TABLE 2. Predicted Times and Distances Travelled by Streamlines Originating from the 1100 Waste Sites to the Columbia River for Conditions of High Recharge.

Streamline	Time (Years)	Distance (Feet)
1	17.09	6960
2	17.20	6960
3	18.29	7320
4	18.04	7320
5	17.86	7320
6	17.61	7320
7	17.37	7320
8	17.28	7320
9	15.81	6840
10	15.29	6840
11	15.09	6840
12	14.86	6840
13	14.50	6840
14	14.18	6840
15	14.17	6840

periods of low recharge, ground-water flow is toward the well field, but may be diverted to some extent by a small mound that remains beneath the recharge basin (Figure 9). Perusal of a series of unpublished water-table maps indicated that considerable fluctuations of the water table, similar to those predicted by the transient model, are plausible.

It should be noted that the fluctuation of the water table (Figure 8) transcends the contact between the Ringold Formation and Hanford formation, which is approximately 355 ft. elevation. Since the model was based on hydrologic properties of Ringold, the higher conductivity of the Hanford formation could be expected to result in faster lateral dissipation of ground water during periods of high water-table conditions. The peaks shown in Figure 8 would then be lower and the mound depicted in Figure 10 would likely be lower but spread out over a larger area.

CONCLUSIONS AND RECOMMENDATIONS

In the context of the limited information that this modeling investigation is based on, the results can be considered a "sensitivity analysis" on the effects of the North Richland well field. The results of both the steady-state and transient models of the 1100 Area and North Richland show that recharge to the North Richland well field has a significant impact on ground-water flow. When operation of the well field and recharge basin produces no net recharge, ground water from the 1100 Area can move toward the well field. However, the predicted travel times are sufficiently long that these periods of hydraulic gradient toward the well field may not be sustained long enough for significant movement of ground water to occur. However, given the uncertainties and resolution associated with the model results, it is possible that one or more of the wells in the North Richland well field could intercept any existing upgradient contamination.

The transient simulations, performed with reasonable estimates of specific yield in the model, demonstrate that the unconfined aquifer responds rapidly to changes in recharge and discharge at the North Richland well field. During periods of high net recharge, a ground-water mound develops that prevents upgradient ground water from entering the well field. This result is illustrated by both the 1100 Area steady-state modeling results and the transient simulation.

The results of the steady-state and transient simulations are similar. Both predict an elevation of the ground-water mound beneath the recharge basin that is greater than 360 ft for periods of high recharge. The mound illustrated in Figure 10 for the transient simulation is slightly higher, but may reflect more recharge than was assumed for the steady-state simulation.

Therefore, the modeling suggests that past operation of the recharge/well field may have kept most of the ground water from the 1100 Area away from the well field. Additional work could be undertaken if more realistic model results are desired. With recharge and pumpage data from the city for the period since June 1988, the transient modeling could be continued to allow for comparison with the monthly water level measurements initiated in January 1989. Hydrologic characterization of the aquifer would also contribute to the calibration of the model. The transient model could be expanded so that the upgradient boundary is not affected by operation of the recharge/well field. With this additional work, the uncertainties associated with the modeling process could be quantified and/or reduced.

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Cearlock, D. B., K. L. Kipp, and D. R. Friedrichs. 1975. The Transmissivity Iterative Calculation Routine - Theory and Numerical Implementation. BNWL-1706, Pacific Northwest Laboratory, Richland, Washington.

Kipp, K. L., A. E. Reisenauer, C. R. Cole, and C. A. Bryan. 1976. Variable Thickness Transient Groundwater Flow Model, Theory and Numerical Implementation. BNWL-1703, Pacific Northwest Laboratory, Richland, Washington.

McDonald, M. G., and A. W. Harbaugh. 1984. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. U. S. Department of the Interior, U. S. Geological Survey, Reston, Virginia.

Schatz, A. L., J. J. Ammerman, and J. A. Serkowski. 1987. Hanford Site Water Table Map, June 1987. WHC-EP-0054, Westinghouse Hanford Company, Richland, Washington.

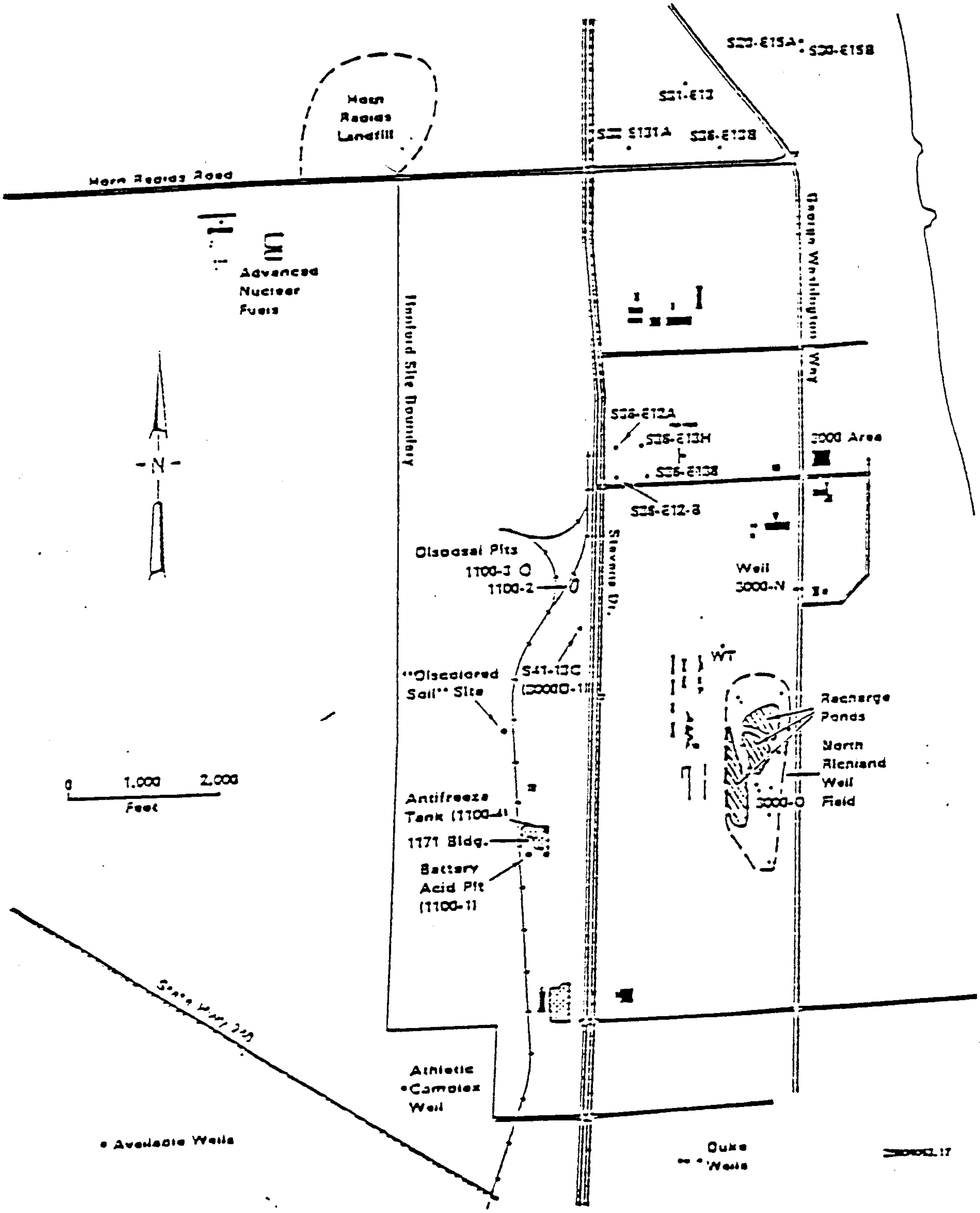

FIGURE 1. 1100 Area Waste Site Locations

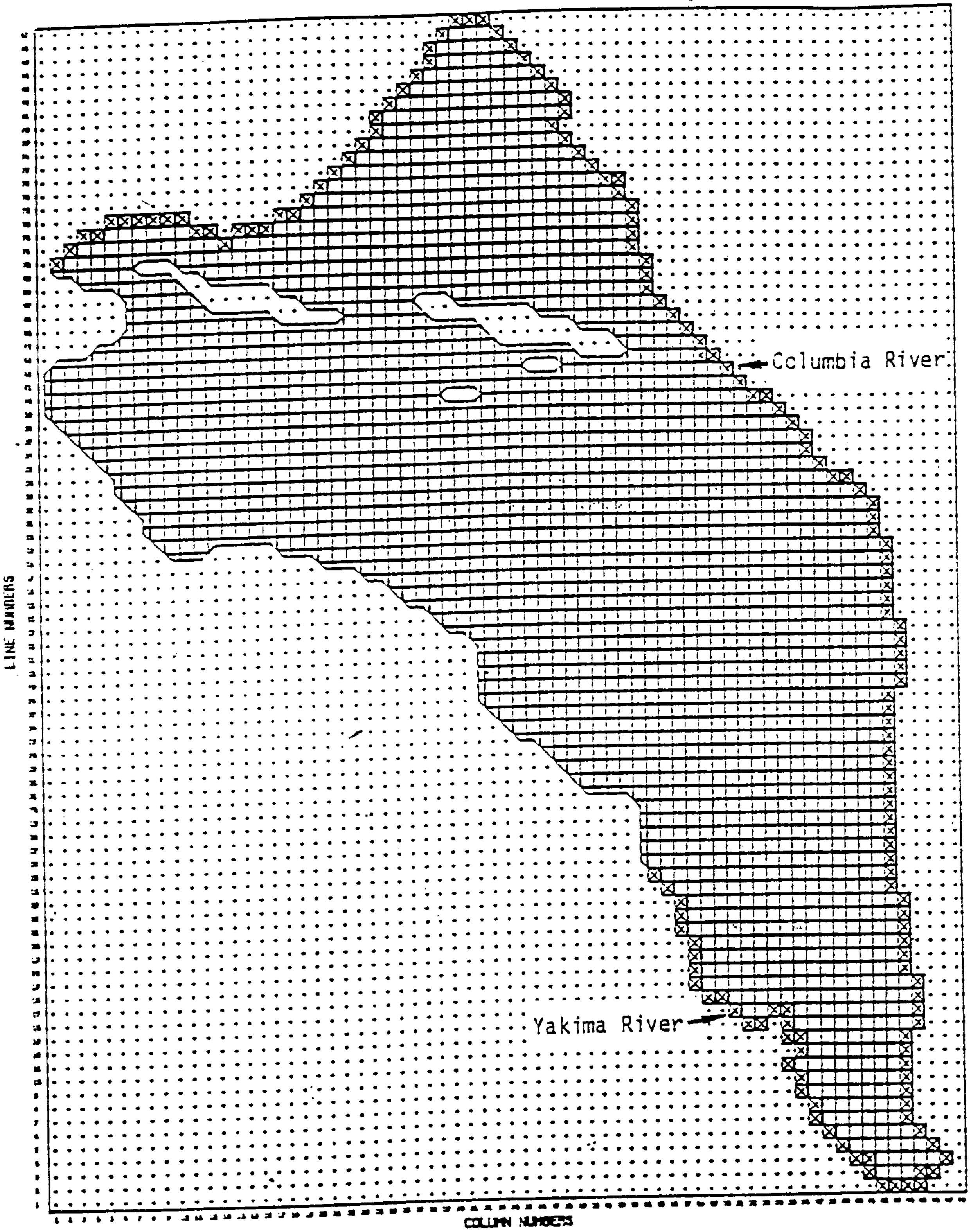

FIGURE 2. Grid for the Regional Model of the Unconfined Aquifer

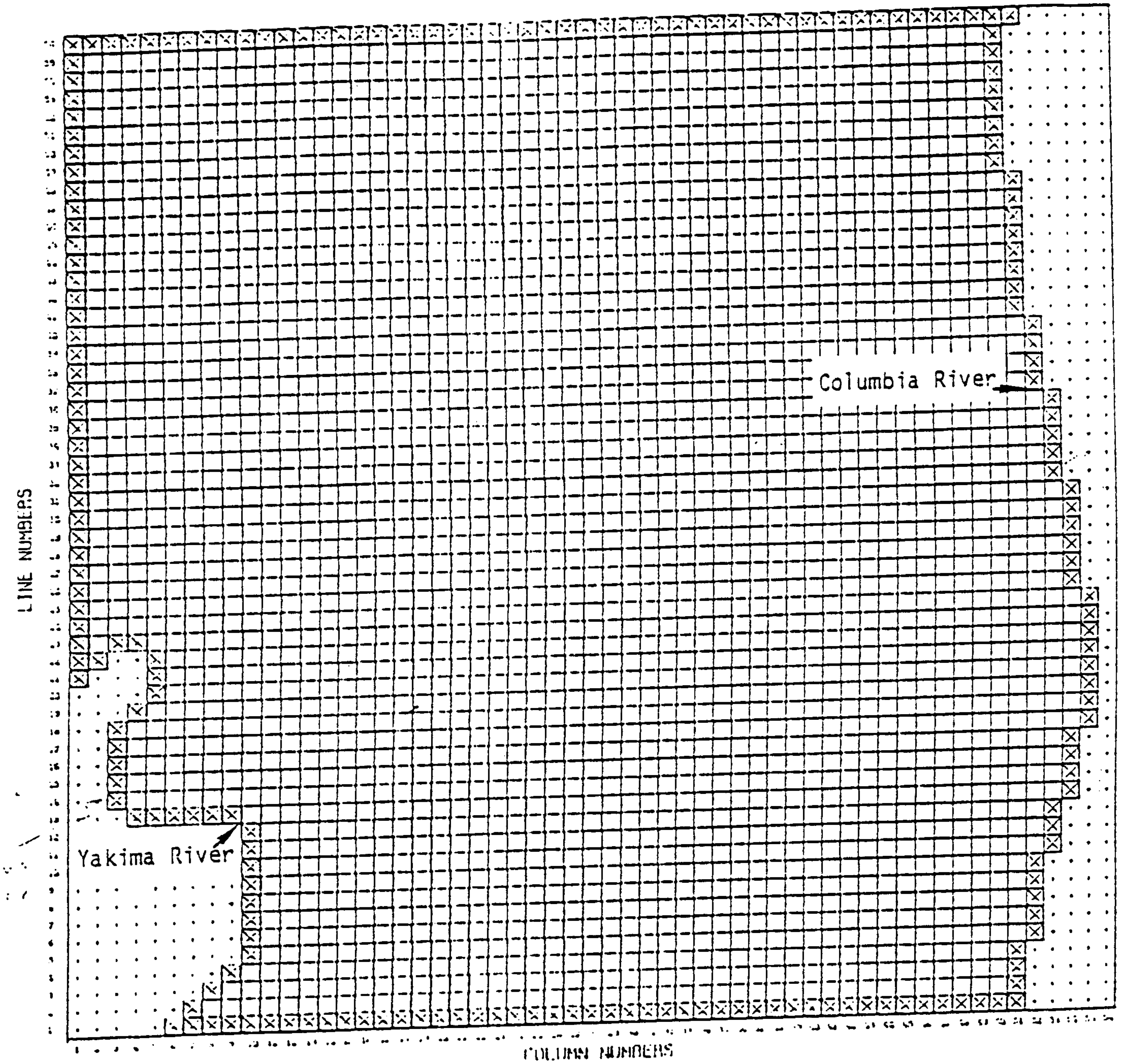

FIGURE 3. Grid for the 1100 Area Steady-State Model Based on VTT

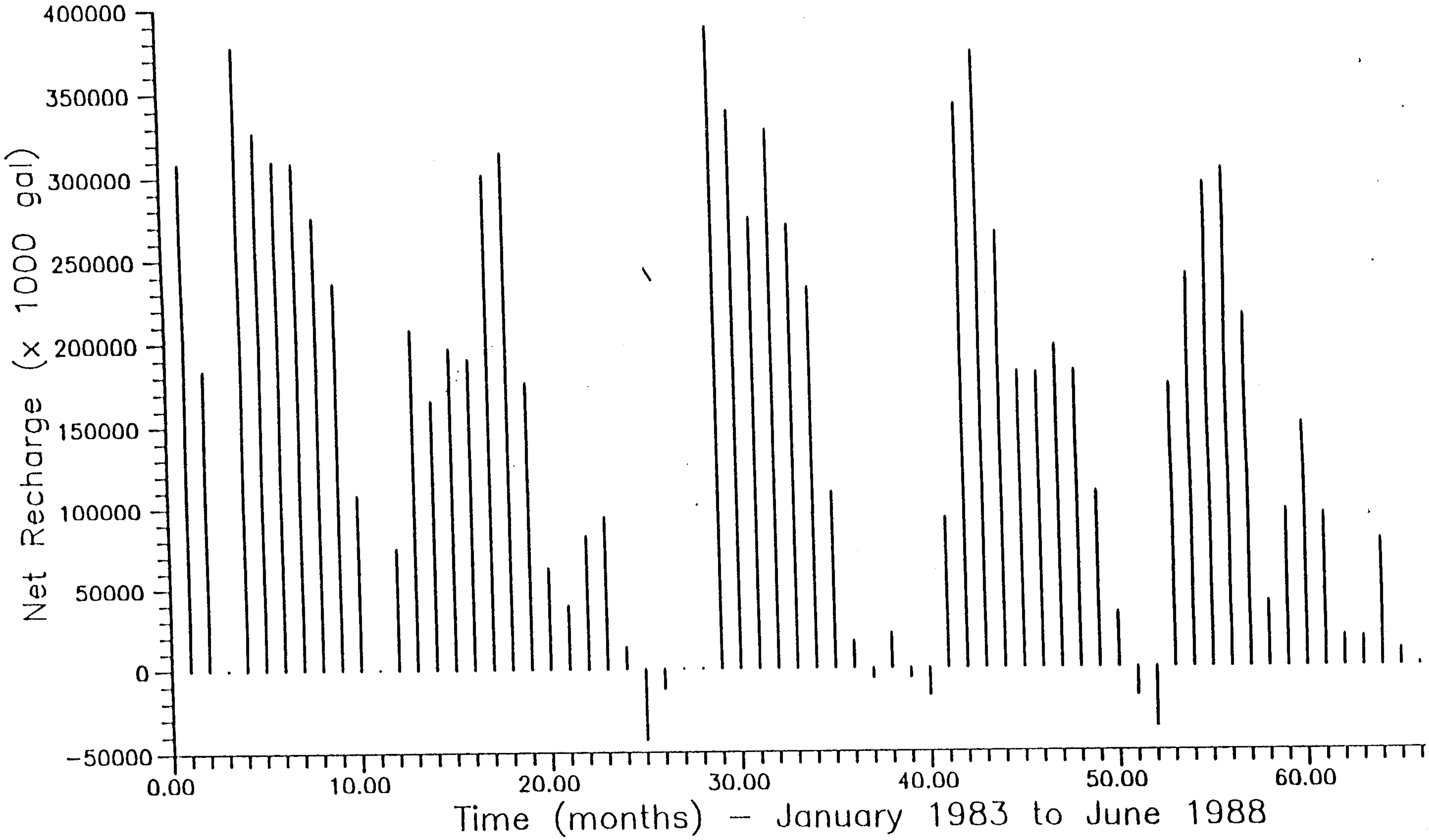

Figure 4. Net Recharge to North Richland Well Field

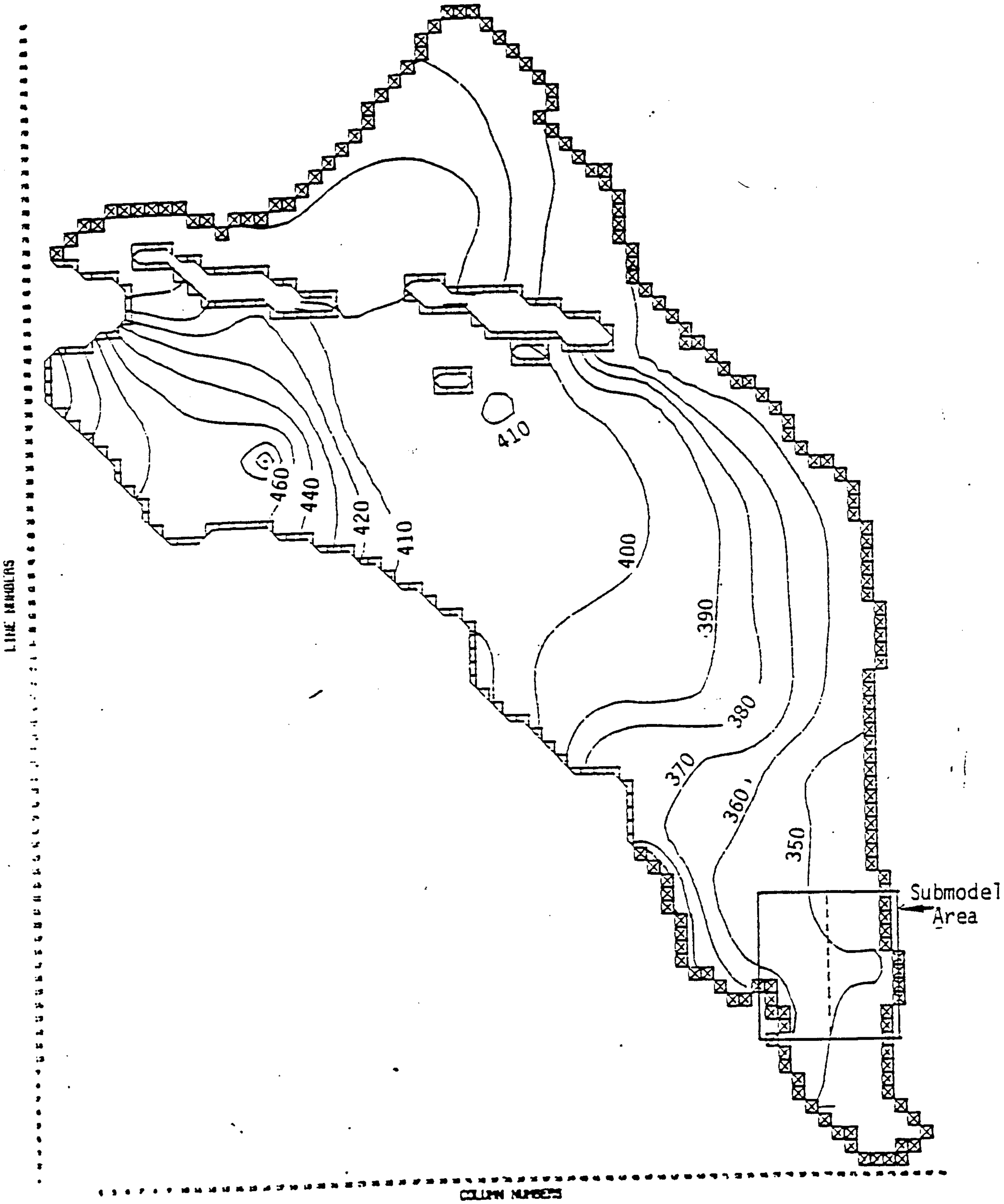

FIGURE 5. Regional Steady-State Model Solution

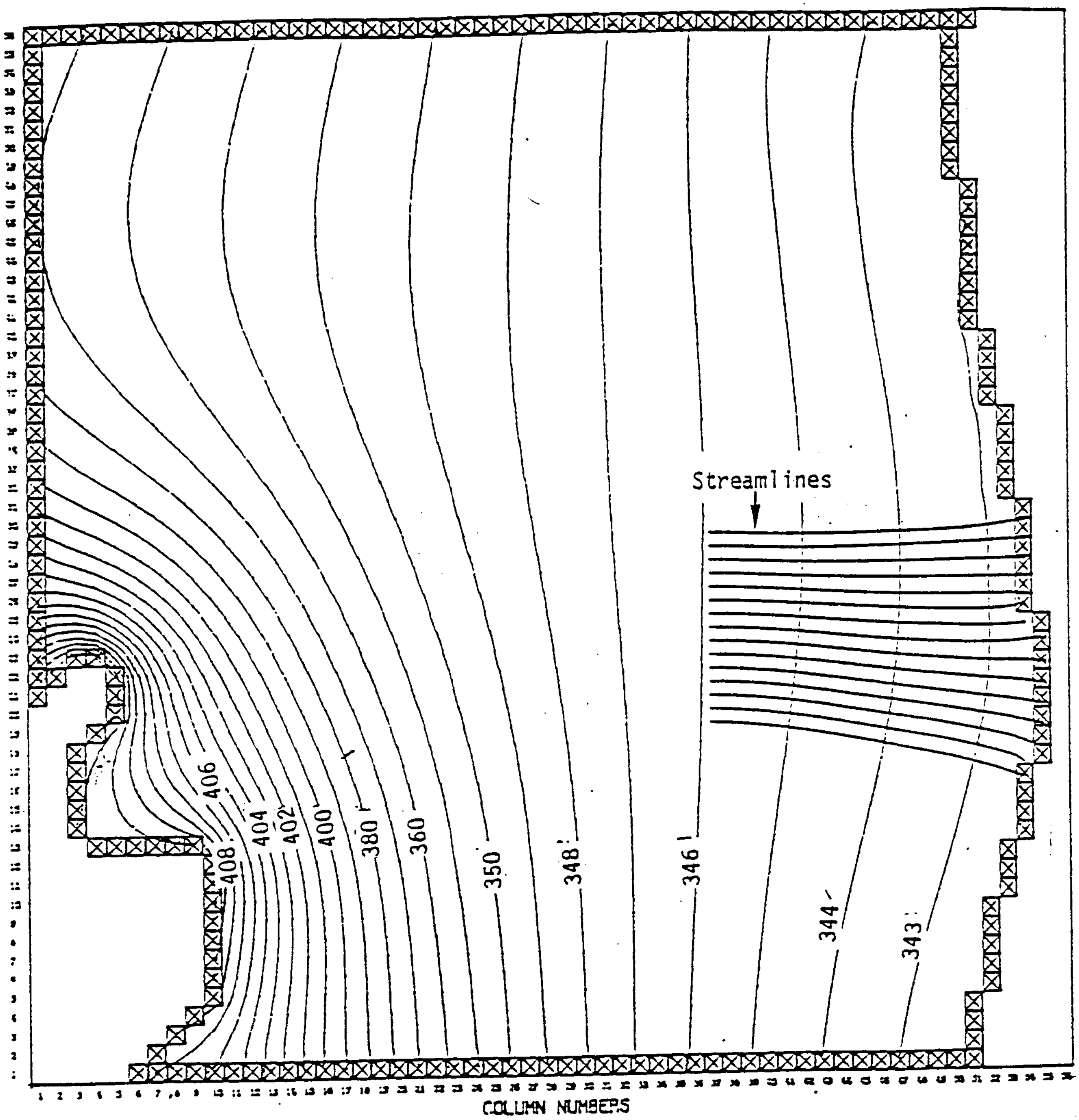

FIGURE 6. 1100 Area Steady-State Model Solution with No Recharge to the North Richland Well Field

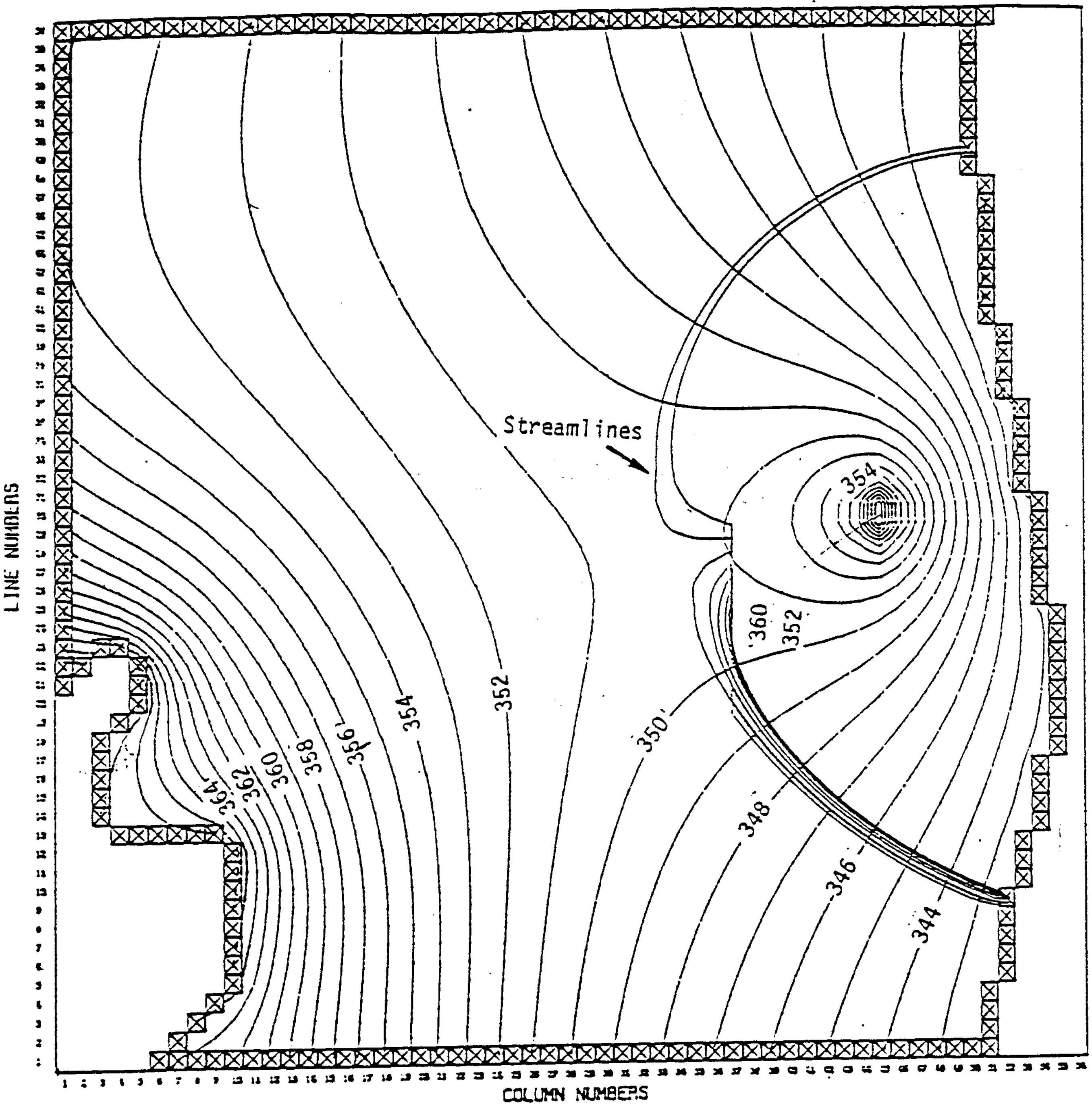

FIGURE 7. 1100 Area Steady-State Model Solution with Recharge to the North Richland Well Field

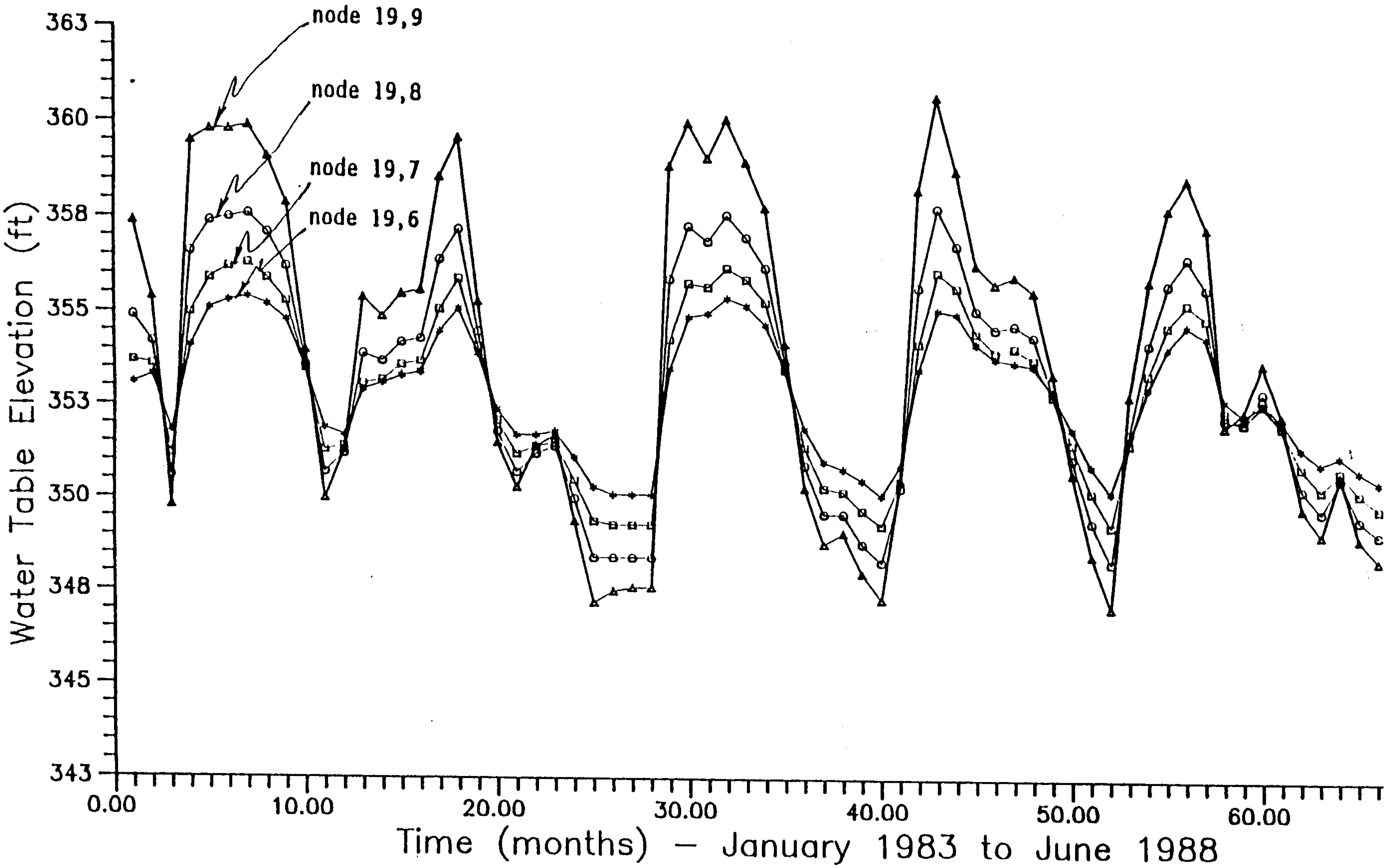

FIGURE 8. Simulated Well Hydrographs

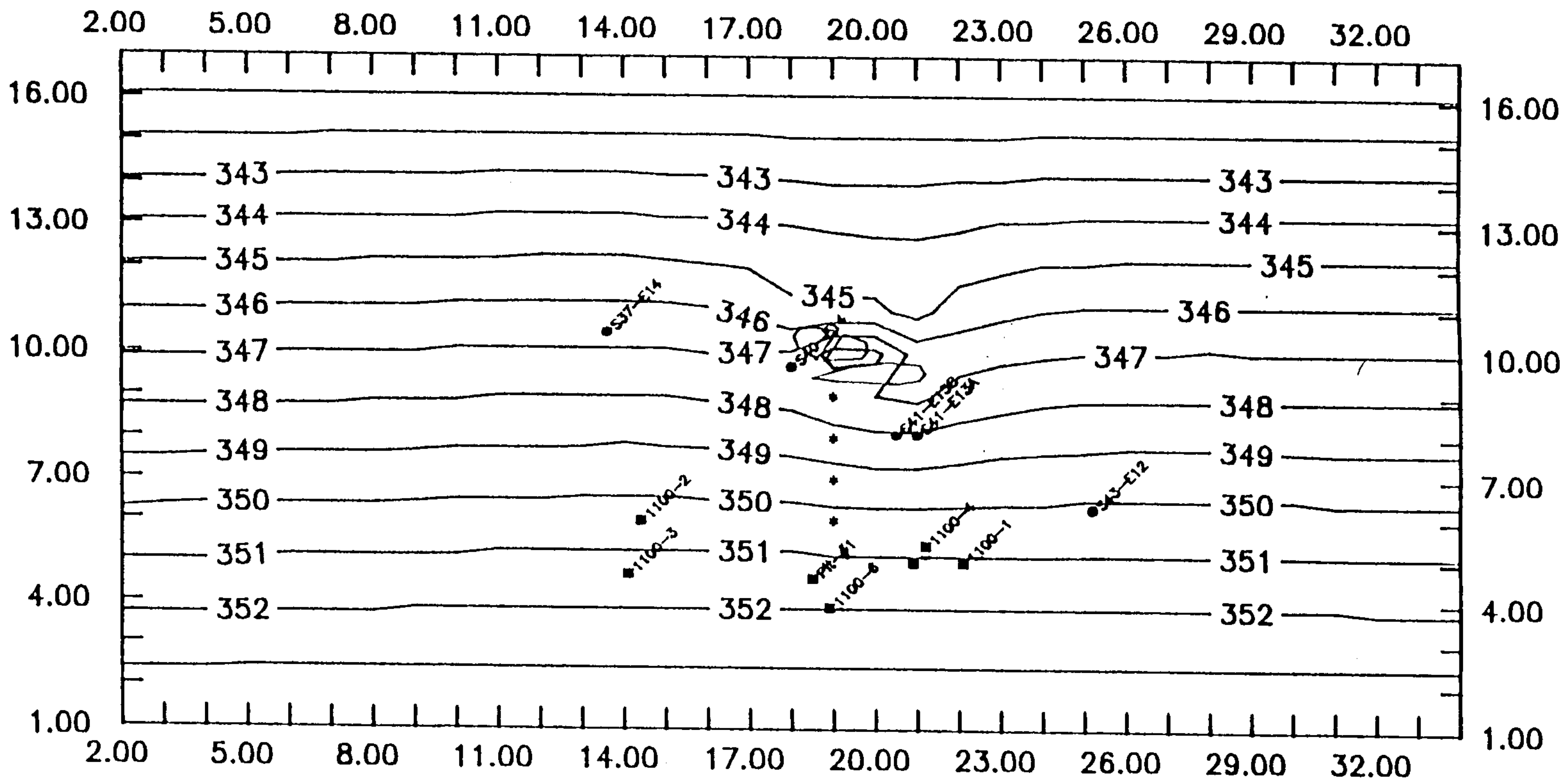

FIGURE 9. Simulated Water-Table Map, Month 25

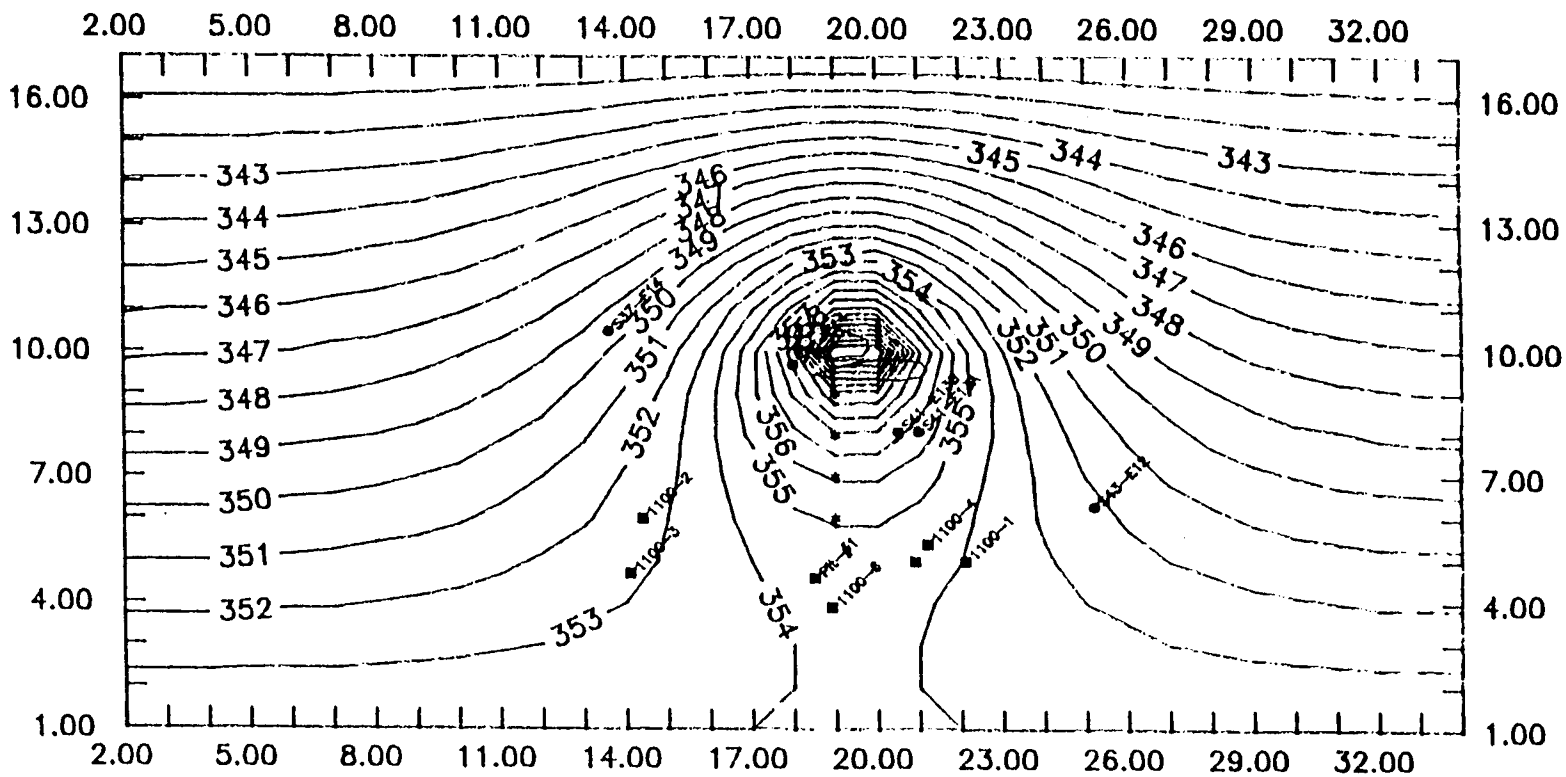

FIGURE 1.0. Simulated Water-Table Map, Month 43