ARIZONA DEPARTMENT OF WATER RESOURCES

# GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODEL CENTRAL PHOENIX, MARICOPA COUNTY, ARIZONA


BY

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HYDROLOGY DIVISION

MODELING REPORT NO. 3

ARIZONA DEPARTMENT OF WATER RESOURCES

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# ARIZONA DEPARTMENT OF WATER RESOURCES GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODELING OF CENTRAL PHOENIX MARICOPA COUNTY, ARIZONA

EPA-ADWR COOPERATIVE AGREEMENT NO. V-009383-01

FEBRUARY 1992

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**CENTRAL PHOENIX GROUNDWATER FLOW
MODELING REPORT**

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## ACKNOWLEDGEMENTS

Arizona Department of Water Resources Hydrology Division would like to thank Paul Plato (ADWR) for assistance in preparing final geologic and hydrogeologic cross-sections. Also, thanks should be extended to the ADWR Basic Data Section for collecting water level data throughout the Central Phoenix area.

**ADDENDUM**

In December 1991 an error was discovered in the 1987 ROGR pumpage database. Groundwater pumpage data is obtained from ADWR's Registry of Groundwater Rights (ROGR) database maintained by the Operations Division. The corrected 1987 pumpage data provided an additional 40,000 acre-feet of pumpage within the Central Phoenix model, primarily from the Roosevelt Irrigation District wells.

Additional model runs were made with corrected 1987 pumpage in February 1992, to ensure that the CPHX model was still in calibration. The first model run (M52-42) with corrected 1987 pumpage indicated excessive drawdown in the RID area. The drawdown was reduced by reassigning pumpage in the RID wells from upper model layers to lower model layers in model run M52-43. This reduced the drawdown in the RID area and overall groundwater flow patterns within the CPHX model remain unchanged. This additional groundwater pumpage has also been taken into account in the conceptual water budget (Table 1, p. 32).

Overall groundwater flow patterns were unchanged between model runs M52-39 and M52-43. This can be observed by comparison of Figure 15 with Figure 15A, and Figure 16 with Figure 16A. The mass balance error of model run M52-43 is an acceptable 1.1%. Therefore, the CPHX model remains in calibration and is suitable for those uses described in the Purpose (p. 5) section of this report.

# I. INTRODUCTION

## Background

The Central Phoenix (CPHX) Regional Groundwater Flow model was developed by ADWR under contract to the U.S. EPA. This report presents the results of the CPHX groundwater flow and contaminant transport model and also provides the data gathered and analyzed through all modeling efforts by ADWR for this area.

In November 1982, Motorola Inc. discovered a discrepancy in the inventory records for 1,1,1-Trichloroethane (TCA) at the Motorola 52nd St. (M52) plant. TCA is a solvent used in various manufacturing processes at the plant and stored in a 5000 gallon underground storage tank. Testing indicated that the TCA tank was leaking. The Arizona Department of Health Services (ADHS) was notified of the TCA leakage and a Preliminary Investigation of potential soil and groundwater contamination was initiated. The Preliminary Investigation included the installation of 29 monitor wells. Results from sampling at monitor wells and private wells indicated that Trichloroethylene (TCE), TCA, and other Volatile Organic Compounds (VOCs) were present in the groundwater.

Upon completion of the Preliminary Investigation at Motorola, a Remedial Investigation/Feasibility Study (RI/FS) was initiated. Motorola entered into a verbal agreement with the U.S. EPA and the ADHS to characterize the environment near the plant site, identify the nature and extent of groundwater contamination, and recommend remedial actions. The RI/FS was completed in 1987 and the Motorola 52nd St. Plant Site was placed on the National Priorities List (NPL) in 1989.

## Description of Plant Site

The Motorola 52nd St. Plant Site is located in the eastern part of the City of Phoenix (Figure 1). Major geographic features near the plant are the Papago Buttes approximately one mile east, and the Salt River about one mile south. The Salt River flows from east to west and is normally dry except during times of water release from the upstream reservoir system or heavy runoff from Indian Bend Wash. Other surface water features near the plant include the Grand Canal south of the plant, which flows from southeast to northwest, and the Old Crosscut Canal, which is located one half mile to the west, flows from north to south, and is used primarily to convey storm water runoff.

The plant site is surrounded by residential and commercial lands on the northern, western, and a portion of the southern boundaries. The eastern boundary adjoins the Phoenix Military Reservation and Papago Park.

Motorola began manufacturing operations at the 52nd St. plant in 1956. On-site disposal practices of VOC's included leach fields, dry wells, sumps, pits, and surface disposal areas. One of the sources identified in the Preliminary Investigation, a dry well, is reported to have received over 100,000 gallons of waste solvent over a period of ten years.

Other potential contaminant sources include the National Guard Facility (Figure 1A) located east and upgradient of the M52 plant. The National Guard Facility uses some of the same solvents as Motorola 52nd St. and has numerous underground storage tanks. Testing indicated some of these tanks leak.

Within the Central Phoenix model area other groundwater contamination sites exist (Figure 1A) and are listed below:

- Motorola 56th Street
- Arizona Air National Guard
- East Washington WQARF (State Superfund) Site
- East Central Phoenix WQARF Site (SRP Well #17E-8N)
- 16th St. Landfill
- 19th Ave. Landfill (CERCLA/Superfund)
- 27th Ave. Landfill
- Estes Landfill
- 40th St. (Bradley) Landfill

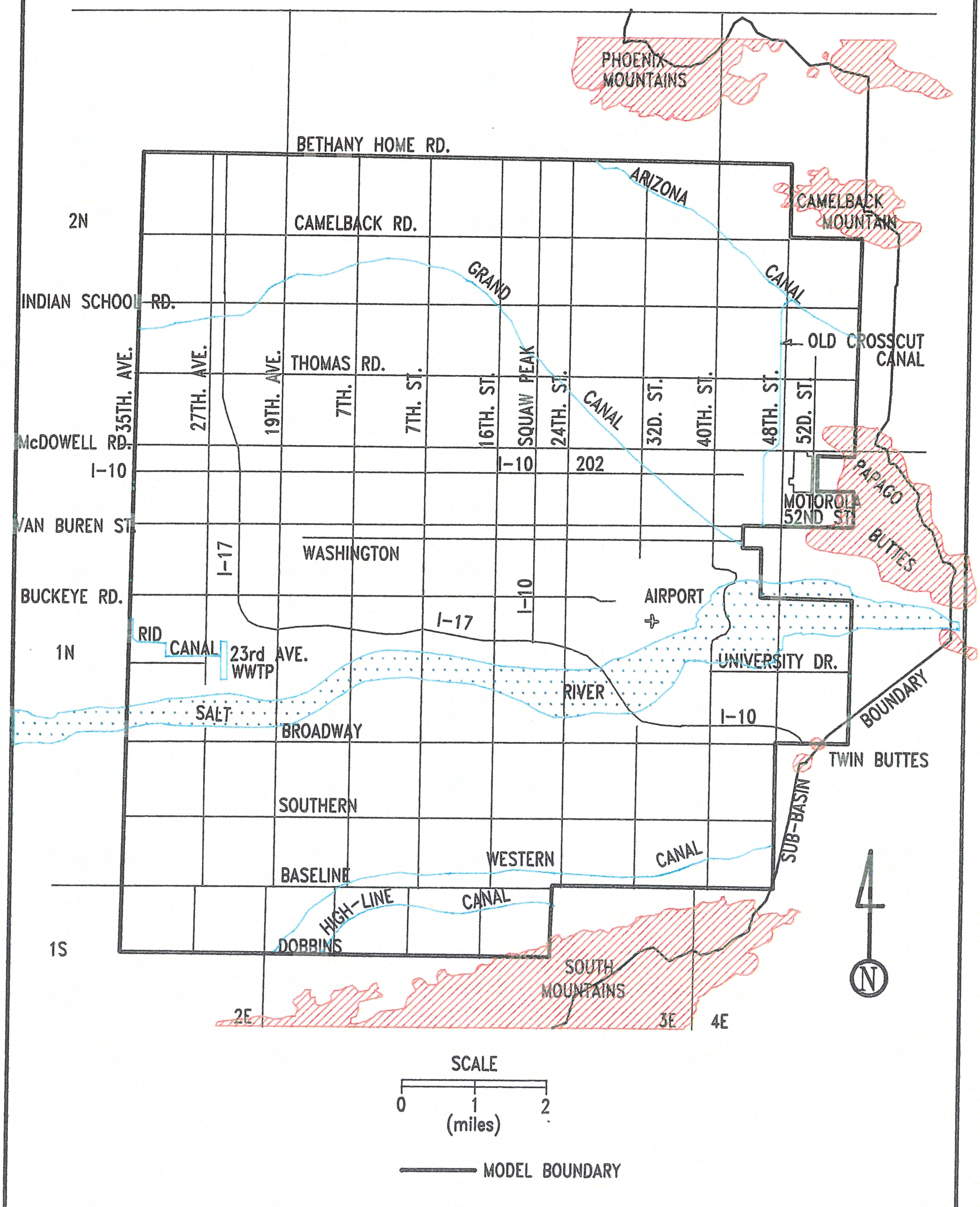
At the M52 plant site observed concentrations of total VOC's vary by more than six orders of magnitude. The minimum concentrations are less than 1 ppb at a few wells not located in the general groundwater flow path of the plume to a maximum concentration of more than 1,000,000 ppb in the Motorola 52nd St. plant Courtyard area, where the leaking storage tank is located.

Groundwater contamination by VOC's is confined primarily to the Upper Alluvial Unit, although beneath the M52 plant site contamination does exist in the weathered bedrock zone.

**Authorization**

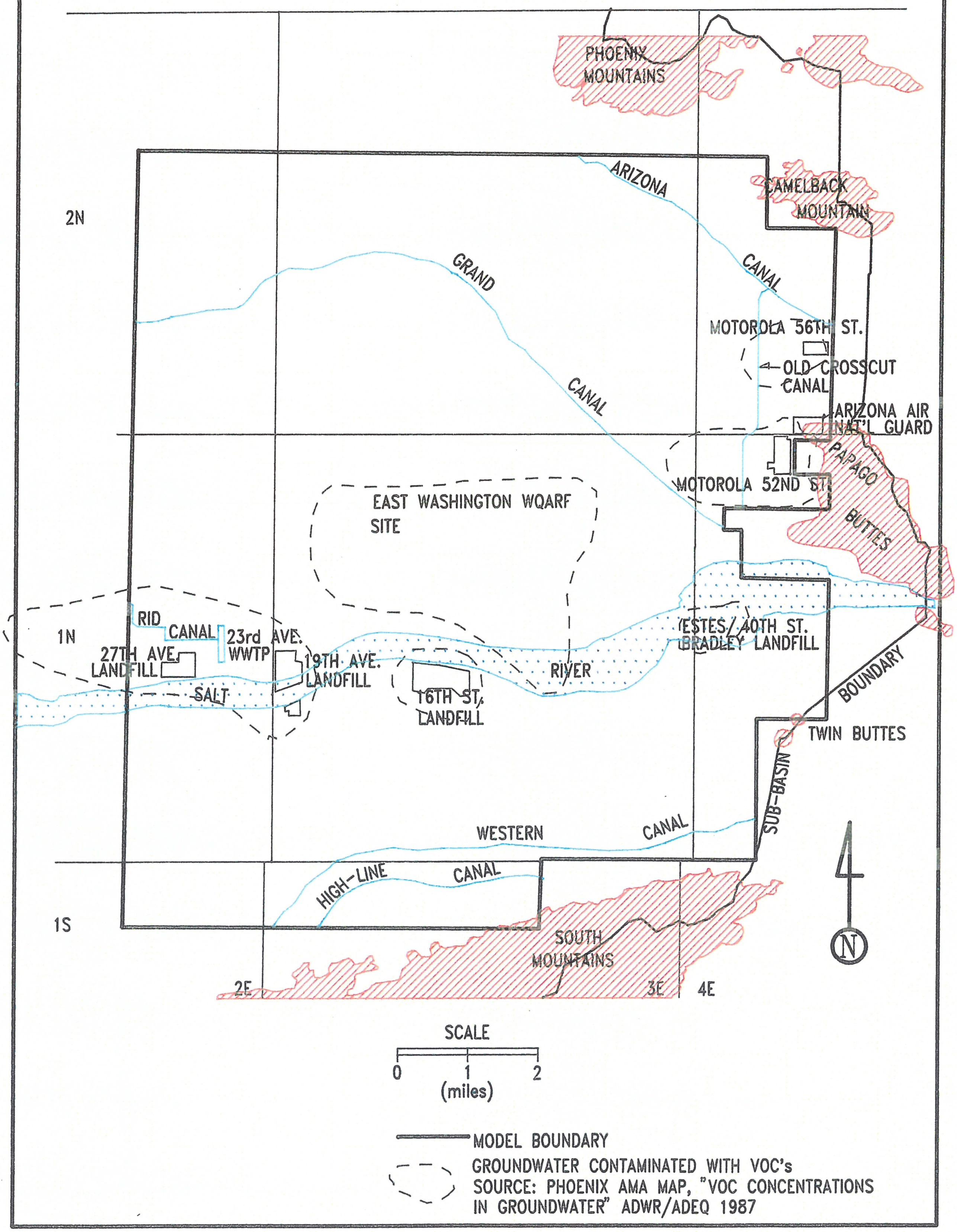
The Arizona Department of Water Resources (ADWR) entered into a Cooperative Agreement (CA; contract No. V-009383-01) with the EPA to develop and operate a computer model of the hydrogeo-

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
LOCATION MAP



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA FIGURE 1A

GROUNDWATER CONTAMINATED WITH VOC's



logic system and construct and maintain a database management system for the Central Phoenix (formerly expanded Motorola 52nd St. Groundwater Flow Model) area.

## Purpose

The purpose of the CPHX Regional groundwater flow and contaminant transport model and database is to address the effects of large scale water use on the groundwater contamination at and near the M52 plant site and at other areas of Central Phoenix, as well as the effect such contamination will have on the ability of nearby groundwater users to withdraw water.

Possible uses of the model are:

- Determine the stability of chosen remedial actions in the face of future pumpage changes, surface water and effluent uses, high surface water runoff (floods) and conservation actions.

- Determine the optimum locations of groundwater withdrawals to avoid causing plume migration within the model area.

- Possibly determine the extent of off site contamination due to disposal practices at the M52 facility.

- Determine the effect of various Remedial Actions (RAs) on ADWR safe yield goals or decline rate rules.

Uses which are not envisioned:

- Specific siting of individual recovery or injection wells.

- Specific siting of individual monitor wells.

- Source identification.

## Scope of Work

The original scope of work for the CPHX modeling study encompassed the following:

- Operate and maintain a computerized database of modeling data.

- Develop and operate a computerized numerical model of the groundwater flow system of the CPHX study area.

- Simulate groundwater flow regimes and movement of selected groundwater contaminants in response to stresses that occur in the groundwater system.

- Calibrate the groundwater flow model using historical data.

- Simulate future migration and capture of contaminants in groundwater for a variety of Remedial Actions (RA's).

**Organization**

The remainder of this report is organized in the following order:

- **Chapter** II discusses the hydrogeologic framework, including the regional setting, hydrogeologic units, groundwater conditions, and Conceptual Water Budget.

- **Chapter** III discusses the modeling approach, including the model code, period of calibration, Target model domain and grid, boundary conditions, model water budget, aquifer parameters and conditions, groundwater flow modeling assumptions, and contaminant transport modeling assumptions.

- **Chapter** IV provides the TARGET model results, and contaminant transport model discussion.

- **Chapter V** provides conclusions and recommendations as a result of this study.

- **Chapter** VI provides the references to the report.

## II. HYDROGEOLOGIC FRAMEWORK

### Regional Setting

The Motorola 52nd St. (M52) plant site is located in East Phoenix in the West Salt River Valley (WSRV) sub-basin, a broad alluvial basin in the Basin and Range physiographic province. The area of study is bounded on the south by the South Mountains and on the west by 35th Ave. (Figure 1). To the north are the Phoenix Mountains and Camelback Mountain. To the east the study area is bounded by the Papago Buttes and Twin Buttes, forming the structural and topographic divide between the East and West Salt River Valley sub-basins. The Salt River flows from east to west in the study area in response to flood events with releases from upstream reservoirs. In the western portion of the study area the Salt River flows perennially due to effluent releases from the 23rd Avenue Waste Water Treatment Plant (Figure 1). Land surface elevations range from 1035' in the the Salt River channel to 1350' above mean sea level in the northeastern portion of the study area.

The WSRV sub-basin is located within the Phoenix Active Management Area (AMA), an area in which ADWR has the authority to regulate and control water use. In this arid region precipitation averages less than eight inches per year (National Oceanic and Atmospheric Administration, 1986). The study area is primarily residential and commercial with some agriculture in the southern portion of the study area. Agricultural irrigation water is supplied by a network of canals which supply surface water and supplemental groundwater. The Motorola 52nd St. plant is located on the eastern boundary of the study area, on the bedrock pediment located adjacent to the regional alluvial aquifer.

### Hydrogeologic Units

The hydrogeologic units in the CPHX area are in descending order: the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), the Lower Alluvial Unit (LAU) and the Basement Complex (Brown and Pool, 1989). The UAU, MAU, and LAU are alluvial basin-fill deposits of Middle to Late Tertiary age (Eberly and Stanley, 1978). The Basement Complex is composed mainly of Precambrian age crystalline rocks (granites, schist, and gneiss) and forms the floor and margins of the WSRV sub-basin. Regional geophysical data indicate that the alluvium may be over 10,000 feet thick near the center of the WSRV sub-basin (Oppenheimer and Sumner, 1980).

## Upper Alluvial Unit (UAU)

The UAU is the youngest alluvial deposit in the CPHX model area. The top of the UAU is at land surface throughout most of the area. The UAU was deposited by the through flowing Salt River system during the last 3.3 my (Laney & Hahn, 1986). The UAU includes channel, flood-plain, terrace and alluvial fan deposits consisting of gravel, sand, and silt. The UAU contains the highest observed concentrations of TCA and TCE in the study area, thus the UAU is the unit of most concern. The UAU is transitional with the MAU and a transition zone of interbedded clay and coarse materials reach a thickness of 100 feet near the central basin. The UAU ranges in thickness from 0 feet at the east and south basin margins to more than 400 feet near the central basin.

The UAU hydraulic conductivity in the CPHX study area ranges from 10 to 267 ft/d (ADWR, 1990). The vertical hydraulic conductivity is assumed to be similar to the vertical hydraulic conductivity at the North Indian Bend Wash study area which is 0.1 ft/d (ADWR, 1990). The UAU contains the water table aquifer and is the primary groundwater-bearing unit in the WSRV sub-basin (Laney and Hahn, 1986). The cross sections and location map (Figures 2, 2A-2F) illustrate the relationships of the UAU, MAU, and LAU.

## Middle Alluvial Unit (MAU)

The MAU underlies the UAU throughout most of the CPHX model area. The MAU was deposited in a closed basin prior to the through-flowing Salt River system, and therefore is probably more than 3.3 my old (Laney & Hahn, 1986). The MAU includes alluvial fan and fluvial deposits of inter-bedded clay, silt, siltstone, sandy silt, and gravel. Thickness of the MAU ranges from zero feet at the basin margins to over 1000 feet near the central basin. Within the CPHX study area the MAU pinches out at the eastern and southern margins where only the UAU is present. The horizontal hydraulic conductivity within the CPHX study area ranges from 11 ft/d to 27 ft/d (ADWR, 1990) and is assumed to be isotropic. The vertical hydraulic conductivity of the MAU is assumed to be similar to that of the MAU of the North Indian Bend Wash modeling study (ADWR, 1990) with vertical hydraulic conductivity of 0.035 ft/d.

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
LOCATION MAP OF WELLS IN CPHX GEOLOGIC AND HYDROGEOLOGIC CROSS-SECTIONS

FIGURE 2

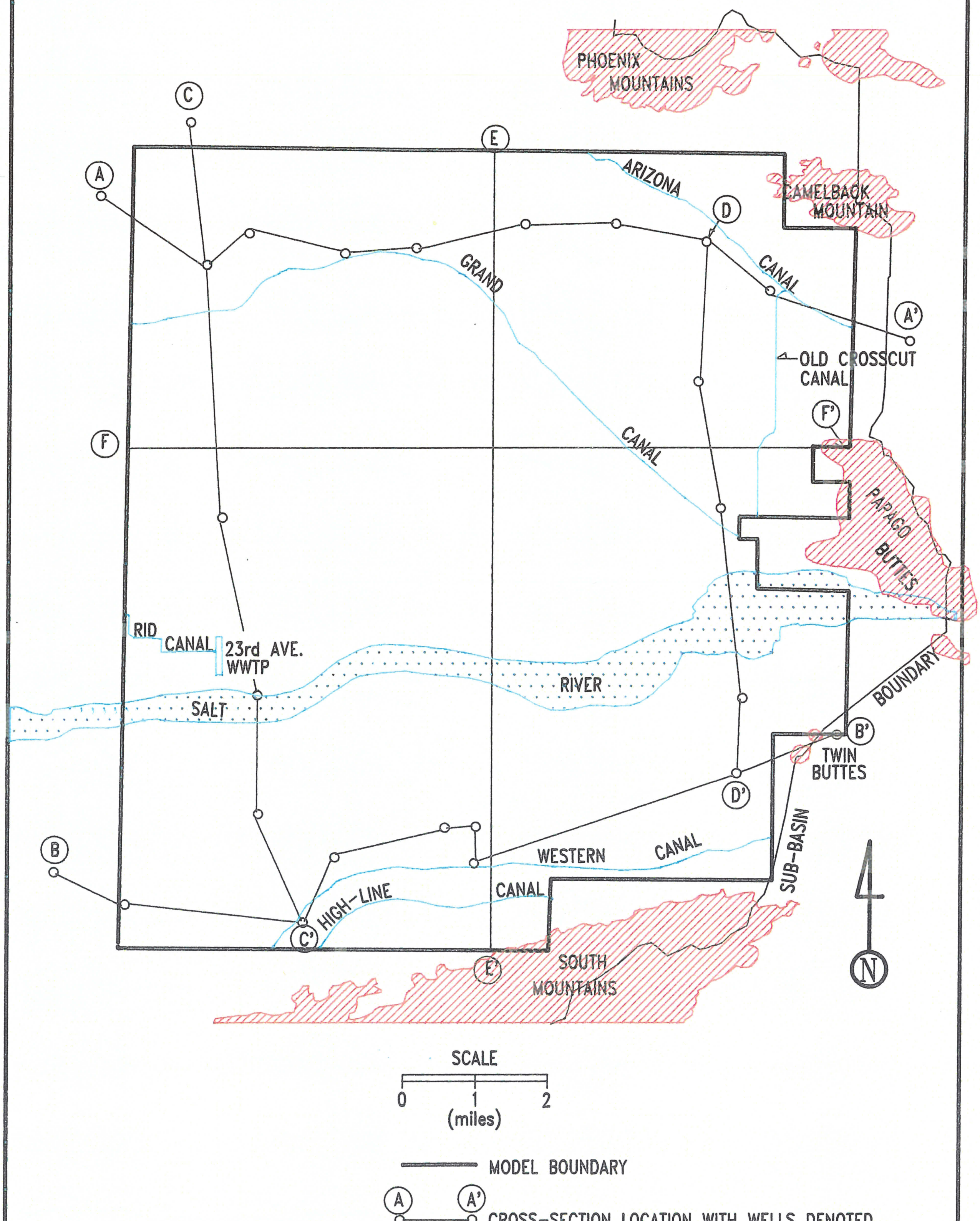
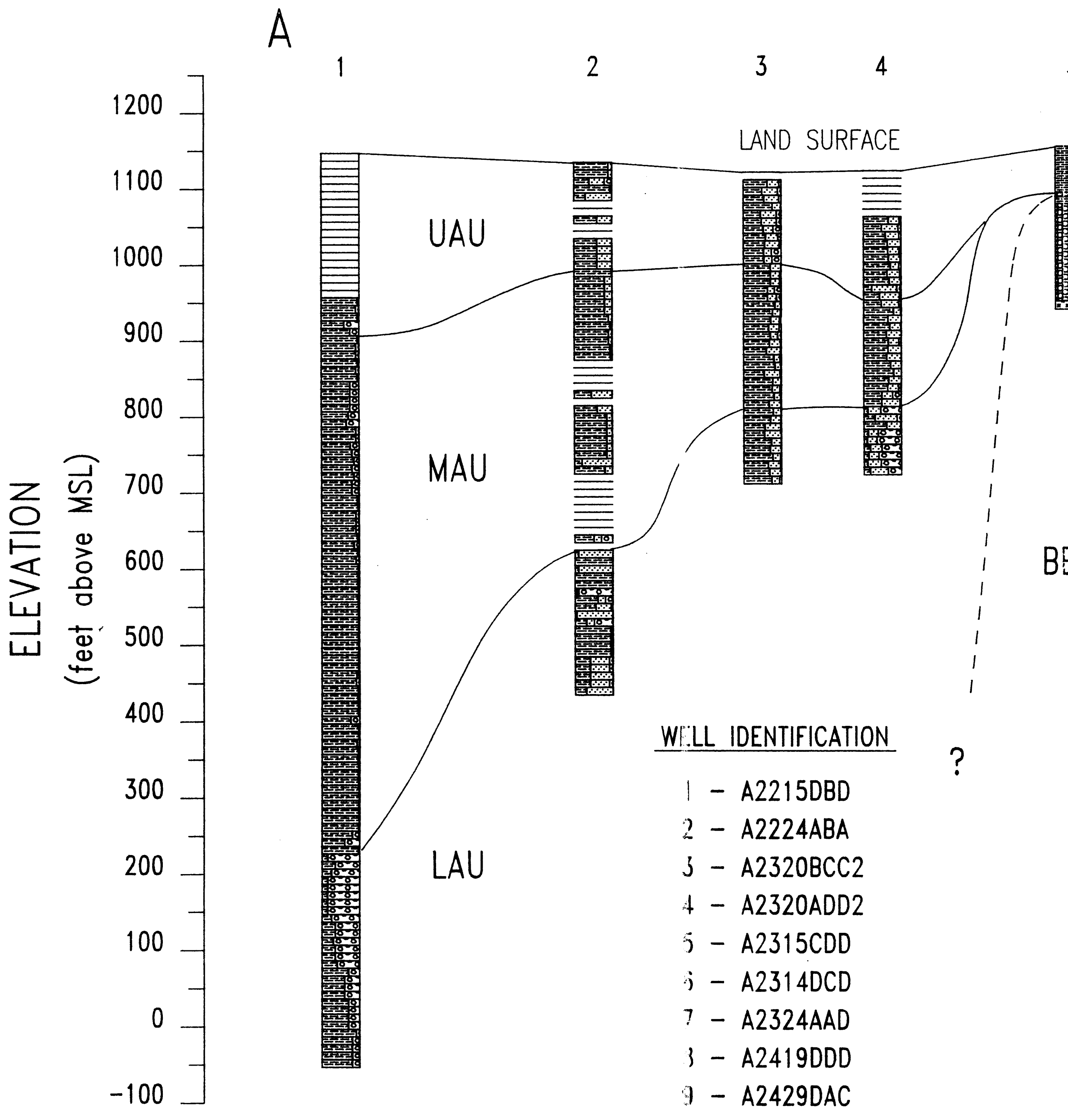


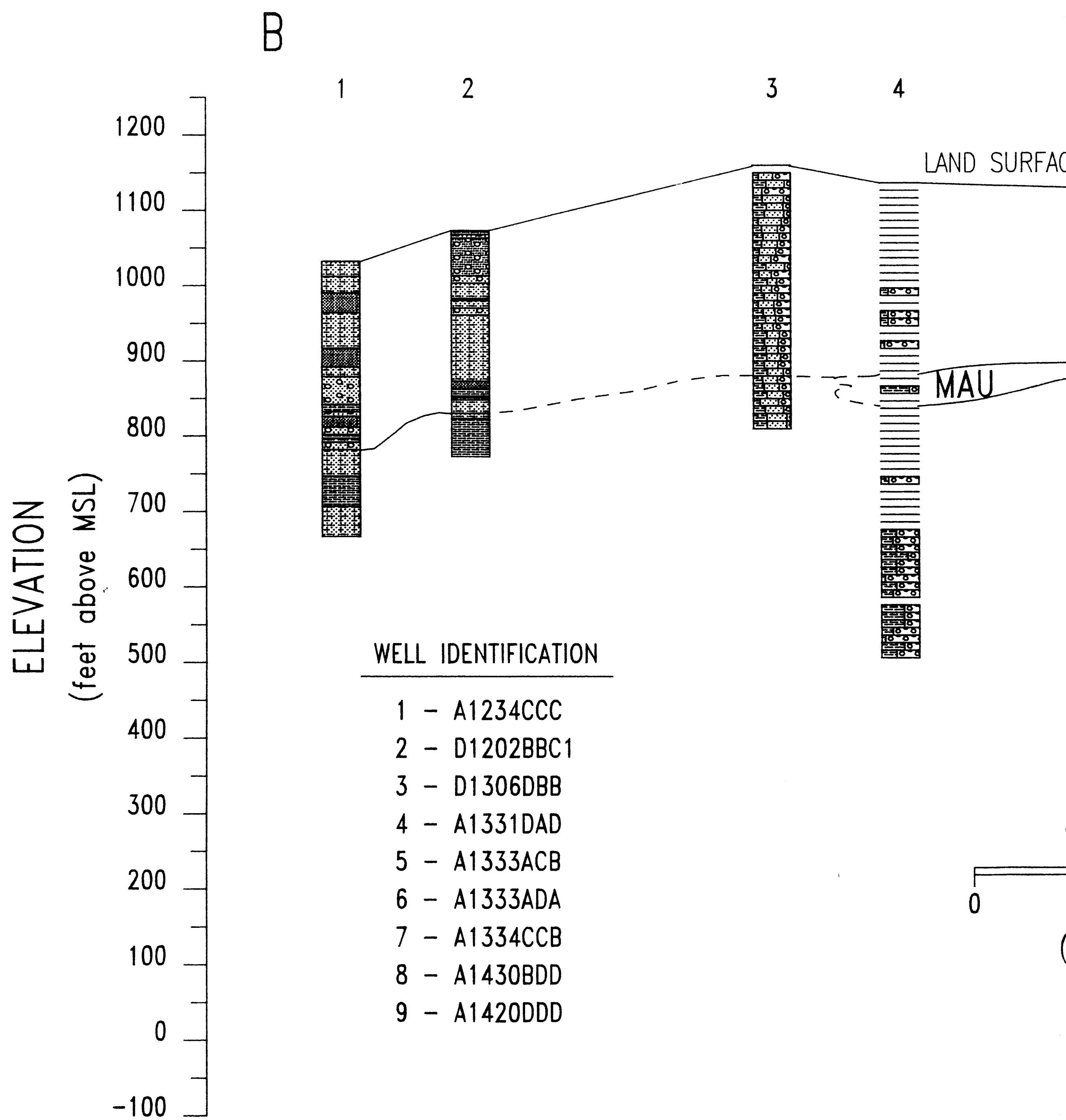
FIGURE 2

GEOLOGIC CROSS-SECTION THROUG



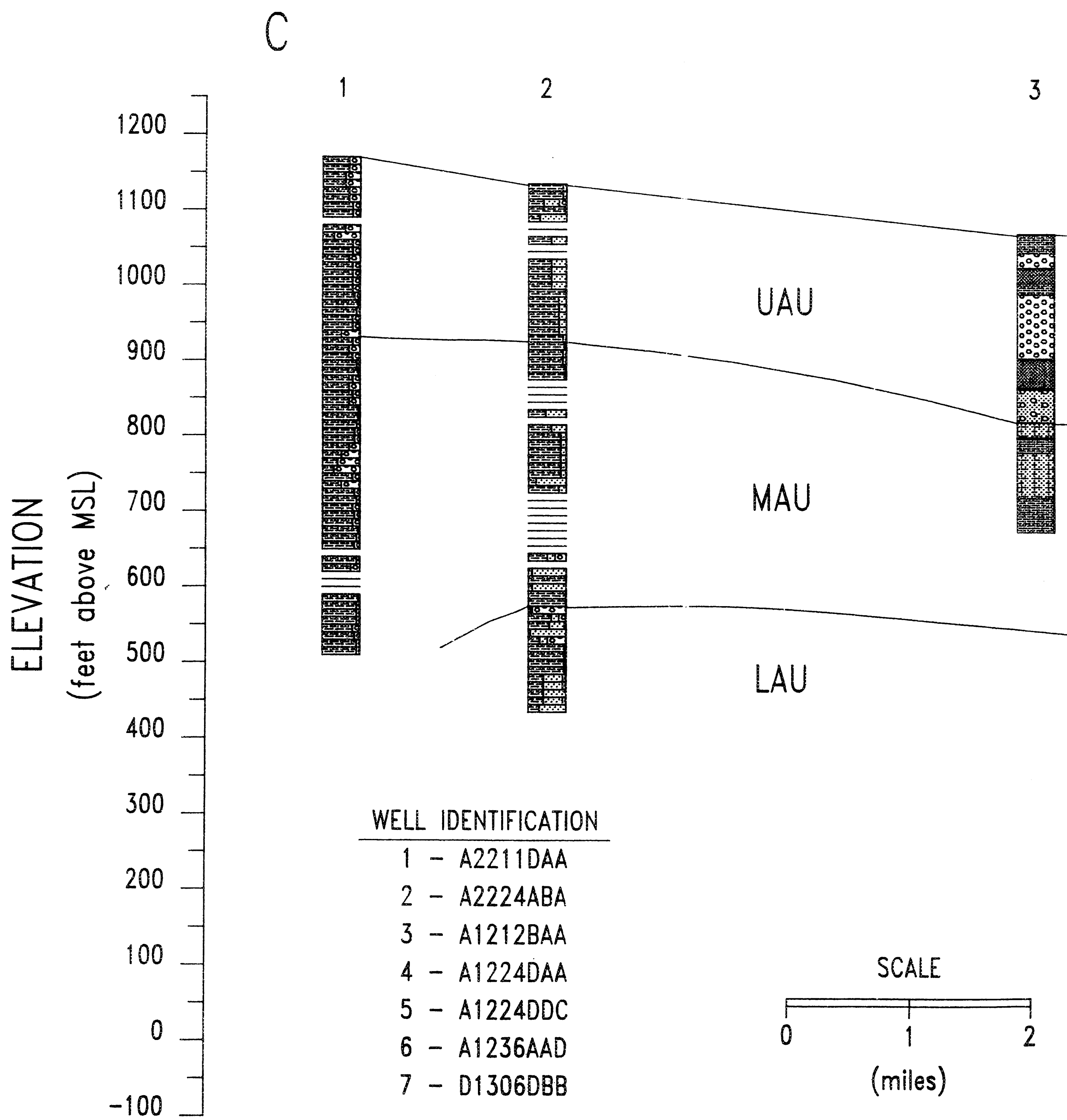
FIGUR

GEOLOGIC CROSS-SECTION THRO



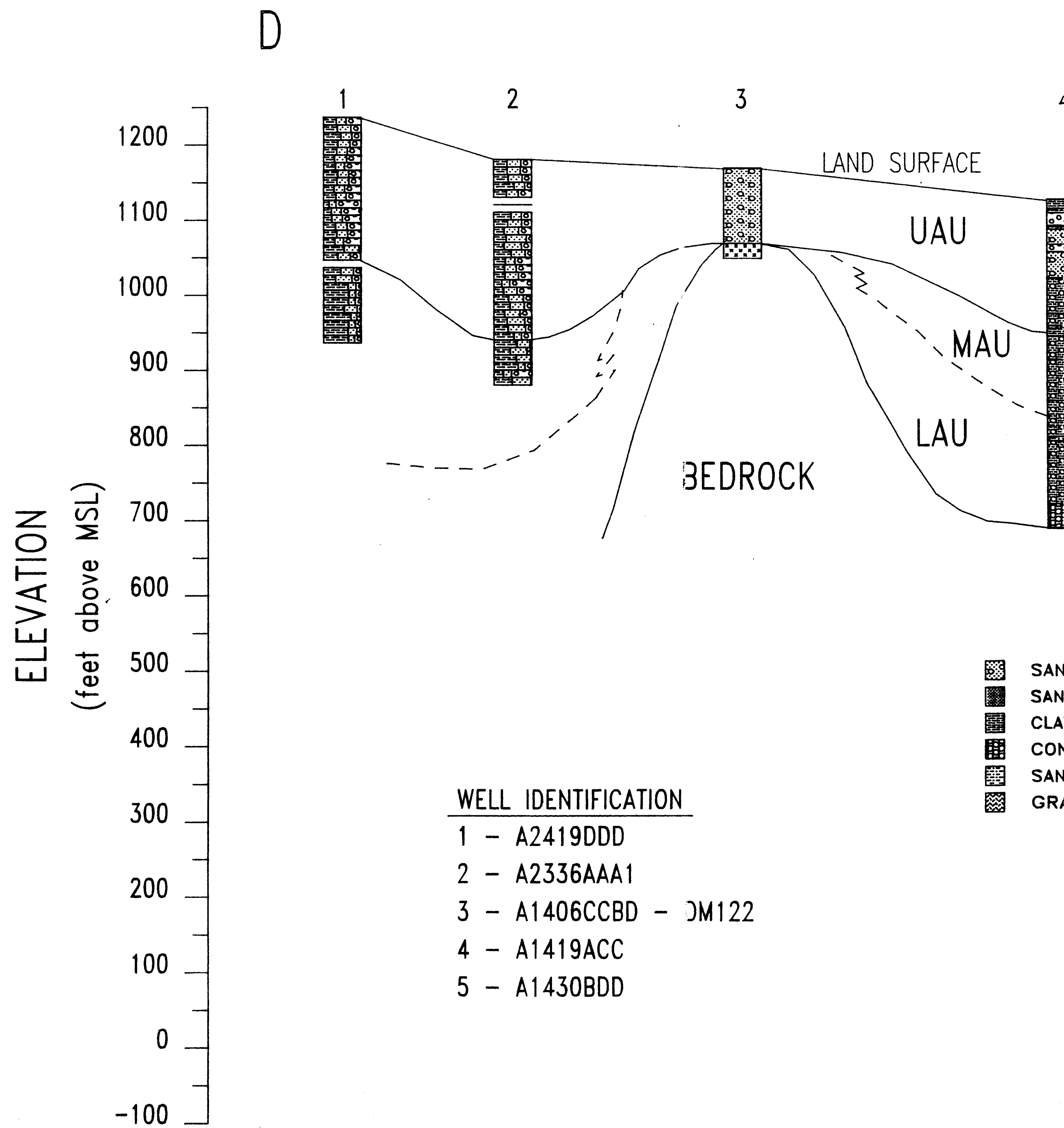
FIGURE

GEOLOGIC CROSS-SECTION THROU



# FIGURE 2D

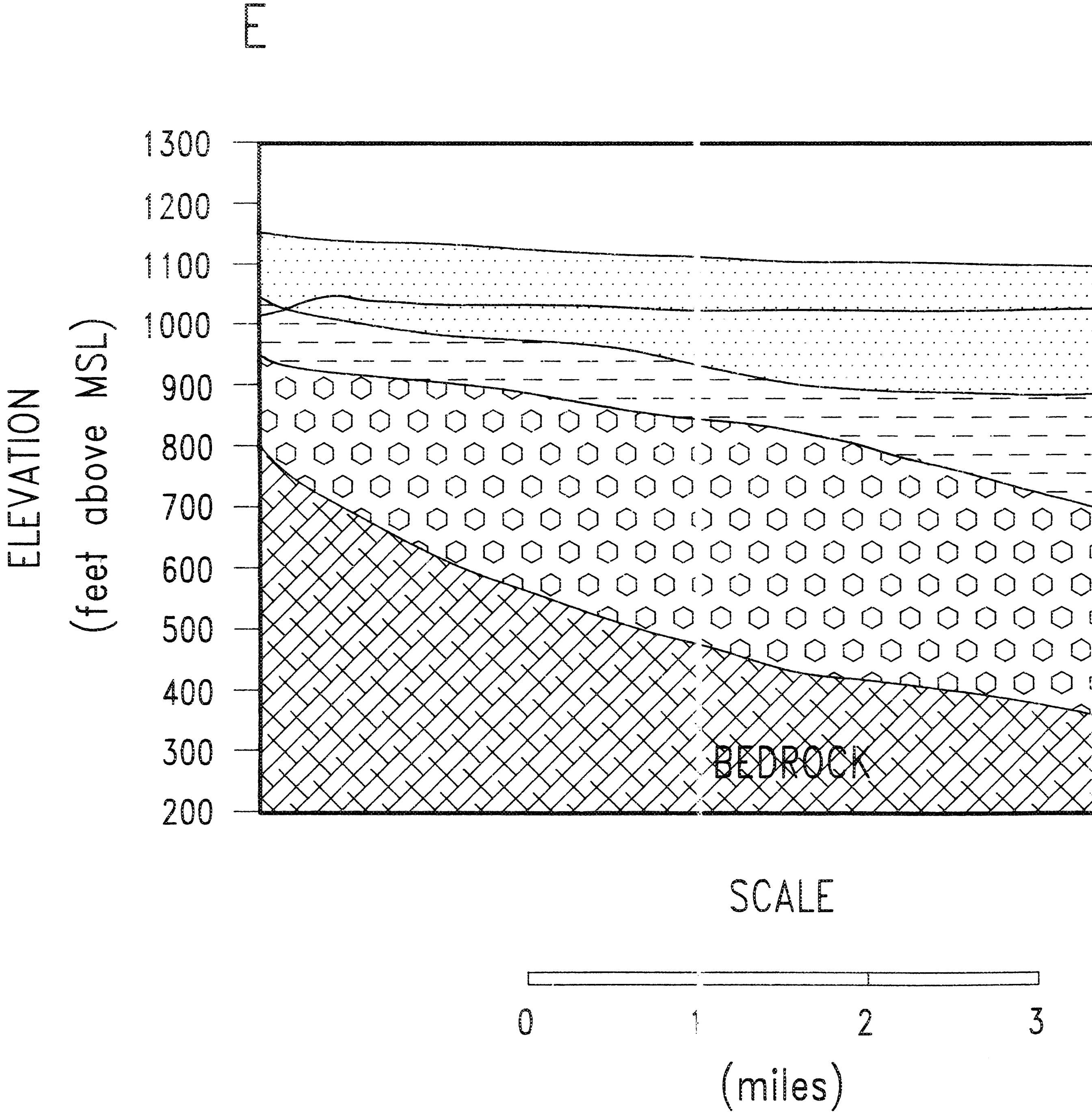
## GEOLOGIC CROSS-SECTION THROUGH (



FIG

GENERALIZED HYDROC

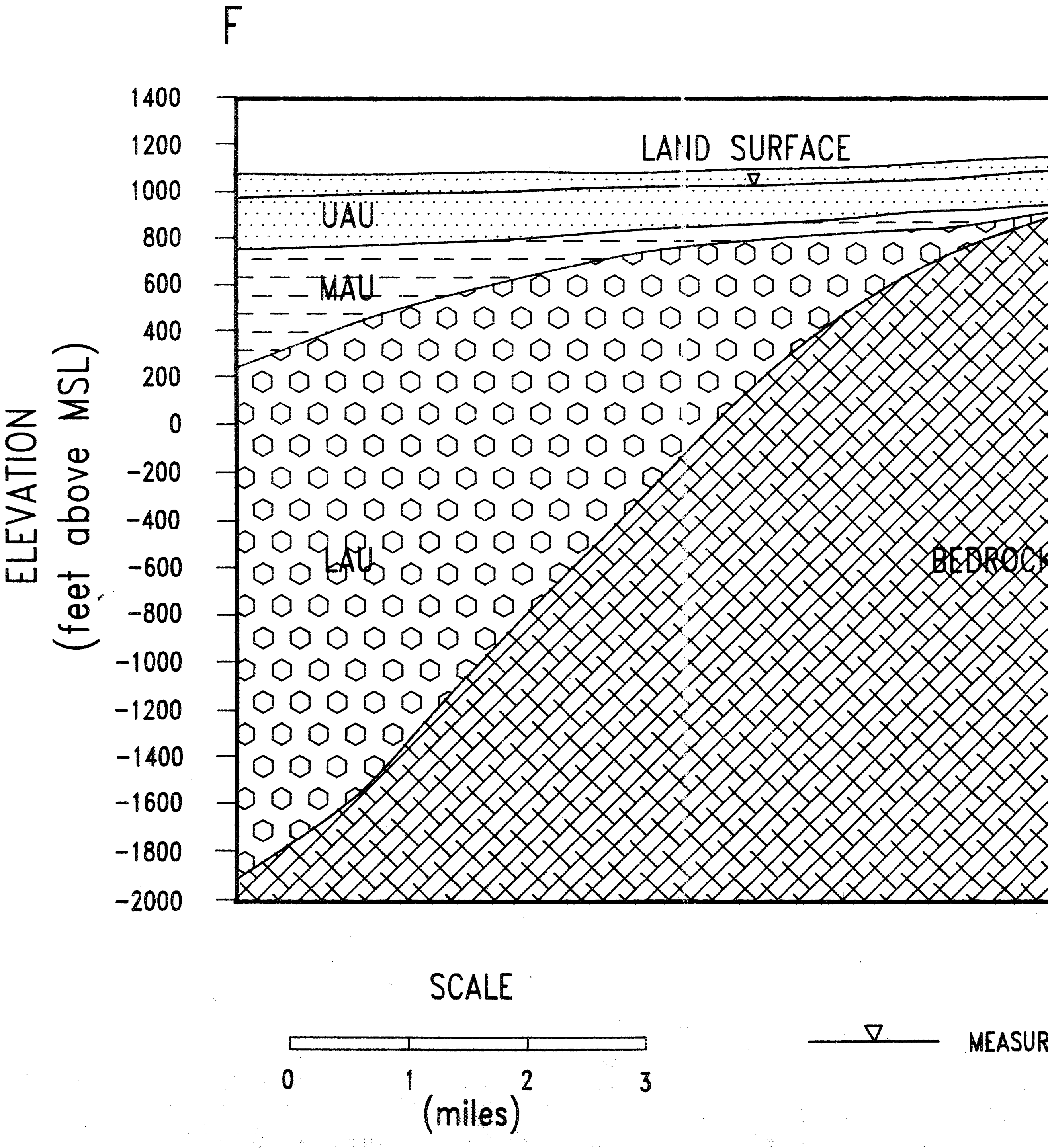
THROUGH CPHX



# FIGURE 2F

# GENERALIZED HYDROGEOLOGIC CRO

# THROUGH CPHX MODEL AREA



## Lower Alluvial Unit (LAU)

The LAU underlies the MAU and UAU in the CPHX model area. The LAU is assumed to have been deposited in a closed basin, and is probably between 8 my and 15 my in age (Laney & Hahn, 1986). The LAU includes playa, alluvial fan, and fluvial deposits and consists of mudstone, anhydrite, conglomerate, clay, silt, sand, gravel, and interbedded basalts. The LAU becomes thicker toward the basin center, reaching a maximum thickness of over 10,000 feet. The LAU has been cemented by calcite to various degrees reducing its ability to store and transmit water. Horizontal hydraulic conductivity is assumed to be isotropic and ranges from 13 ft/d to 80 ft/d (ADWR, 1990) within the model area. The vertical hydraulic conductivity of the LAU is assumed to be similar to that of the LAU at the North Indian Bend Wash modeling study (ADWR, 1990) which is 0.035 ft/d.

## Red Unit

The Red Unit underlies the LAU in the CPHX study area, and overlies the bedrock complex. The Red Unit was deposited before the period of high-angle normal faulting which formed the Basin and Range Province, and is probably no younger than 16 my in age (Laney and Hahn, 1986). The Red Unit consists of debris flows which are reddish-colored, well-cemented breccia, conglomerate, sandstone, and siltstone. The Red Unit is hydrologically similar to the LAU, and is combined with the LAU for modeling purposes. Water is produced from fractures and faults within the Red Unit.

## Bedrock Complex

The Bedrock Complex is comprised of Precambrian schist and granite overlain by the Tertiary age Red Unit (Laney and Hahn, 1986). Locally, Tertiary volcanic rocks may be present. These rocks form the floor and margins of the WSRV basin and present a nearly impermeable barrier to groundwater flow (Ross, 1978).

## Groundwater Conditions

The three main hydrogeologic units described above (UAU, MAU, and LAU) comprise unique aquifers with different physical and hydraulic properties. These aquifers occur within the CPHX study area in the West Salt River Valley sub-basin. The importance and significance of these aquifers are discussed below in descending order beginning with the Upper Alluvial Unit Aquifer. Figure 3 illustrates the land surface elevation in the Central Phoenix model area. Figures 3A to 3F are structure contour and isopach maps of the UAU, MAU, and LAU.

## Upper Alluvial Unit Aquifer

In the CPHX study area, the UAU is the water table aquifer in which unconfined conditions exist. Recharge, including effluent (23rd Ave. Waste Water Treatment Plant), canal losses, and agricultural irrigation returns directly impact the quantity and quality of the groundwater in the UAU. Important flood and recharge events occurred within the Salt River channel in 1983 and 1985. Groundwater flow in the UAU is generally directed toward the west and west-southwest in the CPHX study area. Groundwater flow toward the east occurs at the western model boundary in sections A(01-02)11 and A(01-02)14. This reversal in the direction of general groundwater flow is in response to heavy pumping in the area by the Roosevelt Irrigation District. The reversal in groundwater flow direction is not indicated on the water level maps of Figure 4A and 4B due to data limitations of unit-specific water levels. Many wells in the CPHX study area tap the UAU. Figures 4A and 4B are water level maps for the UAU which are based upon unit specific water level data for January, 1983 and January, 1989 respectively. These two dates bracket the period of time simulated by the groundwater flow model. Between January 1983 (Figure 4A) and January 1989 (Figure 4B) water levels in the UAU rose approximately 10 feet.

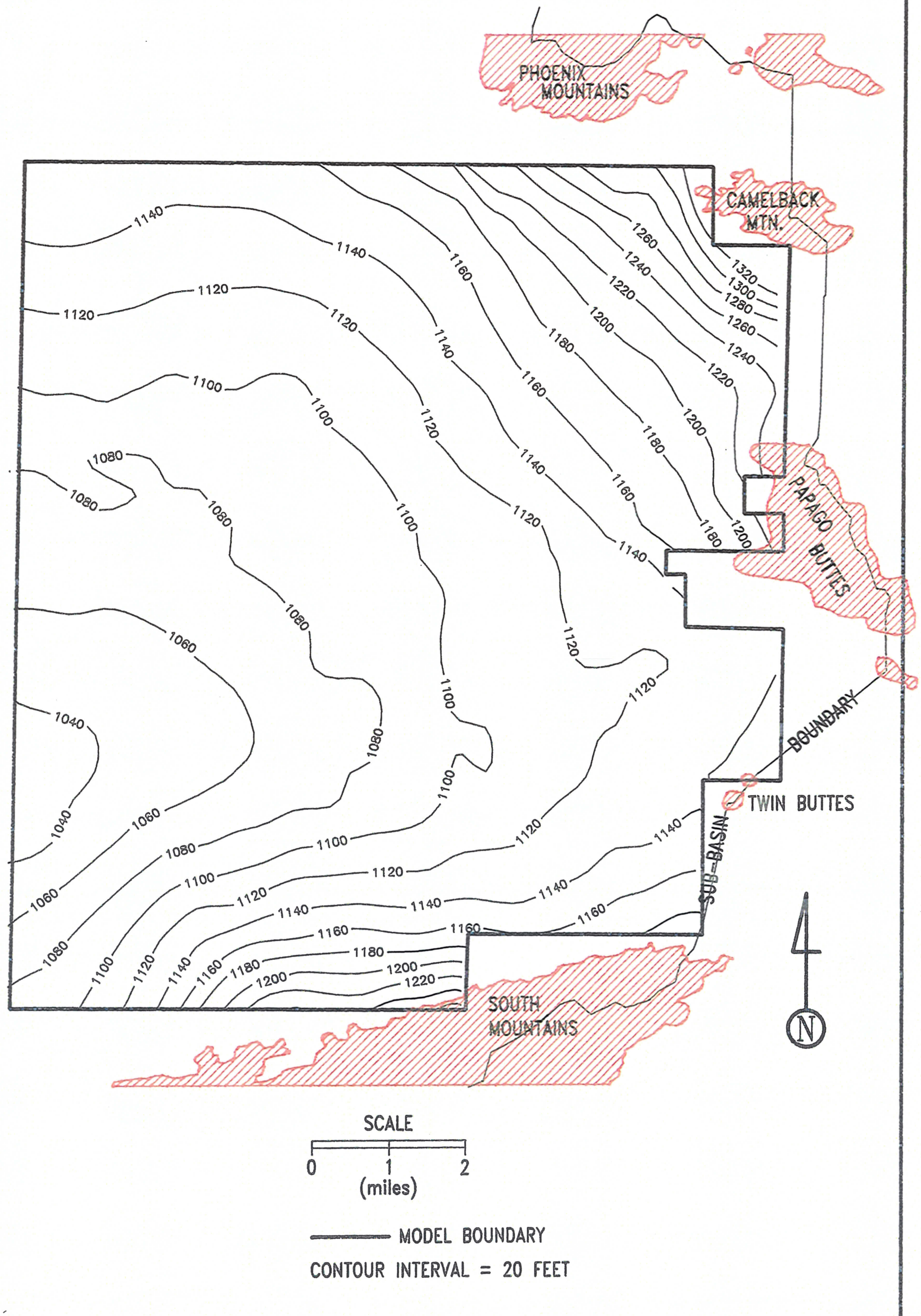
## Middle Alluvial Unit and Lower Alluvial Unit Aquifers

The MAU and LAU are both confined aquifers in the model area. Recharge occurs from overlying alluvial units. Substantial underflow leaves the model domain in the MAU and LAU along the western boundary. Some underflow enters into the model domain along the western model boundary. This inflow is in response to the cone of depression created by the heavy groundwater pumpage in the area by the Roosevelt Irrigation District. Groundwater flow directions for the MAU and LAU are generally toward the west and west-southwest. Figures 4C and 4D illustrate measured water levels for the MAU in January, 1983 and January, 1989 respectively. Figures 4E and 4F illustrate the measured water levels for the LAU in January, 1983 and January, 1989 respectively.

The head distribution shown in the January, 1983 unit-specific water level maps (Figures 4A, 4C, 4E) were used as the starting heads for calibration of the groundwater flow model. The head distribution shown in the January, 1989 unit-specific water level maps (Figures 4B, 4D, 4F) are the final heads to which the model simulated final heads (January 1989) were calibrated to.

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
LAND SURFACE ELEVATION

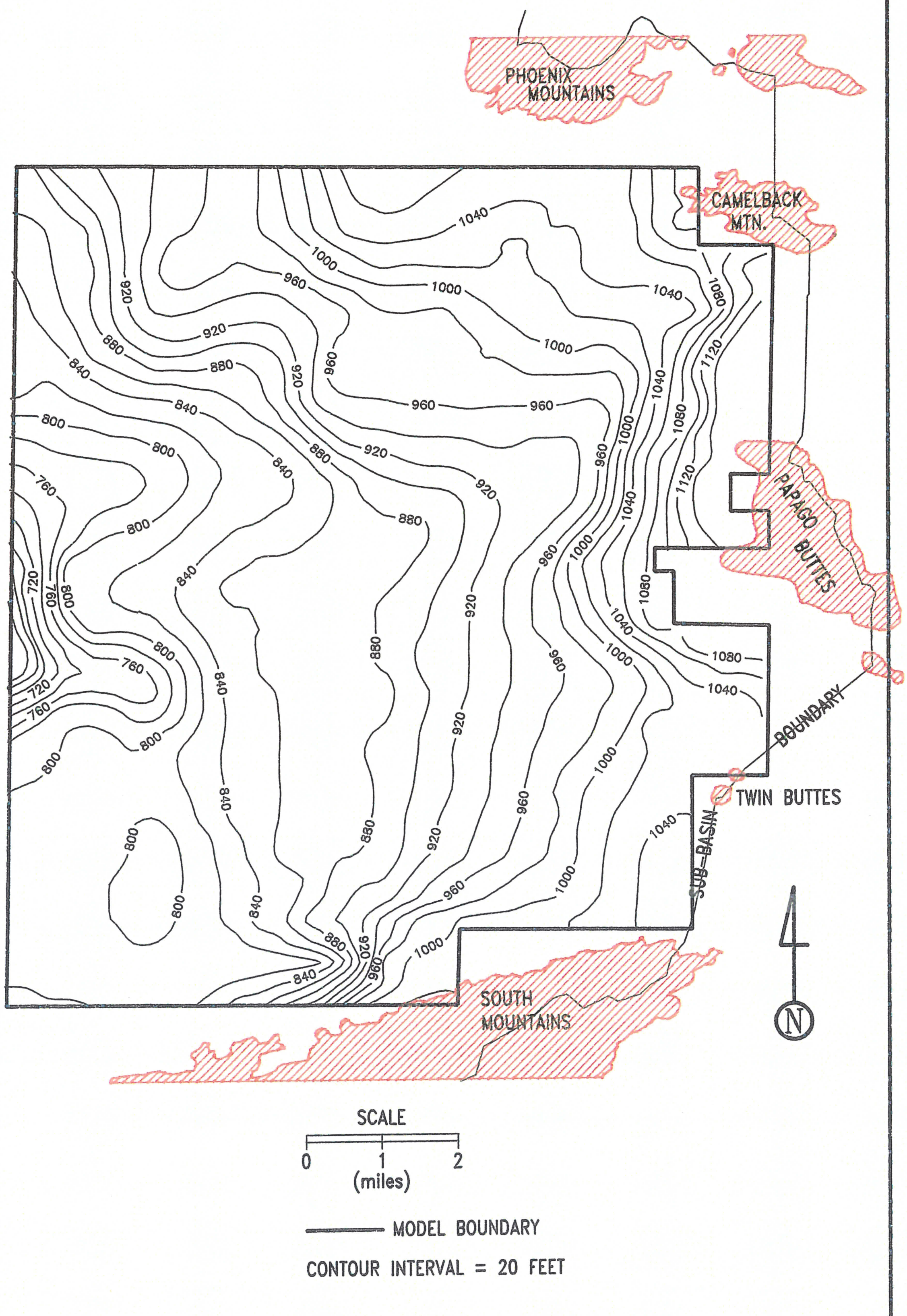
FIGURE 3



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

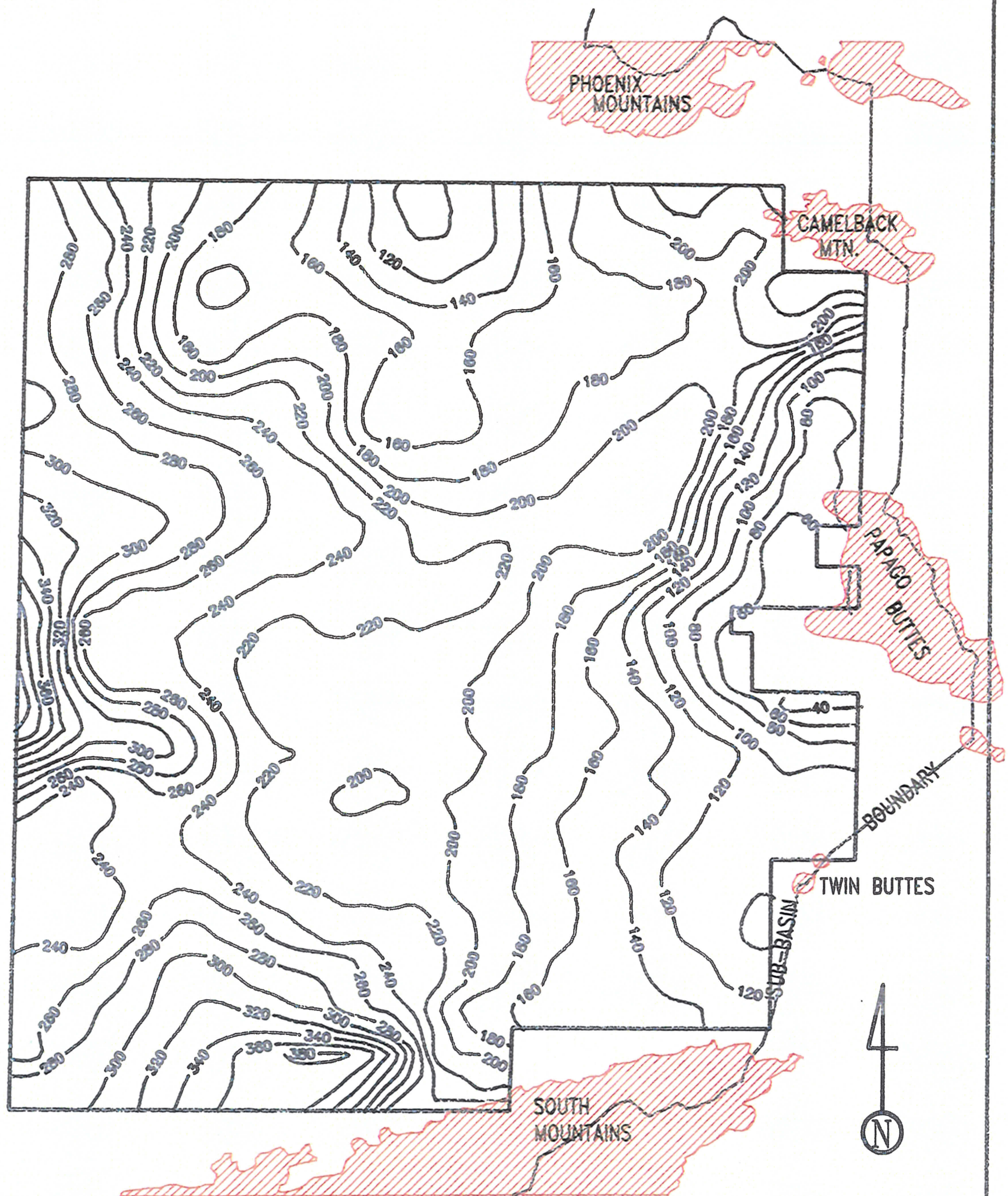
UAU–BOTTOM ELEVATION CONTOURS

FIGURE 3A



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA — FIGURE 3B

UAU-ISOPACH MAP




SCALE

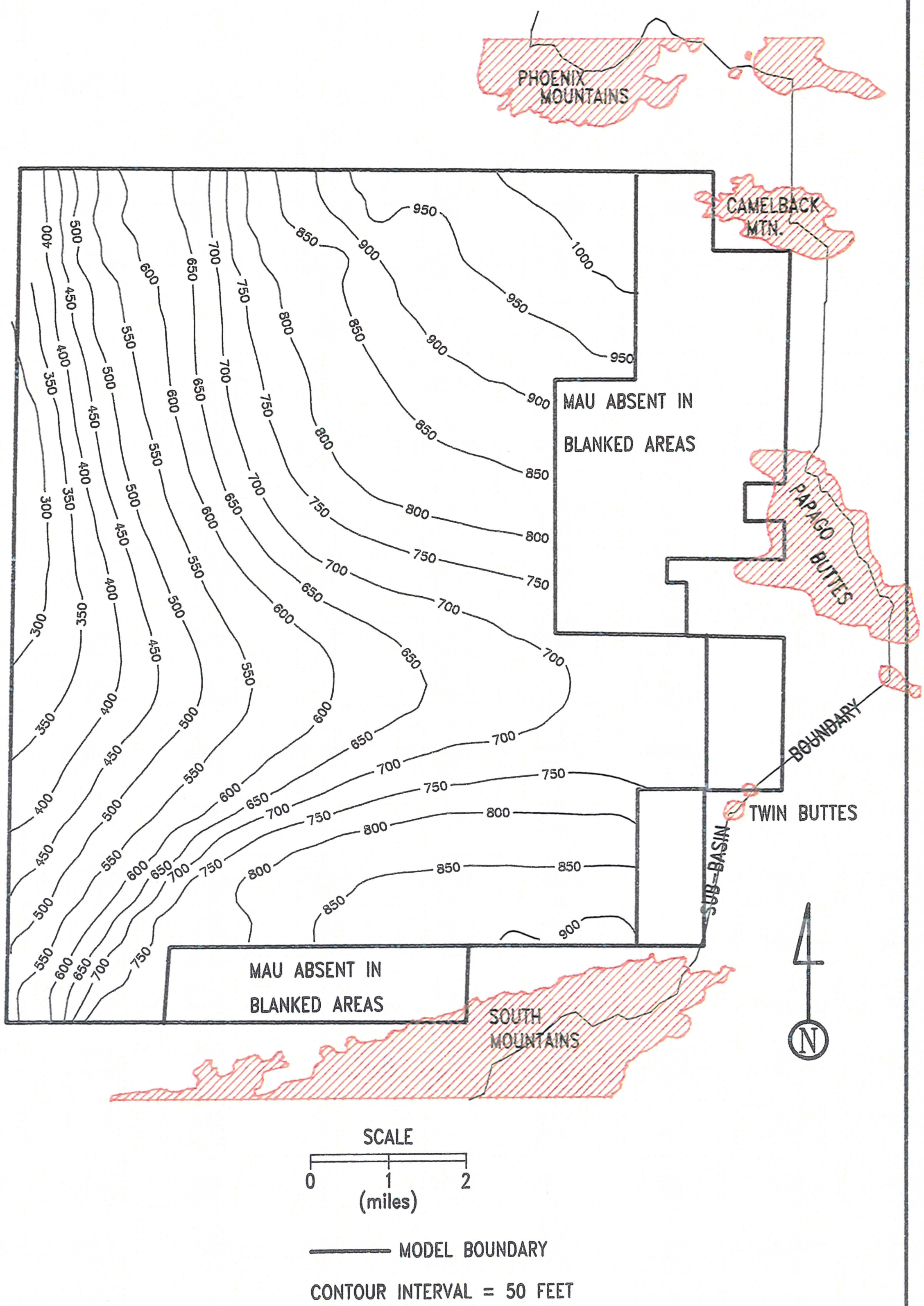
0 1 2
(miles)

MODEL BOUNDARY

CONTOUR INTERVAL = 20 FEET

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA FIGURE 3C

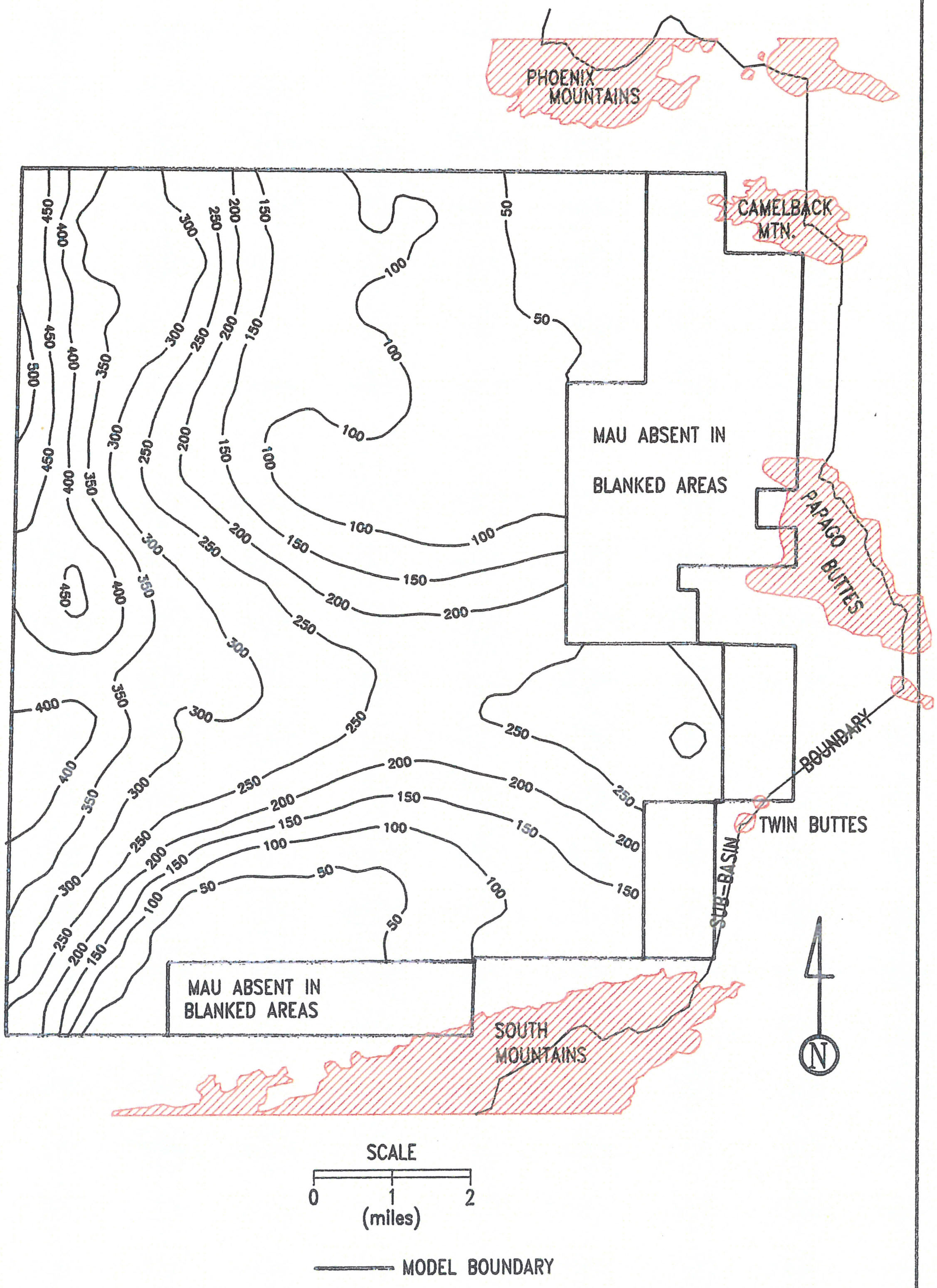
MAU–BOTTOM ELEVATION CONTOURS



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

FIGURE 3D

MAU-ISOPACH MAP

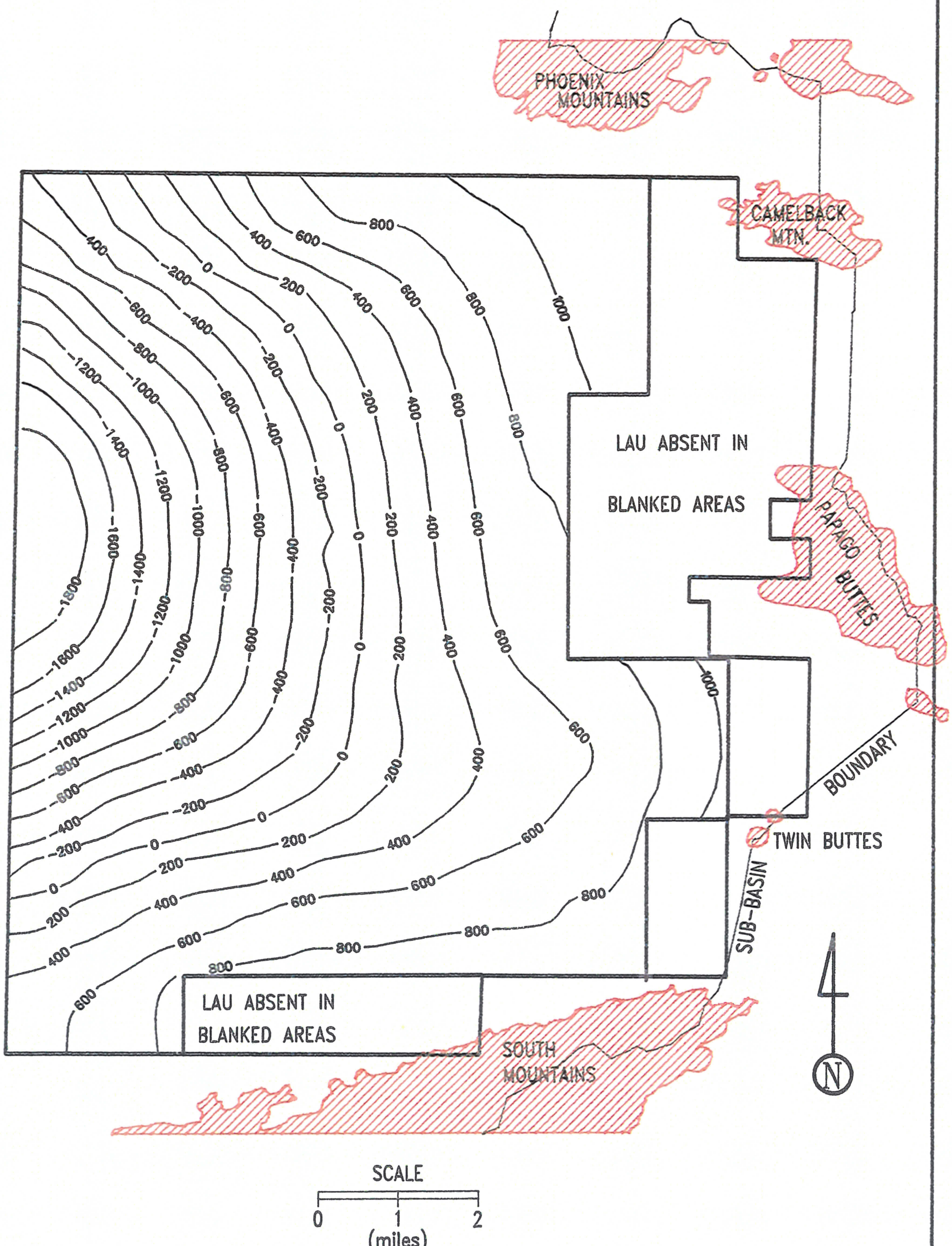



CONTOUR INTERVAL = 50 FEET

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

FIGURE 3E

LAU–BOTTOM ELEVATION CONTOURS



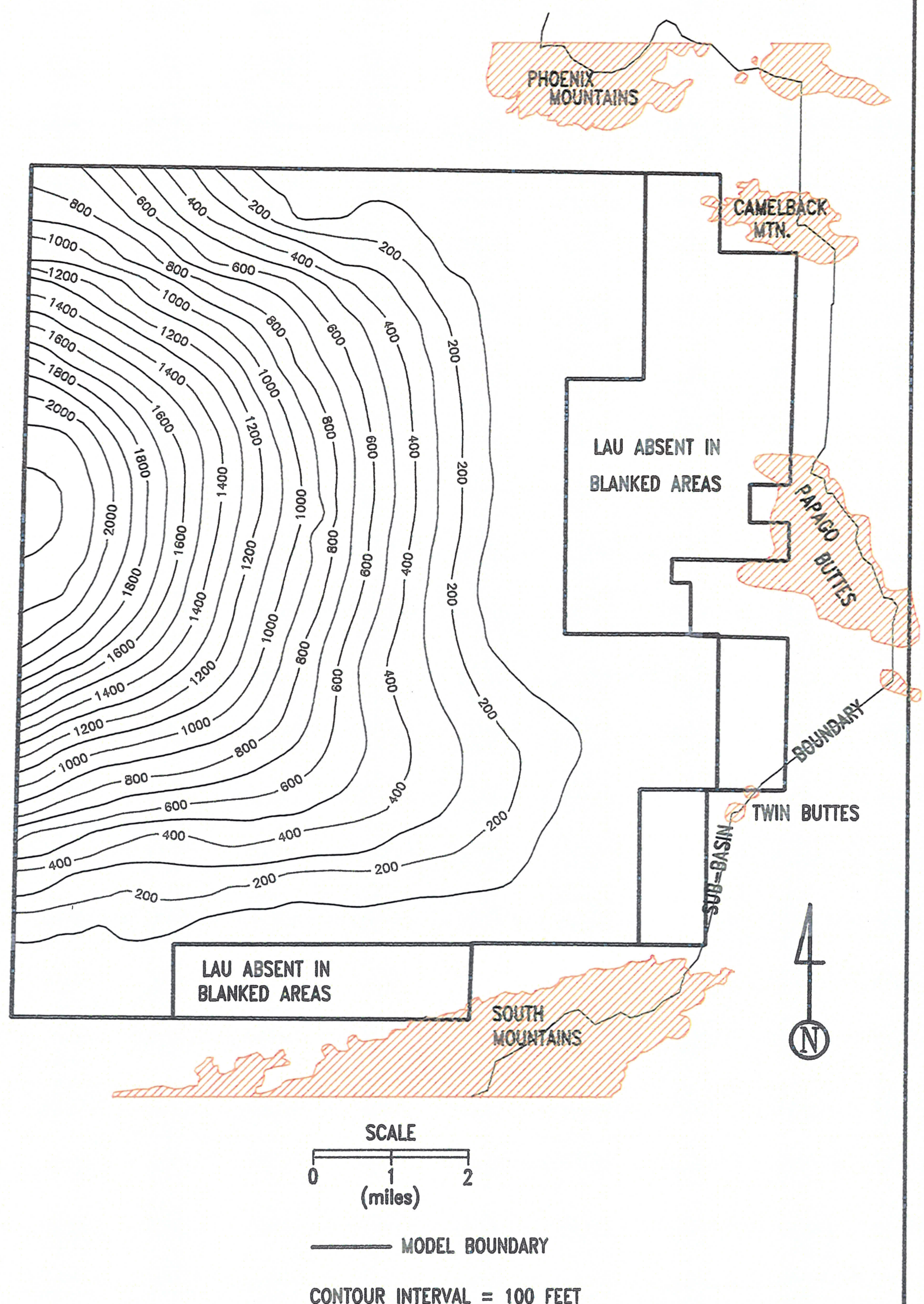

MODEL BOUNDARY

CONTOUR INTERVAL = 200 FEET

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

FIGURE 3F

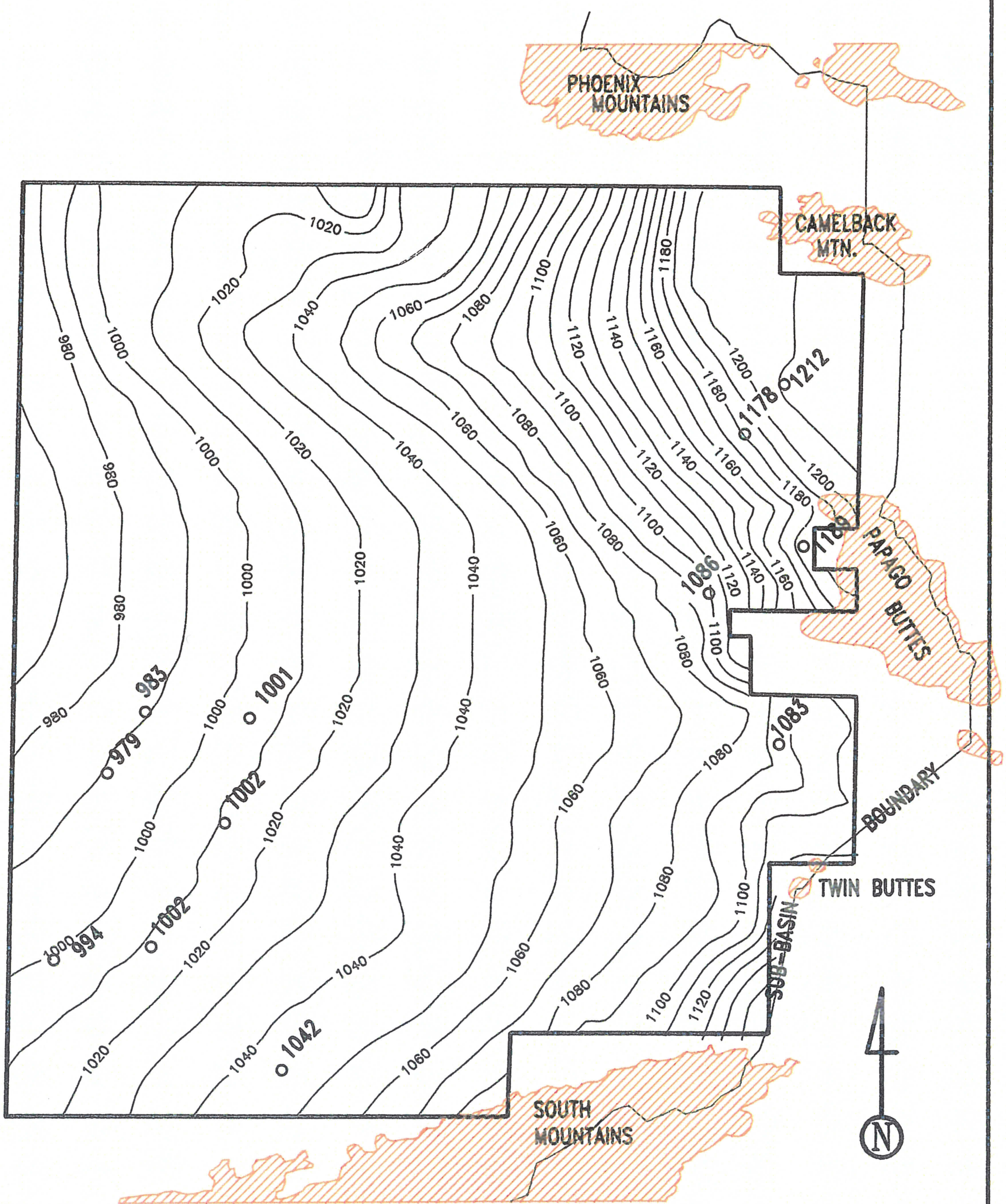
LAU-ISOPACH MAP



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

FIGURE 4A

MEASURED WATER LEVELS FOR THE UAU (JANUARY 1983)




SCALE

0 1 2

(miles)

○ MEASURED WATER LEVEL OF UNIT-SPECIFIC PRODUCTION WELL

● MEASURED WATER LEVEL OF COMPOSITE PRODUCTION WELL (UAU,MAU,LAU COMPLETION)

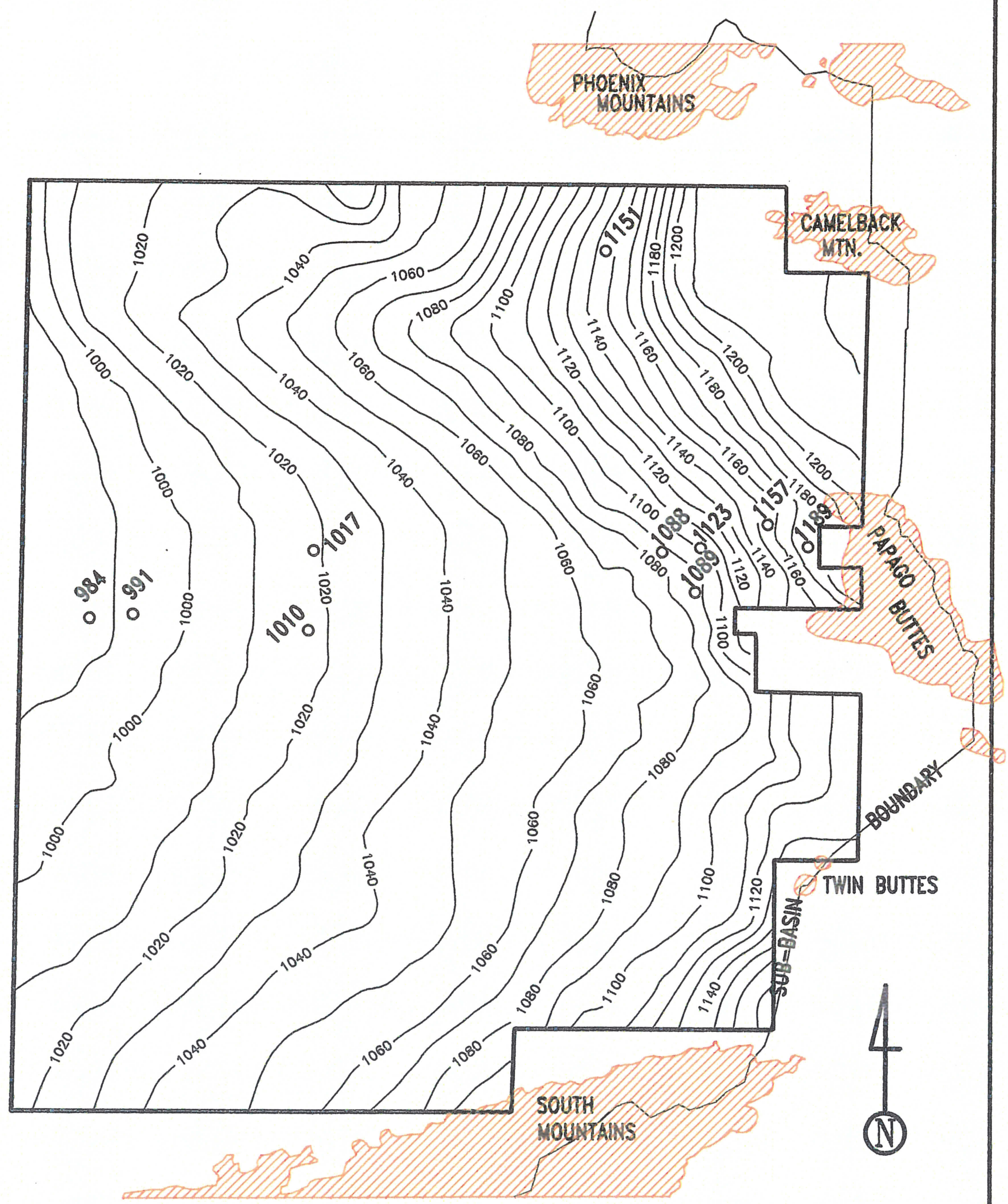
——— MODEL BOUNDARY

CONTOUR INTERVAL = 10 FEET

MEASURED WATER LEVELS OF UNIT-SPECIFIC PRODUCTION AND MONITOR WELLS

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA FIGURE 4B

MEASURED WATER LEVELS FOR THE UAU (JANUARY 1989)




SCALE
0 1 2
(miles)

○ MEASURED WATER LEVEL OF UNIT-SPECIFIC PRODUCTION WELL

● MEASURED WATER LEVEL OF COMPOSITE PRODUCTION WELL (UAU,MAU,LAU COMPLETION)

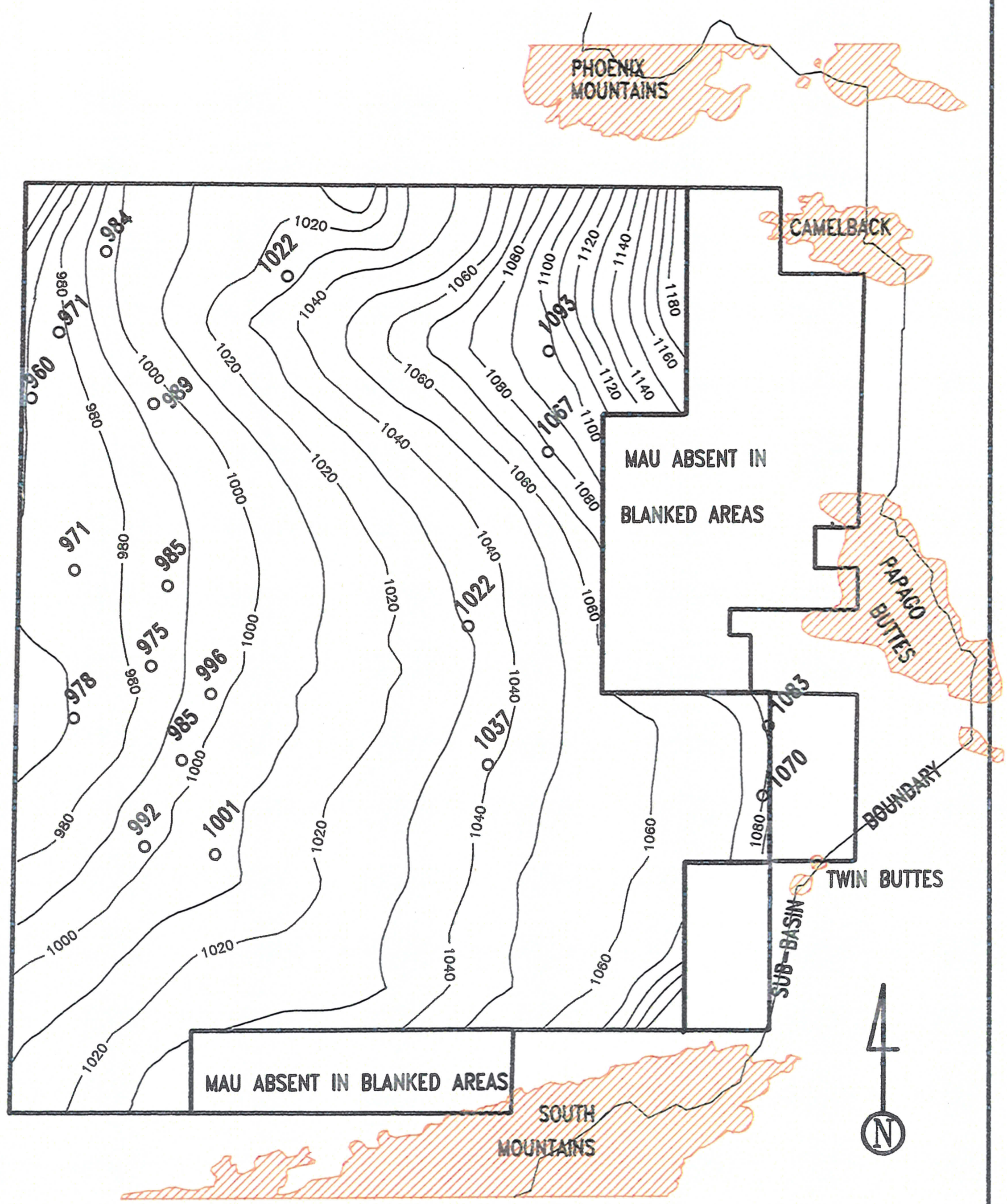
——— MODEL BOUNDARY

CONTOUR INTERVAL = 10 FEET

MEASURED WATER LEVELS OF UNIT-SPECIFIC PRODUCTION AND MONITOR WELLS

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
MEASURED WATER LEVELS FOR THE MAU (JANUARY 1983)

FIGURE 4C




○ MEASURED WATER LEVEL OF UNIT-SPECIFIC PRODUCTION WELL

● MEASURED WATER LEVEL OF COMPOSITE PRODUCTION WELL (UAU,MAU,LAU COMPLETION)

SCALE
0 1 2
(miles)

—— MODEL BOUNDARY

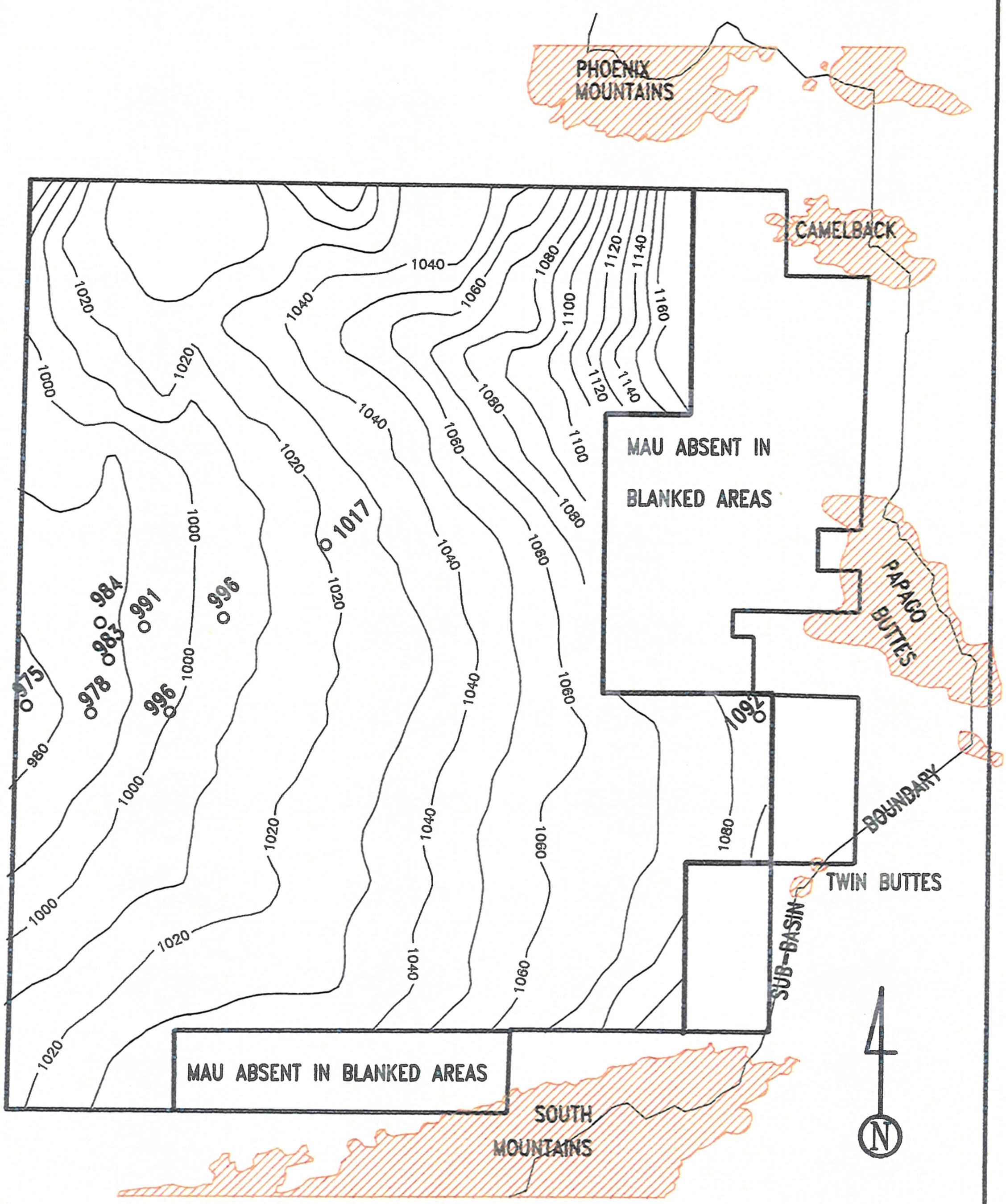
CONTOUR INTERVAL = 10 FEET

MEASURED WATER LEVELS OF UNIT-SPECIFIC PRODUCTION WELLS

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

FIGURE 4D

MEASURED WATER LEVELS FOR THE MAU (JANUARY 1989)




○ MEASURED WATER LEVEL OF UNIT-SPECIFIC PRODUCTION WELL

● MEASURED WATER LEVEL OF COMPOSITE PRODUCTION WELL (UAU,MAU,LAU COMPLETION)

SCALE

0 1 2

(miles)

——— MODEL BOUNDARY

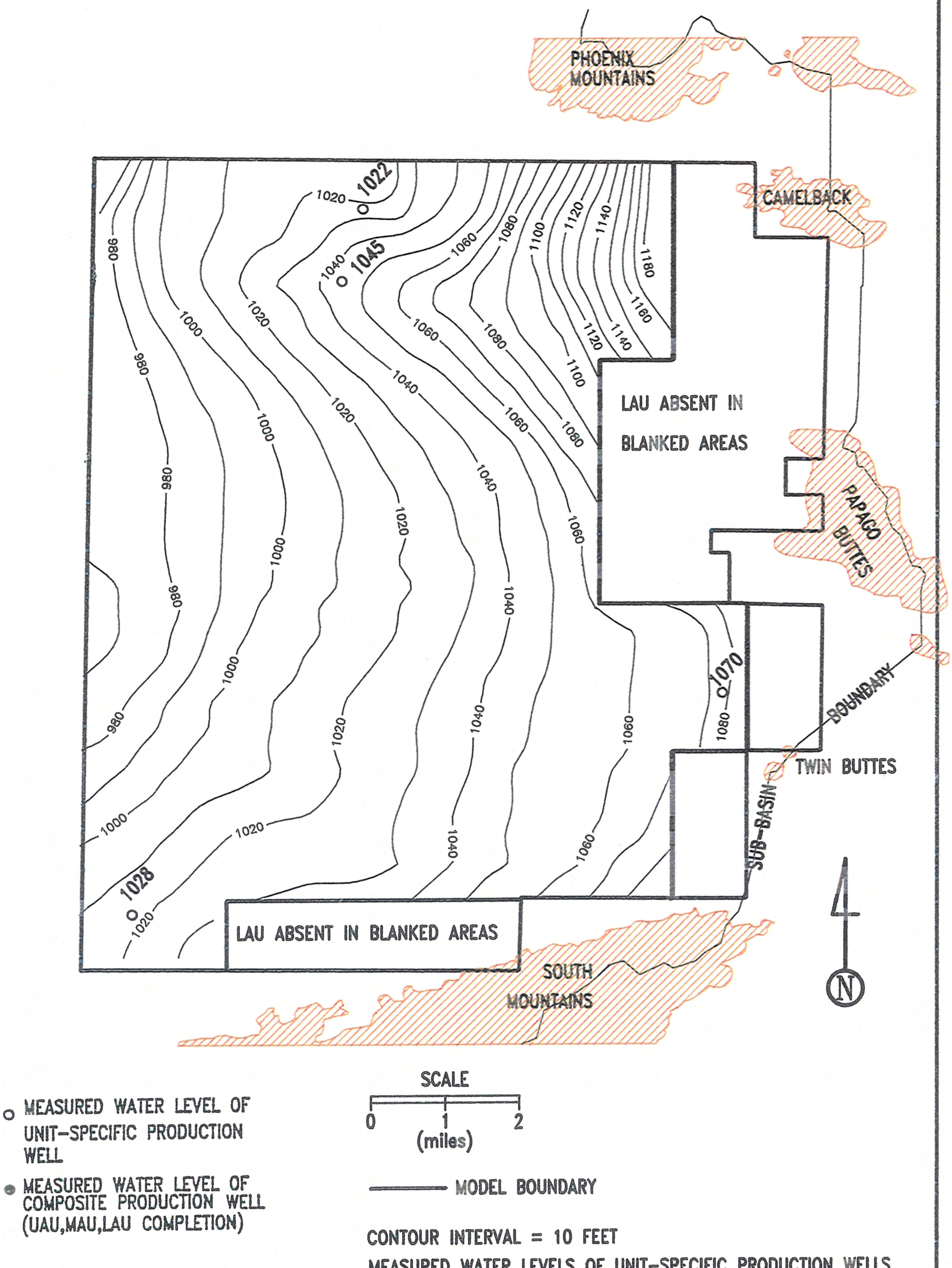
CONTOUR INTERVAL = 10 FEET

MEASURED WATER LEVELS OF UNIT-SPECIFIC PRODUCTION WELLS

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA

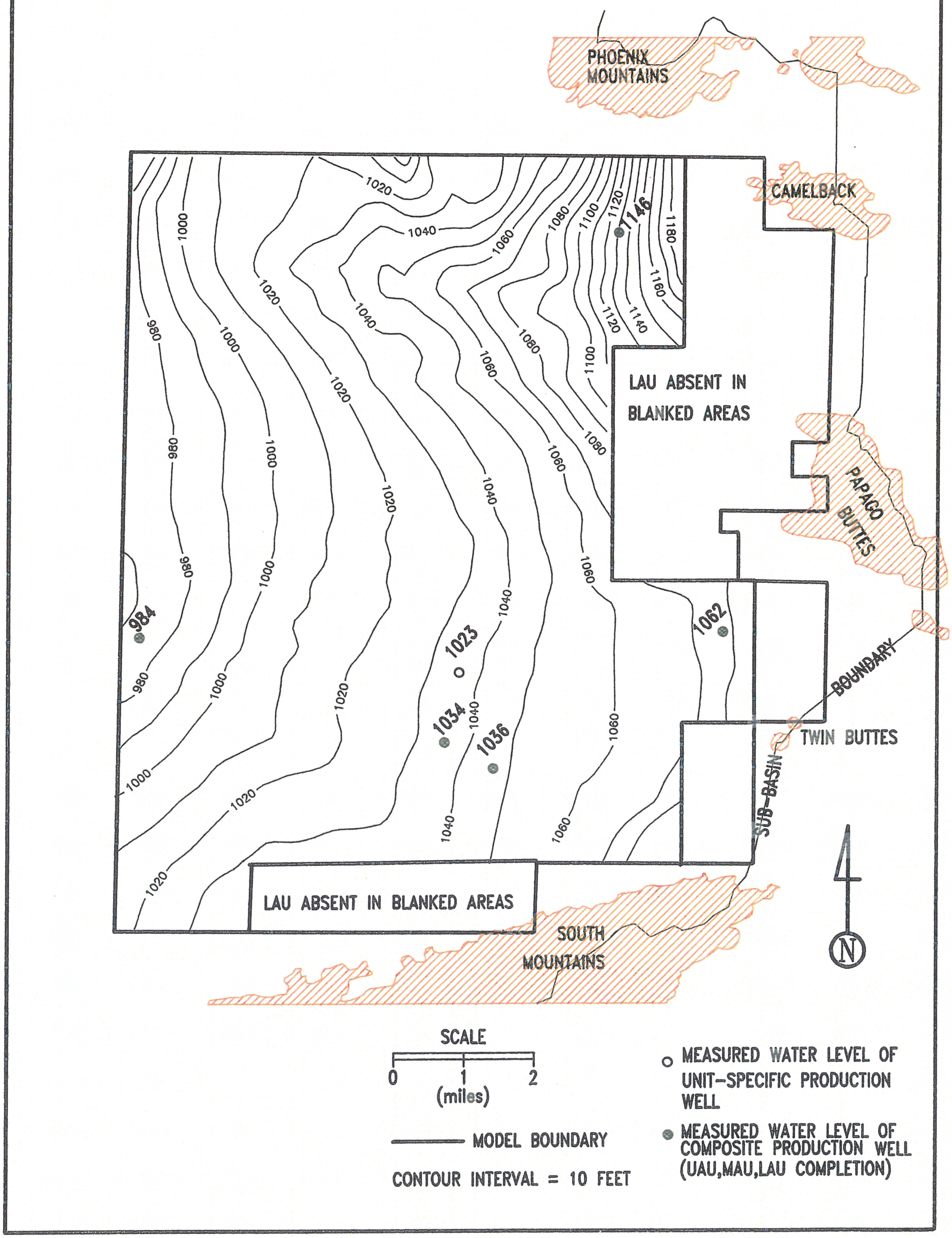
FIGURE 4E

MEASURED WATER LEVELS FOR THE LAU (JANUARY 1983)



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA FIGURE 4F

MEASURED WATER LEVELS FOR THE LAU (JANUARY 1989)



Due to a lack of unit-specific water level data in the LAU, the January, 1989 LAU heads were derived from relatively few unit-specific water level measurements. Also from the January, 1989 MAU water level maps as no significant vertical head differences were observed between the MAU and LAU in the January, 1983 water level maps. The measured January, 1989 MAU water levels were then imposed on the January, 1989 LAU water level map and the contours were adjusted to agree with the measured water levels.

## Conceptual Water Budget

The conceptual water budget summarizes the major inflow and outflow components of the groundwater flow system. A conceptual water budget for the model simulation period of January, 1983 to January, 1989 is presented in Table 1. The inflow components include groundwater recharge and underflow into the model area. The outflow components include groundwater pumpage and underflow out of the model area. The estimated change in the volume of groundwater in storage is also presented. The change in groundwater storage calculated in Table 1 is estimated as a sum of the water budget inflows and outflows. The difference between the estimated total budget inflows and outflows was 9,300 acre-feet.

Another estimate of the amount of change in the volume of groundwater in storage was also provided by comparing the changes in the measured water levels between January, 1983 and January, 1989. The 1983 UAU water level map (Figure 4A) was subtracted from the 1989 UAU water level map (Figure 4B). The resultant volume was then multiplied by the specific yield of the UAU to obtain the change in storage for the CPHX model area. The estimated change in storage is +13,300 acre-feet for the six year model simulation period. It should be noted that this total is directly dependent upon the estimated specific yield of the UAU, and therefore is highly sensitive to the uncertainty of this estimate. The estimated change in storage is also dependent on the head distribution maps (Figures 4A and 4B), and on the quality and distribution of the data that were used to develop these maps. The change in storage in the CPHX study area is entirely within the UAU.

There are three major components of the CPHX groundwater flow system. These include: 1) Groundwater Inflows, 2) Groundwater Outflows, and 3) Groundwater Storage. Groundwater inflows include recharge to the UAU, and underflow near the center of the western model boundary. Groundwater outflows consist of groundwater pumpage from all three units and underflow from the model area occurring along the western model boundary. Changes in the amount of groundwater in storage represent the difference between the total inflow and outflow components within the model domain for a given period of time. A discussion of each of the water budget components follows and is summarized in the Conceptual Water Budget in Table 1.

**TABLE 1**

**CONCEPTUAL WATER BUDGET FOR CPHX MODEL DOMAIN**

JANUARY 1983 THROUGH JANUARY 1989
ALL FIGURES IN ACRE-FEET, ROUNDED TO THE NEAREST 100 ACRE-FT.

| | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|
| **I INFLOW** | | | | | | |
| W. BOUNDARY** | 20500 | 25000 | 27800 | 26000 | 27600 | 26200 |
| AGRICULTURE RECHARGE | 8600 | 8600 | 8600 | 8600 | 8600 | 8600 |
| TURFED ACREAGE RECHARGE | 800 | 800 | 800 | 800 | 800 | 800 |
| SRP CANAL RECHARGE | 33300 | 34100 | 24300 | 24300 | 24300 | 15000 |
| RID CANAL RECHARGE | 700 | 700 | 700 | 700 | 700 | 800 |
| SALT RIVER RECHARGE | 127800 | 20400 | 49000 | 800 | 2400 | 1100 |
| EFFLUENT RECHARGE | 2200 | 1400 | 1300 | 2700 | 3200 | 3200 |
| **TOTAL INFLOW** | 193900 | 91000 | 112500 | 63900 | 67600 | 55700 |
| **II OUTFLOW** | | | | | | |
| W. BOUNDARY** | 42100 | 38900 | 40000 | 40000 | 40000 | 40600 |
| PUMPAGE | 34300 | 74100 | 77200 | 56900 | 51700 | 52700 |
| **TOTAL OUTFLOW** | 76400 | 113000 | 117200 | 96900 | 91700 | 93300 |
| III (TOTAL INFLOW - TOTAL OUTFLOW) = CHANGE IN STORAGE | | | | | | |
| (A) | +117500 | -22000 | -4700 | -33000 | -24100 | -37600 |

STORAGE 83 - 88 = SUM (A)

STORAGE 83 - 88 = -3900 ACRE-FEET

IV CHANGE IN GROUNDWATER STORAGE
CALCULATED FROM MEASURED WATER LEVEL CHANGES = +13,300 ACRE-FEET

* Values present are for a composite groundwater system.
** Revised underflow estimates as indicated by model runs.

## Groundwater Inflows and Recharge

Groundwater inflow to the UAU occurs primarily due to recharge with a small amount of underflow occurring along the central portion of the western model boundary. Groundwater inflows to the MAU and LAU occur as leakage from overlying hydrogeologic units and as minor underflow near the center of the western boundary. The inflows and outflows along the western boundary were estimated by flow net analysis and CPHX groundwater flow modeling calibration runs.

Recharge estimates were obtained from the SRV regional model currently under development at ADWR and are shown in Figure 6. The recharge is applied directly to the UAU over the entire model domain. Recharge sources within the CPHX model area include the following:

- **Agricultural Irrigation:** Determined by aerial photo interpretation, recharge rates based on crop types, reported water applied and consumptive use of crop. Approximately 8600 acre-feet per year in the CPHX model area (ADWR, 1984, 1987, 1988).

- **Canal Seepage (Salt River Project, and Roosevelt Irrigation District):** Determined by the wetted canal area per cadastral section and multiplied by a representative infiltration rate based on seepage tests. Canal seepage in the CPHX model area ranges from 15,000 to 34,100 acre-feet per year (Chapman et al., 1977; USGS, 1980; SRVWUA, 1983, 1986, 1989).

- **Salt River Channel:** Discharges from the Granite Reef Dam which reached the model area were analyzed and quantified within the model domain using available flow records and prior studies. Recharge from the Salt River channel in the CPHX model area ranged from 800 to 127,800 acre-feet per year (Mann and Rohne, 1983; USBR, 1989; SRVWUA, 1988).

- **Effluent Discharge:** From the 23rd Ave. Waste Water Treatment Plant to the Salt River channel was analyzed and quantified. Recharge in the model area from the waste water treatment plant ranged from 1300 to 3200 acre-feet per year (ADWR PGA memo, 1987).

- **Artificial Lakes:** Infiltration from artificial lakes greater than 10 acres was analyzed and quantified using data from prior studies (SRP, 1981). Recharge from artificial lakes within the Central Phoenix study area was negligible and not taken into account.

- **Precipitation:** Considered negligible, annual precipitation is very small (approximately 8 inches/year) and sporadic (Anderson et al., 1990).

- **Turfed Facilities:** Turfed facilities greater than 10 acres in size were analyzed (eg. Golf Courses, Parks, Schools, and Cemeteries). Recharge was estimated by subtracting the estimated consumptive use of each turfed area from the total measured volume of irrigation water applied. Within the CPHX model area recharge from turfed facilities averaged approximately 800 acre-feet per year (Phoenix AMA, 1988; ADWR 1989; USDA, 1982).

- **Mountain Front Recharge:** Negligible and not considered (Anderson et al., 1990).

## Groundwater Outflow

Groundwater outflow from the UAU, MAU and LAU occurs in significant volumes as pumpage and from underflow along the western boundary of the CPHX model area (Figure 5). Pumpage data was provided by the ADWR Registry of Groundwater Rights (ROGR) pumpage database. Small capacity wells (exempt wells) were located and analyzed. Exempt well pumpage was added to pumpage totals for years simulated during modeling, assuming 10 acre-feet/year per well. Wells perforated in multiple alluvial units (UAU, MAU, LAU) withdraw water from more than one alluvial unit. The amount of water that each alluvial unit contributes is dependent on the hydraulic conductivity and perforated saturated thickness of that alluvial unit as compared to the hydraulic conductivity of the overall saturated thickness of the alluvial unit(s) the well is perforated in. The amount of water each alluvial unit contributes to the well was calculated using the following equation:

(1) $$Qn=\frac{Kn*bn}{Tt}*Qt*100$$

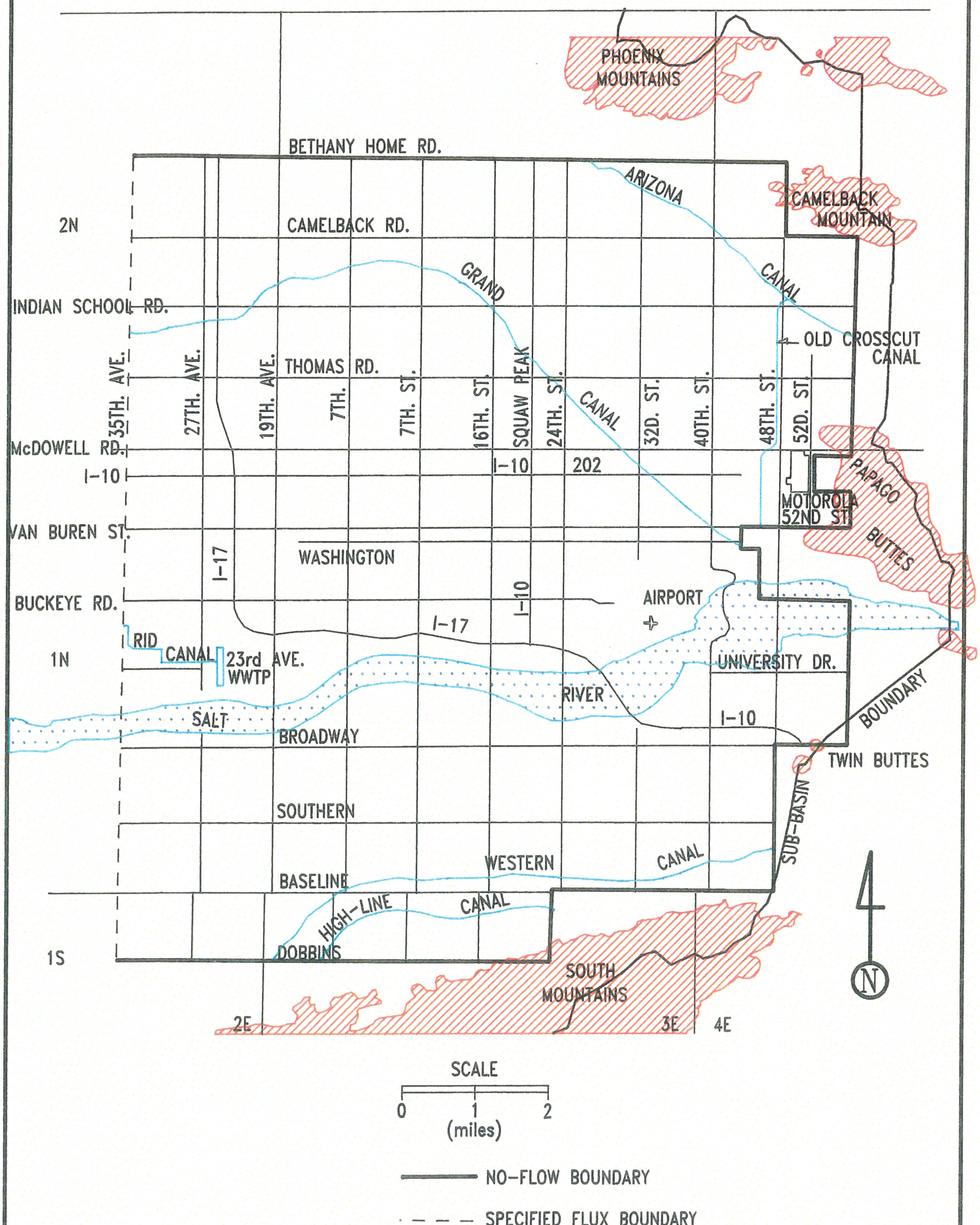
And:

(2) $$Qt=Q1+Q2+Q3+...+Qn$$

(3) $$Tt=K1b1+K2b2+K3b3+...+Knbn$$

FIGURE 5

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
MODEL BOUNDARY CONDITIONS



Where: Qn= percentage of total well pumpage contributed by hydrogeologic unit n.

Kn= hydraulic conductivity of alluvial unit n

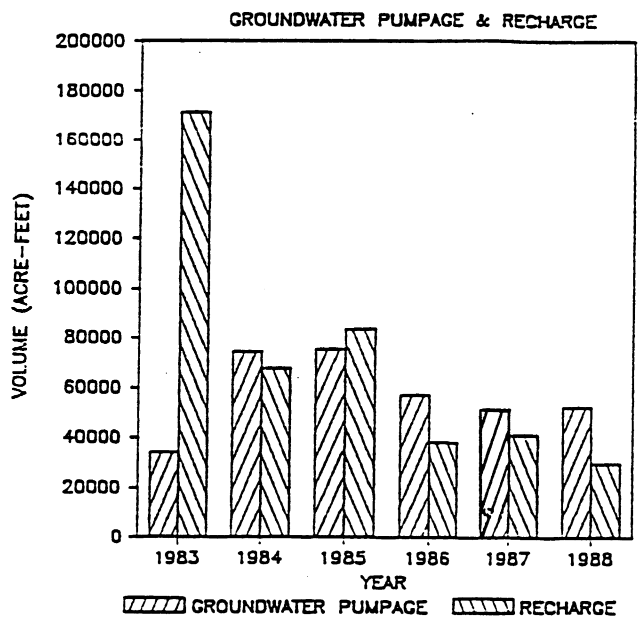
bn= saturated perforated thickness of alluvial unit n

Tt= total transmissivity of saturated perforated alluvial units

Qt= total pumpage from well

The individual well pumpage was then incorporated into the model in the proper cell and model layer. Figure 6 illustrates the volume of pumpage and recharge in the CPHX model domain per year.

Figure 6




- **Phreatophytes:** Within the Salt River channel, total consumptive use was considered negligible in the model area (Erie et al., 1981; Graf 1980).

# III. MODELING APPROACH

A phased approach was employed to conduct the modeling study for the CPHX groundwater flow model. This approach consisted of extensive data collection including field collection of water level data in the study area, development of a three dimensional groundwater flow model, and finally a contaminant transport model. The flow chart presented in Figure 7 illustrates the phased approach employed by ADWR. Three hydrogeologic units were modeled, the Upper, Middle, and Lower Alluvial Units (UAU, MAU, and LAU respectively).

## Model Code

The numerical model used in the CPHX study is TARGET (**T**ransient **A**nalyzer of **R**eacting **G**roundwater and **E**ffluent **T**ransport) developed by Dames & Moore. TARGET_3DS is three-dimensional, fully saturated, density coupled, transient groundwater flow, and contaminant transport model. Useful features of the TARGET model include: independent solution of hydrodynamics or coupled solution of hydrodynamics and solute transport as required; detailed mass balance print-out for each step in the calculations; density and viscosity effects incorporated for treatment of solute with properties distinct from those of groundwater at background water quality; and vector, contour, time-history, and three-dimensional graphics capabilities for ease of interpretation and presentation of predicted results.

## Period of Calibration

The period of time simulated by the TARGET_3DS model for transient calibration purposes began in January, 1983 and extends to January 1989. The model simulation was divided into six stress periods corresponding to calendar years.

The results of the groundwater flow and contaminant transport model using the TARGET model code are presented in this report. Unless noted otherwise, the term model will refer to the three-dimensional groundwater flow and contaminant transport model developed using the TARGET code.

## TARGET Model Domain and Grid

The CPHX model domain encompasses an area of approximately 101 square miles. The model domain was chosen to fully include the East Washington WQARF (State Superfund) site, Motorola 52nd St. site, 19th Ave. Landfill and other sites within the CPHX model domain. The extent of the East Washington contamination site was determined from the 1987 Phoenix AMA Map, "VOC Concentrations in Groundwater."

The TARGET_3DS model grid is an orthogonal mesh composed of 42 columns, 36 rows, and 17 layers. Figures 8, 9A, and 9B illustrate the layout of the horizontal and vertical grids. The smallest grid cells encompass 40 acres while the largest grid cells encompass 80 acres. The length and width of the 40 acre cells are 1320 feet by 1320 feet. The length and width of the 80 acre cells are 2640 feet by 1320 feet. The model grid is finest in areas of known TCE contamination, with the level of discretization commensurate with constraints on data confidence.

## Boundary Conditions

The regional direction of groundwater flow in the model area is to the west and west-southwest as shown in the most recent water level map (Figure 4B). Therefore the major directional axes of the model grid were oriented orthogonal to the flow direction to help minimize numerical dispersion. The boundary conditions for the CPHX model are illustrated in Figure 5.

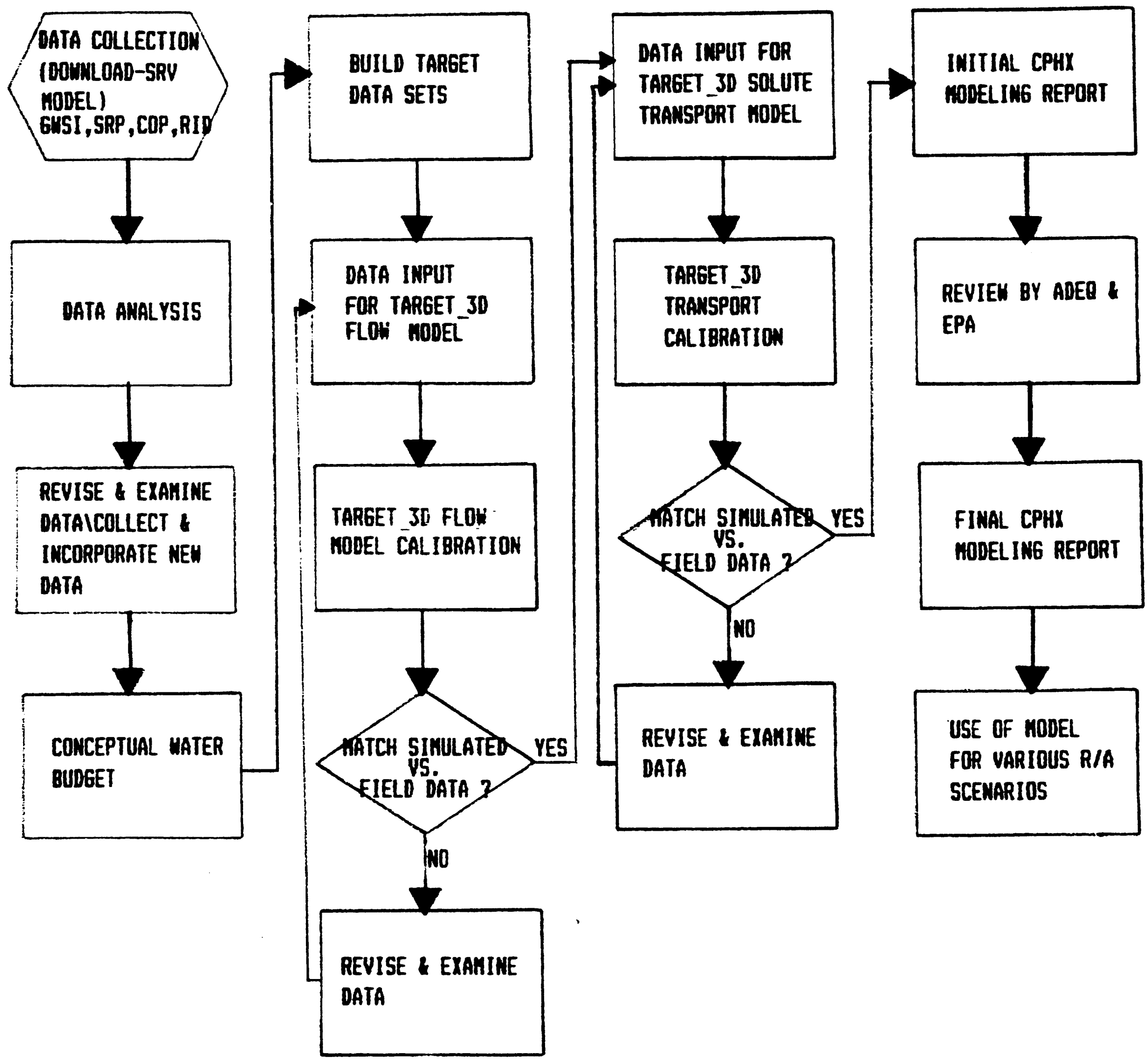
The UAU, MAU, and LAU are bounded by no-flow cells on the north, east, and south (Figure 5). The UAU, MAU, and LAU are bounded by fixed head cells on the west. A discussion of each boundary follows.

The northern boundary is chosen on the basis of the geology and hydrology of the area. The northern boundary runs east to west following Bethany Home Rd. and Lincoln Dr. The eastern half of the boundary is formed by the Phoenix Mountains which provide a hydrogeologic barrier that is represented by no-flow cells. The western half of the boundary is also no-flow because streamlines parallel the boundary (Figures 4A to 4F).

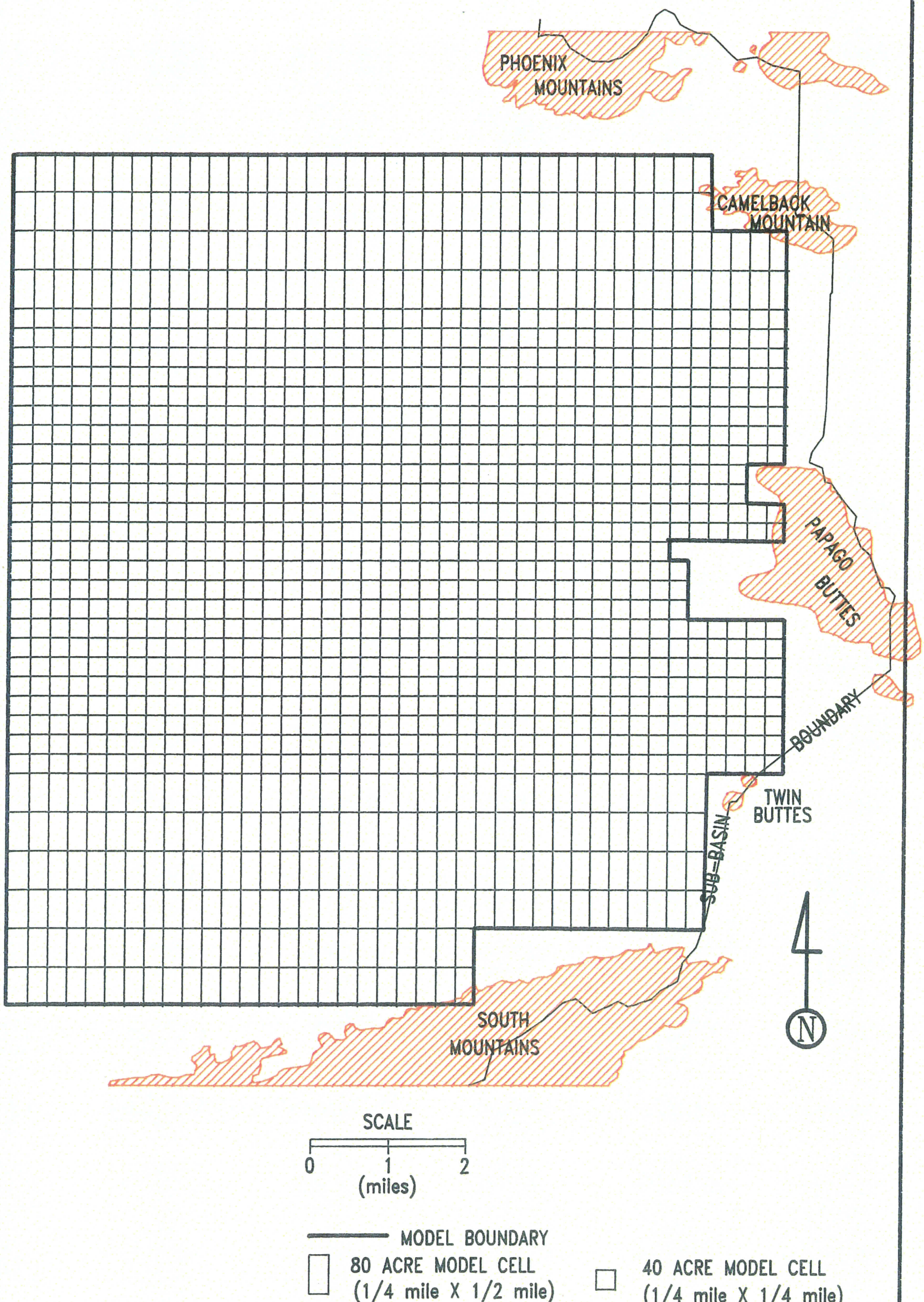
The no-flow condition simulated along the northern half of the eastern boundary is based on the geology of the area. Geologic cross sections constructed across the boundary indicate the presence of a fault between Papago Buttes and Camelback Mountain. This fault has uplifted an impermeable bedrock barrier which impedes groundwater flow across this boundary. The UAU, MAU, and LAU are represented in the model by no-flow cells at this boundary. Along the southern half of the eastern boundary, a groundwater divide has been identified from 1983 and 1989

FIGURE 7

OVERVIEW OF THE MODELING PROCESS BY ADWR
FOR THE CENTRAL PHOENIX MODELING STUDY



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA FIGURE 8
GRID DESIGN IN THE HORIZONTAL PLANE



composite water level maps prepared for the conceptual water budget report (Corell, S., 1990). The groundwater divide effectively prevents flow between the east and west Salt River Valley sub-basins. The groundwater divide trends generally north, from the eastern edge of the South Mountains to the Papago Buttes.

The no-flow condition simulated along the southern boundary is based on the geology of the area and follows Dobbins Rd. and Baseline Rd. The hard rock outcrop of the South Mountains serves as a hydrogeologic barrier to groundwater flow for the UAU, MAU, and LAU along this boundary which is represented by no-flow cells.

The western boundary is not selected for hydrologic or geologic considerations, but was chosen to fully include the East Washington WQARF site (East Lake Park) within the model domain (Figure 1A). Water level orientations along the western boundary indicate that groundwater outflow occurs in response to a hydraulic gradient. Model simulations indicate that groundwater inflow also occurs locally along the western boundary in sections A-01-02-11 and A-01-02-14 (Figure 5). The inflow is directed towards a cone of depression caused by pumping in the area by the Roosevelt Irrigation District. Constant head cells bound the UAU, MAU, and LAU on the western boundary of the model domain to simulate underflow.

The model bottom is defined by the impermeable bedrock pediment to the east and is truncated at an elevation of -900 feet (MSL) to the west, although bedrock exists at greater depths. This minimum elevation is considered satisfactory as few wells are completed at this depth and no wells are completed below this depth.

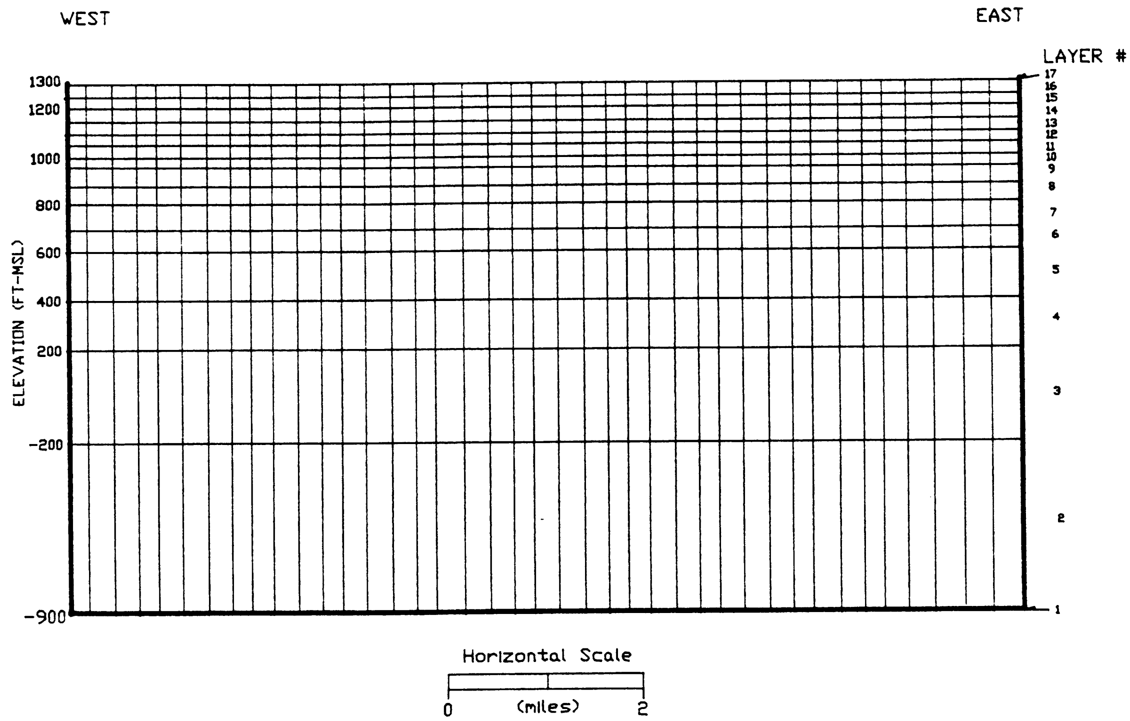
Figure 9B displays the vertical discretization of the geology to TARGET layers. The CPHX groundwater flow model is discretized into 17 layers with thicknesses ranging from 50' to 700' (the top and bottom model layers are zero thickness layers which are required by the TARGET model code). In areas where a higher resolution of detail is required, the level of vertical discretization increases with layer thicknesses decreasing to 50 feet. Areas of higher level contamination, primarily in the UAU, are discretized into finer layers of 50 feet in thickness. Table 2 indicates the correspondence between TARGET model layers and the alluvial units at various locations along the cross-section of Figure 9B.

TABLE 2

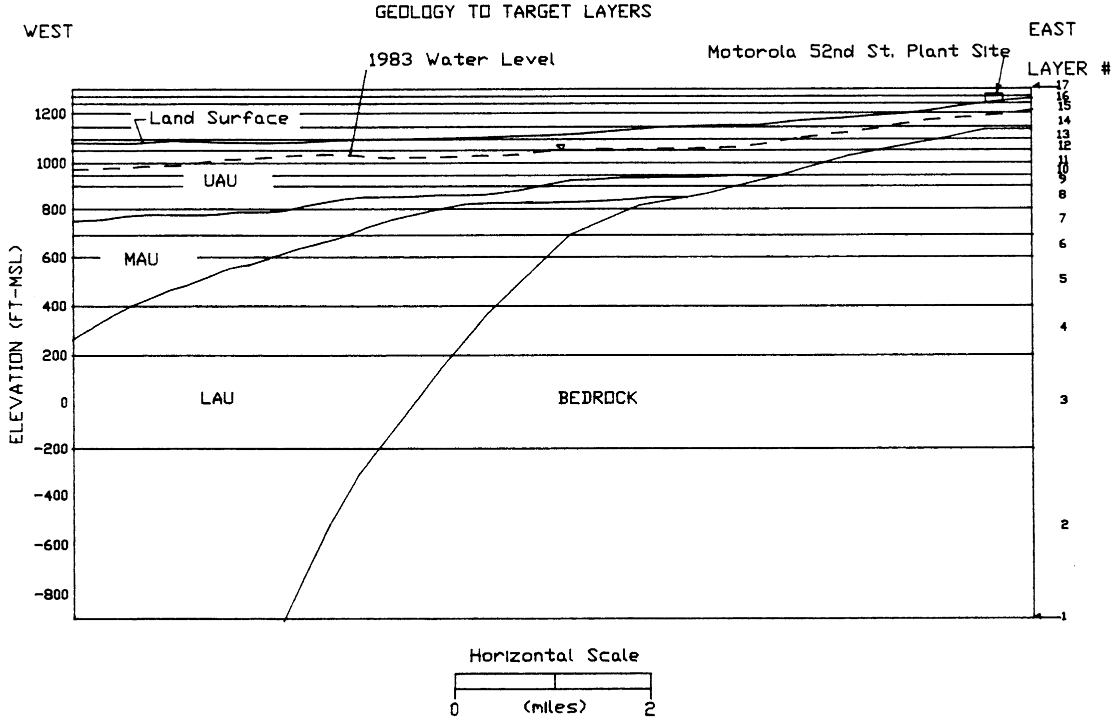
Representative TARGET Layers and Thickness

| Location | Alluvial Unit and approximate thickness | Representative TARGET layers and thickness |
|---|---|---|
| M52 Plant Site (MAU, LAU not present) | UAU 60 feet | 17 0 feet<br>16 50 feet<br>15 50 feet<br>14 50 feet |
| Central Area of the Cross-Section | UAU 210 feet | 13 50 feet<br>12 50 feet<br>11 50 feet<br>10 50 feet<br>9 50 feet |
| | MAU 100 feet | 8 100 feet |
| | LAU 600 feet | 7 100 feet<br>6 100 feet<br>5 200 feet |
| Western portion of the Cross-Section | UAU 320 feet | 12 50 feet<br>11 50 feet<br>10 50 feet<br>9 50 feet<br>8 100 feet |
| | MAU 450 feet | 7 100 feet<br>6 100 feet<br>5 200 feet |
| | LAU 2100 feet | 4 200 feet<br>3 400 feet<br>2 700 feet |

CENTRAL PHOENIX GROUNDWATER FLOW MODEL FIGURE 9A
GRID DESIGN IN THE VERTICAL PLANE




CENTRAL PHOENIX GROUNDWATER FLOW MODEL FIGURE 9B
CROSS-SECTION DISPLAYING VERTICAL DISCRETIZATION
GEOLOGY TO TARGET LAYERS



## Model Water Budget

There are three major water budget components of the hydrologic system that have been indentified in the CPHX groundwater modeling effort. These include: (1) groundwater inflow and outflow, (2) groundwater recharge from agriculture, canals, the Salt River channel and miscellaneous sources and (3) groundwater discharge due to pumpage from municipal, industrial and agricultural production wells.

Groundwater inflow and outflow values are listed in Table 1. These estimates are based on flow net analysis of the UAU, MAU, and LAU at the western model boundary, and results of CPHX groundwater flow modeling calibration runs. Due to data limitations of water level maps used in flow net analysis, inflow along the western boundary in sections A-01-02-11 and A-01-02-14 was not indicated prior to groundwater flow modeling calibration.

Total recharge to the groundwater system from all sources is shown in Figure 10. Miscellaneous recharge sources include turfed acreage (golf courses, parks) and effluent discharged from the 23rd Ave. Waste Water Treatment Plant. Table 1 provides recharge values used in the model from all sources.

The last major water budget component is groundwater discharge due to pumpage. Figure 11 illustrates all of the pumpage within the CPHX model domain. Annual groundwater withdrawals within the model domain for 1983 to 1988 range from 34,300 acre-feet in 1983 to 77,200 acre-feet in 1985.

## AQUIFER PARAMETERS AND CONDITIONS

Hydraulic conductivies (K) for all three alluvial units were obtained from the SRV regional groundwater flow model. Hydraulic conductivity data specific to the hydrogeologic unit was collected and analyzed from Salt River Project well tests. Specific capacity data from ADWR's Groundwater Site Inventory (GWSI) database and particle size logs were also used.

Hydraulic conductivity (K) values of the UAU range from 10 to 267 feet/day and are input as a heterogeneous array as depicted in Figure 12. The K value of 267 feet/day is assigned to model cells which correspond to the area of the Salt River channel. Little information concerning the storage properties of the aquifer materials in the CPHX model area is available. Therefore values for specific yield and specific storativity were estimated from those of similar materials determined at the nearby Indian Bend Wash superfund site. A specific yield of 0.20 was estimated for the UAU. The specific storage of the UAU was assumed to average 1.OE-5 ft-1 This value was applied as a constant over the model domain for the UAU.

Hydraulic conductivities of the MAU were input as a heterogeneous array ranging from 11 to 27 feet/day as indicated in Figure 13. A specific yield of 0.05 was estimated for the MAU (IBW model, ADWR 1990). The specific storativity of the MAU was assumed to average 6.0E-5 ft-1, and was applied as a constant over the model domain for the MAU.

The LAU hydraulic conductivities were also input as a heterogeneous array with values ranging from 13 to 80 feet/day (Figure 14). A specific yield of 0.05 was estimated for the LAU. The LAU storativity was assumed to average 3.5E-6, the same value used in the Indian Bend Wash study, and was applied as a constant over the model domain for the LAU.

The aquifer type (eg. confined or unconfined) of each hydrogeologic unit is not specifically designated in the TARGET_3DS model code. Instead the TARGET model code interprets the model layer which contains the water table to be unconfined, and a specific yield value is assigned for storage calculations within this uppermost partially saturated layer. If a model cell lies completely below the water table then confined conditions are assumed to exist and a value of specific storativity multiplied by the cell thickness is applied for all storage calculations.

In the CPHX model area the water table lies completely within the UAU. Therefore the uppermost partially saturated UAU model cells are unconfined while all the lower cells in the UAU, MAU, and LAU are confined.

Aquifer parameter data for the groundwater flow and contaminant transport model are presented in Table 3. The majority of the parameters were obtained from the Salt River Valley groundwater flow model.

Table 3

**AQUIFER PARAMETER DATA FOR THE CPHX GROUNDWATER FLOW MODEL**

| Parameter | Hydrogeologic Unit UAU | MAU | LAU |
|---|---|---|---|
| Horizontal Hydraulic Conductivity (ft/d)(a) | 10-267 | 11-27 | 13-80 |
| X-Y Anisotropy(b) | 1 | 1 | 1 |
| Vertical Hydraulic Conductivity (ft/d)(b) | 0.1 | 0.035 | 0.035 |
| Effective Porosity(b) | 0.3 | 0.1 | 0.1 |
| Specific Storativity (ft-1) | 0.00001 | 0.00006 | 0.0000035 |
| Specific Yield(a) | 0.20 | 0.05 | 0.05 |
| Dry Bulk Density Ratio (lb/ft^3)(b) | 2.6 | 2.6 | 2.6 |
| Longitudinal Dispersivity (ft)(b) | 100 | 100 | 100 |
| Transverse Horizontal Dispersivity (ft)(b) | 10 | 10 | 10 |
| Adsorption Distribution Coefficient (Ft^3/lb.)(b) | 0.0 | 0.0 | 0.0 |
| Specific Gravity (TCE)(b) | 1.46 | 1.46 | 1.46 |
| Viscosity (CP) (TCE)(b) | 0.58 | 0.58 | 0.58 |
| Background TCE (ppb) | 0.0 | 0.0 | 0.0 |
| Molecular Dispersion (Ft^2/day) x Tortuosity (b) | 1.6E-6 | 1.6E-6 | 1.6E-6 |

(a) Based on pump test data, ADWR drillers log program
(b) Based on literature review

FIGURE 10

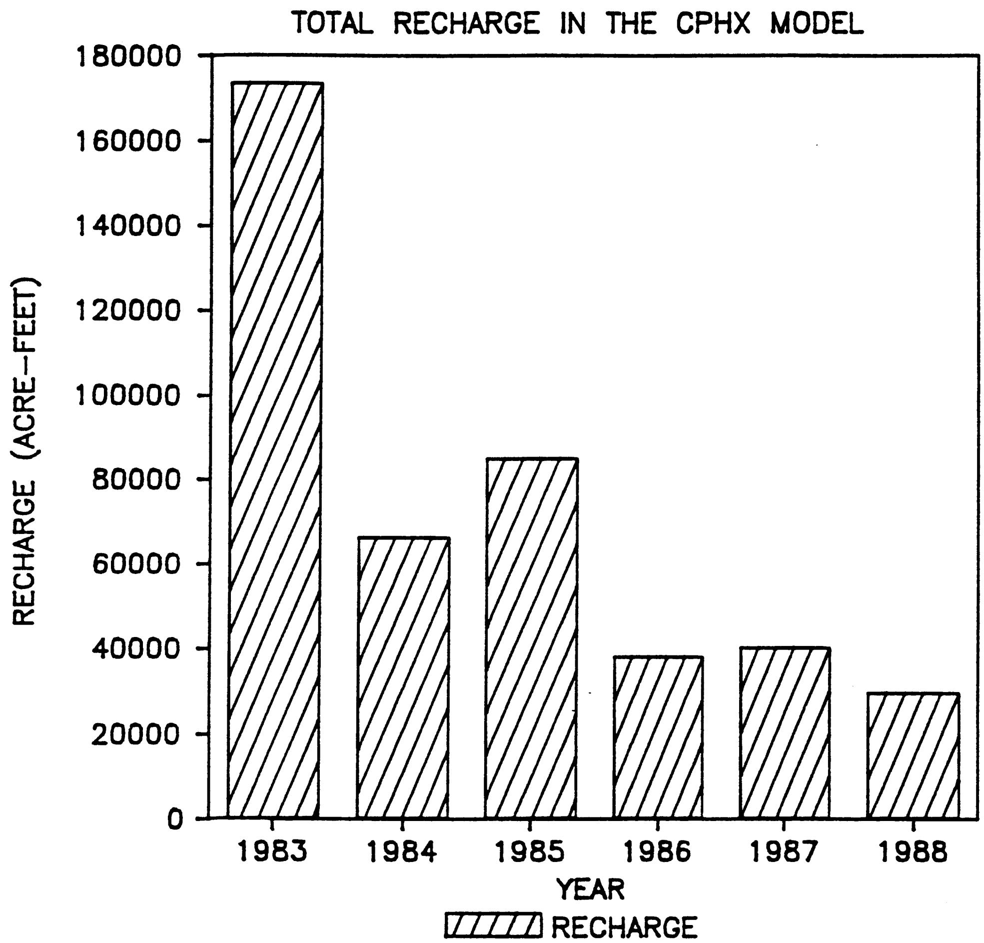
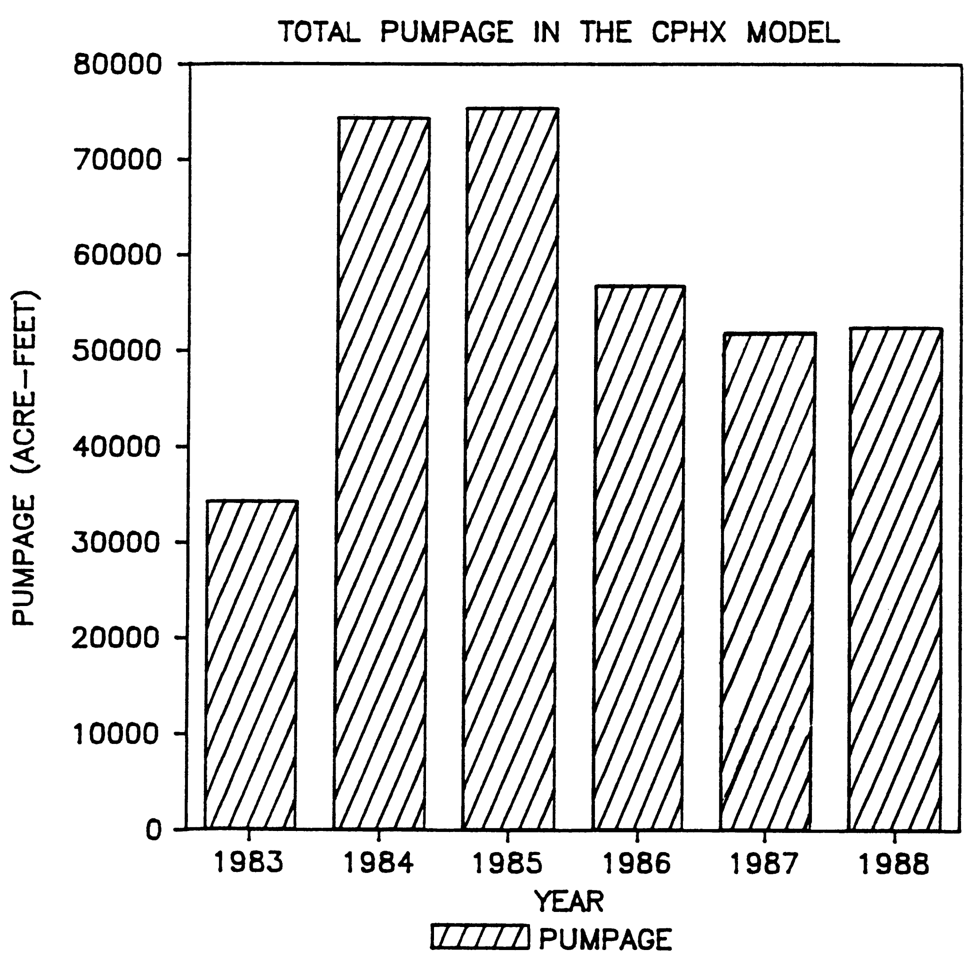



FIGURE 11



CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
UPPER ALLUVIAL UNIT HYDRAULIC CONDUCTIVITY ZONES
IN THE HORIZONTAL PLANE

FIGURE 12

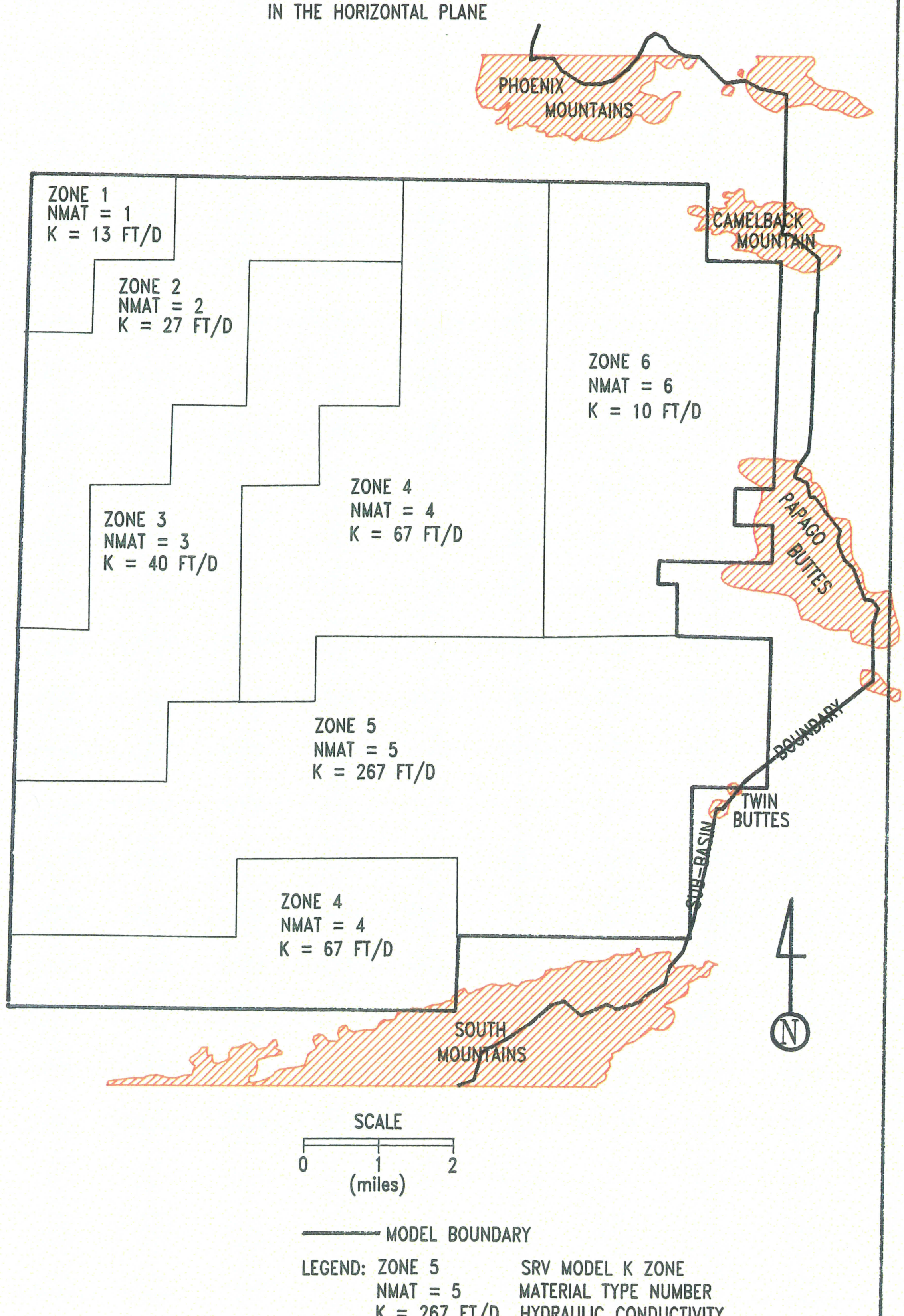
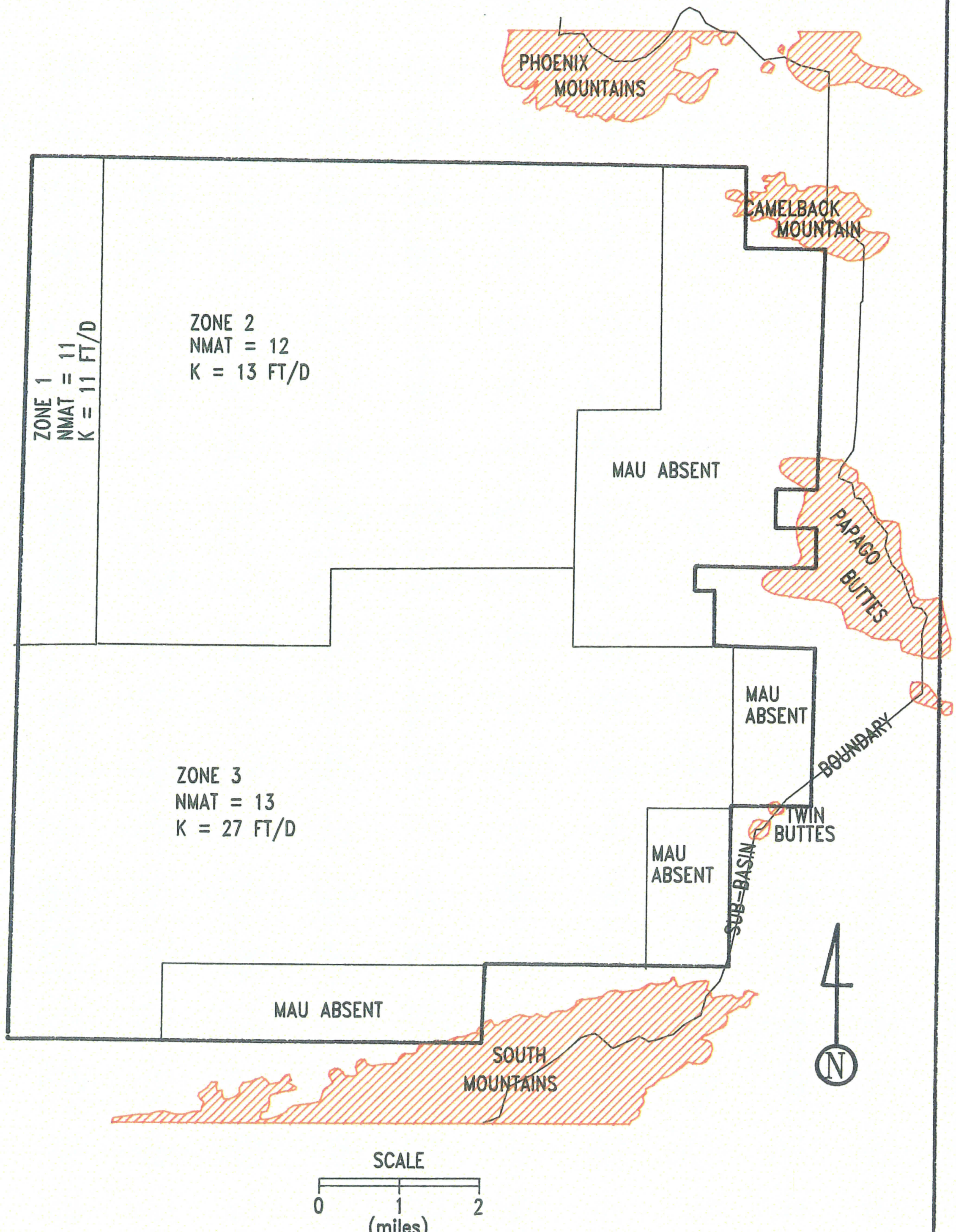


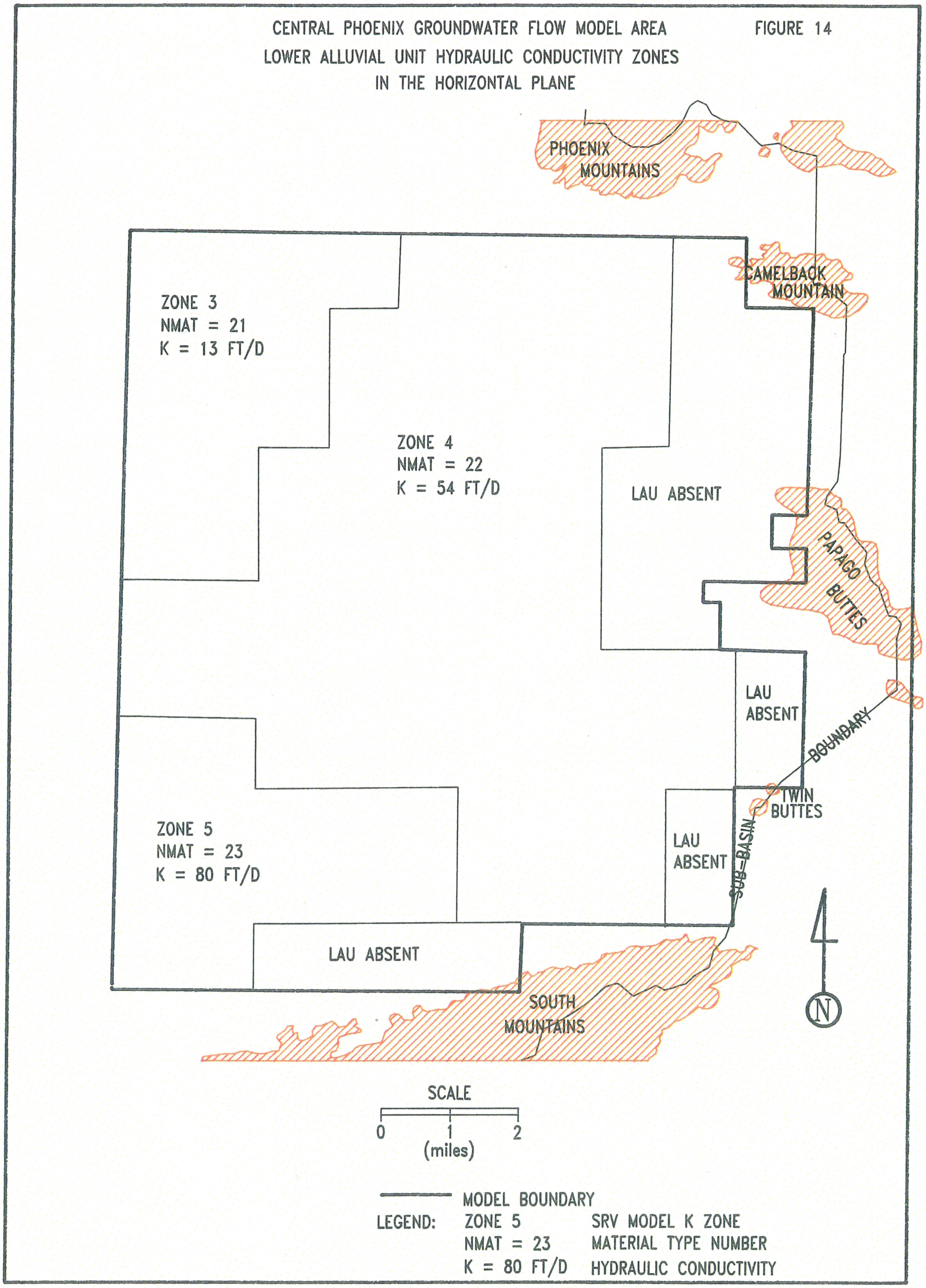
FIGURE 13

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
MIDDLE ALLUVIAL UNIT HYDRAULIC CONDUCTIVITY ZONES
IN THE HORIZONTAL PLANE




MODEL BOUNDARY

LEGEND: ZONE 3 — SRV MODEL K ZONE
NMAT = 13 — MATERIAL TYPE NUMBER
K = 27 FT/D — HYDRAULIC CONDUCTIVITY


CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
FIGURE 14
LOWER ALLUVIAL UNIT HYDRAULIC CONDUCTIVITY ZONES
IN THE HORIZONTAL PLANE
PHOENIX MOUNTAINS
CAMELBACK MOUNTAIN
ZONE 3
NMAT = 21
K = 13 FT/D
ZONE 4
NMAT = 22
K = 54 FT/D
LAU ABSENT
PAPAGO BUTTES
LAU ABSENT
BOUNDARY
TWIN BUTTES
SUB-BASIN
ZONE 5
NMAT = 23
K = 80 FT/D
LAU ABSENT
LAU ABSENT
SOUTH MOUNTAINS
N
SCALE
0
1
2
(miles)
MODEL BOUNDARY
LEGEND:
ZONE 5 SRV MODEL K ZONE
NMAT = 23 MATERIAL TYPE NUMBER
K = 80 FT/D HYDRAULIC CONDUCTIVITY

## Groundwater Flow Modeling Assumptions

The following groundwater flow modeling assumptions were made in order to simplify problems where data uncertainties exist or were necessary due to lack of data. Throughout the modeling process prior assumptions have been revised to reflect the current level of information known about the site. The major groundwater flow modeling assumptions are listed below.

- **Available groundwater level data adequately represent the flow system within the model domain. Water table distributions reflect the stresses (natural and artificial) imposed on the hydrologic system by pumpage, recharge and fluxes along the boundaries of the model domain.** The historic water level maps (Figures 4B, 4D, and 4F) are the basic data available to which the model was calibrated. In addition to water table distributions for the respective alluvial units UAU, MAU, and LAU hydrographs illustrated in Figures 22 through 27 provide relative head distributions between the alluvial units. This information, along with the conceptual water budget (which provides the magnitude of stresses in or out of the system), was used as the basis for calibrating the model.

- **Static water level measurements taken during the winter months are representative of the site when the hydrologic system is considered to be the most quiescent.** Changes in the system during this period of time are assumed to be a direct result of the hydrologic system's long term adjustment to regional influences and not to transient influences such as local pumpage. Pumpage is a major stress on the hydrologic system and winter water levels are assumed to be reflective of the system after drawdowns from short term heavy pumpage during summer months have had a chance to recover.

- **Wells perforated in multiple alluvial units (UAU, MAU, and LAU) are withdrawing water from each alluvial unit. The amount of water that each alluvial unit contributes is dependent on the hydraulic conductivity and perforated saturated thickness of that alluvial unit as compared to the hydrauic conductivity of the overall saturated thickness of the alluvial unit(s) the well is perforated in.** The precise proportion and distribution of water flowing into perforations in wells in this area are unknown. Therefore the amount of water each alluvial unit contributes to the well was estimated using the following equation:

$$Qn = \frac{Kn*bn}{Tt} * Qt * 100 \qquad (1)$$

And:

$$Qt = Q1 + Q2 + Q3 + \ldots + Qn \qquad (2)$$
$$Tt = K1b1 + K2b2 + K3b3 + \ldots + Knbn \qquad (3)$$

Where: Qn = percentage of total well pumpage contributed by alluvial unit n

Kn = hydraulic conductivity of alluvial unit n

bn = saturated perforated thickness of alluvial unit n

Tt = total transmissivity of saturated perforated alluvial units

Qt = total pumpage from well

Although equation (1) ignores well losses and the effects of partial penetration due to the complexity and extent of the well field within the study area and the lack of any other data, this type of limiting and simplifying assumption was necessary.

- **Evaporation of water from the water table is considered negligible.** This is due to the fact that the depth to water in most of the study area is greater than 20 feet; therefore this assumption is appropriate.

- **Recharge from precipitation is considered negligible in the model area.** Depth to water considerations preclude effective recharge by direct precipitation. High intensity, short term precipitation events are more likely to contribute to flash floods rather than recharge the groundwater. This is because soil moisture that occurs close to the land surface would tend to evaporate, thereby decreasing the relative conductivity and inhibiting flow through the unsaturated zone. In addition, annual precipitation averages less than 8 inches in the study area and is generally of less than 0.1 inch per event, while annual open-water evaporation averages more than 6 feet.

### Contaminant Transport Modeling Assumptions

The major contaminant transport modeling assumptions used in the TARGET model analysis are listed below. These assumptions allow for the simplification of problems where data uncertainties exist.

- **TCE is soluble and can be treated as a solute for the purpose of transport calculations at the concentrations observed in the groundwater.** The solubility of TCE is 1,100,000 parts per billion (ppb) at 25° C (Nyer, 1985). The concentrations observed in the groundwater at the Motorola 52nd St. site range from non-detect to over 1,000,000 ppb. Although the overall solubility of a mixture of a solvent decreases, it is assumed for the purposes of the contaminant transport modeling that TCE is a single solvent.

- **Adsorption of TCE onto the aquifer material may be neglected.** The results of the Motorola 52nd St. adsorption and solubility studies as presented in the RI/FS documents (Dames & Moore, 1987) indicated very little if any TCE adsorbed onto the soil matrix.

- **The longitudinal and transverse dispsersivity values are assumed to be 100 and 10 feet respectively due to a lack of definite source information from which to simulate plume generation.** The values for longitudinal and transverse dispersion, normally considered unknowns during transport calculations, are usually determined during the calibration of the transport model. However, it is not possible to calibrate to a known plume given the lack of historic source information and distribution in the groundwater system. The values chosen are reported in Anderson (1979) and are representative of the aquifer material found at the IBW site.

- Solvent sources in the unsaturated zone may be neglected for the purposes of modeling TCE transport and migration. This includes attenuation, dilution and dispersion of contaminant in the unsaturated zone. This assumption was made on the basis of no continuous source of TCE found in the unsaturated zone throughout the Remedial Investigation (Dames & Moore, 1987).

- The dry well, Source 2 (1987 Motorola 52nd St. RI/FS) is estimated to be the source of nearly 90 percent of TCE disposed at the Motorola 52nd St. plant site. It is assumed that the location of Source 2 may be used as the sole source of continuing contamination of TCE for modeling purposes.

- Biodegradation of TCE may be neglected for the purposes of transport modeling at this site. Degradation products were not incorporated into this analysis because TCE was chosen as the indicator parameter. This assumption was made in order to simplify the problem.

- The 1985 and 1986 field sampling events accurately define the extent and concentration of TCE contamination at this site for the purpose of evaluating the remedial alternatives. These field sampling events represent the most comprehensive contaminant data available.

# IV. TARGET MODEL RESULTS

## January, 1983 to January, 1989 Transient Simulation

The final head maps from the January 1983 to January 1989 transient simulation are shown in Figures 15 to 20. The posted water levels are those of monitor wells and other hydrogeologic unit specific water wells in the CPHX model area. The results of the transient model simulation were evaluated using three criteria: 1) Agreement of the general flow field from model results with the analysis of the detailed water level survey, 2) Agreement of heads and hydraulic gradients from model results with monitor well data, 3) Agreement of hydrograph responses through time from model cells and monitor wells.

To ensure proper interpretation of the figures presented, some background information is provided. An important concept to keep in mind is that the TARGET model is comprised of an orthogonal vertical grid (Figure 9B). The vertical layers of the TARGET model correspond to vertical depth intervals rather than specific hydrogeologic units. From Figure 9B it can be seen that one or more hydrogeologic units may be present in the same model layer. Therefore, the heads in any TARGET model layer are actually depth specific heads, rather than unit-specific heads. The correspondence established between the TARGET model layers and the hydrogeologic unit in the area of the Motorola 52nd St. plant site is that model layer 14 is equivalent to the UAU. Refer back to Table 2 (page 43), which indicates the correspondence between TARGET model layers and the alluvial units at various locations along the cross-section of Figure 9B.

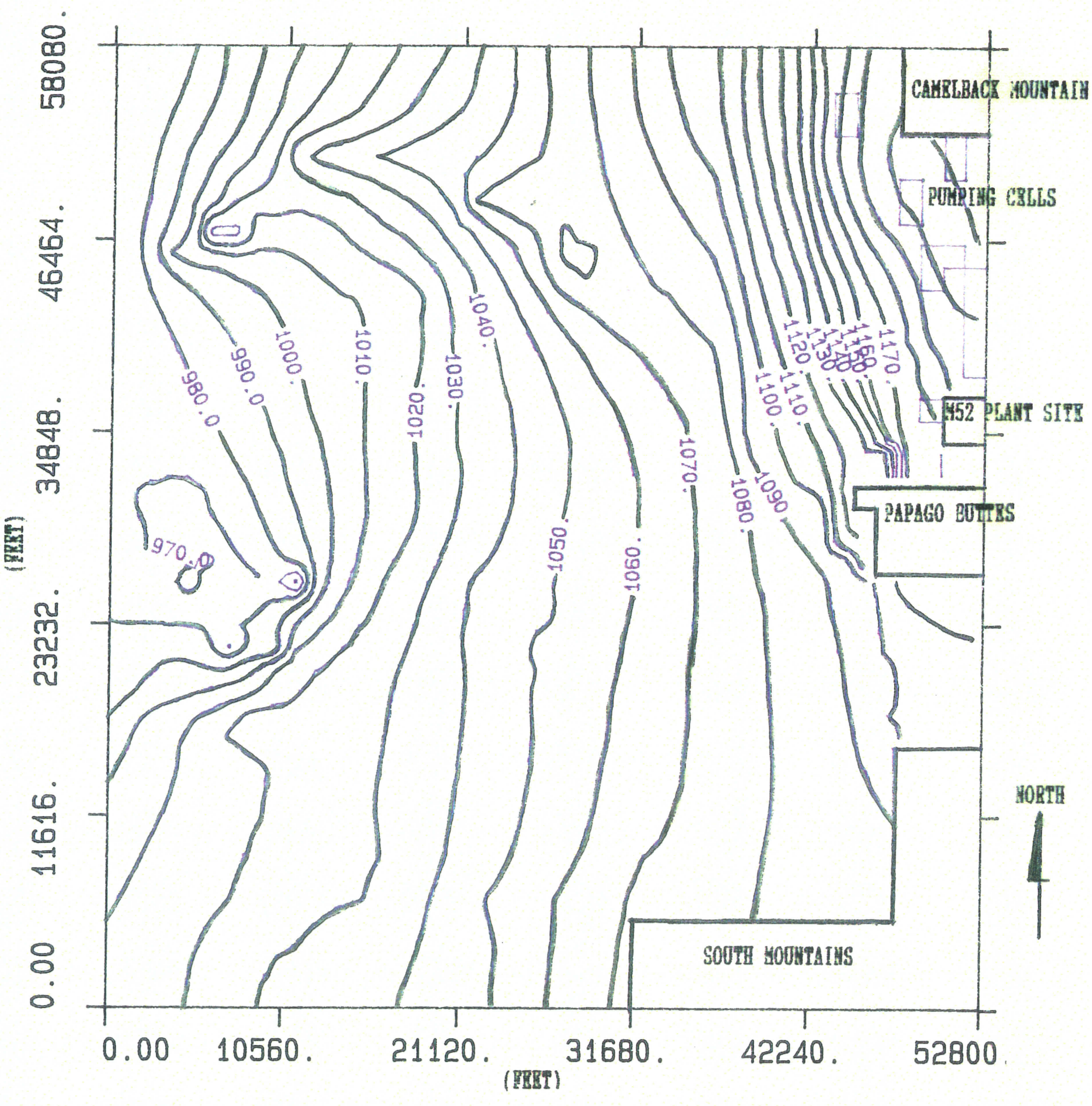
As modeled, the MAU and LAU are not present in the area of the Motorola 52nd St. plant site, where the UAU directly overlies bedrock. In the central area of the model domain, layer 8 corresponds to the MAU, and layers 5, 6, and 7 correspond to the LAU.

Figure 15 represents water level elevations in TARGET model layer 14 and is representative of the UAU near the Motorola 52nd St. plant site. Figures 15 through 20 represent water levels in various TARGET model layers as noted throughout the CPHX model domain.

The flow fields represented in Figures 15 to 20 closely resemble the unit-specific flow fields interpreted from the detailed water level survey (Figures 4B, 4D, and 4F). Figures 20B to 20G are vertical groundwater flow cross-sections represented by contours and vectors. The location of the groundwater flow cross-sections is illustrated by Figure 20A. The model-simulated heads also provide a close match to the water levels measured in the monitor wells. The flow directions for the Motorola 52nd St. monitor wells are known to be west and west-southwest, for the UAU. The model-simulated flow directions and hydraulic gradients are very similar to the known flow directions and gradients for each hydrogeologic unit. The similarity of heads and flow directions in the area of greater interest (near the Motorola 52nd St. monitor wells) indicates that the model provides acceptable results in that area.

The general agreement of the hydrograph responses through time from model cells and monitor wells provides additional support for the model results.

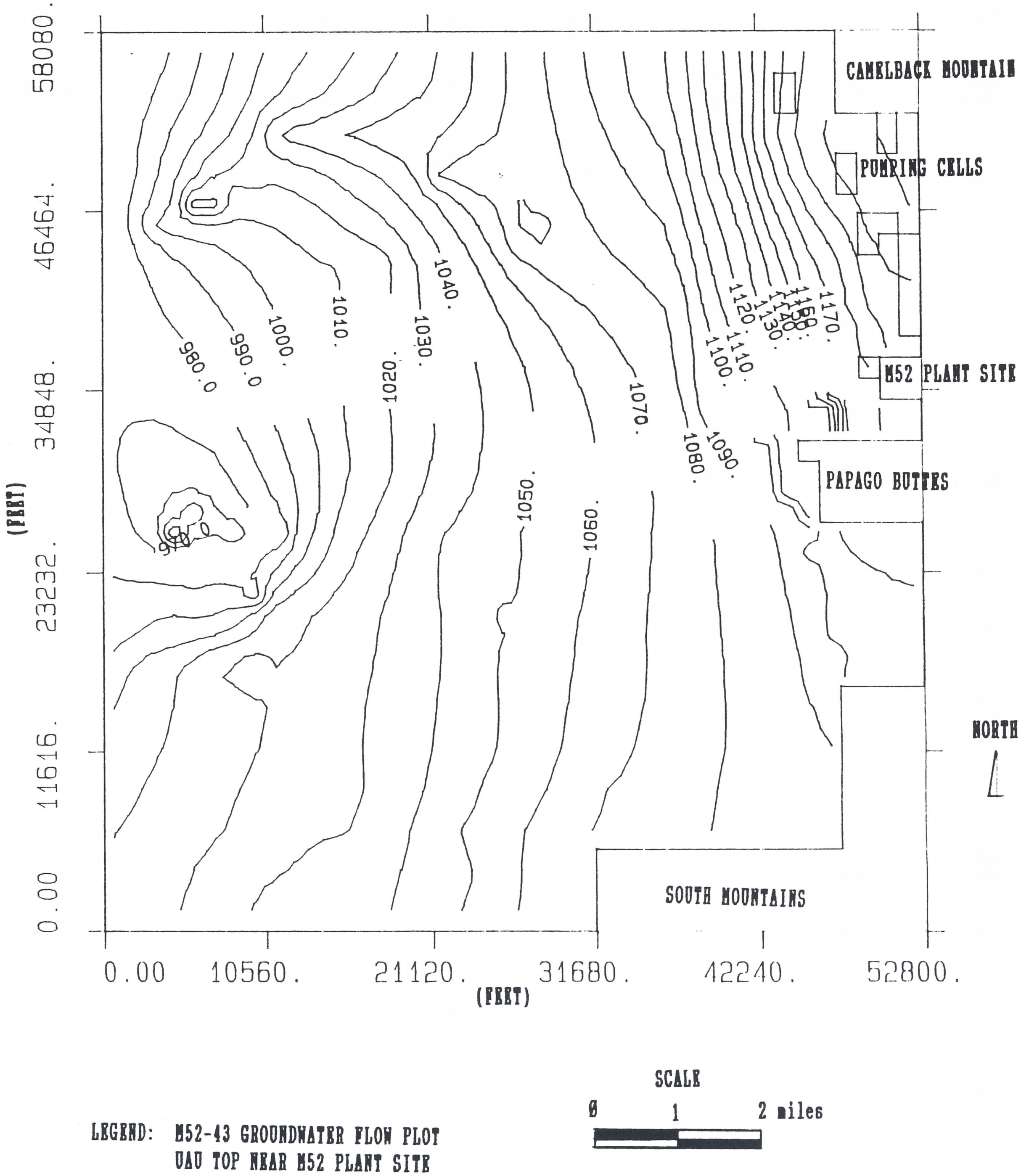
CPHX FINAL CALIBRATED WATER LEVELS FOR THE UAU (JAN 1989)
TARGET MODEL LAYER 14




LEGEND: M52-39 GROUNDWATER FLOW PLOT
UAU TOP NEAR M52 PLANT SITE
TIME = 2190 DAYS (JAN 1989)
LAYER = 14
CONTOUR INTERVAL = 10 FEET

SCALE
0 1 2 mile

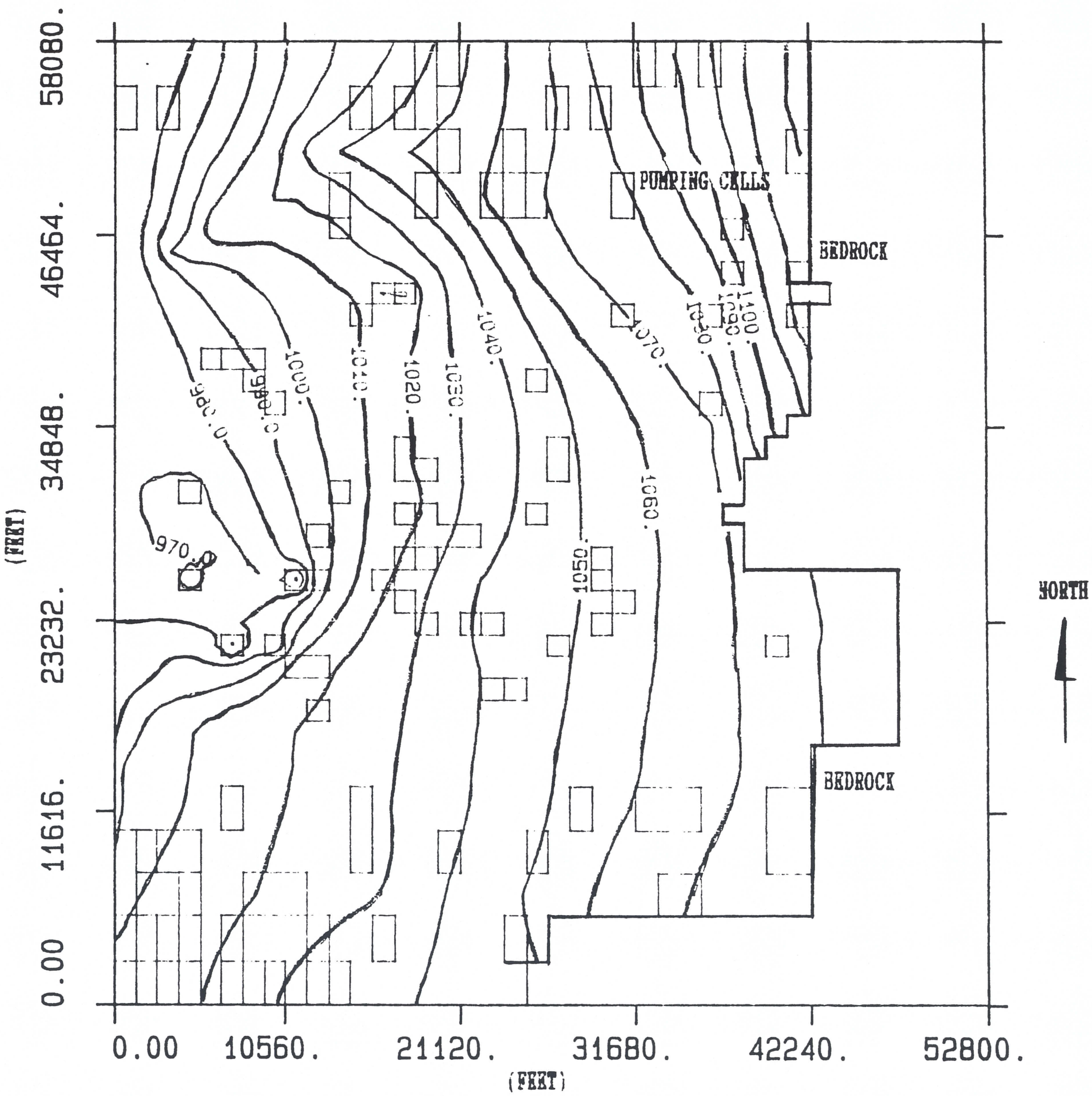
CPHX FINAL CALIBRATED WATER LEVELS FOR THE UAU (JAN 1989)
TARGET MODEL LAYER 14




LEGEND: M52-43 GROUNDWATER FLOW PLOT
UAU TOP NEAR M52 PLANT SITE
TIME = 2190 DAYS (JAN 1989)
LAYER = 14
CONTOUR INTERVAL = 10 FEET

* NOTE: SEE ADDENDUM FOR EXPLANATION OF MODEL RUN M52-43

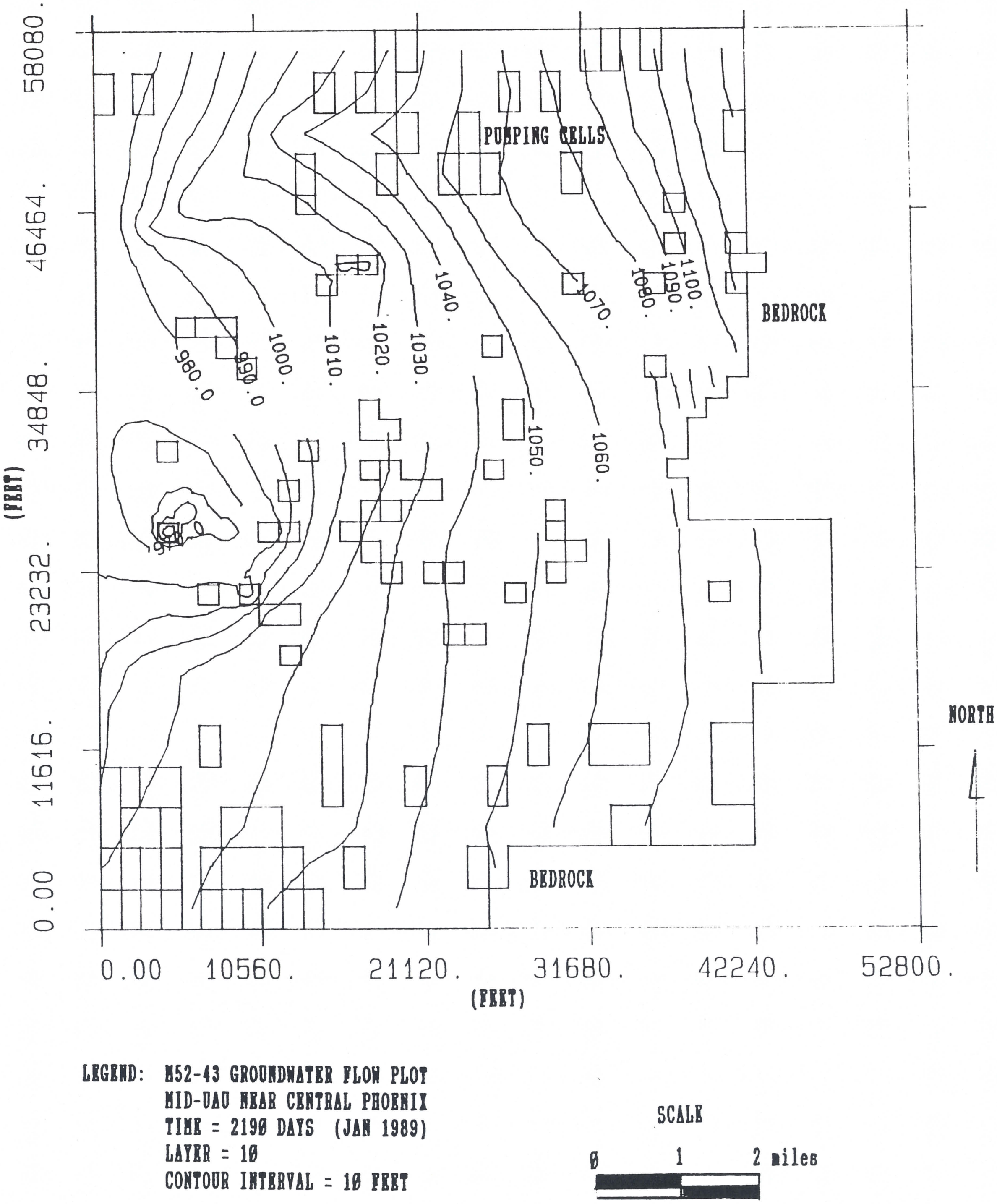
CPHX FINAL CALIBRATED WATER LEVELS FOR THE MID-UAU NEAR CENTRAL PHOENIX
(JAN 1989)
TARGET MODEL LAYER 10




LEGEND: M52-39 GROUNDWATER FLOW PLOT
MID-UAU NEAR CENTRAL PHOENIX
TIME = 2190 DAYS (JAN 1989)
LAYER = 10
CONTOUR INTERVAL = 10 FEET

SCALE
0 1 2 mile

**CPHX FINAL CALIBRATED WATER LEVELS FOR THE MID-UAU NEAR CENTRAL PHOENIX**
**(JAN 1989)**
**TARGET MODEL LAYER 10**

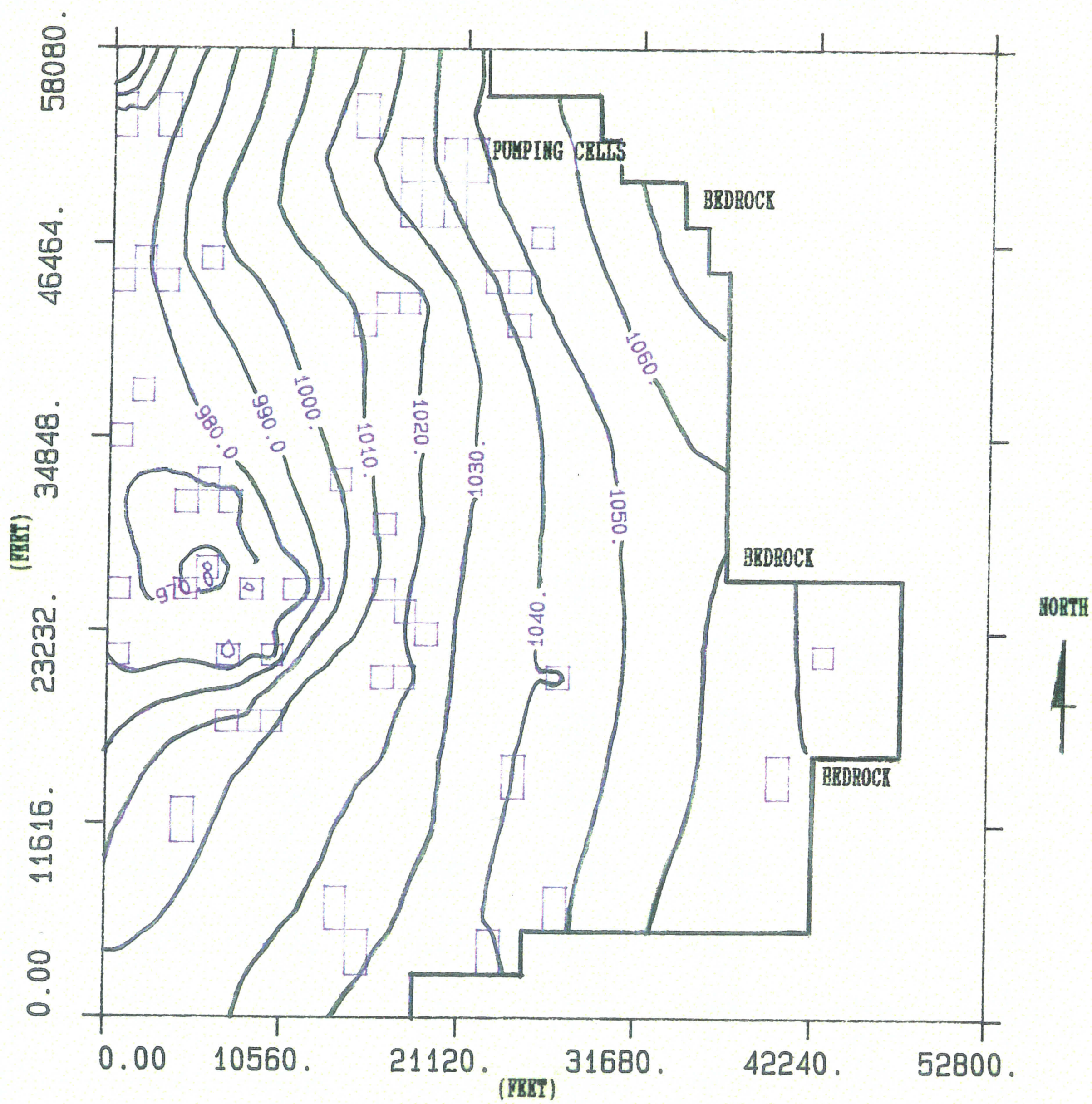



LEGEND: M52-43 GROUNDWATER FLOW PLOT
MID-UAU NEAR CENTRAL PHOENIX
TIME = 2190 DAYS (JAN 1989)
LAYER = 10
CONTOUR INTERVAL = 10 FEET

* NOTE: SEE ADDENDUM FOR EXPLANATION OF MODEL RUN M52-43

FIGURE 17

CPHX FINAL CALIBRATED WATER LEVELS FOR THE MID-MAU NEAR CENTRAL PHOENIX
(JAN 1989)
TARGET MODEL LAYER 8

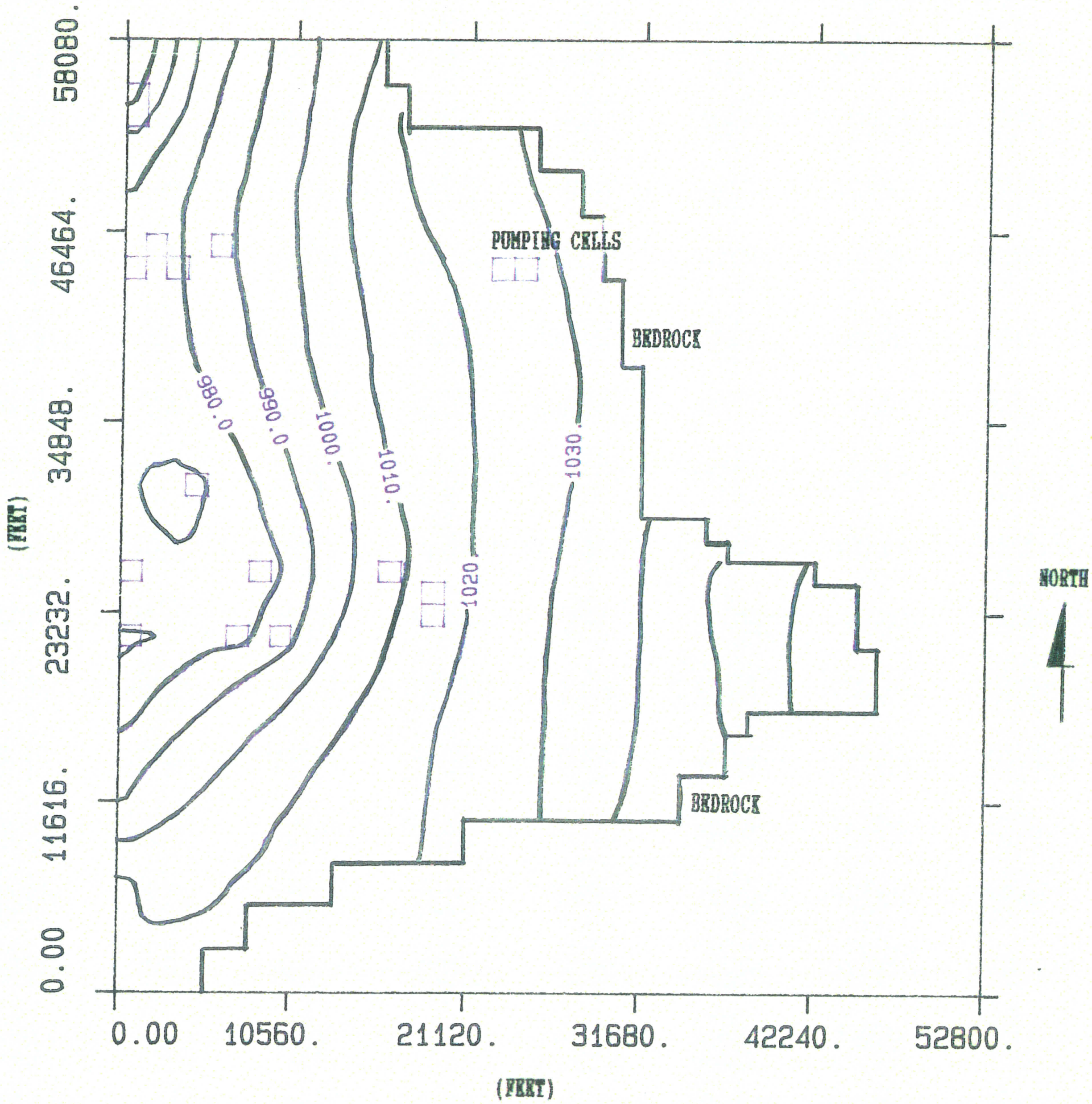



LEGEND: M52-39 GROUNDWATER FLOW PLOT
MID-MAU NEAR CENTRAL PHOENIX
TIME = 2190 DAYS (JAN 1989)
LAYER = 8
CONTOUR INTERVAL = 10 FEET

SCALE

0 1 2 mile

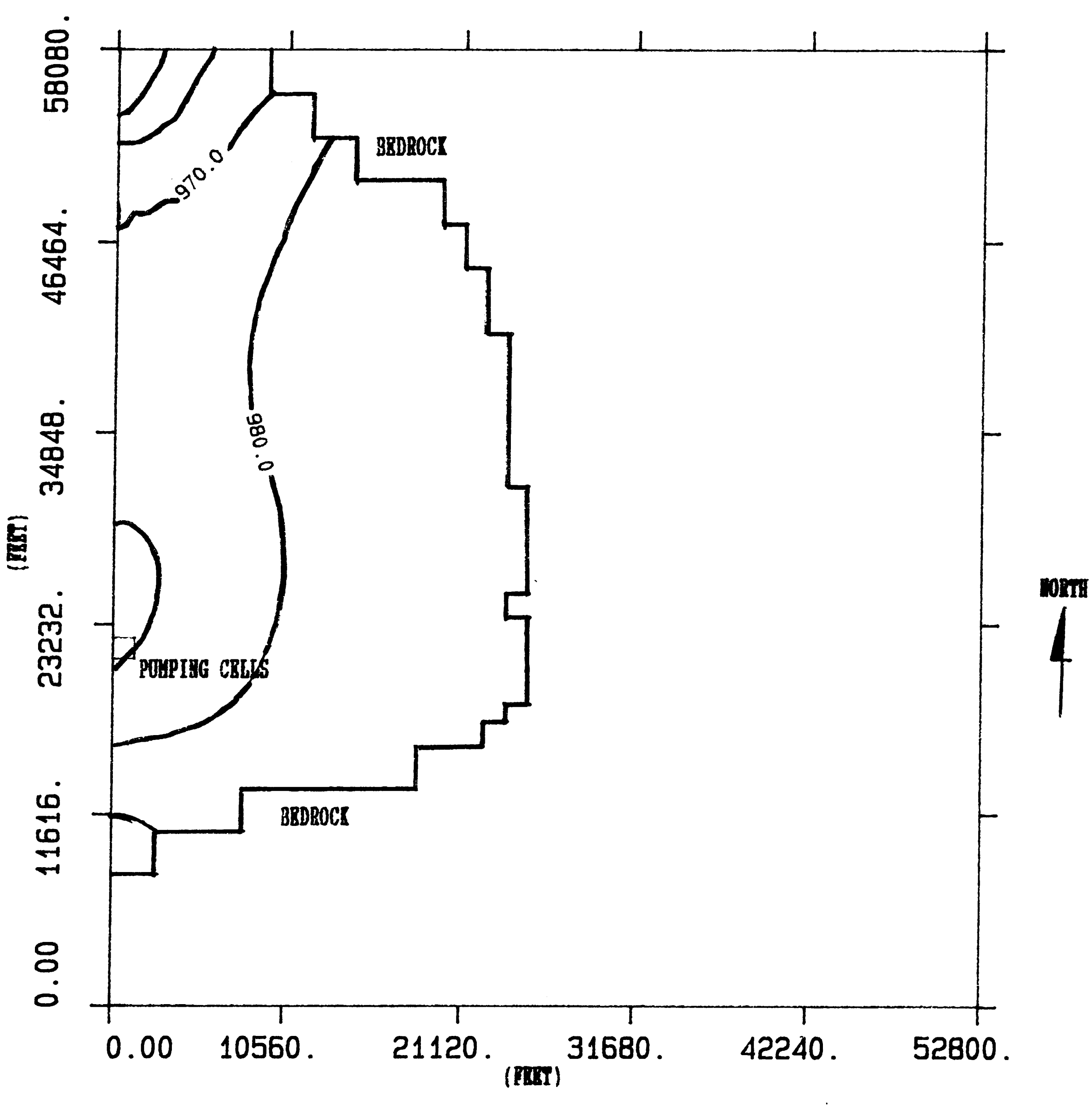
CPHX FINAL CALIBRATED WATER LEVELS FOR THE TOP-MID LAU
NEAR CENTRAL PHOENIX (JAN 1989)
TARGET MODEL LAYER 6




LEGEND: M52-39 GROUNDWATER FLOW PLOT
TOP-MID MAU NEAR CENTRAL PHOENIX
TIME = 2190 DAYS (JAN 1989)
LAYER = 6
CONTOUR INTERVAL = 10 FEET

SCALE
0 1 2 mile

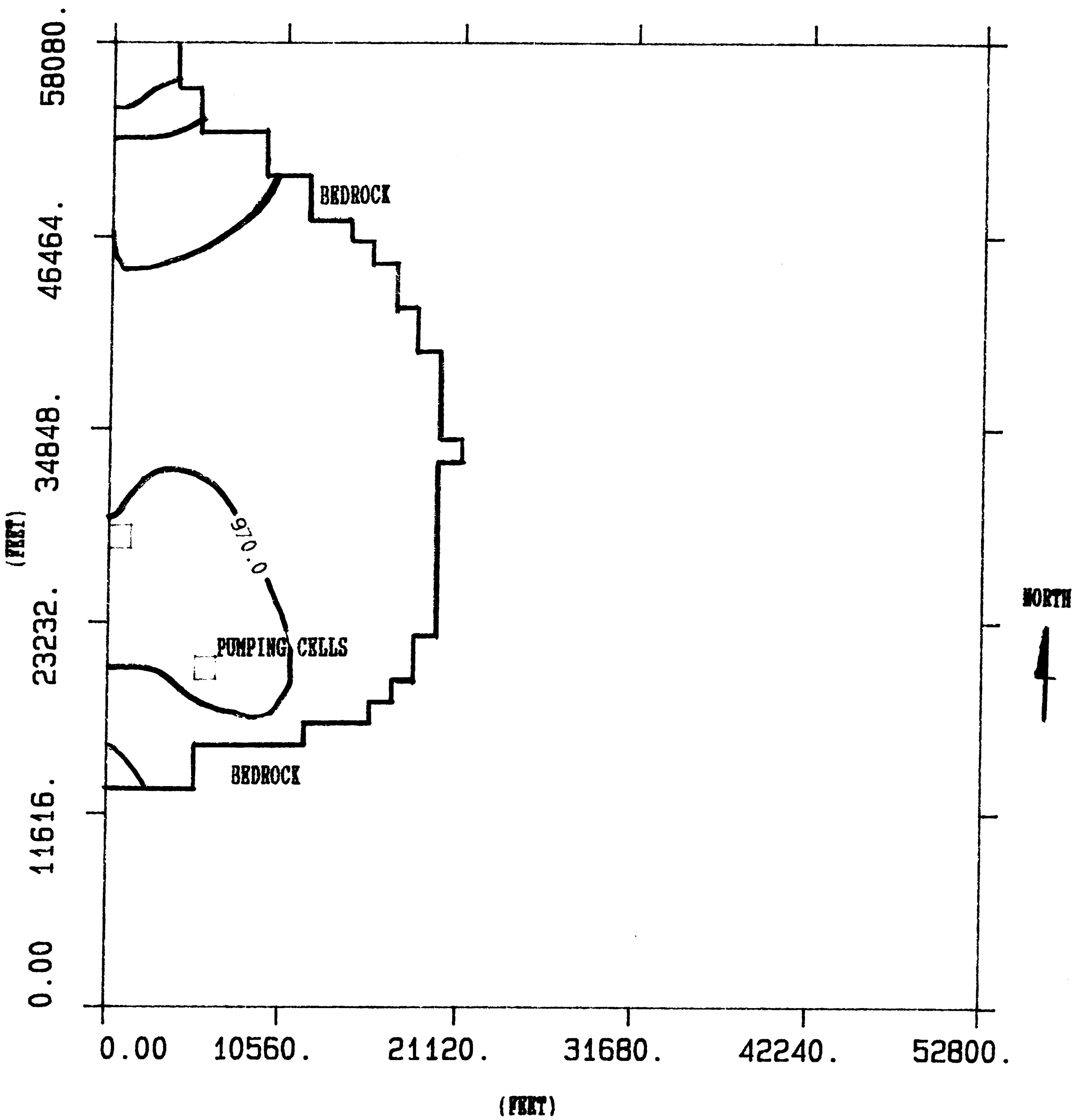
CPHX FINAL CALIBRATED WATER LEVELS FOR THE MID-LAU WEST
CENTRAL MODEL DOMAIN (JAN 1989)
TARGET MODEL LAYER 3




LEGEND: M52-39 GROUNDWATER FLOW PLOT
MID-LAU WEST CENTRAL MODEL DOMAIN
TIME = 2190 DAYS (JAN 1989)
LAYER = 3
CONTOUR INTERVAL = 10 FEET

SCALE
0 1 2 mile

CPHX FINAL CALIBRATED WATER LEVELS FOR THE LAU BOTTOM
WEST CENTRAL MODEL DOMAIN (JAN 1989)
TARGET MODEL LAYER 2

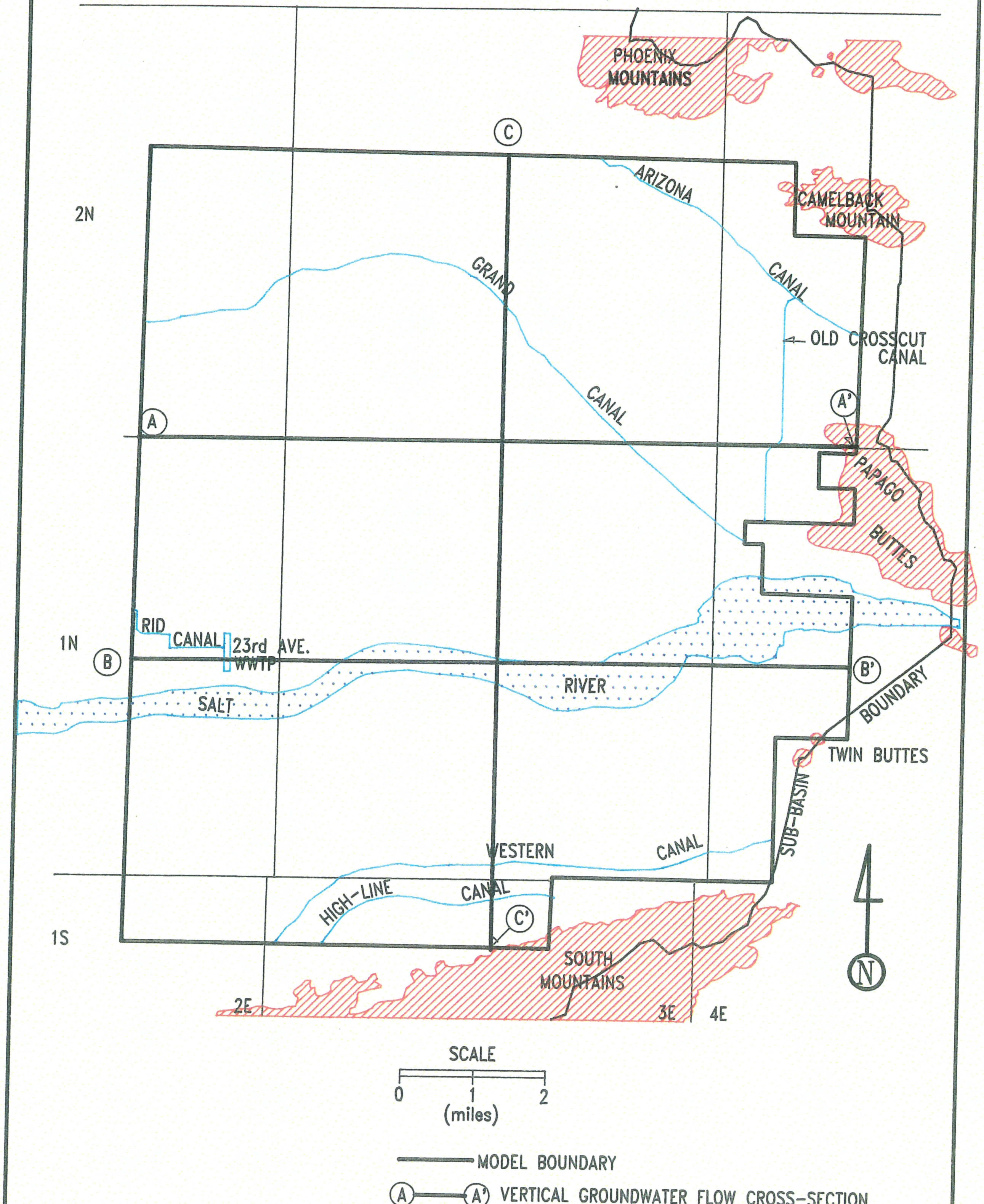



LEGEND: M52-39 GROUNDWATER FLOW PLOT
LAU BOTTOM WEST CENTRAL MODEL DOMAIN
TIME = 2190 DAYS (JAN 1989)
LAYER = 2
CONTOUR INTERVAL = 10 FEET

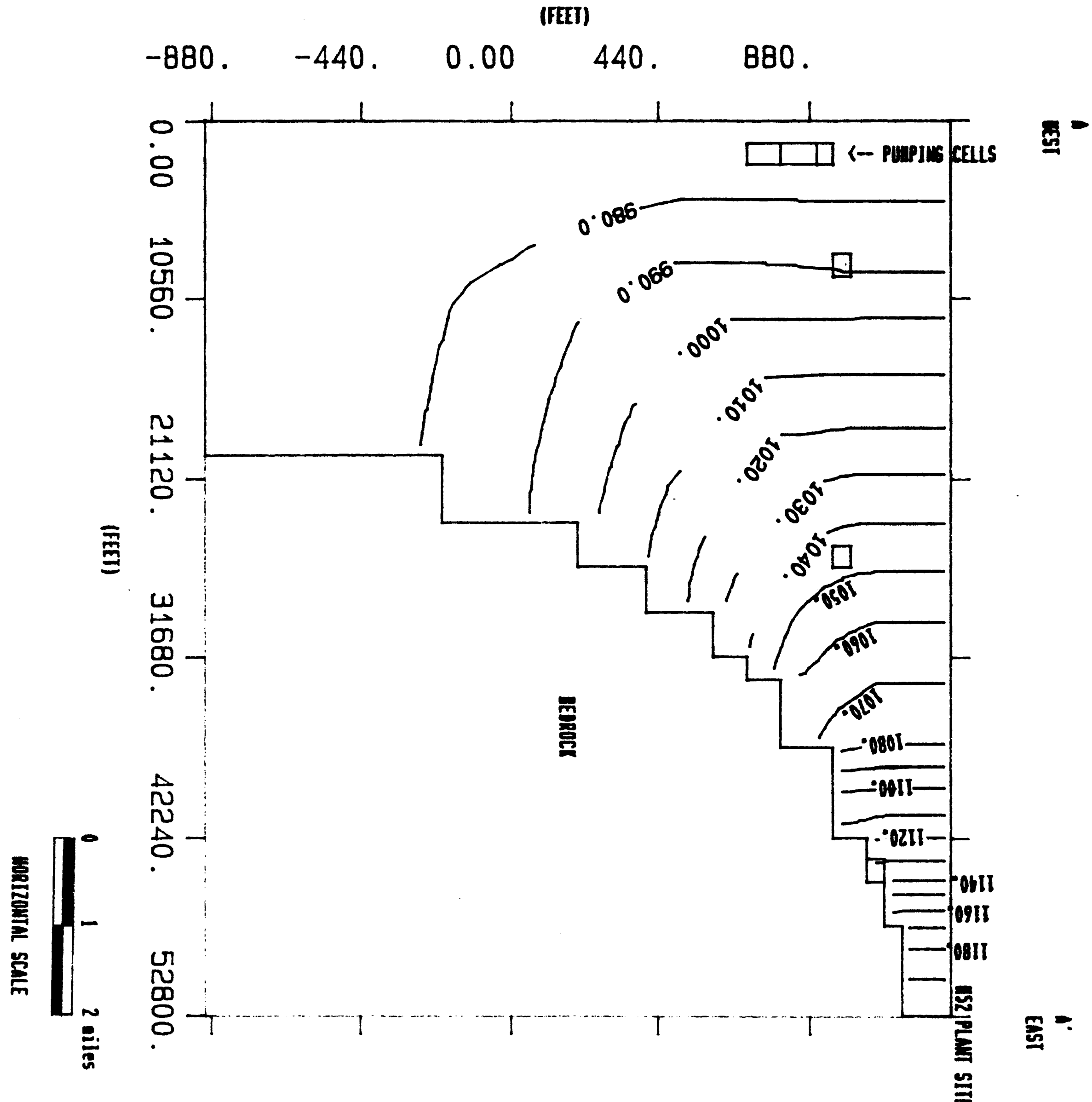
SCALE
0 1 2 mile

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
MODEL-SIMULATED VERTICAL GROUNDWATER FLOW
CROSS-SECTIONS (JAN., 1989)

FIGURE 20A



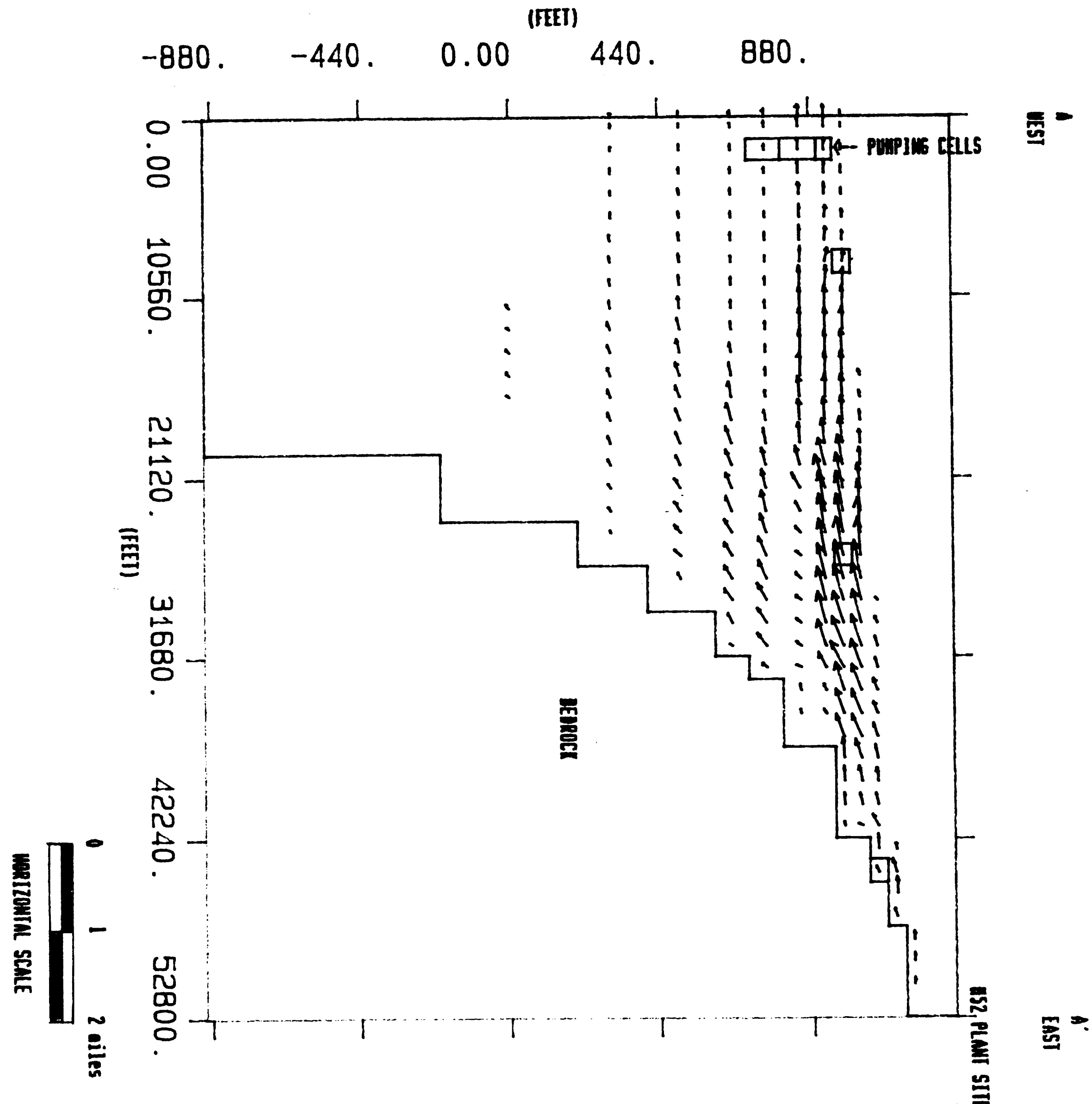
CPHX VERTICAL GROUNDWATER FLOW CONTOURS
E-W AT MCDOWELL RD.
(JAN., 1989)




| | |
|---|---|
| FIGURE CPHX VERTICAL GROUNDWATER FLOW CONTOURS (M52-39) | |
| E-W AT MCDOWELL RD. | time = 2190. DAYS J = 24 (ROW) |
| contour interval = 10.0 | 03-May-91 18:31:21 239 |

CPHX VERTICAL GROUNDWATER FLOW VECTORS
E-W AT MCDOWELL RD.
(JAN., 1989)

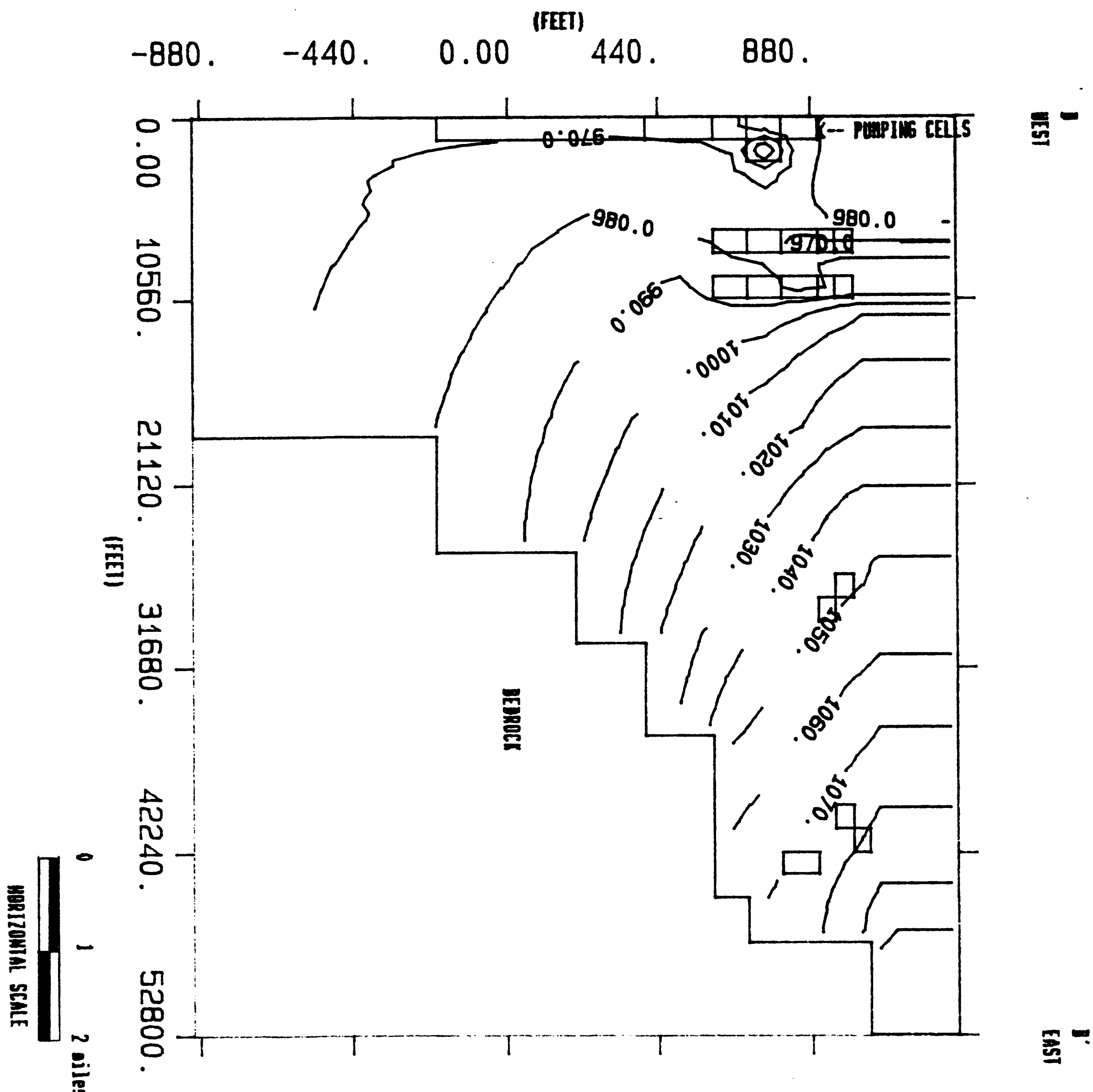
FIGURE 20C




| | |
|---|---|
| FIGURE CPHX VERTICAL GROUNDWATER FLOW VECTORS (M52-39) | |
| E-W AT MCDOWELL RD. | time = 2190. DAYS J = 24 (ROW) |
| → = 1.00 Ft/day | 03-May-91 18:31:21 239 |

CPHX VERTICAL GROUNDWATER FLOW CONTOURS
E-W AT UNIVERSITY DR.
(JAN., 1989)

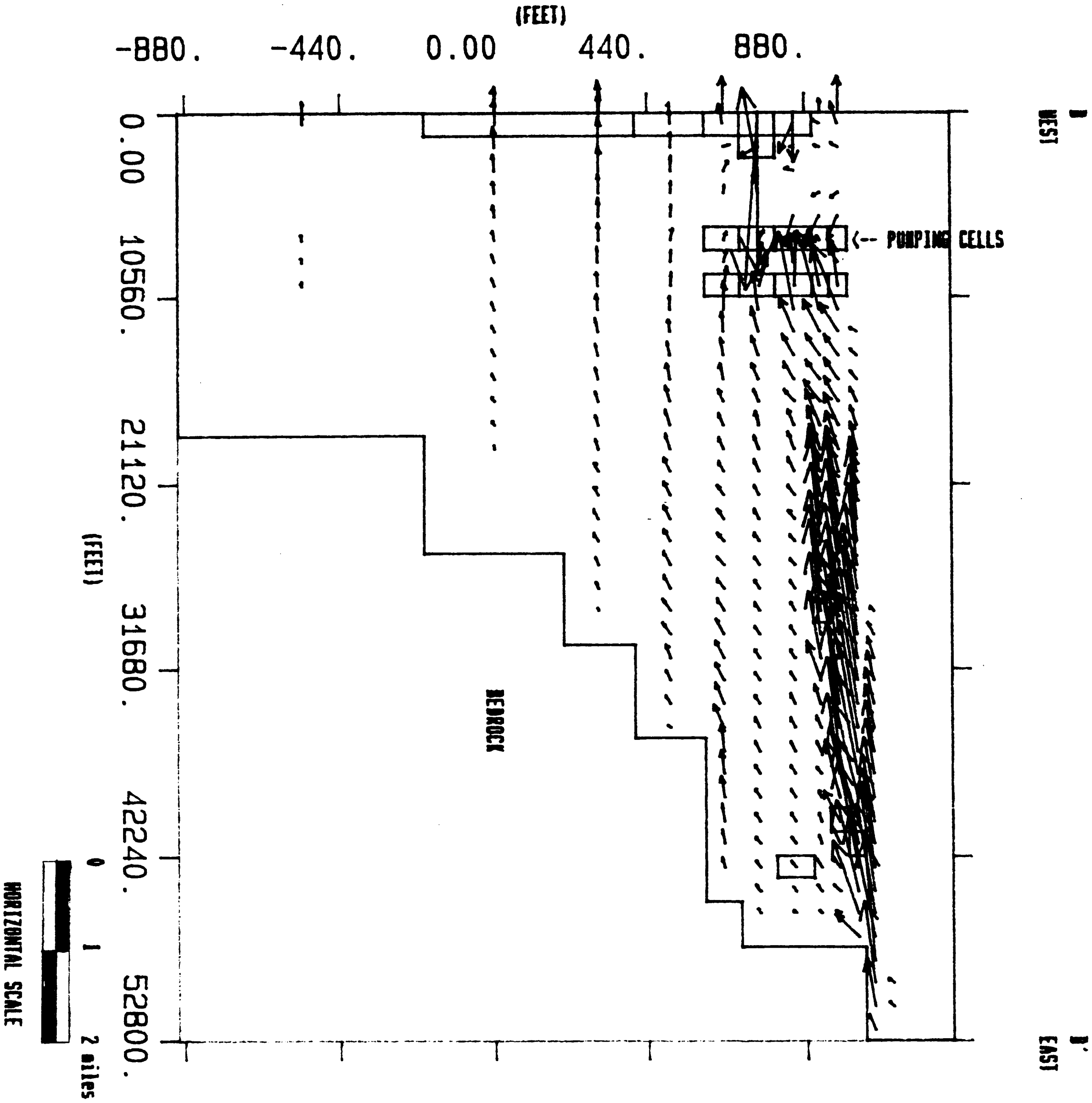
FIGURE 20B




| FIGURE CPHX VERTICAL GROUNDWATER FLOW CONTOURS (M52-39) | |
|---|---|
| E-W AT UNIVERSITY DR. | time = 2190. DAYS J = 12 (ROW) |
| contour interval = 10.0 | 03-May-91 18:31:21 239 |

CPHX VERTICAL GROUNDWATER FLOW VECTORS
E-W AT UNIVERSITY DR.
(JAN., 1989)

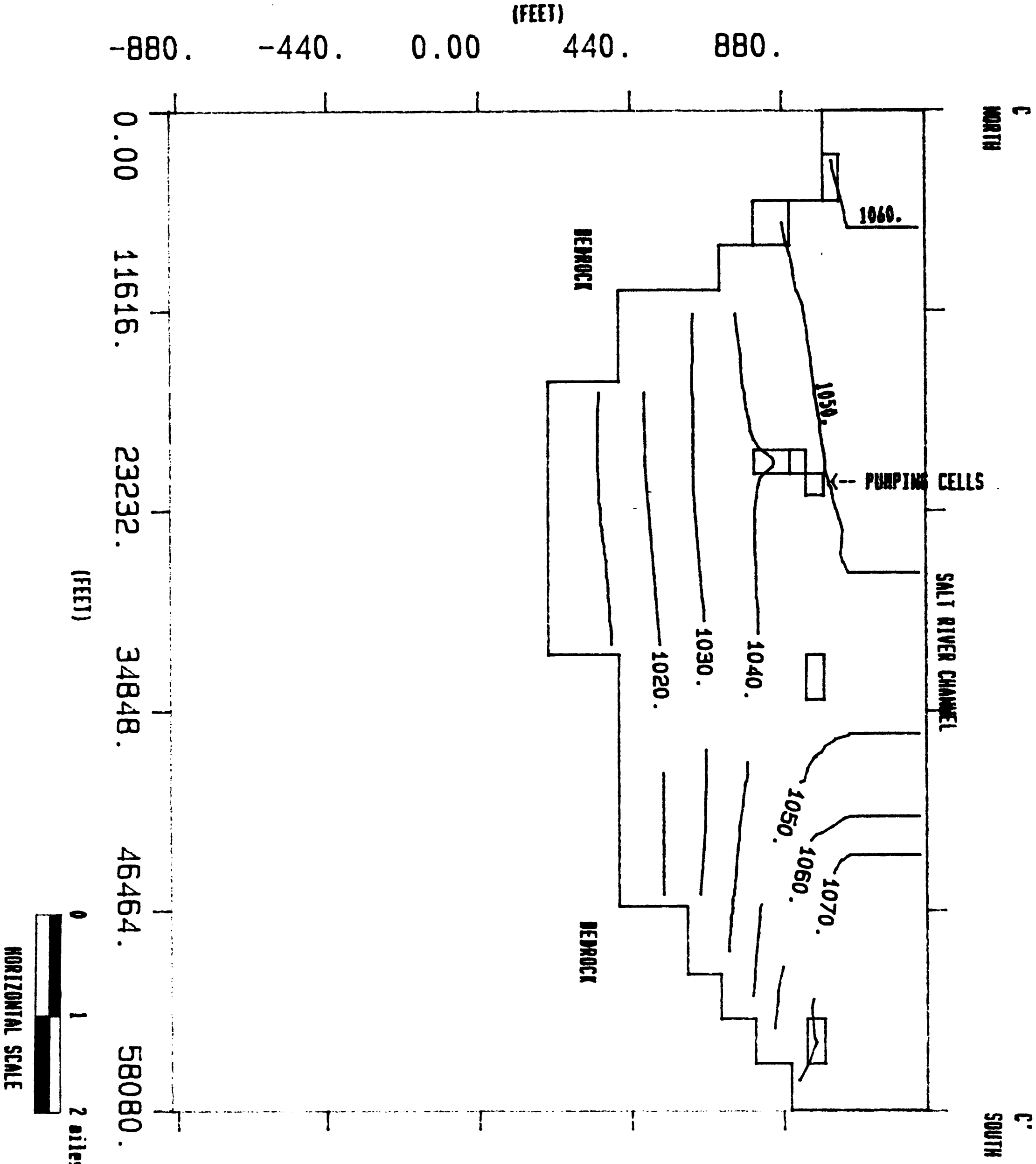
FIGURE 20E




| FIGURE CPHX VERTICAL GROUNDWATER FLOW VECTORS (M52-39) | |
|---|---|
| E-W AT UNIVERSITY DR. | time = 2190. DAYS J = 12 (ROW) |
| ——> = 1.00 Ft/day | 03-May-91 18:31:21 239 |

CPHX VERTICAL GROUNDWATER FLOW CONTOURS
N-S AT 16th ST.
(JAN., 1989)

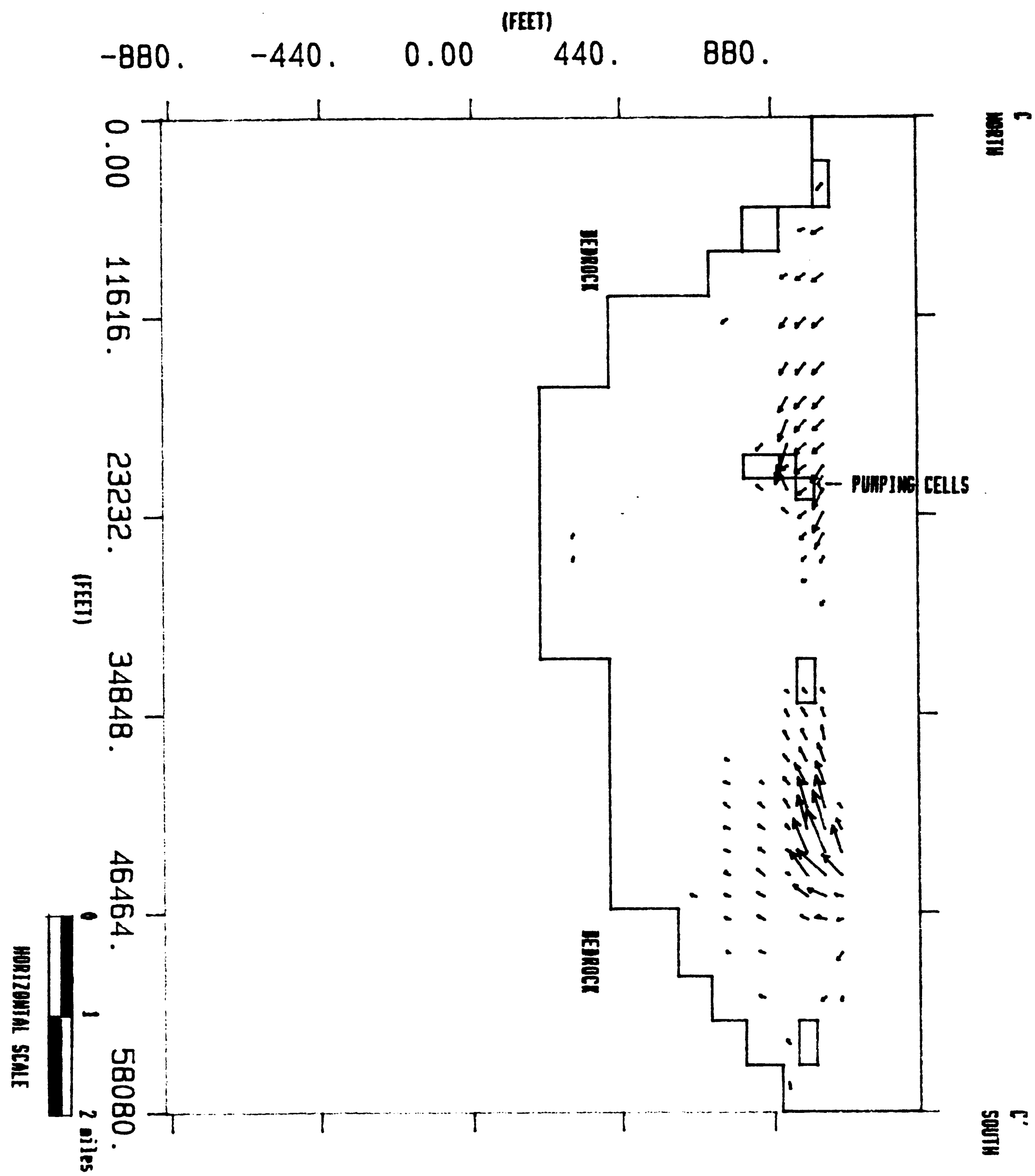
FIGURE 20F




| FIGURE CPHX VERTICAL GROUNDWATER FLOW CONTOURS (M52-39) | |
|---|---|
| N-S AT 16TH ST. | time = 2190. DAYS I = 22 (COL) |
| contour interval = 10.0 | 03-May-91 18:31:21 239 |

CPHX VERTICAL GROUNDWATER FLOW VECTORS
N-S AT 16th ST.
(JAN., 1989)

FIGURE 20G




| | |
|---|---|
| FIGURE CPHX VERTICAL GROUNDWATER FLOW VECTORS (M52-39) | |
| N-S AT 16TH ST. | time = 2190. DAYS I = 22 (COL) |
| ——> = 1.00 Ft/day | 03-May-91 18:31:21 239 |

Figure 21 is a well location map indicating wells selected for hydrographs. Figures 22 to 27 are hydrographs of water levels measured in wells versus model simulated water levels in corresponding model cells. It can be seen that a reasonable correlation exists between the model simulated head fluctuations and the well head fluctuations. The hydrographs also show that the model is responsive to changing stresses, and successfully simulates the general trends of water level change in the system.

In summary, the results indicate that the TARGET_3DS model reasonably simulates groundwater flow and is in agreement with the results of the 1989 detailed water level survey (ADWR, 1989). The model simulated heads and hydraulic gradients generally agree with field data in the area of greatest interest (near the M52 plant site). Well hydrographs indicate that the model simulates actual water level changes and trends reasonably well. The different components of inflow and outflow presented in the conceptual water budget (Table 1) generally agree with the water budget of the calibration model run (Table 4). In addition, a mass balance error of 1.1 percent was obtained for the calibrated simulation; an acceptable error for transient simulations.

**Table 4**

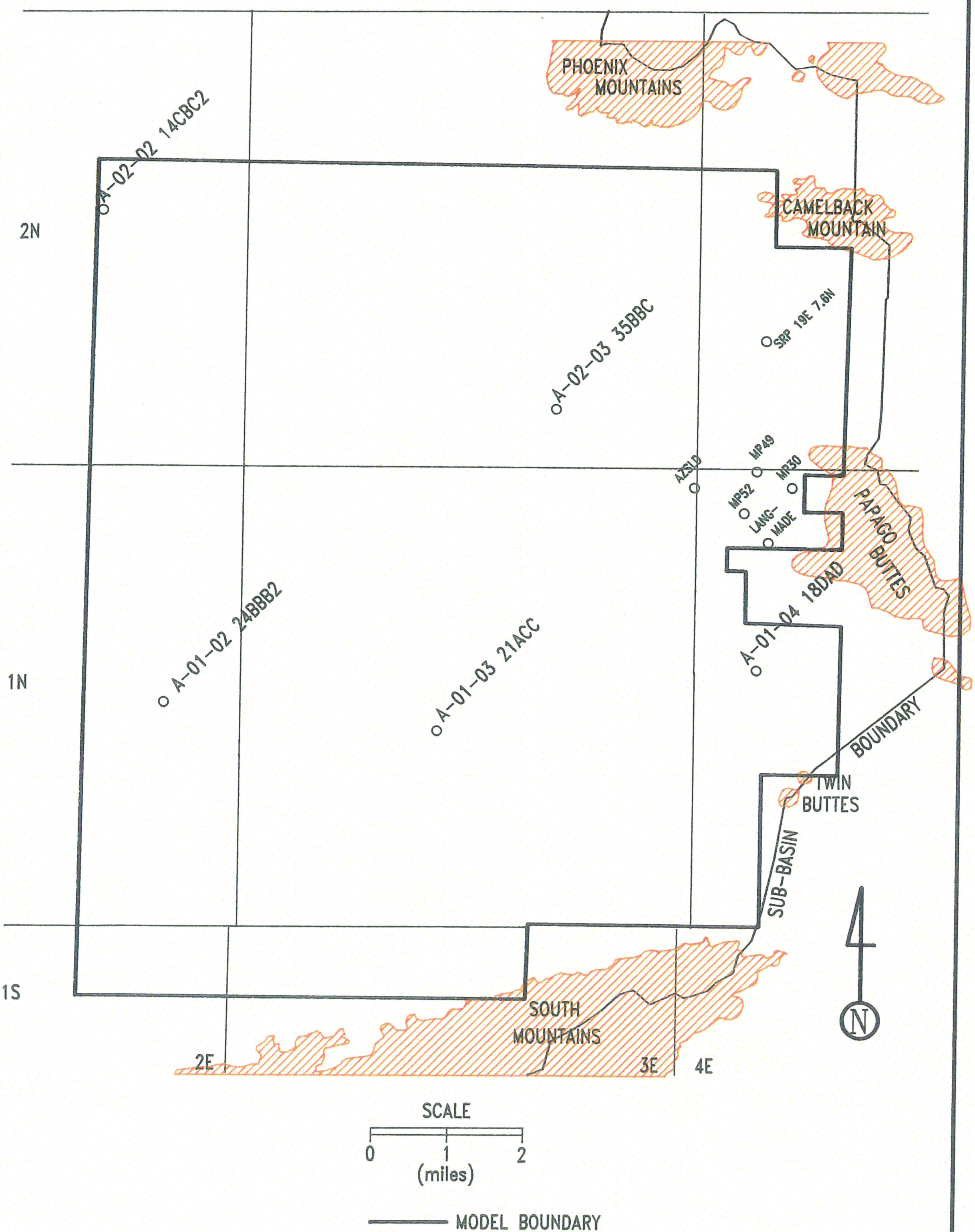
**Model Water Budget**
**for January 1983 to January 1989 Transient Simulation**
**(Figures rounded to the nearest 100 acre-feet)**

| Inflows | | Outflows | |
|---|---|---|---|
| Underflow | 153,200 | Underflow | 241,700 |
| Recharge | 425,000 | Pumpage | 345,000 |
| Total | 578,200 | | 568,700 |

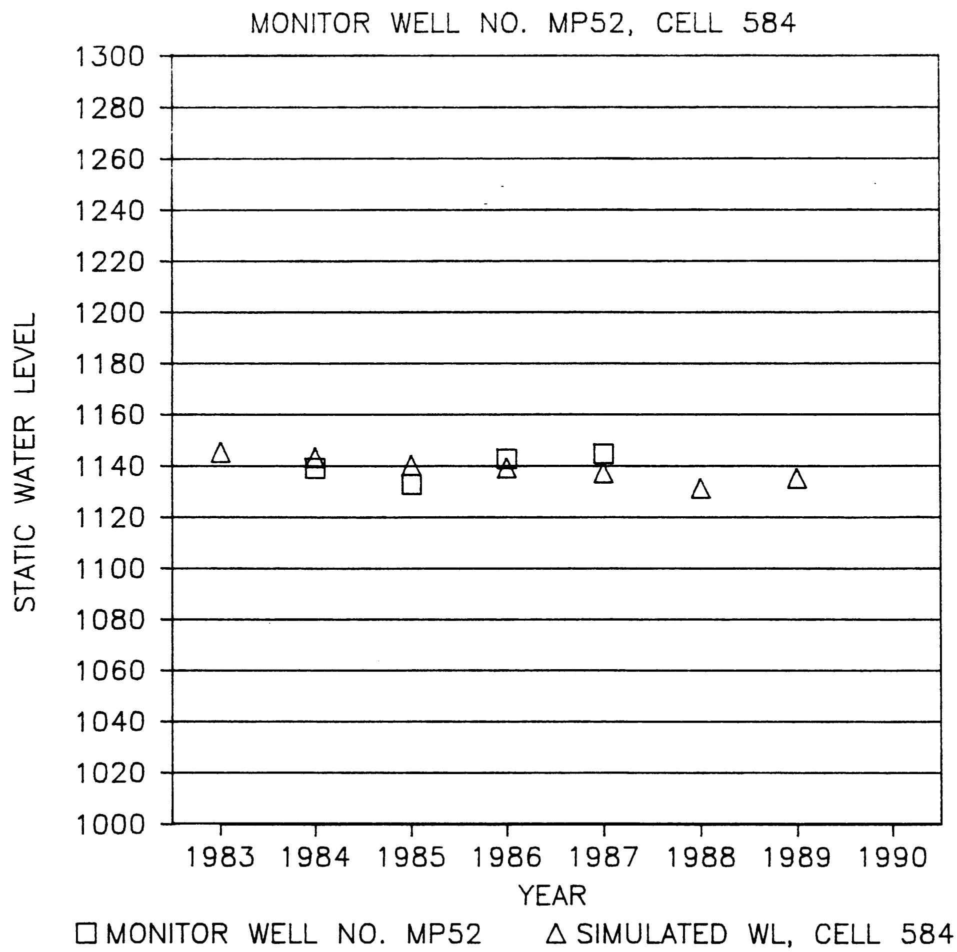
Model calculated change in storage = (Inflows - Outflows)
= +9,500 acre-feet

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
WELL LOCATIONS OF SELECTED HYDROGRAPHS

FIGURE 21



HYDROGRAPH OF MONITOR WELL NO. MP52

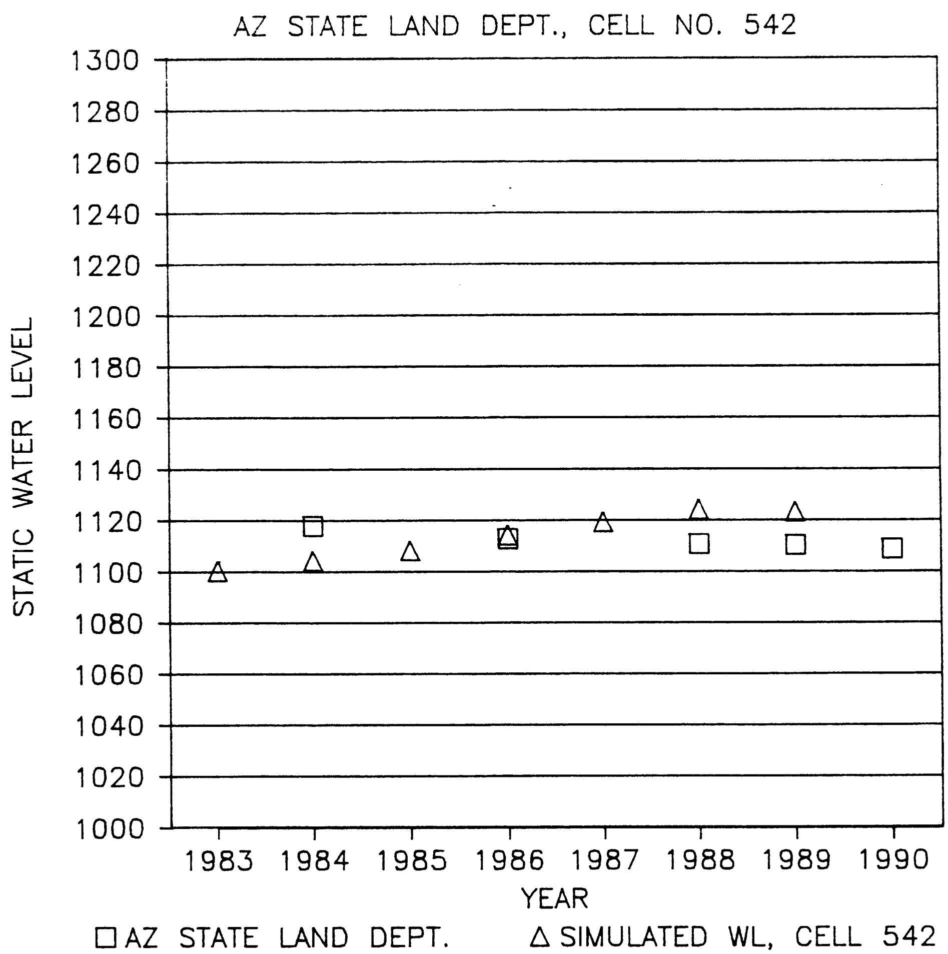



(COLUMN, ROW, LAYER) 37.21.13

UAU

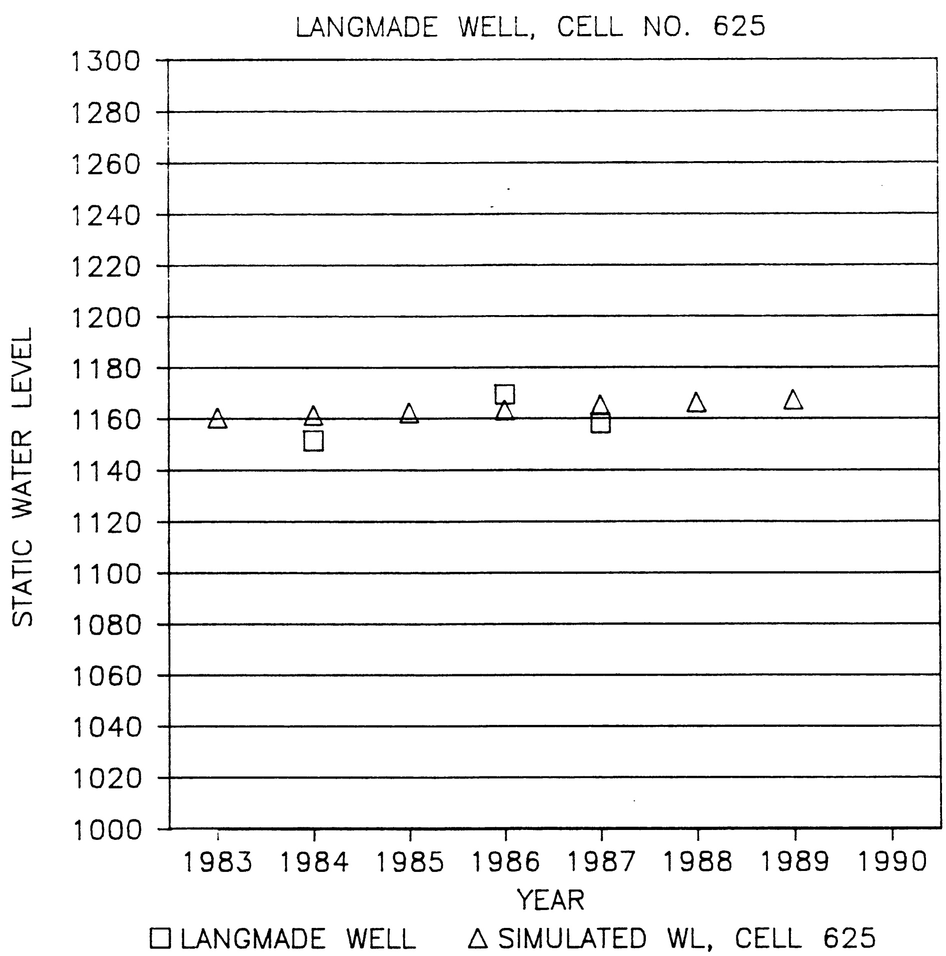
FIGURE 23

HYDROGRAPH OF ARIZONA STATE LAND DEPT. WELL



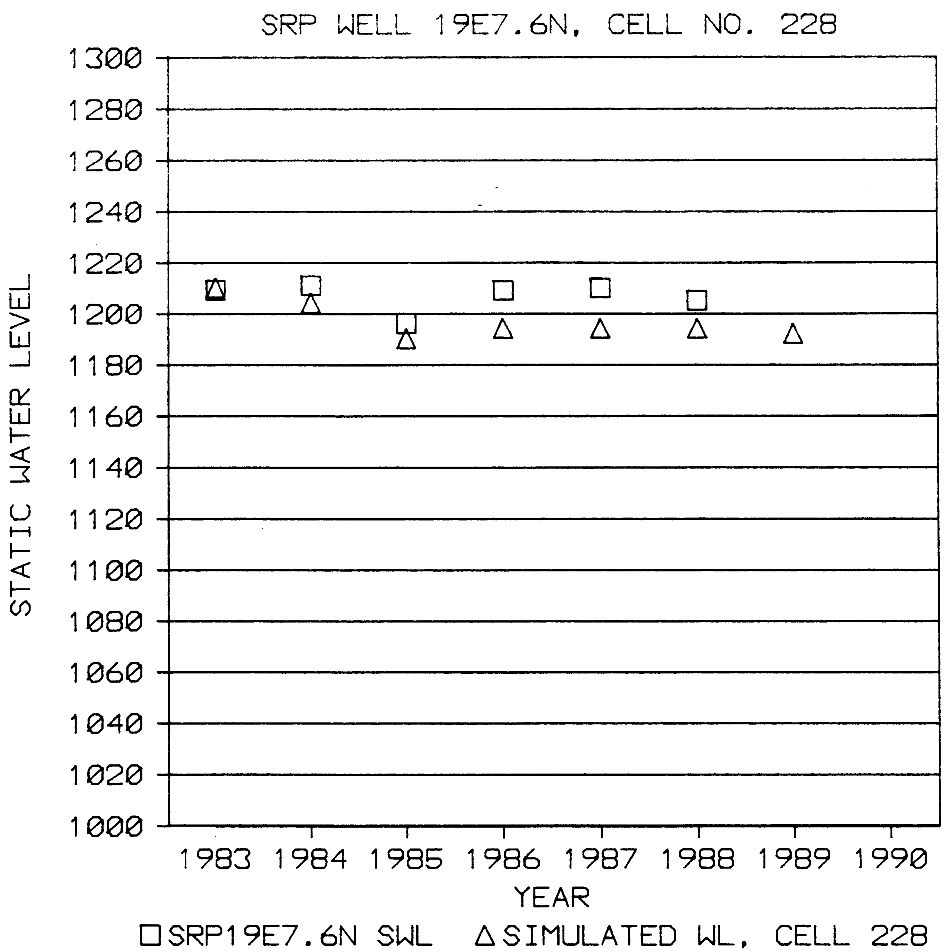

(COLUMN, ROW, LAYER) 33,22,11
UAU

HYDROGRAPH OF LANGMADE WELL




(COLUMN, ROW, LAYER) 38,20,14
UAU

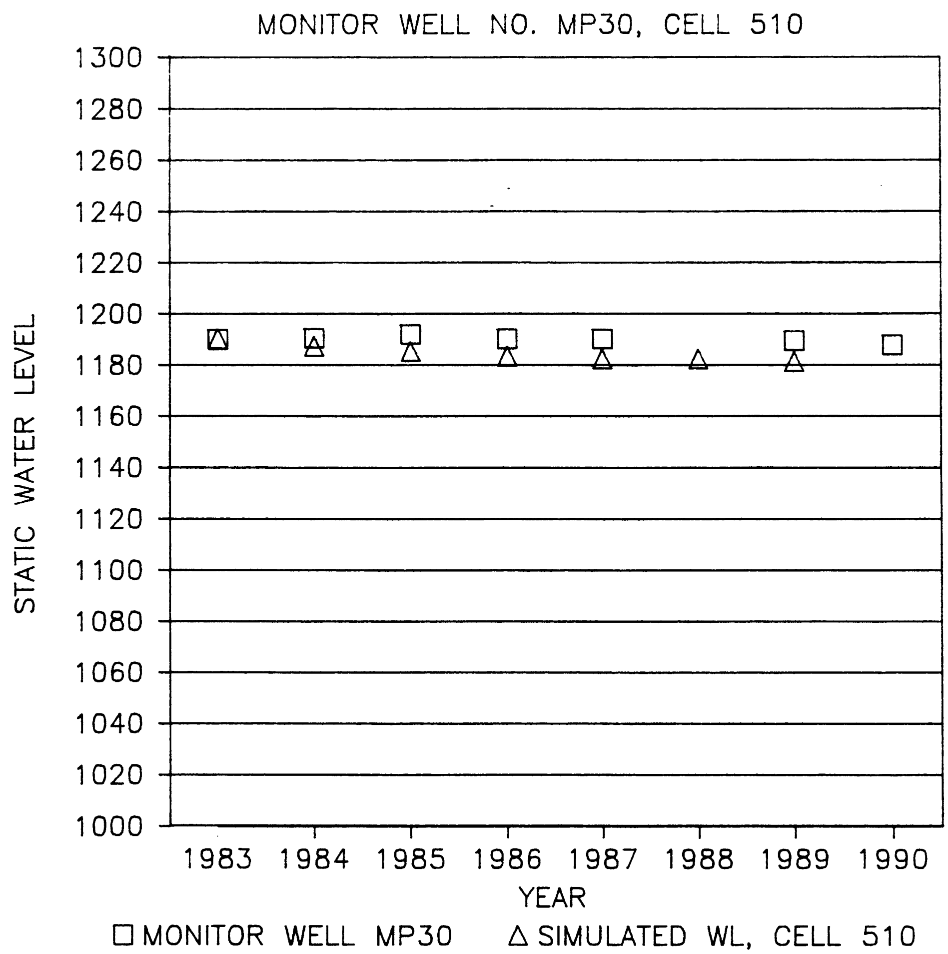
HYDROGRAPH OF SALT RIVER PROJECT WELL 19E 7.6N




(COLUMN, ROW, LAYER) 37,30,14

UAU

HYDROGRAPH OF MONITOR WELL NO. MP30

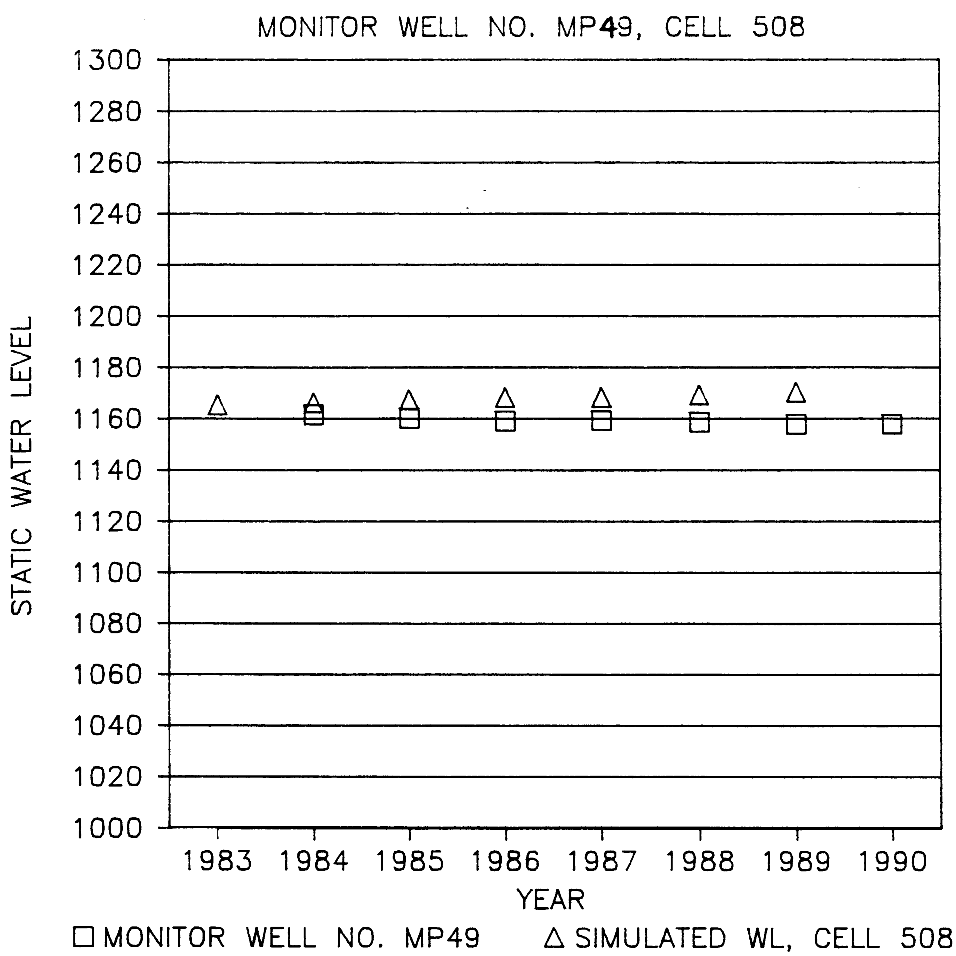



(COLUMN, ROW, LAYER) 39,23,14

UAU

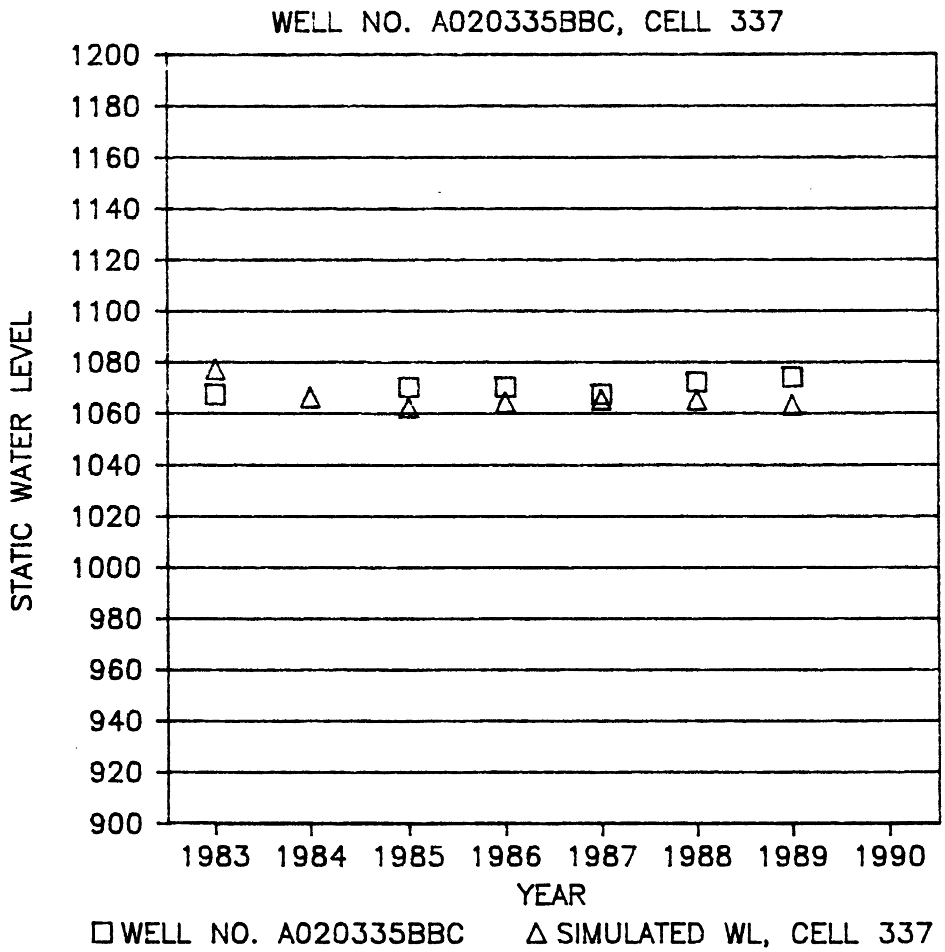
FIGURE 27

HYDROGRAPH OF MONITOR WELL NO. MP49




(COLUMN, ROW, LAYER) 37,23,14
UAU

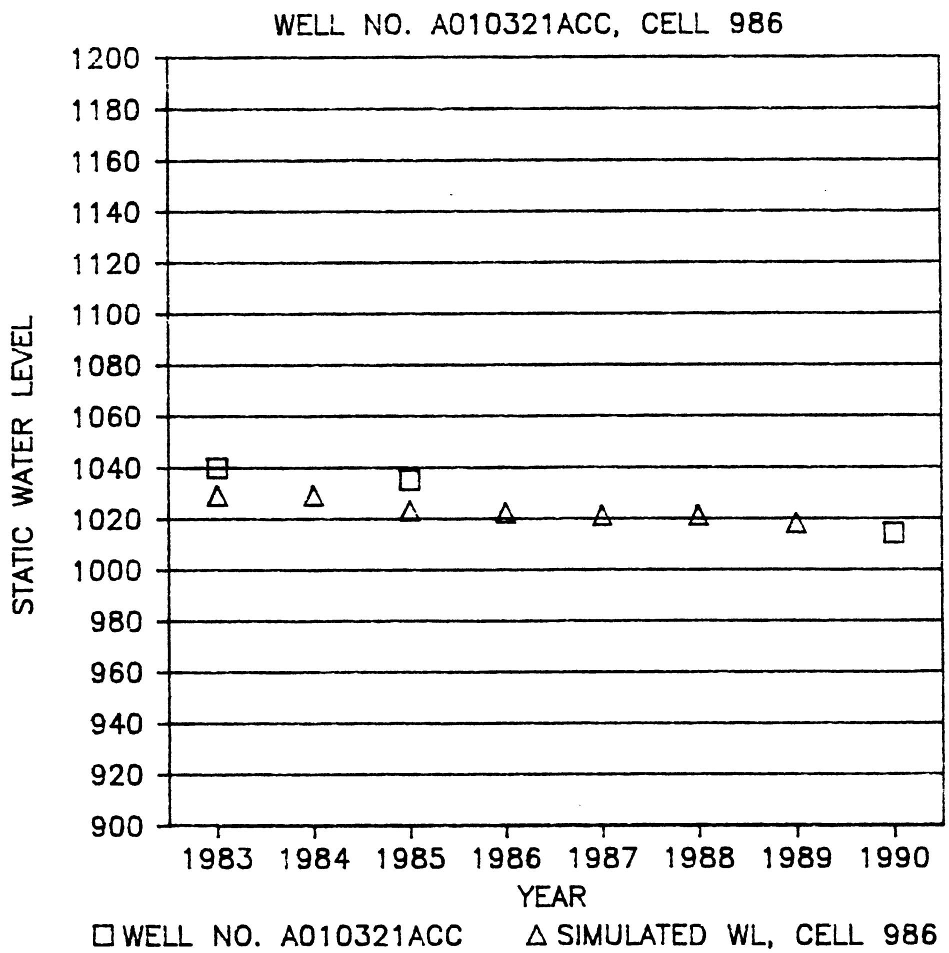
HYDROGRAPH OF WELL NO. A020335BBC




(COLUMN, ROW, LAYER) 26,7,8

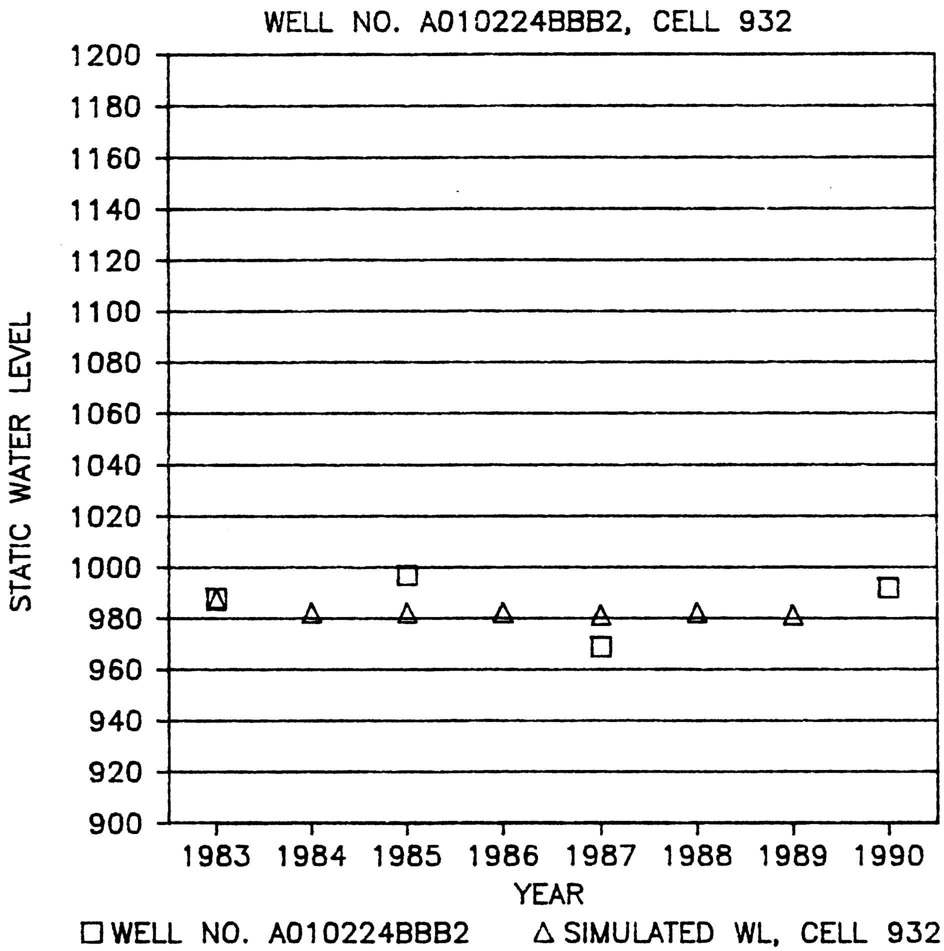
MAU

# HYDROGRAPH OF WELL NO. A010321ACC




(COLUMN, ROW, LAYER) 20,10,5
LAU

HYDROGRAPH OF WELL NO. A010224BBB2

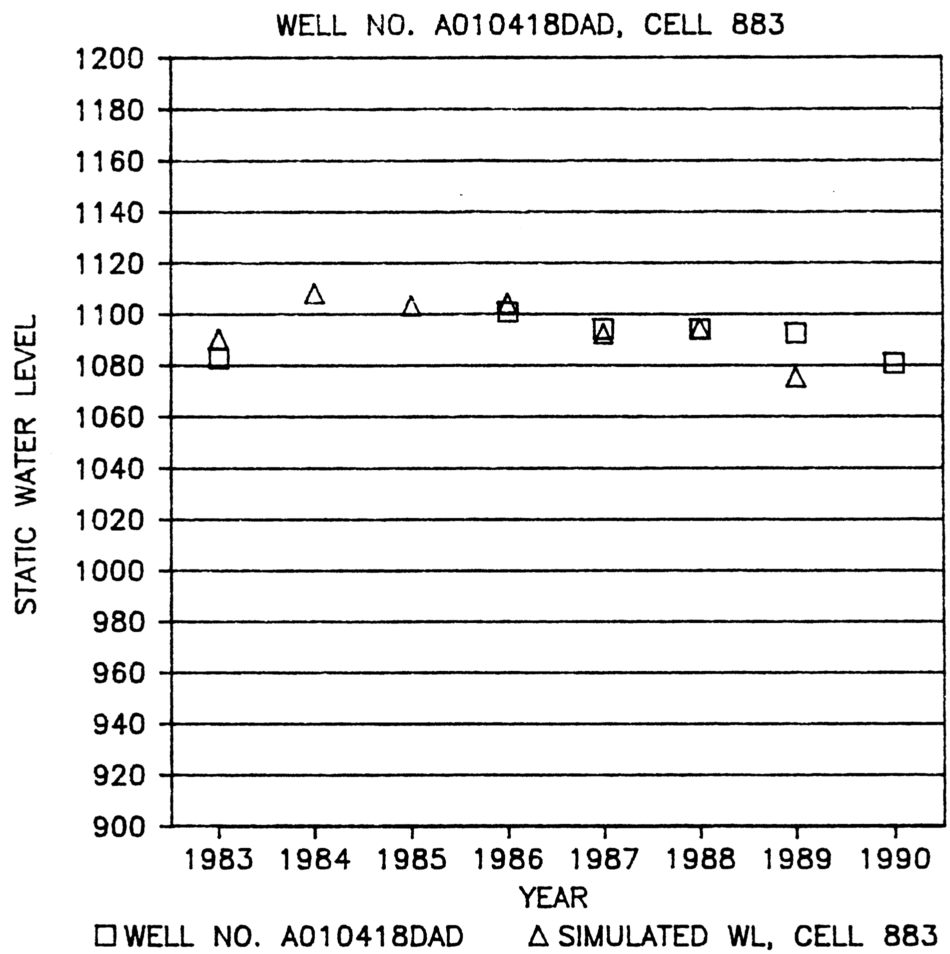



(COLUMN, ROW, LAYER) 6,11,3

UAU,MAU,LAU

FIGURE 31

HYDROGRAPH OF WELL NO. A010418DAD

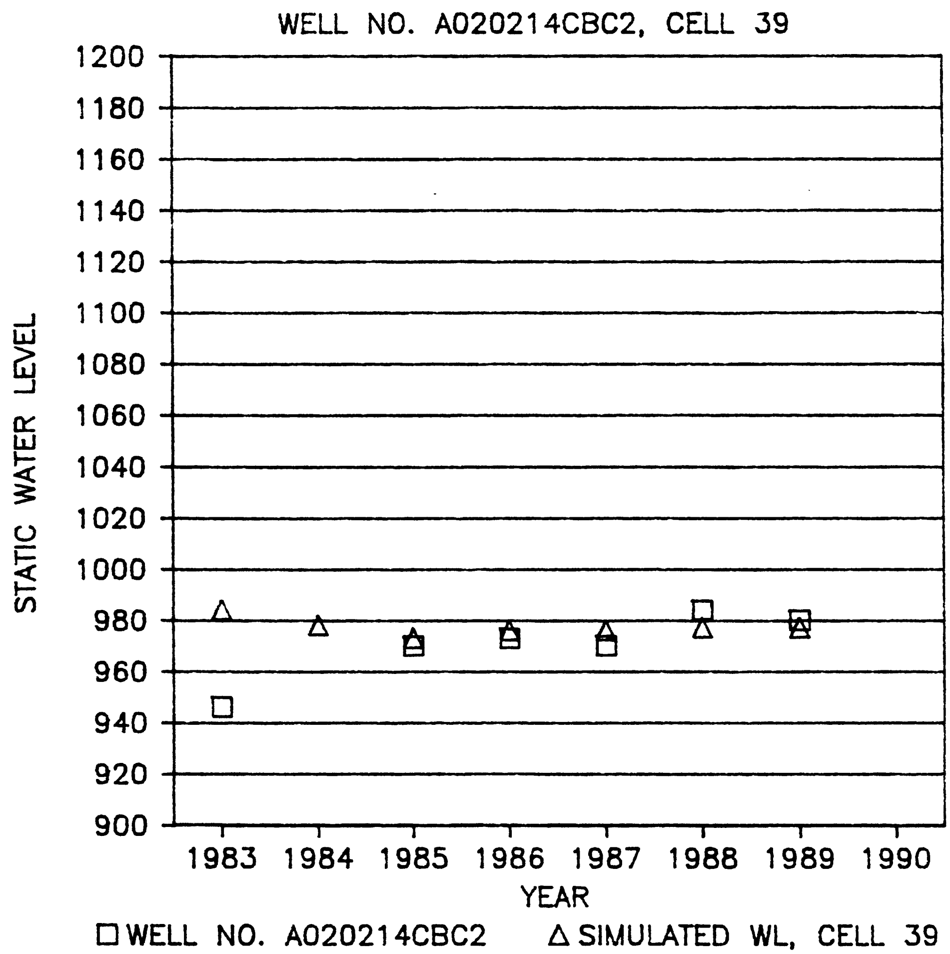



(COLUMN, ROW, LAYER) 37,13,10

UAU

FIGURE 32

HYDROGRAPH OF WELL NO. A020214CBC2




(COLUMN, ROW, LAYER) 4,34,8

MAU

## Simulation of Contaminant Plume (TCE) From the Motorola 52nd St. Plant Site

To test the contaminant transport portion of the model, a contaminant plume originating from the Motorola 52nd St. site was simulated based upon available data. More refined contaminant data are to be input to the model in cooperation with ADEQ as they become available. The contaminant transport model incorporated data from the 1987 Motorola 52nd St. RI/FS report prepared by Dames & Moore. The contaminant transport model that is described in the following section incorporates contaminant data from the Motorola 52nd St. (CERCLA) groundwater contamination site and is not verified against field data.

### Contaminant Transport Model Discussion:

The contaminant data for the CPHX contaminant transport model was obtained from the 1987 Motorola 52nd St. RI/FS report (Dames & Moore). The extent of contamination in 1983 was delineated and input into the model as an initial condition of the projection run. Figure 34 illustrates the initial contaminant distribution in ppb as it was discretized into the model domain (source: Fig 5.47, 1987 RI/FS, Development of Predicted Plumes in the Alluvium). In addition to the initial contaminant distribution in 1983 a continually leaking source of TCE (215 gallons/year) was also included. This source simulates the amount of virgin TCE which is thought to enter the groundwater system through advective and dispersive processes per year in the area of a once-used TCE disposal dry well (Source 2, Figure 33). This dry well (Source 2) is estimated to be the source of nearly 90% of TCE disposed at the plant site. It is assumed that the location of Source 2 may be used as the sole source of TCE for modeling purposes. The model simulated TCE distribution for January 1989 of layers 7 to 14 are indicated in figures 35 to 42. It should be noted that the model simulated TCE distribution is an uncalibrated contaminant transport model run. The contaminant transport model run was made to ensure that this portion of the model would run successfully in order to incorporate water quality data as it becomes available.

The initial mass of solute in the groundwater in the alluvium (bedrock source not simulated) is 4515 gallons TCE.

- Source active 1962 to 1983

- 215 gallons/year TCE newly dissolved in the Alluvium

  215 gal/yr (TCE) x 21 yr = 4515 gal TCE

To achieve an initial mass of solute in storage similar to that estimated in the RI/FS, a concentration of 35,000 ppb was calculated for the model cell corresponding to Source 2. The continuing source of 215 gal/year (TCE) was also simulated in the Source 2 model cell. All solvent concentrations were input into the model in the lowermost partially saturated model cell in the alluvium, a bedrock source was not simulated. Some assumptions incorporated into the CPHX contaminant transport model are listed below and are discussed in more detail beginning on page 55.

- Adsorption of TCE may be neglected.
- Solvent sources in the unsaturated zone may be neglected for the purposes of modeling TCE transport.
- 215 gallons/year (TCE) newly dissolved in the alluvium.
- Dispersivity values input:

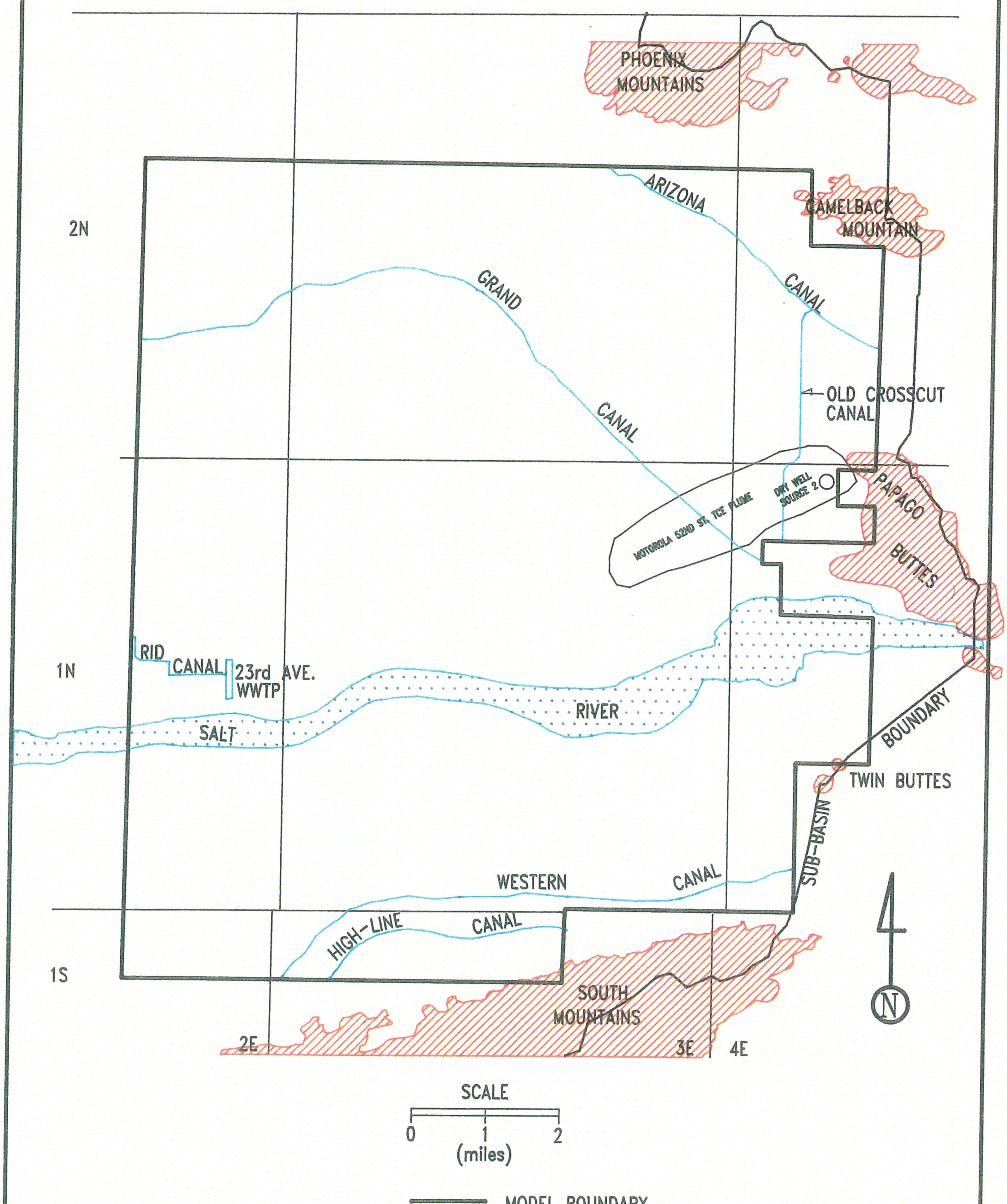
  Longitudinal Dispersivity (DL) = 100 FT.
  Transverse Dispersivity (DT) = 10 FT.

**Contaminant Transport Model Summary**

While the model-simulated plume concentrations are not verified against field data (i.e., uncalibrated), the success of this initial contaminant transport model simulation indicates that future simulations will be possible as additional contaminant data become available.

FIGURE 33

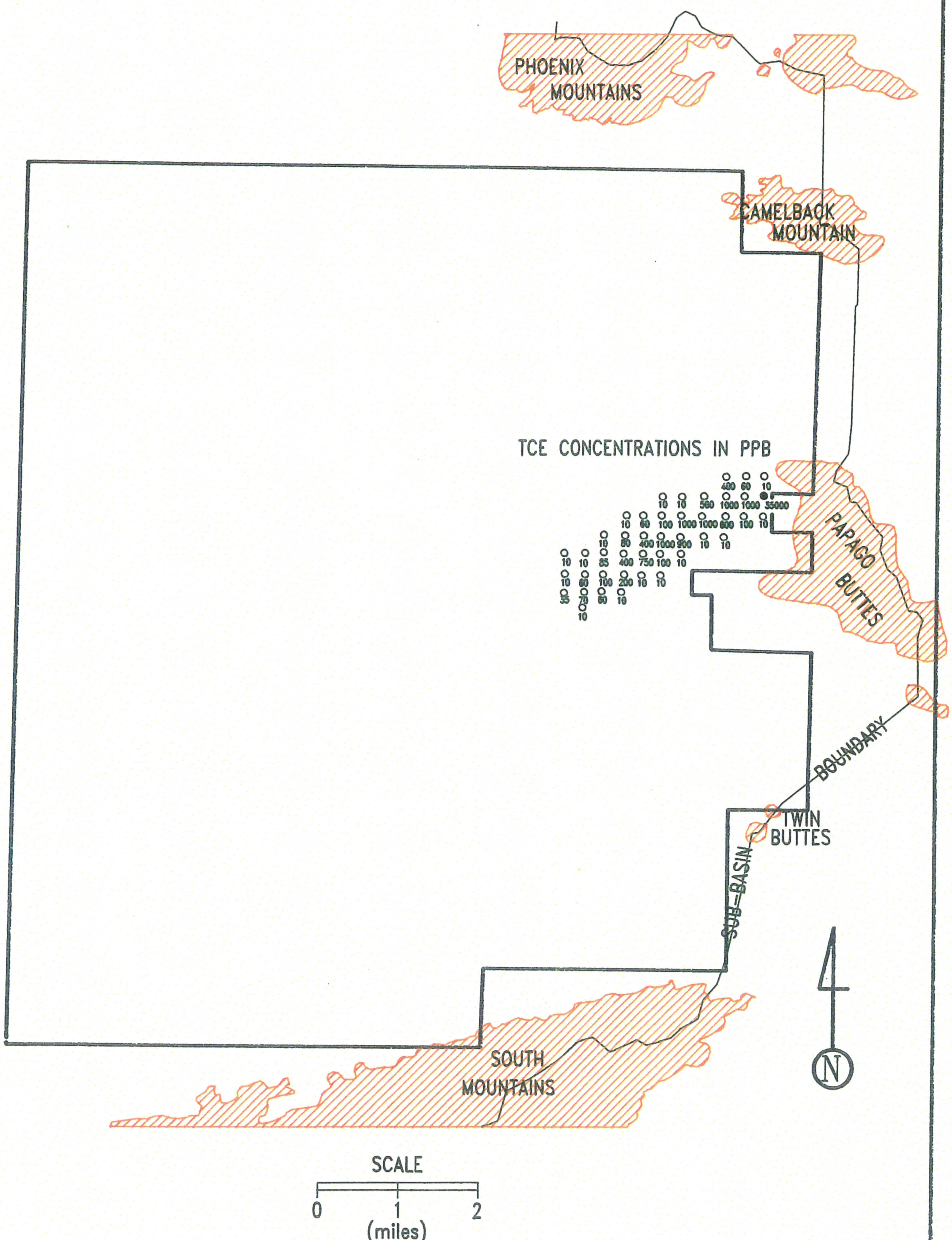
CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
MOTOROLA 52ND ST. CONTAMINANT (TCE) PLUME (1983)




DATA SOURCE: 1987 MOTOROLA 52ND ST. RI/FS
DAMES & MOORE

CENTRAL PHOENIX GROUNDWATER FLOW MODEL AREA
INITIAL TCE DISTRIBUTION ALLUVIUM (JAN 1983)

FIGURE 34

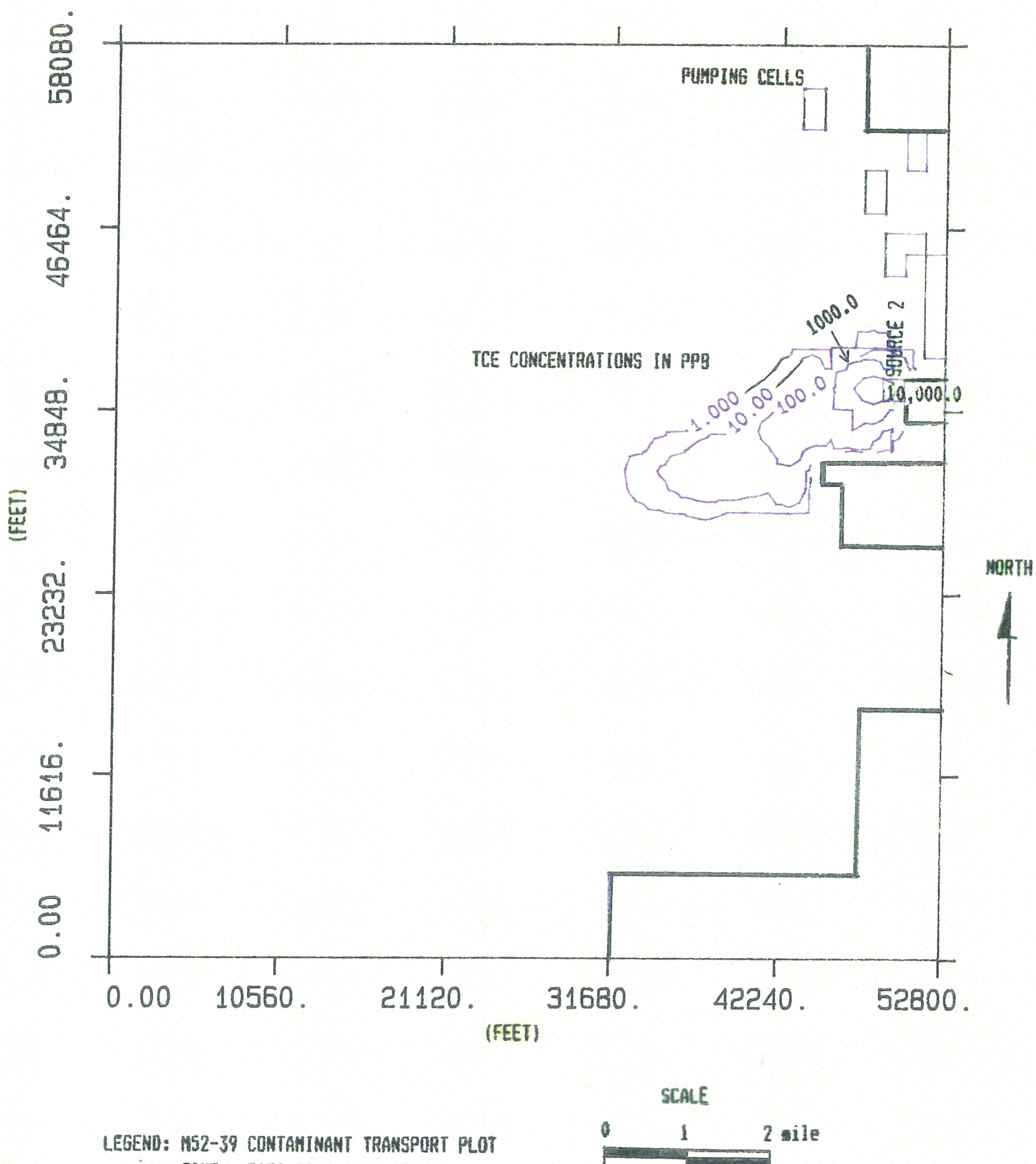



MODEL BOUNDARY

LEGEND: ● 35000 LOCATION OF SOURCE 2 (DRYWELL) CONTINUING SOURCE IN ALLUVIUM 215 GALLONS TCE/YEAR

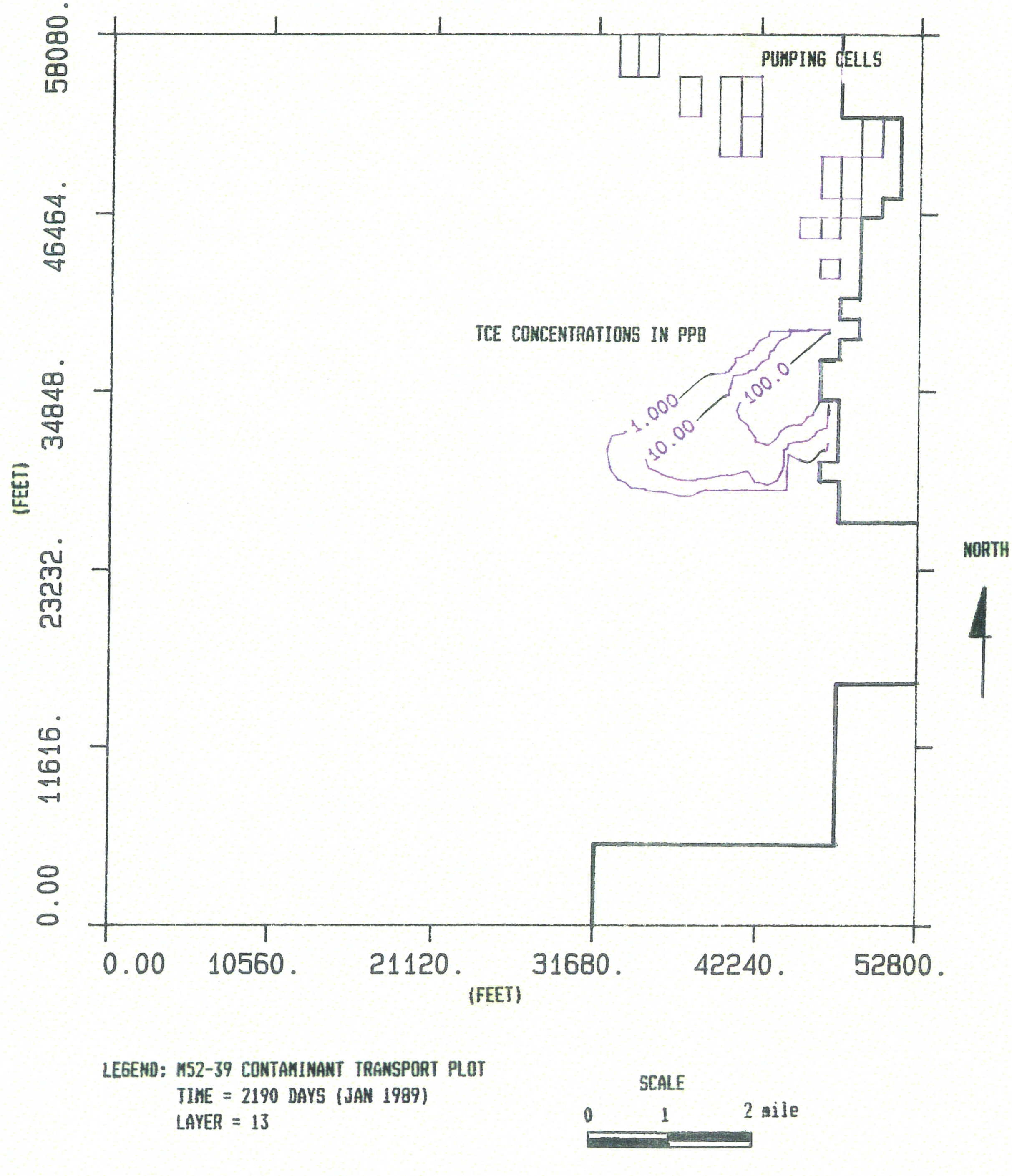
SOURCE: 1987 MOTOROLA 52ND ST. RI/FS

CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 14



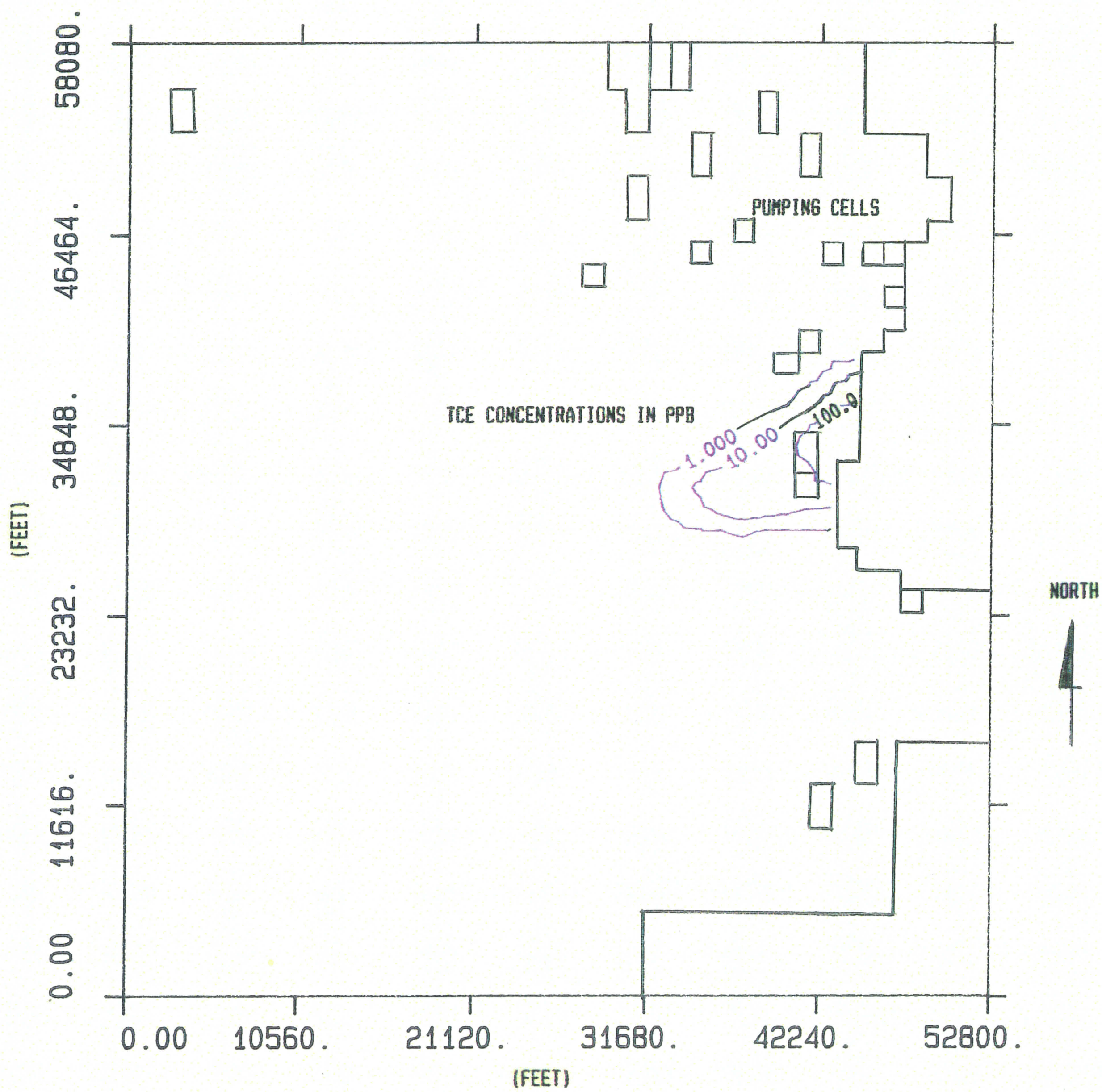

LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 14

CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 13




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 13

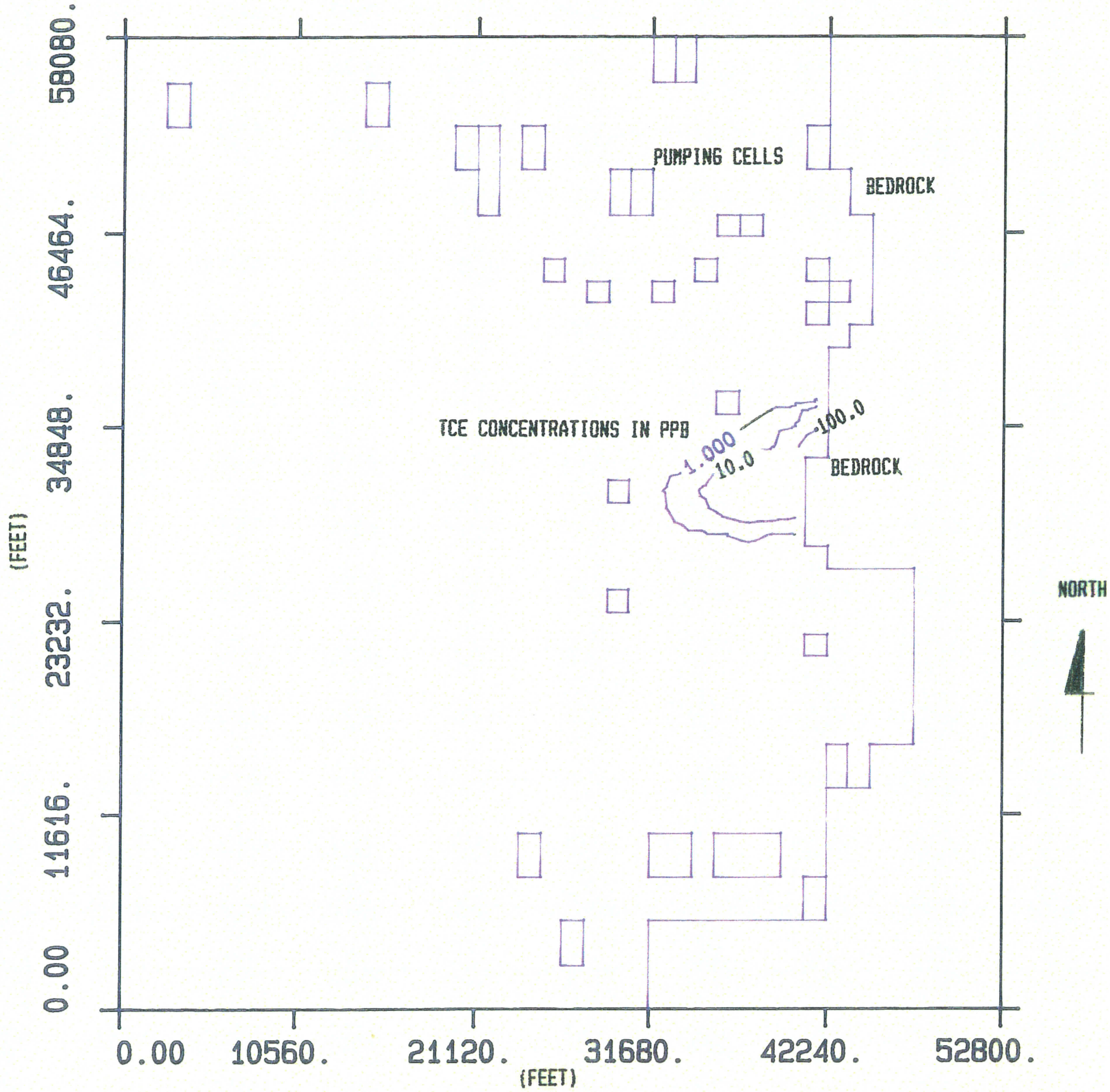
CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 12




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 12

SCALE
0 1 2 mile

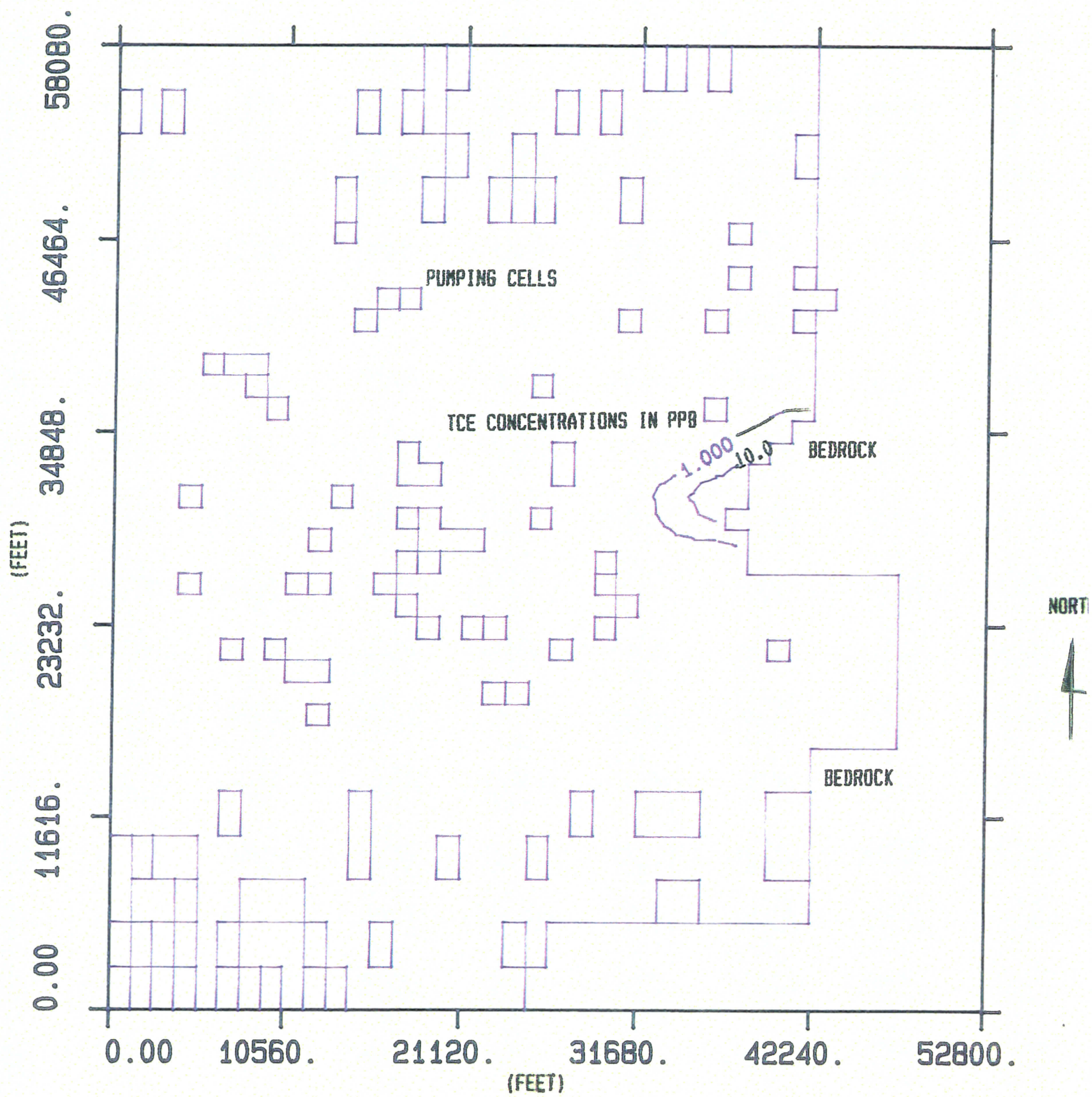
CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 11




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 11

SCALE
0 1 2 mile

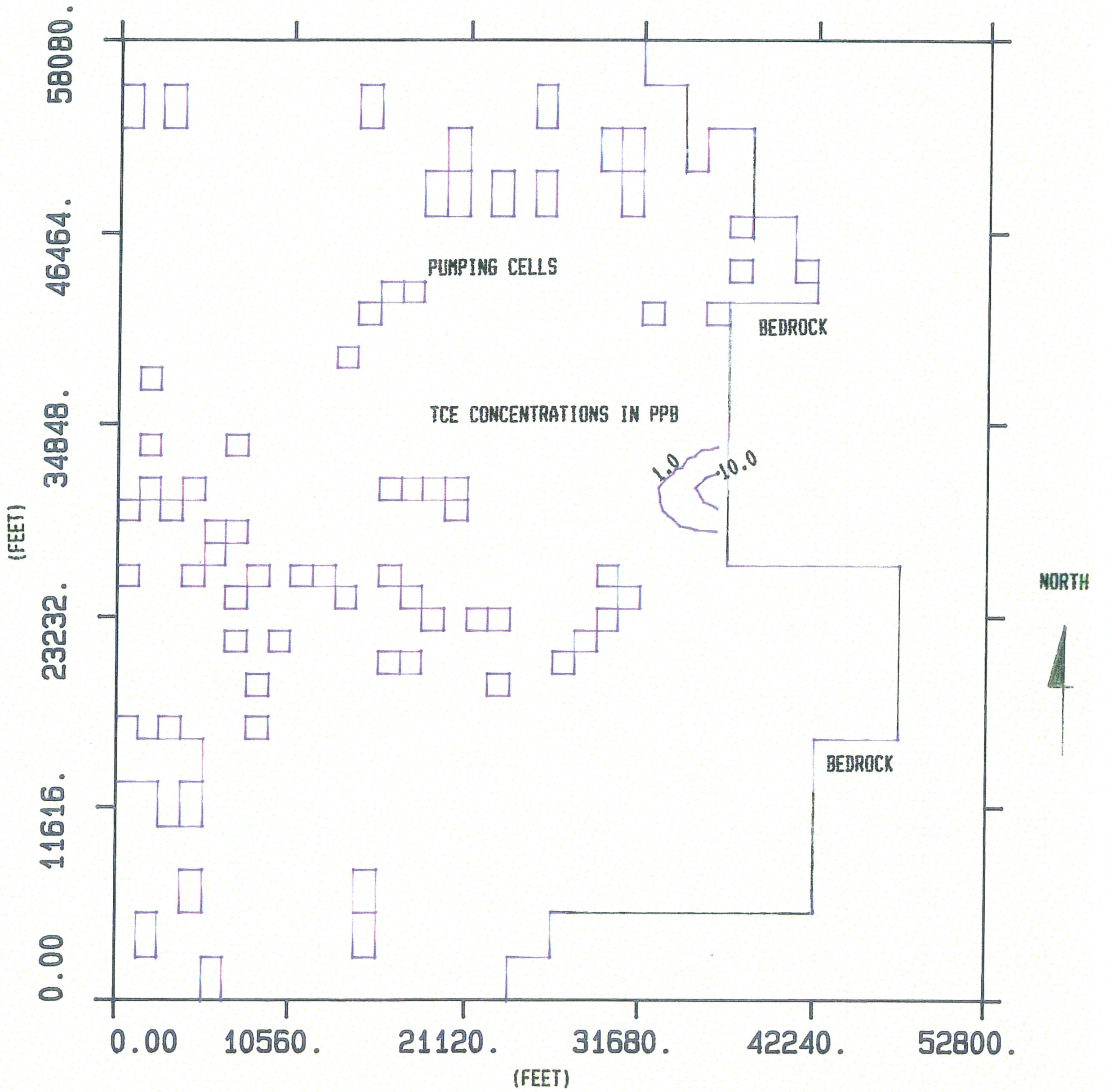
CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 10




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 10

SCALE
0 1 2 mile

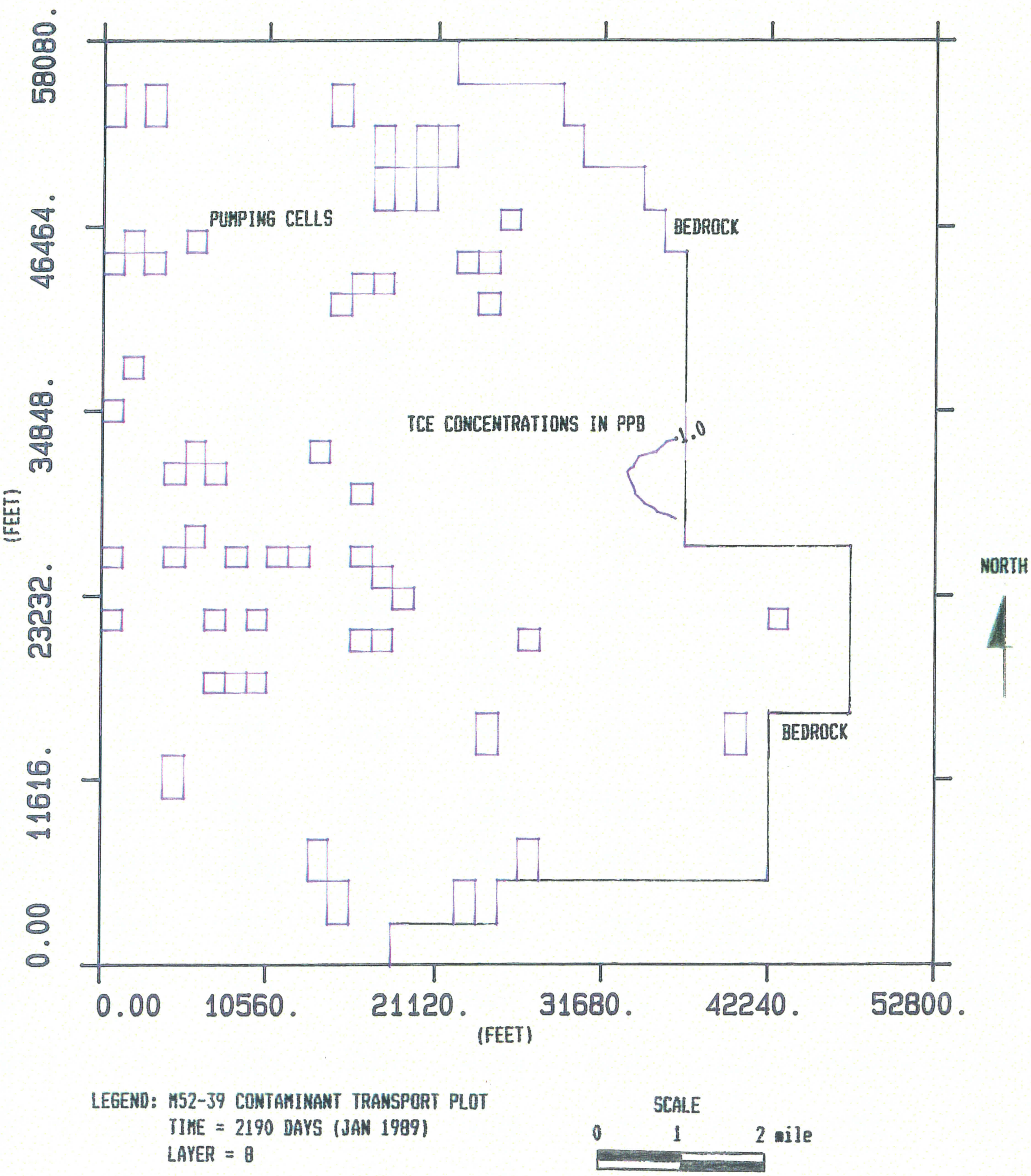
CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 9




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 9

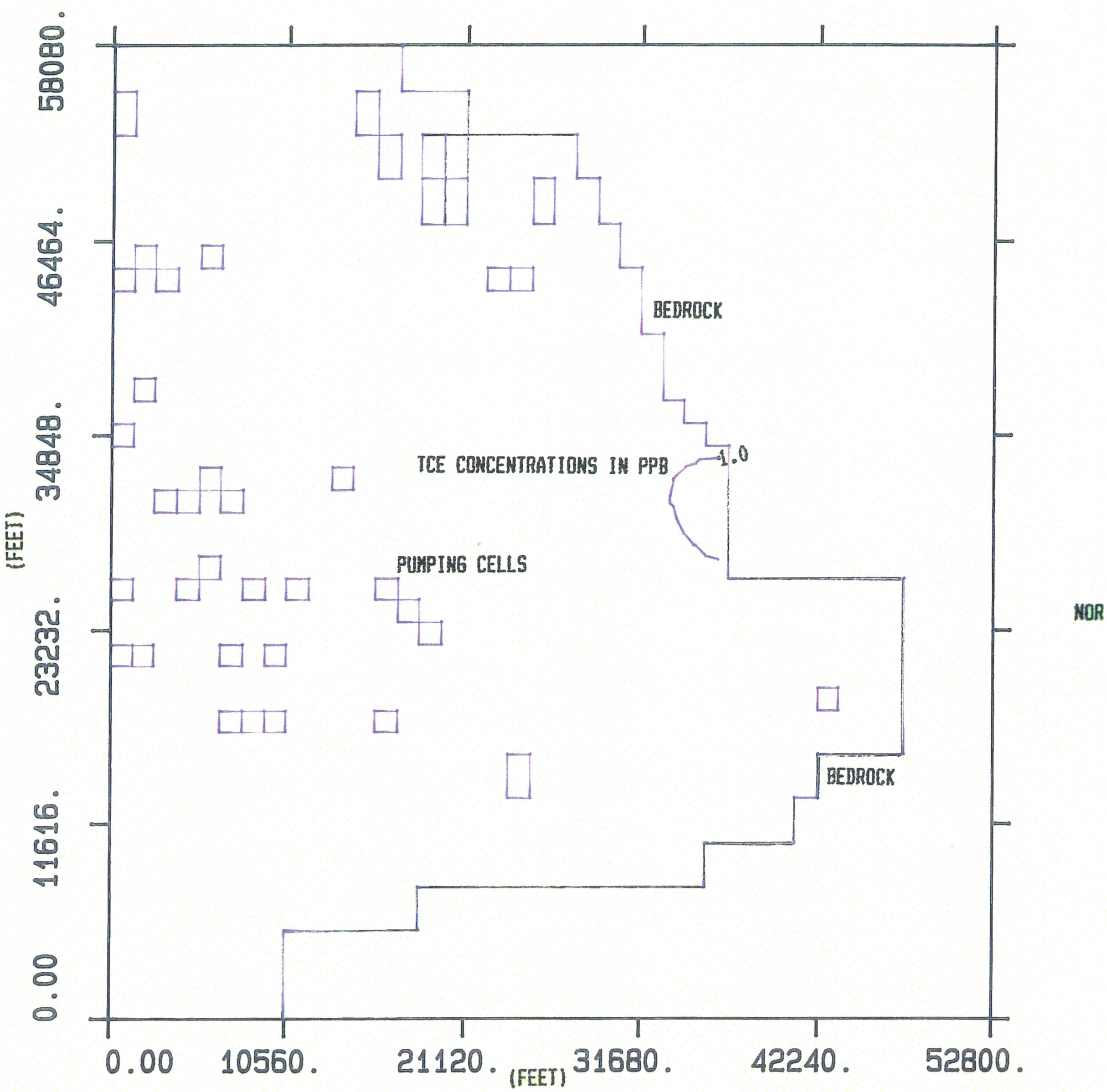
SCALE
0 1 2 mile

CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 8

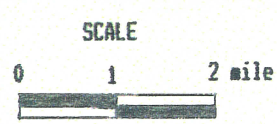



LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 8

CPHX-FINAL DISTRIBUTION TCE (JAN 1989)
TARGET MODEL LAYER 7




LEGEND: M52-39 CONTAMINANT TRANSPORT PLOT
TIME = 2190 DAYS (JAN 1989)
LAYER = 7



## V. CONCLUSIONS AND RECOMMENDATIONS

It is ADWR's position that the model produces reasonable results based upon the stated modeling assumptions and data limitations. This is based on the general agreement between the model simulated heads and the heads of the detailed water level survey of 1989. There is also general agreement of the hydrographs of model cell heads and monitor well heads.

In general, it has been found that the final model-simulated head distributions are sensitive to leakage rates between aquifer units and recharge from the Salt River, 23rd Avenue Waste Water Treatment Plant, and seepage from the Grand Canal. Groundwater flow directions are sensitive to the pumpage distribution. The volumetric water budget calculated by the model indicates an acceptable mass balance error of 1.1 percent.

Certain data deficiencies have been identified which may introduce potential error into the model results. The deficiencies identified include: lack of unit specific water level information, lack of aquifer parameter information, and lack of water quality data.

The model is also limited in scope and accuracy by some of its basic assumptions and lack of detailed data in all areas. It is important to realize that the model can provide only a reasonable estimate of future groundwater and contaminant conditions, not an absolute prediction. For this reason, it is important that the model be used in conjunction with other forms of analysis and evaluation of the groundwater system. The model is not intended to be used as a site specific-planning tool. Model data limitations and uncertainties prohibit the use of the model to provide more than a regional understanding of the hydrogeologic system.

### Recommendations

The model may be improved with future modifications. The following recommendations are made to achieve that goal.

1. Continuing acquisition of new field data is necessary for future model improvements. Many questions currently exist regarding unit-specific parameters for water level data and water quality data within the Motorola 52nd St. site and the East Washington WQARF site. More water level data is also needed in the area of the Roosevelt Irrigation District.

2. The accuracy of the model could also be improved by dividing the pumpage and recharge into summer and winter stresses (two stress periods per year). This would lessen the discrepancy between well hydrographs and model cell heads.

3. The greatest limitation in making long-term model projections is the uncertainty in predicting future conditions. Therefore, it is necessary that the model be developed with the best estimates of future groundwater pumpage and recharge plans. Thus, it is necessary that the major groundwater producers, and potential groundwater rechargers provide their best estimates of future water production and recharge plans in their service areas. Timely cooperation in this area can help to limit unnecessary model updates. Such updates will be needed however, whenever major changes occur in stresses on the groundwater system of the CPHX area.

4. As new hydrogeologic data become available, it is recommended that the model be maintained and updated periodically. In this way, the model may be made available to run new scenarios within a reasonable length of time.

5. It is recommended that groundwater flow modeling projection runs be made as new water quality data become available. These would be 5-year projection runs to bracket such changes as:

   High\Low surface water flows
   High\Low pumpage
   High\Low recharge

   The purpose of which would be to determine what effect two consecutive flood events (Salt River) would have on regional groundwater flow and water quality patterns. Additional scenarios could also be made.

6. Adsorption of TCE onto the aquifer material was neglected in the CPHX model. This was based on the results of the Motorola 52nd St. adsorption and solubility studies presented in the RI/FS documents (Dames & Moore, 1987) indicated very little, if any, TCE adsorbed onto the soil matrix. Should additional adsorption studies become available, this may warrant further investigation.

7. A review of the MI 52nd St. Bedrock Data Report (Dames & Moore, February 1991) and the Motorola 52nd St. Draft Well Installation Report (Dames & Moore, June 1991) indicates that the bedrock geology in the vicinity of the Motorola site may need to be more adequately defined in the CPHX model. Recently installed monitor wells (DM501-DM509) indicate that the bedrock elevations as defined in the CPHX model may be too low in this area. It is recommended that this newly acquired geologic data be incorporated into the CPHX model.

8. Recent field data indicates that, in conjunction with recommendation 1, it is possible that some groundwater flow and contaminant transport occurs within the upper weathered bedrock layer(s), and may need to be simulated in the model.

9. Initial contaminant transport model runs should concentrate on a smaller area. A contaminant transport model run incorporating water quality data from the East Washington WQARF and Motorola 52nd St. sites will simplify calibration. A water quality sampling round of the East Washington WQARF and Motorola 52nd St. sites is to be conducted in July 1991. This water quality data will be anaylzed and compiled, and provided to ADWR, and should be ready for model input by Fall 1991.

10. A formal sensitivity analysis should be conducted on the second phase of contaminant transport modeling.

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