DEPARTMENT OF THE ARMY
SOUTH PACIFIC DIVISION, CORPS OF ENGINEERS
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REPLY TO
ATTENTION OF

CESPD-ED-PM (415-10i) [illegible]

MEMORANDUM FOR: Commander, Los Angeles District, ATTN: CESPL-ED-HE

SUBJECT: Ft. Huachuca Ground Water Modeling Study

We have reviewed the draft report of subject study and have no comments. Please proceed to the final report.

FOR THE COMMANDER:

A. E. WANKET
Chief, Engineering Division

# FORT HUACHUCA

# GROUND WATER MODELLING

# STUDY

U.S. ARMY ENGINEER DISTRICT, LOS ANGELES

CORPS OF ENGINEERS

SEPTEMBER, 1987

## EXECUTIVE SUMMARY

This report outlines a study of the effects of ground water pumping on the water table of the Upper San Pedro River Basin.

At current withdrawal rates, the ground water table in the vicinity of Fort Huachuca is expected to decline at a maximum rate of 2.3 feet per year. A scenario of increased growth of Sierra Vista-Fort Huachuca to a projected population of 48,000 by the year 2000 would increase the rate of decline to 2.7 feet per year. Pumping operations at Fort Well #1 will be adversely affected by the year 2030 based on current withdrawal rates. By transferring half of the water supplied by Fort Wells 1, 2, and 3 over to the two East Range production wells, however, the integrity of Fort Well #1 could be reasonably assured for an indefinite period of time.

Despite the growing cone of depression in the Huachuca City area, the integrity of the water supply wells are not expected to be threatened for many years to come.

It was further determined that the proposed ground water withdrawals by Southland Utilities Company at SW of SE 30-22-21 and NE of NE-30-22-21 will not significantly impinge upon the Fort operations.

Further study of the ground water hydrology should include the installation of observation wells around the Fort Huachuca-Sierra Vista area and a more definitive evaluation of the water bearing aquifer parameters.

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# I. INTRODUCTION

## 1.01 Problem Identification

The growing population of Sierra Vista, Huachuca City and environs has resulted in a greater demand on water supply in the Upper San Pedro Basin. An increase in the number of withdrawal wells and discharge rates is a trend that is expected to continue in order to support the population's needs. In the early 1940's, before the heavy usage of the basin's water resources, wells extracted what would have been excess runoff out of the basin. Increased withdrawal rates of present and future water use scenarios, however, result in water being extracted from the aquifer storage volume. Thus, water levels throughout the basin are generally declining, with several local areas experiencing rapid declines due to overlapping cones of depression. Despite the apparently huge water supply of the underground reservoir, further population growth in the region will accelerate the decline of the water table, and may even threaten the operability of existing wells, particularly in and around the major concentrated withdrawal centers.

## 1.02 Purpose and Scope

This report uses pertinent available information to: quantify the ground water parameters associated with the basin; estimate several future water use scenarios; determine the effect of these future uses on the ground water conditions; and propose several rehabilitative measures to be further investigated. A modular three-dimensional finite-difference ground water flow model developed by M.G. McDonald and A.W. Harbaugh of the U.S. Geological Survey (Ref. 8) is used for the analysis of the ground water system. The numerical model was developed as a guide to help evaluate the existing ground water conditions and predict the basin response to future water use scenarios.

## 1.03 Location and General Features

The study area (plate 1) is bordered on the west by the Huachuca Mountains, the Canelo Hills, the Mustang Mountains and the southern tip of the Whetstone Mountains (plate 2). The Mule Mountains and the Tombstone Hills border the area on the east. The Tombstone Hills extend across the axis of the basin at its north end and the international border marks the south end of the study area. Altitudes in the mountainous areas range from 4,400 to nearly 9,500 feet above mean sea level (msl), and in the interior of the basin from 3,900 to 4,800 feet. Land surface gradient from the mountain fronts to the basin axis ranges from 2.5 to 200 feet per mile.

The basin is drained by the Upper San Pedro River which runs northward from the headwaters in the Mexican State of Sonora to its confluence with the Gila River at Winkelman, Arizona. The total drainage area of the San Pedro River basin comprises 4,483 square miles, of which 696 square miles are in Mexico. The model area (plate 2) covers about 470 square miles, of which about 90 percent is north of the border. The gradient of the San Pedro River flood plain is from 12 to 15 feet per mile. The river contained perennial flow before irrigation diversions began, but now the river only locally flows perennially. The flow in the river is intermittently supplemented by Greenbush Creek, Government Draw and other small washes that enter from east or west.

The Babocomari River, which is also perennial in places, drains the Mustang Mountains, the Canelo Hills and the north end of the Huachuca Mountains. Its confluence with the San Pedro River is just south of Fairbank, Arizona.

Fort Huachuca is located in Cochise County in the southeast portion of Arizona, about 75 miles southeast of Tucson. The Fort Huachuca Military Reservation is irregularly shaped and comprises 115 square miles, of which one third lies in the rugged terrain of the Huachuca Mountains and its foothills. Elevations within the reservation vary from 3,900 to 8,700 feet msl. The reservation is climatically dominated by mild winters and warm summers. Average annual rainfall is about 15 inches on the valley floor and as much as 30 inches in the mountains to the west.

## 2. CONCEPTUAL MODEL

As a prelude to the numerical analysis of the ground water system, a conceptual model describing the relationship between the physical environment and the movement of ground water must be developed. The conceptual model reduces the prototype to its principal elements. This is followed by the development of a mathematical model that represents, to a good degree of approximation, the conceptual model.

### 2.01 Definition of the Hydrologic System

The water supply to the Upper San Pedro Basin originates from precipitation. The water budget for the study area is comprised of mountain front recharge, ground water underflow, surface water streamflow, evapotranspiration losses from vegetation, and well pumpages.

#### (a) Mountain Front Recharge

The underground reservoir of water is chiefly recharged by infiltration of runoff along the mountain fronts. Mountain runoff only reaches the river during prolonged precipitation or torrential storms. The majority of runoff seeps through highly permeable rocks along the mountain fronts. Several factors affect the amount of ground water recharge, the most significant being the total amount of precipitation falling on the mountains. Other factors include valley evapotranspiration, amount of runoff and riverbed percolation. The Huachuca Mountains receive more than 25 in./yr. of precipitation and the Mule Mountains and the Whetstone Mountains receive between 15 and 25 in./yr. Table 1 shows a summary of meteorological data for the basin and plate 3 shows the mean monthly precipitation for the 1951 - 1980 period at Tombstone.

Table 1 (ref: 11). Summary of Annual Precipitation and Temperature Data at Weather Observation Stations in the Upper San Pedro Basin. (Data in Climatological Data Annual Summaries, Arizona, NOAA; and Sellers and Hill, 1974).

| Station | Latitude | | Longitude | | Elev. (Ft.) Above Mean Sea (Level) | Annual Precipitation (in.) | | | Tempt. (°F) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Min. | Ave. | Max. | Min. | Ave. | Max. |
| Benson | 31 | 58 | 110 | 18 | 3590 | 4.17 | 11.53 | 19.87 | 6 | 62.8 | 113 |
| Fairbank | 31 | 43 | 110 | 12 | 3850 | 4.82 | 11.66 | 19.63 | - | - | - |
| Ft. Huachuca | 31 | 43 | 110 | 20 | 4664 | 7.21 | 15.24 | 25.57 | 9 | 62.2 | 104 |
| Tombstone | 31 | 42 | 110 | 03 | 4610 | 7.60 | 13.93 | 23.82 | 6 | 63.7 | 108 |

Plate 4 shows the normal average precipitation for the study area. Using these precipitation values with evapotranspiration rates known for climatically similar areas, recharge along the Huachuca Mountains was estimated to be from 5.5 to 6.9 $ft^3/s$ (Refs. 5, 6); recharge along the Mule Mountains was estimated to be 2.8 $ft^3/s$ (Ref. 5); recharge along the Babocomari River mountain ranges was estimated to be 5.5 $ft^3/s$ (Ref. 5); and recharge bordering the Tombstone Hills was assumed to be negligible. These recharge zones are shown on plate 5.

These conceptual estimates were modified locally during the calibration and verification of the mathematical model. These adjustments allowed a more accurate simulation of historical water levels.

(b) Ground Water Flow

Ground water underflow from Mexico was previously estimated from a flow net analysis. Reference 5 used this information to estimate an inflow ranging between 1.0 and 4.8 $ft^3/s$. No ground water movement to or from adjacent basins is presumed, due to the generally impermeable character of the mountains on the east and west sides of the basin. Northern underflow out of the basin is estimated from a flow net analysis to be about 0.16 $ft^3/s$ (Ref. 5). These estimates were not used as input to the mathematical model, however, they were later used to check the reasonableness of the model results.

The relatively stable baseflow of the San Pedro River is augmented in the late summer or early fall by periods of high runoff. A ground water barrier of consolidated volcanic and sedimentary rocks (Bronco Hill), which crops out near Charleston, causes perennial base flow in this area. Otherwise, the watercourse no longer sustains a perennial flow throughout the basin. The Babocomari River sustains a perennial flow a few miles from its confluence with the San Pedro River, but like all other tributaries, is ephemeral at its mouth.

(c) Evapotranspiration

Natural water consumption in the basin is primarily attributable to vegetation, wildlife and evaporation. Evapotranspiration is the component of water transpired by riparian vegetation along the river flood plain. Water use by these phreatophytes is estimated by determining percent cover for various species of flora and calculating annual consumptive use number based on published water use figures for each species. It should be noted that the term "consumptive use" includes all transpiration and evaporation losses from lands on which there is growth of vegetation of any kind, whether agricultural crops or native vegetation, plus evaporation from bare land and from water surfaces. It is considered synonymous with the term "evapotranspiration" and is an excellent index of irrigation requirements. The Arizona Department of Water Resources (AZDWR) provided an analysis and categorization of the distribution of phreatophytes within the basin (Refs. 11, 12). In order to refine the distribution, two density categories were used to define the vegetative cover, which is predominantly comprised of mesquite, cottonwood and seep willow. Dense riparian (85 percent areal density) cover was determined to have an annual consumptive use of 44.2 inches/acre and light riparian (35 percent areal density) cover was determined to have an annual consumptive use of 19.1 inches/acre. Areal photographs were analyzed for 1955, 1977, and 1983/85 to determine the coverage areas. A representative distribution based on available data was used to simulate the historical changes. The depth to which evapotranspiration rates fell to zero was taken to be 10 feet (Ref. 5). The evapotranspiration rates at the ground surface throughout the model area are shown in Appendix C. As specified by the mathematical model, the rate was assumed to decrease linearly to zero from the ground surface.

(d) Water Well Pumpages

The man-made component of water consumption is derived from wells which draw water from the ground water reservoir. Pumped wells service a variety of needs including domestic, industrial, stock, irrigation and public supply. The locations of the major wells for the study area are shown on plate 6. In 1984, 81 percent of pumpage was attributed to agriculture, 18 percent to domestic and public supply, and 1 percent to industrial and stock usage. The largest use of well pumpage is agriculture (primarily along the San Pedro River flood plain); however municipal water supply demands are growing in concentrated areas, particularly around Ft. Huachuca and Sierra Vista. The future trend of water use would likely tend towards urban water supply and away from agriculture, however, no studies have yet quantified a future trend. Future water use distributions have been developed for a variety of scenarios presented in section 4.02.

Prior to large scale development, the underground reservoir of water would be stored in the basin aquifer. Excess water would leave the filled aquifer through surface water flow, evapotranspiration and ground water flow. Then development of public and commercial supplies began to alter the water budget and the original direction of ground water movement.

Current withdrawal rates have created cones of depression within the original ground water table around major withdrawal centers. This phenomena has not been identified elsewhere in the basin. Most other wells are far enough apart or pump small enough amounts that an established cone of depression has not developed. The other wells that are spaced close together are located along the river's flood plain aquifer, which is frequently recharged during high water in the river. Any possible cone formation is suppressed by this annual recharge.

The increase in withdrawal has also affected the discharge of ground water to the San Pedro and Babocomari Rivers, thus altering the stream-aquifer interrelationship. Prior to 1983, Ft. Huachuca used 144 acre ft. of surface water by diverting flows from tributary streams within the basin. Since that time, all diversion structures have been washed out or silted up.

Well pumpages were estimated from a variety of sources. The original U.S. Geological Survey model (Ref. 5) provided the most reliable information along the flood plains; Arizona Department of Water Resources estimates (Ref. 11) most adequately defined pumpage by the large water companies; and Fort Huachuca records (Ref. 6) provided the most reliable information of Fort well pumping.

2.02 Definition of the Aquifer System

There have been several studies that have previously discussed the geohydrology of the Upper San Pedro Basin, the most detailed descriptions found in reference 3 and 6. This section briefly discusses the geohydrologic characteristics of the aquifer within the study area. A map showing the generalized surficial geology for the basin is shown on plate 7. A generalized cross section showing the geologic relationships is shown on plate 8.

A tertiary conglomerate (Pantano Formation) is exposed near the mountain fronts. It is made up of reddish brown sand, gravel and boulders, cemented to form a conglomerate. The material is course grained near the mountain fronts, generally measuring 500 to 700 feet thick. The hydraulic conductivity is low, except where fracturing or faulting may have caused an increase. Faults within the study area may cause localized discontinuities where ground water flow is decreased or increased significantly. This formation is a basement rock, yielding relatively small amounts of water due to its lower specific yield.

The valley fill deposits (St. David Formation) are made up of an upper part and a lower part. The lower basin fill consists of gravel, sandstone and siltstone beds. It has an average thickness of 250 feet, ranging from 10 feet thick along the mountains to greater than 1,000 feet thick in the valley. The upper basin fill consists of clayey and silty gravel beds near the mountains and silt and sandy silt in the valley. This unit is generally 300 to 800 feet thick with an average thickness of 200 to 300 feet.

Hydrologically, the upper and lower units can be considered as one unit. Heterogeneity within each unit overshadow any significant hydrologic differences between the two units. The fills generally grade from fan gravel near the mountain fronts to silt and clay near the valley axis; however, lateral changes in packing, sorting and degree of consolidation often negate this seemingly simple progression from high to low hydraulic conductivity.

The flood plain alluvium is made up of gravel, sand and silt, and is coarser and less cemented than the basin fill. It is located along the San Pedro River and its major tributaries, generally measuring 40 to 150 feet thick. The hydraulic conductivity of the alluvium may be 2 to 10 times higher than that of the basin fill; however, the limited areal distribution and relatively small saturated thickness of this unit reduces its influence on the regional ground water system.

## 2.03 Aquifer Parameters

Most of the hydraulic properties of the ground water basin were initially assumed to be the same as those determined for the U.S. Geological Survey's 1982 report entitled "Hydrologic Analysis of the Upper San Pedro Basin from the Mexico-United States International Boundary to Fairbank, Arizona" (Ref. 5). Several data sources were used to determine the distribution of the parameter's values within the model. The upper and lower basin fill units are reasonably similar in their hydraulic properties. The hydraulic conductivity ranges from

2 to 22 feet/day, based on a flow-net analysis using specific-capacity and aquifer test values as check points. Areal distribution of these values is graphically shown on plate 9. Areal distribution of the saturated thickness of the upper aquifer is shown on plate 10. The product of this thickness and the hydraulic conductivity of the aquifer determines its transmissivity.

Transmissivity is the ability of an aquifer to transmit water, and is measured from aquifer pump tests. A total of 16 aquifer tests were used to determine the transmissivity distribution: three were conducted by the Arizona Water Commission in 1973, two were conducted by the U.S. Geological Survey in 1958 and 1960, eight were conducted by the U.S. Army Corps of Engineers in 1971 and 1973, one was conducted by the Bureau of Reclamation in 1966 and two were conducted by private consulting firms in 1973 (Refs. 6, 14).

The transmissivity of the basin fill ranges from 100 $ft^2$/day along the mountain fronts to 15,000 $ft^2$/day in the valley. Data from these tests were of variable reliability due to less than ideal testing conditions. All of the tests were conducted in the upper central part of the study area. The total transmissivity distribution for the model area is shown on plate 11.

The storage coefficient of an aquifer is the volume of water released from storage in a one square foot vertical column when the water table or piezometric surface declines one foot. Only two aquifer tests with sufficient data to determine reasonably good values were available in the study area. This was supplemented with specific yield information from available water-well drillers' logs to obtain storage coefficients ranging from .02 to .15 for unconfined (water table) conditions. Due to delayed drainage characteristics of the aquifer, it was felt that after several years of pumping, the storage coefficient values could be somewhat higher (Ref. 9). Long term storage coefficients of nearby alluvial basins were in the order of 0.12, more than twice the measured short-term value near the fort wells. This information would be used later in the verification procedure. The final specific yield distribution for the upper aquifer is shown on plate 12. The storage coefficient for confined (artesian) conditions was determined from pump tests (Ref. 3) to be $1 \times 10^{-5}$. The difference in storage coefficients between the confined and unconfined conditions is because the confined aquifer is under higher than atmospheric pressure, causing both the water stored in the aquifer and the material itself to compress slightly. Pumping from an artesian aquifer releases some of this pressure, allowing the aquifer material to expand a very small amount. It is the very small volumes of water squeezed out by these expansions that provide water to an artesian well.

The (vertical) flow between the upper and lower aquifers is based on the difference in head between the two layers (as shown on plate 13). Leakage, expressed as the leakance coefficient, is the ratio of hydraulic conductivity to the thickness of the confining bed. Vertical connection between layers was determined by the model from the assigned properties of each layer.

Definitive information on the hydraulic parameters of the flood plain alluvium is currently lacking. Hydraulic conductivity and storage coefficients are thought to be higher than the valley fill due to higher porosity and lower consolidation. Hydraulic conductivities for fine to medium sand range from 10 to 80 ft/day (Ref. 11) which translates to transmissivities ranging from 1,000 to 8,000 $ft^2$/day for this aquifer. Roeske and Werrell (Ref. 13) estimated a transmissivity of 10,700 $ft^2$/day for the flood plain material. The storage coefficient ranges from .05 to .15.

2.04 <u>Aquifer Boundaries</u>

The west side of the subject basin is confined by the Huachuca Mountains. The east and north sides are bounded by the San Pedro River and Babocomari Rivers, respectively. The bottom of the aquifer is the contact between the tertiary conglomerate and the undifferentiated basement complex; however, where the conglomerate is highly cemented, the useable aquifer may be as high as the lower basin fill unit.

2.05 <u>Ground Water Conditions</u>

In general, the ground water table reflects the same hydraulic gradient as the topographic gradient of the basin. Water level contours indicate that mountain front recharge enters the regional aquifer (basin fill) and moves in a northeasterly direction towards the Babocomari and San Pedro Rivers. The upstream pointing contours indicate that ground water discharges into the streams which act as drains for effluent flow from the ground water system.

The water level contours further indicate that the flood plain alluvium receives recharge from ground water underflow from the regional aquifer as well as from streamflow. In some reaches, water discharges from the stream alluvium to comprise baseflow to the river courses.

The flood plain aquifer is in hydraulic continuity with the regional aquifer; however, it is estimated to make up only one percent to the total reservoir volume, based on an estimate of the basin storage. Between the

International Border and Charleston, streamflow analyses have indicated that ground water recharge to the river is about 420 acre-feet per river mile (Ref. 11). Between Charleston and Tombstone, seasonal patterns of gains and losses exist, with an average annual streamflow gain of 1,300 acre/ft per river mile. There are no apparent longterm declines in the flood plain water levels. In general, flood plain water levels are at a maximum during the summer and at a minimum in late fall and late spring. After a high river flow, the river level recedes, leaving the saturated flood plain aquifer above the lower river level. The water drains back to the river at a slow rate, sustaining river flow for a few weeks or months.

Heavy pumping in the Fort Huachuca-Sierra Vista and Huachuca City areas has created cones of depression in the ground water table. The zone of influence around the Fort measures about 4 miles by 1-1/2 miles wide and is following new commercial development as it moves eastward. The cone in the Huachuca City area is about 3 miles by 1 mile wide and in this zone, the ground water flow along the Babocomari River has reversed direction for some distance downstream. Ground water that previously flowed eastward, is now attracted to the pumping center.

There are numerous other wells located outside of these major cones of depression; however, they are dispersed, and consequently only produce a local lowering of the water table. A large number of wells that support agricultural production are found in the flood plain aquifer and are thus close to a renewable supply of water from the river.

Between Palominas and Hereford, artesian wells have produced water that flows up to the land surface. These artesian conditions are created by clay lenses, 40 to 80 feet below the ground surface. Substantial zones of clay deposits in the regional aquifer have also caused confined ground water conditions.

## 3. MATHEMATICAL MODEL

The simulation of the hydrologic system of the Upper San Pedro River Basin was accomplished using a modular quasi-three-dimensional finite-difference ground water flow model. A full explanation of the theoretical development, the solution technique used, and the mathematical treatment of each simulated condition is included in Reference 9.

This model was chosen for the study because the necessary simulative options were available, the documentation was easily understood, the output format was easily adapted to plotting programs, and the data base for the basin had been previously developed in an appropriate format (Ref. 5).

Several changes were made to the 1982 data base to update and refine the simulation. Modification of the evapotranspiration data was based on new information from reference 11; modified and updated pumpage estimates were based on information from reference 11 and Fort Huachuca well records; water levels to refine the calibration and verification of the model were based on Fort Huachuca well records; refined storage coefficient values were based on simulation runs of the new data base and the rationale was provided by reference 6. This rationale involved increasing the storage coefficients to more closely match those of adjacent basins.

### 3.01 Description of the Model

A mathematical model constitutes a set of equations which describes ground water system behavior, subject to certain assumptions. When solved with the appropriate initial and boundary conditions, the equations predict the unknown state of the system.

The basic equations of ground water flow are the mass conservation equation known as the continuity equation and Darcy's Law.

The mathematical model of the Upper San Pedro River Basin represents a two aquifer system. The aquifers are linked in the model by a leakage term that represents vertical flow through the confining layers of silt and clay deposits.

The digital model selected for this study has the capability of describing the total system in quantitative terms; interrelationships between components of the system and stresses on the system can be simultaneously considered. The selection of the mathematical model was predicated on the following considerations:

- The model is well-documented and the majority of the available data was in a format compatible with model input requirements;
- the model can handle quantitatively, both in spatial and temporal contexts, conjuntive surface water-ground water interrelationships, including stream recharge, as well as artificial recharge from existing and/or proposed basins;
- the model provides the capability for the study of effectiveness of ground water replenishment programs, strategies and basin management plans in conjunction with various alternatives;
- the model can assist in determining sensitivity of underlying assumptions and approximations in both modeling techniques and input data;
- the model is capable of simulating ground water flow in a confined (artesian) aquifer, and unconfined (watertable) aquifer or a combination of the two such as those encountered in the Upper San Pedro River Basin;
- the model can handle heterogeneous and anisotropic conditions--an important consideration in the simulation of a hydrogeologically complex basin such as the Upper San Pedro River Basin.

These features and capabilities of the chosen model enable consideration of a realistic representation of a complex hydrogeologic system. The main benefit in using such a comprehensive numerical model is that most, if not all of the relevant processes and their interactions can be simultaneously investigated with sufficient accuracy at a large number of discrete points in the simulation domain and the ground water system reasonably well understood so as to predict the impact of hydraulic stresses resulting from various water use alternatives and scenarios.

The quasi-three-dimensional movement of ground water through porous earth material may be described by the following partial-differential equations:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right) - S\frac{\partial h}{\partial t} - W - \frac{K}{b}(h-h') = 0$$

and

$$\frac{\partial}{\partial x}\left(T\frac{\partial h'}{\partial x}\right) + \frac{\partial}{\partial y}\left(T\frac{\partial h'}{\partial y}\right) - S\frac{\partial h'}{\partial t} - W' - \frac{K}{b}(h'-h) = 0$$

where x and y are cartesian coordinates, t = time, and

T is the transmissivity of the first aquifer (lower aquifer layer) ($ft^2/s$),
S is the storage coefficient of the first aquifer (dimensionless),
W is the flux of a source or sink in the first aquifer ($ft^3/s$),
h is the head in the first aquifer (ft),
K is the vertical hydraulic conductivity of the confining layer (ft/s),
b is the thickness of the confining layer (ft),
T' is the transmissivity of the second aquifer ($ft^2/s$),
S' is the storage coefficient of the second aquifer (dimensionless),
W' is the flux of a source or sink in the second aquifer ($ft^3/s$), and
h' is the head in the second aquifer (ft).

The physical significance of these equations is illustrated on plate 8. The finite difference method used by the model approximates the time and space derivatives as differences in time or space. The flow system is divided into grid cells and the difference approximations are made at the centers of each cell. The finite difference approximation equations cannot be solved directly for the head at node 1 (plate 14) because the head is not known at the four other nodes. However, a similar approximation can be made for each of the other nodes. If these approximations are collected and certain boundary conditions are included, the result is a set of "n" simultaneous equations with "n" unknown values of head. The linear simultaneous equations are then solved iteratively, by the strongly implicit procedure (Ref. 9). It was concluded (Ref. 16) that this procedure is the most powerful solution technique available, not only because of its relatively high convergence rates but also because it generally is not necessary to conduct numerical experiments to select the parameters associated with the solution procedure.

Before the equations can be solved, three components of input data are required: aquifer parameters (storage coefficient, transmissivity and leakance), boundary conditions (constant head and/or flux), and initial conditions (for a transient model).

Boundary conditions describe mathematically the geometry of the flow system boundary and the values of head, discharge, or appropriate derivatives at the boundaries. The San Pedro and Babocomari Rivers are assumed to essentially provide a constant head boundary and the mountains provide a zero flow boundary. Flow into the study area from the south and out to the north was calculated by the model based on potentiometric levels and storage. These were later compared with the conceptual estimates to verify the reasonableness of the results.

Initial conditions describe mathematically the initial state of the entire system. These are required for a transient model. The initial head at each node (i.e., cell center) is determined from assumed steady state conditions.

The most voluminous of the input components is the aquifer parameters. The study area was modeled by dividing the region into 740 rectangular blocks in each of two layers. The grid is shown on plate 2. Each block is assumed to be homogeneous, the hydraulic properties being defined by six data arrays: starting head, altitude of the interface between the upper and lower layer, hydraulic conductivity of the upper layer, transmissivity of the lower layer, specific yield of the upper layer and storage coefficient of the lower layer. The saturated thickness of the upper layer is derived from the difference between the water table and the interface between the two aquifer layers. The distribution of the hydraulic conductivity of the upper layer approximates those values derived from the flow net analysis using specific-capacity and aquifer-test values as check points. The storage coefficient of the upper layer is equivalent to the specific yield.

The volumetric flux term, W, simulates the effects of wells, recharge, river leakance, evapotranspiration, streamflow and underflow. These values are also included in the model as arrays and may vary as a function of time. The volumetric flux associated with river leakance and evapotranspiration are also a function of the potentiometric head of the block in which the stress occurs.

Ground water withdrawal at each node is simulated as a constant discharge during a specified pumping period. The data was obtained from historic pumpages in the basin. The divisions were determined by the uniformity of the annual pumpage within a period of time and by the availability of comparative water-level data. Pumpage information is tabulated in Appendix C.

### 3.02 Model Sensitivity

The parameters used in this ground water model were initially based on previous work (Ref. 5). The sensitivity of the model results to variations in certain key parameters was also tested in the previous work. The results are summarized in this section. By varying the values of riverbed leakance, evapotranspiration and vertical leakance between reasonable ranges, the sensitivity of the model was analyzed. The degree of sensitivity was measured as percent change in net flux and standard error of the mean head change.

The riverbed leakance term determines the amount of flow between the river channel and aquifer, the quantity being a function of hydraulic conductance, elevation of river-bed, river stage and head in the cell. It was determined that the riverbed leakance could be increased without causing a significant change in either net flux or mean head; however, decreasing the riverbed leakance by a factor of 10 would lower the net flux below conceptual model estimates.

The evapotranspiration in the basin is modeled as a consumptive stress that varies linearly between a maximum rate at the ground surface, to 0 at some depth below the ground surface. By varying the maximum evapotranspiration rate (and alternatively depth to where evapotranspiration ceases), it was found that the discharge by evapotranspiration was very sensitive;

however, the change in total system discharge was considerably smaller. The change in evapotranspiration is compensated for by changes in other terms in the water budget (i.e., underflow and discharge to streamflow). Consequently, a considerable change in the amount of evapotranspiration causes insignificant head changes in the aquifer. Thus, the relative model sensitivity of evapotranspiration in terms of head changes is low though sensitivity in terms of changes in water-budget components is high.

Vertical leakance between the upper and lower aquifers was the means by which a quasi-three dimensional ground water flow model was developed. Increases and decreases in the vertical leakance by a factor of 1,000 produced little effect on head changes and water budget values. This is attributable to the fact that most wells do not penetrate beyond the basin fill. The relative sensitivity of head changes and model water budget to changes in vertical leakance between layers is low. This indicates that the ground water hydrologic system could be modeled essentially as a two-dimensional system.

### 3.03 Calibration: Simulation of the Steady State Condition

Calibration of the numerical ground water flow model involved a comparison of simulated water levels with historical water levels and those calculated based on water budget analyses. The hydologic regime would reflect equilibrium conditions, if over a certain period of time, the average water levels remained relatively constant. System outflow would equal system inflow and the basin storage would not change. These conditions essentially existed before excessive ground water withdrawal disturbed equilibrium. Water level data for steady state conditions were determined from sparse data. Trends in historical water levels were used with extensive water level measurements of

1968 (Ref. 13) to generate a water-level contour map for the predevelopment period. A potentiometric (water-level contour) map was thus developed (Ref. 5) to reflect the steady state conditions (plate 15). Water budget values (i.e., mountain front recharge, ground water underflow, surface water streamflow, pumpage and evapotranspiration) were estimated from various sources (Ref. 5).

The value of each hydrologic component changes throughout the year, as do the ground water levels. These seasonal fluctuations can sometimes be recorded or estimated (as in the case of streamflow, precipitation or evapotranspiration). Other components such as well discharges and ground water levels are measureable, however, monthly information is not available for the study area. Despite the less than ideal data base, the trend type analysis is adequate over the 45 year simulation period. The calibration of the model water levels to historical levels was limited by the small number of available observed water level data.

The computer model was tested by specifying starting water levels, aquifer and evapotranspiration parameters, and system inflow; then allowing the model to calculate new water levels at each grid node after a one year time period. A theoretically perfect calibration would result in zero change in water level at each grid node; however, because of the inexactitude of the model input values and the interpolation of field water-levels, a lesser degree of accuracy is warranted. Because the historical ground water-level contour map was generated using a 50-foot contour interval, model calibration was considered to be acceptable when differences between the model and field water levels were within ±25 feet. A greater difference was accepted in areas of large water-level fluctuations (such as along mountain fronts) and where steady-state data were sparse or of questionable accuracy.

Quantitative refinement of the spatial distribution of phreatophytes in the basin was made by the Arizona Department of Water Resources (refs. 8, 9). Analysis of areal photography supplemented by field reconnaissance, allowed them to compute consumptive use values throughout the basin. These spatially variant values were used in the model instead of the constant values stipulated in prior modeling studies. Refinement of the evapotranspiration component of the USGS model improved the calibration results by less than 1 foot in all areas. Recharge values were adjusted to calibrate and verify the mathematical model. The inexact nature of the conceptual recharge estimates is caused by the unknown effect of transmissivity created by subterranean geologic restraints (such as fault zones). Thus, this particular model parameter (i.e, recharge) could justifiably be adjusted during the calibration and stage. By increasing the recharge values at the nodes adjacent to the Fort wells, an excellent correlation between simulated and historical water levels for the Fort wells was achieved (plates 16 to 20). Recharge and discharge values for the conceptual model are compared to the corresponding values for the numerical model in table 2.

ble 1
Comparison of recharge and discharge values from the conceptual model and the numerical model
(Recharge (+) and discharge (-) values are in cubic feet per second)

| Recharge and discharge values and hydraulic properties | Conceptual-model estimates* | Numerical Model** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Steady State | | Transient state for 1968 (Pumping period 7) | | Transient state for 1985 (Pumping period 13) | |
| | | Input | Output | Input | Output | Input | Output |
| Recharge and discharge values: | | | | | | | |
| Huachuca Mountains | +5.5 to +6.9 | +8.7 | | +8.7 | | +8.7 | |
| Mule Mountains | +2.8 | +3.6 | | +3.6 | | +3.6 | |
| Babocomari Valley | +5.5 | +5.9 | | +5.9 | | +5.9 | |
| Tombstone Hills | 0 | +.2 | | +.2 | | +.2 | |
| Underflow from Mexico | +1 to+4.8 | | +4.4 | | +4.6 | | +4.9 |
| Underflow at Fairbank | 0 | | -0.5 | | -0.5 | | +0.5 |
| Stream losses | 0 to +5.9 | | +1.8 | | +2.6 | | +2.7 |
| Stream gains | -2.6 to -19.8 | | -9.5 | | -6.1 | | +6.1 |
| Evapotranspiration | -5 to -17 | | -14.6 | | -12.6 | | -11.3 |
| Pumping | | 0 | | -19.3 | | -20.0 | |
| Storage | | 0 | | | +13.4 | | +11.7 |
| Total recharge (+) | +14.8 to +25.9 | -24.6 | | +38.9 | | +37.8 | |
| Total discharge (-) | -7.6 to -36.8 | -24.6 | | -38.9 | | -37.8 | |

*Reference 2
**From Computer Analysis

## 3.04 Verification: Simulation of the Transient State Condition

The model characteristics used for the steady state simulation were retained for a transient state simulation. Aquifer storage properties and pumpage estimates were added to the model. The transient state simulation calculates water levels and water budget values for the model area for each simulation period. During each period, ground water withdrawal at each grid node is assumed to be constant. Aquifer and evapotranspiration parameters, and quantity and distribution of mountain front recharge are also kept constant throughout the entire simulation. A new water table is calculated at the end of each simulation period taking into account the added stress on the system created by ground water withdrawal during the simulation period. At the end of each simulation period, the new ground water table is used as a starting point for the next simulation period. The simulation periods were separated based on the uniformity of the annual pumpage within a period and by the availability of comparative water-level data. The simulation periods of the USGS data base were retained for this study.

Well pumpage data for the model area was deficient. Several sources of information were used to evaluate past and future ground water withdrawals. The original USGS model provided the most reliable information on ground water withdrawals along the flood plains (for agricultural supply). The record was extended from 1978 to 1985 assuming a similar withdrawal pattern. For all simulations of future years, the agricultural pumpage was assumed to stay the same. Additional well records were provided by Fort Huachuca personnel, enabling refinement of the historical ground water withdrawals on the Fort. It was further determined that the surface water diversions by the Fort diversions were thus neglected. Pumpage records of the Arizona Department of Water Resources (Ref. 11) closely matched known pumpage records at the Fort and were considered reliable in extending the model records from 1978 to 1985. The pumpage records of this source, however, did not locate the withdrawals at each well, but rather recorded the pumpage service areas of each water company. The pumpage quantities were prorated among nodes within each service area by locating the wells using quadrangle mapping and USGS model distributions (Ref. 5). These AZDWR records allowed refinement of the pumpage information in the growth centers both for domestic and public supply.

Relatively small ground water pumpage by individuals, however, are impossible to locate accurately. A rough estimate of total withdrawal from the basin is possible by analyzing the total power usage required to run the pumps; however, locating each user is not possible at this time. The relatively small withdrawal magnitude of each well may affect the regional water table as the number of wells increases and it would be wise to enforce a stricter monitoring system of active and proposed wells. Though, as a whole, these uncharted wells may slightly affect the overall water budget, their effect on fort operations is deemed negligible since they generally operate outside of the zone of influence of the fort wells.

The ground water model was run using the transient state data base. Results of the transient state run were compared with known water levels to verify the calibrated model. A water-level contour map for 1977-78 (Ref. 13) was used to compare the transient response of the model with the historical water levels. Water level records were retrieved from the USGS National Water Data Storage and Retrieval System (WATSTORE) and from observed hydrographs at various wells within the study area (Ref. 8).

The storage coefficient values were originally based on only two aquifer tests supplemented by drillers' logs. It was felt (Ref. 6) that these values could have been much higher due to the delayed drainage characteristics of the aquifer. The sensitivity of the model to storage coefficient values was tested by increasing the storage coefficient for specific areas within the model and comparing new heads to the original ones. It was found that increasing the storage coefficient values from 0.05 to 0.12 around the Fort and Sierra Vista area facilitated a much better match between calculated and historical water levels.

There was very limited data on which to base the distribution of the storage coefficient values. There is some rationale in increasing the storage coefficient values especially around the Fort wells, where doubling of these values would still keep them in the 0.12 range, which is consistent with documented values of adjacent ground water basins (Ref. 6). The storage coefficients were thus increased during the verification procedure.

## 3.05 Results and Model Reliability

The quasi-three-dimensional finite-difference ground water flow model developed for this study adequately simulates the hydrologic system of the Upper San Pedro Basin as described in Section 3.03.

The stress conditions induced by ground water pumpage resulted in a considerable decline of the pre-development water table. Water levels at the Fort wells have been recorded for a number of years. The transient state model appears to simulate the declining water table to an acceptable degree. Plates 16 through 20 present a comparison of the computed and historical water levels at all of the Fort wells, excluding #5, for which recorded levels were uncertain. The model simulates the declining water levels and conceptual ground water budget values with moderate accuracy on a regional scale. Plate 21 shows potentiometric contours of historical records along with those calculated by the model for 1977.

The reliability of the model results are somewhat limited by the reliability of (1) the estimated hydrologic parameters of stress (basin recharge, pumping, evapotranspiration), (2) the aquifer parameters (transmissivity and storage coefficient), and (3) the historical water levels to which the aquifer parameters were compared. The reliability of the model input data is spatially illustrated on plate 22.

3.06 <u>Support Programs</u>

In addition to the main ground water flow computer program, a contour mapping program and a hydrograph plotting program were used in conjunction with the results of the ground water program. The unnamed contour program developed by Corps of Engineers' Waterways Experiment Station allowed potentiometric maps to be developed for a variety of scenarios. The calculated ground water model elevations were retrieved from the output files of the main program and rearranged into the contour program through an interface program, GRABZ, developed by the Los Angeles District. This program arranged the ground water elevations to match their corresponding coordinate positions. The contour program used interpolation techniques to plot lines of equal water level elevations throughout the study area. The resulting map was plotted with a CALCOMP plotter, enabling an easy comparison of calculated to historical ground water contour maps. These are presented on plates 10 and 16.

The limited amount of historical static water level measurements at individual wells were compared to calculated levels at the corresponding model nodes by using the Corps Extended Easy Graphing (CEEG) computer program 803-F3-R0203, also developed by the Waterways Experiment Station. This program graphically plots the calculated hydrographs against historical hydrographs over a specified time period (e.g., plates 16-20).

# 4. SUMMARY AND CONCLUSIONS

## 4.01 Perennial (Safe) Yield

A ground water reservoir is a renewable natural resource from which a certain quantity of water can be withdrawn annually. The maximum quantity of water that can be extracted from the underground reservoir, while still maintaining that supply unimpaired, depends on the perennial yield. The perennial yield of a ground water basin defines the rate at which water can be withdrawn perennially under specified operating conditions without producing undesirable results such as progressive reduction of the water resource, mining, development of uneconomical pumping conditions, degradation of ground water quality, intereference with prior water rights, or land subsidence caused by lowered ground water levels. Excessive costs may be associated with lowered ground water levels, thereby necessitating deepening of wells, lowering of pump bowls, and installation of larger pumps.

If ground water is continually withdrawn at a rate exceeding the long term average annual natural recharge, an overdraft or ground water mining condition will continue to exist. Overdraft or ground water mining areas constitute the largest potential ground water problem in the southwestern part of the United States. Until the withdrawal in these basins is reduced to a level below perennial yields, permanent damage or depletion of ground water supplies must be anticipated.

The perennial yield of a basin may vary with the different patterns of recharge, development and use of water in the basin. If ground water levels are lowered, subsurface inflow will be increased and subsurface outflow will be decreased. Evapotransportation losses would also be reduced. Changes in vegetation and even in crops, particularly where root depth is affected, may influence surface infiltration and subsequent percolation to the water table. Urbanization of an area, accompanied by greater surface runoff and installation of sewer systems, can be correspondingly expected to reduce recharge.

In the study of the Upper San Pedro ground water basin, a number of estimates have been made for the perennial yield. For this study the perennial yield equals the long-term average annual ground water recharge. The sum of recharge components is estimated to be in the order of 37,000 acre-feet annually (as determined from steady state conditions). Another estimate (Ref. 6) places the perennial yield for the model area at 11,500 acre-feet per year. Despite the vast amount of ground water storage within the entire basin, it is evident (Ref. 11) that the basinwide existing and future withdrawal amounts far exceed the perennial (i.e., safe) yield (plate 23). Thus, not only are the Fort Huachuca water rights affected, but the basinwide interests are also threatened. Continued population growth will require a ground water management plan to ensure that an adequate water supply will remain available.

## 4.02 Future Water Use Scenarios

The calibrated and verified mathematical model of the study area was used to examine eight future water use scenarios. Each scenario conceptualized different water use distributions for the period 1985-2000. Three simulation periods, each 5 years in length, were used for the eight predictive model runs. The results are graphically illustrated on plates 24 and 25.

Future water use within the study area was based on several suppositions. A large part of the agricultural water supply is from pumping located along the flood plain alluvium (plate 6). This supply is recharged during floodflows rather than from mountain front recharge and is not expected to significantly affect (or be affected by) the regional aquifer. Major water supply changes were considered to come from municipal needs. Agricultural needs were assumed to remain the same for all future simulations. The agricultural withdrawals from the last year of the original model were repeated for future years' simulations.

The first scenario assumes that the current (1985) ground water withdrawal rates would continue for 15 years, up to the year 2000. The results indicate that there would be local declines of the regional water table, and that they would be relatively small. The cone of depression around Fort Huachuca-Sierra Vista would continue to grow, with the maximum decline in water level occurring around Fort wells 1, 2, and 3. At the present rate of withdrawal, the decline over the next fifteen years would be in the order of 34 feet, an average decline of 2.25 feet per year. Consequently, in the year 2000, the static water table is estimated to be 4,067 feet msl, whereas the water level inside the well itself would be in the order of 60 feet lower due to well losses. This would place the water level inside the well at an elevation of about 4,007 feet. At Fort well 1, it is estimated that the lower aquifer begins at an elevation of 3,950 feet. The Post Well #1 penetrates into the lower aquifer to an elevation of 3,939 feet. At the present withdrawal rates, the water level in the well will be only about 68 feet above the bottom of the well in the year 2000. At an annual water table decline of 2.25 feet, the well would likely dry out by the year 2030.

The second scenario assumes that throughout most of the region, the ground water pumping occurring in 1985 would continue up to the year 2000 everywhere except the community of Sierra Vista, where it was assumed to increase based on a land use element projection given by reference 4. The following table from reference 4 shows projected population estimates for the Sierra Vista and Fort Huachuca areas.

| Year | Population |
|---|---|
| 1970 | 17,324[a] |
| 1975 | 20,121[b] |
| 1977 | 24,250[c] |
| 1978 | 25,425[a] |
| 1979 | 26,629[d] |
| 1985 | 33,121[e] |
| 1990 | 37,487[f] |
| 2000 | 48,442[f] |

Source: [a]Sierra Vista Community Profile
[b]Housing Element
[c]Arizona Statistical Review
[d]Fort Huachuca Impact Statement
[e]Housing Element Projection
[f]Land Use Element Projection

## Population Characteristics

(1) Average Annual Growth = +4.9% (Sierra Vista Community Profile)

(2) Elderly Population (over 65) = 1.5%
Youth Population (18 and under) = 42%
Median Age = 22.8
Median Income = $9,039
Percentage Below Poverty Level = 7.5%

(3) Median Age = 23.1

The water supply would be provided by extracting water from the aquifer underlying the property to be developed. The servicing water company has been extracting about 750 acre-feet of water annually, however the new project would call for a peak annual withdrawal of 6,574 acre-feet. The planned future development is detailed in reference 4. Plate 26 shows the area of proposed development with the existing and proposed future well locations. The computer results indicate that there would be regional declines in the water table of relatively small magnitude. The cone of depression around Fort Huachuca and Sierra Vista would continue to grow, but at a faster rate (2.7 feet per year) than had been previously experienced. It is estimated that the Post Well #1 would dry out in about 38 years (i.e., the year 2023). Plate 18 compares this scenario to Scenario 1 (status quo).

The third scenario examines the effect of proposed pumping by the Southland Utilities Company at SW of SE 30-22-21 (1,230 acre-feet annually for domestic use) and at NE of NE-30-22-21 (170 acre-feet annually for commercial and business use). These rates were assumed to continue up to the year 2000. This scenario was developed in response to a request by the Fort to review a Notice of Application to Appropriate Water from the Arizona Department of Water Resources. The results showed that there would be a local lowering of the water table in the vicinity of the wells, but they would have a negligible effect on the pumping operations at the fort wells.

The fourth scenario, also developed in response to a request by the Fort, examines the effect of a proposed increase in pumping by Tenneco West Incorporated at SW of SW-10-23-22 (425 acre-feet annually) and at NW of SE-16-23-22 (1,250 acre-feet annually for irrigation). This proposal was later abandoned after the land was obtained by the Bureau of Land Management. These rates were also assumed to continue up to the year 2000. These wells are located along the San Pedro River and were found to have no impact on the Fort operations.

The fifth scenario examines a possible solution to the rapidly declining water table anticipated at the Fort wells. This alternative assumes that the entire water supply provided by Fort wells 1, 2 and 3 would instead be provided by the two production wells at the East Range. These two wells are located about 800 feet west of what is referred to in previous reports (ref. 4) as the "spatial resolution well". The two wells are about 1,500 feet apart. At this time, these wells are not providing a significant supply to the Fort reservoirs. By using these wells located about 3 miles from the center of the cone of depression, the stress on the water table would be redistributed, thereby relieving the heavily concentrated drawdown at the Fort wells. It was determined that the static water table at the Fort would experience a rise of about 36 feet (to an elevation of 4,137 feet) over the next 5 years and would decline at a rate of about 0.7 feet per year.

The sixth scenario involves a redistribution of half of the water supply from Fort wells 1, 2 and 3 to the East Range wells. The remaining half is assumed to be still supplied by the Fort wells. It was determined that this redistribution would result in the static water level at the Fort rising about 13 feet (to an elevation of 4,114 feet) over the next 5 years. Once the regional water levels stabilize, the water level at Fort well 1 would decline at a rate of about 0.7 feet per year. Assuming a reduced drawdown of 30 feet, this alternative would ensure the integrity of the Fort well #1 for about 150 years (the year 2135). Scenarios 6 and 7 can be compared to Scenario 1 (status quo) on plate 24.

The seventh scenario combines Scenario #6 with Scenario #2, i.e., a redistribution of half of the pumpage of Fort wells 1, 2 and 3 to the East Range wells and anticipated growth of Sierra Vista. It was determined that the water table resulting from this scenario would decline at a rate of abut 0.7 feet per year. This alternative would ensure the integrity of the Fort well #1 for about 142 years (the year 2127). Scenario 7 can be compared to Scenario 1 (status quo) on plate 19.

The eighth scenario examines the effects of growth of 300 percent over 15 years at Huachuca City. It was determined that the water table would decline at a maximum rate of about 0.7 feet per year, only about 0.10 feet faster than would be expected with no growth (status quo). The public supply wells in this area would not be threatened by this relatively small decline. Scenario 8 is compared to Scenario 1 (status quo) on plate 25.

4.03. Possible Solutions and Further Study Requirements

It is evident that even at the current rate of pumping, the Fort Huachuca water supply may be threatened at some time in the not too distant future. Proposed growth of Sierra Vista would speed up the process of declining water levels, and one o- more of the Fort wells may dry out within 45 years. Though the decline in the regional aquifer may be relatively small (i.e., less than one foot per year), it is nonetheless evident that overall ground water withdrawals are exceeding the safe yield. Several areas where intensive pumping is occurring will experience noticeable declines in the water table. As stated in many of the previous studies of the water supply for the basin, there is a vast supply of water within the basin aquifers (Refs. 1, 2, 3). The problem concerns the possibility of existing wells "drying out" from the declining water levels. The first scenario (status quo) showed that the Fort well #1 would approach a condition where the water level would fall to within 68 feet of the bottom of the well by the year 2000. The second scenario (anticipated growth in Sierra Vista) showed that the water level would actually fall below the bottom of the well by the year 2023, thereby rendering it inoperable. This would severely retard the water supply operations of the Fort.

This situation could be avoided by redistributing the Fort's ground water withdrawal. Use of the pumping wells in the East Range would reduce thero stress on the water table near the Fort and would still afford the Fort the same quantity of water as before. These wells are located beyond the zone of influence around the Fort Huachuca-Sierra Vista area.

The influence of other wells on the fort operations depends upon the location and magnitude of the proposed withdrawals. The results of Scenario 2 show that the large pumpage associated with Sierra Vista development may impact upon the Fort operations if withdrawal amounts and distributions are not carefully planned. It would be wise to review any such proposals for major development as part of a ground water management plan. The most acceptable well locations could be determined in the early stages of project development. Any proposed operations should not have a significant deliterious effect on the Fort's pumping operations.

At this time, it is strongly recommended that a monitoring program be established in order to better identify the ground water conditions of Fort Huachuca. Observation wells would provide an accurate definition of the static water table, providing information that is only poorly defined from a pumped well.

It is becoming increasingly evident that definition of the aquifer's properties (i.e., the storage coefficient and the transmissivity) is very important in the modeling of the ground water system. Borehole and geophysical investigations would allow a clearer understanding of the anticipated drawdown of the water table. Wherever possible, pumping tests should be performed to supplement this analysis. Furthermore, the basin geology should be mapped in detail. This would help locate the boreholes, observation wells, and geophysical investigations. This report is limited by the available data for which a number of assumptions have been made and a complete definition of the substrata would help refine the model results.

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# APPENDIX A

# TECHNICAL GLOSSARY

| | |
|---|---|
| Alluvium | Soil, sand, gravel or similar detrital material deposited by running water over geologic time; usually deposited at places where streams issuing from mountains lose velocity and deposit their contained sediment on a valley floor. |
| Anisotropic | Exhibiting variation of a physical property when tested along axes in different directions. |
| Aquifer | A water-bearing bed or stratum of earth, gravel or porous stone. |
| Artesian | A condition wherein the ground water is confined under pressure greater than atmosphere by overlying relatively impermeable strata. |
| Baseflow | Portion of streamflow derived from ground water discharge. |
| Conductance | The product of hydraulic conductivity and surficial area of a material divided by the thickness of the material, ($ft^2/s$, cfs/ft, etc.). |
| Cone of Depression | A conic depression of the ground water table formed around a pumping well or system of wells. |
| Confined Aquifer | See Artesian. |

| | |
|---|---|
| Ground Water Barrier | Surface across which there is little or no flow. Folds, faults, ground water divides and rock outcrops often form barriers. |
| Ground Water Basin | A closed system that contains the entire flow paths followed by all the water recharging the basin. |
| Heterogeneity | Having unlike physical properties. |
| Homogeneity | Having similar physical properties from point to point in the medium. |
| Hydraulic Conductivity | A measure of the permeability of a porous medium; ratio of Darcy flow velocity to hydraulic gradient (ft/s, ft/day, etc). |
| Hydraulic Gradient | Difference in hydraulic head per unit length of flow path. |
| Infiltration | The inflow of water into earth materials. |
| Leakance | Hydraulic conductivity of a material divided by its thickness (ft/day/ft, etc). |
| Perennial Stream | Some degree of surface water flow is maintained throughout the year. |

| | |
|---|---|
| Permeable | The ability of a material to allow the passage of ground water. |
| Phreatophyte | A deep-rooted plant that draws water from the water table or the soil just above it. |
| Porosity | Proportion of the total volume of porous medium occupied by voids. |
| Recharge | A natural or artificial addition of water to the ground water system. |
| Riparian | Of, pertaining to, or living on, the bank of a river or lake. |
| Safe Yield | The rate at which water can be withdrawn for human use without depleting the supply to such an extent that withdrawal at this rate is no longer economically feasible; it is determined for a specific set of controlling conditions and subject to change as a result of changing economic or physical conditions. |
| Specific Capacity | Yield in gallons per minute per foot of drawdown for a well at a selected time after pumping is started, (dimensionless). |

| | |
|---|---|
| Specific Storage | Quantity of water in storage that is released from (or taken into) a unit volume of aquifer per unit change in hydraulic head, (dimensionless). |
| Specific Yield | Amount of water yielded per unit draw down per unit of horizontal area dewatered, (dimensionless). |
| Steady-State Condition | A state wherein the hydraulic stresses are constant and the resulting fluid movement is not time dependent. |
| Storage Coefficient | Quantity of water released from (or taken into) storage in a column of aquifer with unit cross-section and length equal to thickness of aquifer per unit change in hydraulic head. |
| Transient State Condition | A state wherein the hydraulic stresses are varying with time and the resulting ground water levels are a function of time. |
| Transmissivity | Rate of horizontal water flow through a vertical strip of aquifer 1 foot wide and extending the full saturated thickness under hydraulic gradient of one foot per foot. |

| | |
|---|---|
| Unconfined Aquifer | A condition wherein the aquifer water table rises and falls in response to recharge and discharge. |
| Volumetric Flux | The rate of flow from one region to another. |
| Water Table | Surface along which the water pressure is atmospheric. |
| Zone of Influence | Area within the cone of depression, i.e., where the water table is affected by pumping. |

# APPENDIX B

# AQUIFER PARAMETERS

TABLE B1. Aquifer Parameters

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0* | 0 | 0 | 0 | 1 |
| 2 | 1 | 2 | 0 | 0 | 0 | 0 | 1 |
| 3 | 1 | 3 | 0 | 0 | 0 | 0 | 1 |
| 4 | 1 | 4 | 0 | 0 | 0 | 0 | 1 |
| 5 | 1 | 5 | 0 | 0 | 0 | 0 | 1 |
| 6 | 1 | 6 | 0 | 0 | 0 | 0 | 1 |
| 7 | 1 | 7 | 0 | 0 | 0 | 0 | 1 |
| 8 | 1 | 8 | 0 | 0 | 0 | 0 | 1 |
| 9 | 1 | 9 | 0 | 0 | 0 | 0 | 1 |
| 10 | 1 | 10 | 0 | 0 | 0 | 0 | 1 |
| 11 | 1 | 11 | 0 | 0 | 0 | 0 | 1 |
| 12 | 1 | 12 | 0 | 0 | 0 | 0 | 1 |
| 13 | 1 | 13 | 0 | 0 | 0 | 0 | 1 |
| 14 | 1 | 14 | 0 | 0 | 0 | 0 | 1 |
| 15 | 1 | 15 | 0 | 0 | 0 | 0 | 1 |
| 16 | 1 | 16 | 0 | 0 | 0 | 0 | 1 |
| 17 | 1 | 17 | 0 | 0 | 0 | 0 | 1 |
| 18 | 1 | 18 | 0 | 0 | 0 | 0 | 1 |
| 19 | 1 | 19 | 0 | 0 | 0 | 0 | 1 |
| 20 | 1 | 20 | 0 | 0 | 0 | 0 | 1 |
| 21 | 1 | 21 | 0 | 0 | 0 | 0 | 1 |
| 22 | 1 | 22 | 0 | 0 | 0 | 0 | 1 |
| 23 | 1 | 23 | 0 | 0 | 0 | 0 | 1 |
| 24 | 1 | 24 | 0 | 0 | 0 | 0 | 1 |
| 25 | 1 | 25 | 0 | 0 | 0 | 0 | 1 |
| 26 | 1 | 26 | 0 | 0 | 0 | 0 | 1 |
| 27 | 1 | 27 | 0 | 0 | 0 | 0 | 1 |
| 28 | 1 | 28 | 0 | 0 | 0 | 0 | 1 |
| 29 | 1 | 29 | 0 | 0 | 0 | 0 | 1 |
| 30 | 1 | 30 | 0 | 0 | 0 | 0 | 1 |
| 31 | 1 | 31 | 0 | 0 | 0 | 0 | 1 |
| 32 | 1 | 32 | 0 | 0 | 0 | 0 | 1 |
| 33 | 1 | 33 | 0 | 0 | 0 | 0 | 1 |
| 34 | 1 | 34 | 0 | 0 | 0 | 0 | 1 |
| 35 | 1 | 35 | 0 | 0 | 0 | 0 | 1 |
| 36 | 1 | 36 | 0 | 0 | 0 | 0 | 1 |
| 37 | 1 | 37 | 0 | 0 | 0 | 0 | 1 |

*A zero indicates that the grid was inactive in the flow simulation.

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 38 | 2 | 1 | 0 | 0 | 0 | 0 | 1 |
| 39 | 2 | 2 | 0 | 0 | 0 | 0 | 1 |
| 40 | 2 | 3 | 0 | 0 | 0 | 0 | 1 |
| 41 | 2 | 4 | 0 | 0 | 0 | 0 | 1 |
| 42 | 2 | 5 | 0 | 0 | 0 | 0 | 1 |
| 43 | 2 | 6 | 0 | 0 | 0 | 0 | 1 |
| 44 | 2 | 7 | 0 | 0 | 0 | 0 | 1 |
| 45 | 2 | 8 | 0 | 0 | 0 | 0 | 1 |
| 46 | 2 | 9 | 0 | 0 | 0 | 0 | 1 |
| 47 | 2 | 10 | 0 | 0 | 0 | 0 | 1 |
| 48 | 2 | 11 | 0 | 0 | 0 | 0 | 1 |
| 49 | 2 | 12 | 0 | 0 | 0 | 0 | 1 |
| 50 | 2 | 13 | 0 | 0 | 0 | 0 | 1 |
| 51 | 2 | 14 | 0 | 0 | 0 | 0 | 1 |
| 52 | 2 | 15 | 0 | 0 | 0 | 0 | 1 |
| 53 | 2 | 16 | 0 | 0 | 0 | 0 | 1 |
| 54 | 2 | 17 | 0 | 0 | 0 | 0 | 1 |
| 55 | 2 | 18 | 0 | 0 | 0 | 0 | 1 |
| 56 | 2 | 19 | 0 | 0 | 0 | 0 | 1 |
| 57 | 2 | 20 | 0 | 0 | 0 | 0 | 1 |
| 58 | 2 | 21 | 0 | 0 | 0 | 0 | 1 |
| 59 | 2 | 22 | 1571 | 53 | 106 | 10 | 1 |
| 60 | 2 | 23 | 1269 | 53 | 106 | 10 | 1 |
| 61 | 2 | 24 | 1087 | 53 | 106 | 10 | 1 |
| 62 | 2 | 25 | 846 | 53 | 106 | 10 | 1 |
| 63 | 2 | 26 | 785 | 2135 | 4269 | 10 | 1 |
| 64 | 2 | 27 | 785 | 2135 | 4269 | 21 | 1 |
| 65 | 2 | 28 | 725 | 2135 | 4269 | 21 | 1 |
| 66 | 2 | 29 | 725 | 2135 | 4270 | 21 | 1 |
| 67 | 2 | 30 | 423 | 2135 | 4268 | 4 | 1 |
| 68 | 2 | 31 | 423 | 747 | 1494 | 4 | 1 |
| 69 | 2 | 32 | 423 | 747 | 1494 | 4 | 1 |
| 70 | 2 | 33 | 362 | 533 | 1067 | 8 | 1 |
| 71 | 2 | 34 | 362 | 533 | 1067 | 8 | 1 |
| 72 | 2 | 35 | 362 | 533 | 1067 | 4 | 1 |
| 73 | 2 | 36 | 362 | 533 | 1067 | 4 | 1 |
| 74 | 2 | 37 | 0 | 0 | 0 | 1 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 75 | 3 | 1 | 0 | 0 | 0 | 0 | 1 |
| 76 | 3 | 2 | 0 | 0 | 0 | 0 | 1 |
| 77 | 3 | 3 | 0 | 0 | 0 | 0 | 1 |
| 78 | 3 | 4 | 0 | 0 | 0 | 0 | 1 |
| 79 | 3 | 5 | 0 | 0 | 0 | 0 | 1 |
| 80 | 3 | 6 | 0 | 0 | 0 | 0 | 1 |
| 81 | 3 | 7 | 0 | 0 | 0 | 0 | 1 |
| 82 | 3 | 8 | 0 | 0 | 0 | 0 | 1 |
| 83 | 3 | 9 | 0 | 0 | 0 | 0 | 1 |
| 84 | 3 | 10 | 0 | 0 | 0 | 0 | 1 |
| 85 | 3 | 11 | 0 | 0 | 0 | 0 | 1 |
| 86 | 3 | 12 | 0 | 0 | 0 | 0 | 1 |
| 87 | 3 | 13 | 0 | 0 | 0 | 0 | 1 |
| 88 | 3 | 14 | 0 | 0 | 0 | 0 | 1 |
| 89 | 3 | 15 | 0 | 0 | 0 | 0 | 1 |
| 90 | 3 | 16 | 0 | 0 | 0 | 0 | 1 |
| 91 | 3 | 17 | 0 | 0 | 0 | 0 | 1 |
| 92 | 3 | 18 | 0 | 0 | 0 | 0 | 1 |
| 93 | 3 | 19 | 0 | 0 | 0 | 0 | 1 |
| 94 | 3 | 20 | 0 | 0 | 0 | 0 | 1 |
| 95 | 3 | 21 | 1994 | 53 | 106 | 10 | 1 |
| 96 | 3 | 22 | 1571 | 53 | 106 | 10 | 1 |
| 97 | 3 | 23 | 1329 | 53 | 106 | 10 | 1 |
| 98 | 3 | 24 | 846 | 2135 | 4268 | 10 | 1 |
| 99 | 3 | 25 | 725 | 2135 | 4268 | 10 | 1 |
| 100 | 3 | 26 | 725 | 2135 | 4269 | 10 | 1 |
| 101 | 3 | 27 | 725 | 2135 | 4269 | 10 | 1 |
| 102 | 3 | 28 | 725 | 2135 | 4269 | 10 | 1 |
| 103 | 3 | 29 | 725 | 2135 | 4270 | 4 | 1 |
| 104 | 3 | 30 | 483 | 2135 | 4269 | 4 | 1 |
| 105 | 3 | 31 | 604 | 601 | 3203 | 4 | 1 |
| 106 | 3 | 32 | 604 | 601 | 3202 | 4 | 1 |
| 107 | 3 | 33 | 362 | 533 | 1067 | 8 | 1 |
| 108 | 3 | 34 | 362 | 533 | 1067 | 8 | 1 |
| 109 | 3 | 35 | 362 | 533 | 1067 | 4 | 1 |
| 110 | 3 | 36 | 362 | 533 | 1067 | 4 | 1 |
| 111 | 3 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 112 | 4 | 1 | 0 | 0 | 0 | 0 | 1 |
| 113 | 4 | 2 | 0 | 0 | 0 | 0 | 1 |
| 114 | 4 | 3 | 0 | 0 | 0 | 0 | 1 |
| 115 | 4 | 4 | 0 | 0 | 0 | 0 | 1 |
| 116 | 4 | 5 | 0 | 0 | 0 | 0 | 1 |
| 117 | 4 | 6 | 0 | 0 | 0 | 0 | 1 |
| 118 | 4 | 7 | 0 | 0 | 0 | 0 | 1 |
| 119 | 4 | 8 | 0 | 0 | 0 | 0 | 1 |
| 120 | 4 | 9 | 0 | 0 | 0 | 0 | 1 |
| 121 | 4 | 10 | 0 | 0 | 0 | 0 | 1 |
| 122 | 4 | 11 | 0 | 0 | 0 | 0 | 1 |
| 123 | 4 | 12 | 0 | 0 | 0 | 0 | 1 |
| 124 | 4 | 13 | 0 | 0 | 0 | 0 | 1 |
| 125 | 4 | 14 | 0 | 0 | 0 | 0 | 1 |
| 126 | 4 | 15 | 0 | 0 | 0 | 0 | 1 |
| 127 | 4 | 16 | 0 | 0 | 0 | 0 | 1 |
| 128 | 4 | 17 | 0 | 0 | 0 | 0 | 1 |
| 129 | 4 | 18 | 0 | 0 | 0 | 0 | 1 |
| 130 | 4 | 19 | 0 | 0 | 0 | 0 | 1 |
| 131 | 4 | 20 | 2115 | 53 | 106 | 10 | 1 |
| 132 | 4 | 21 | 1873 | 53 | 106 | 14 | 1 |
| 133 | 4 | 22 | 967 | 2135 | 4267 | 14 | 1 |
| 134 | 4 | 23 | 846 | 2135 | 4267 | 14 | 1 |
| 135 | 4 | 24 | 785 | 2135 | 4268 | 10 | 1 |
| 136 | 4 | 25 | 664 | 2135 | 4268 | 10 | 1 |
| 137 | 4 | 26 | 725 | 2135 | 4269 | 10 | 1 |
| 138 | 4 | 27 | 725 | 2135 | 4269 | 10 | 1 |
| 139 | 4 | 28 | 725 | 4270 | 4270 | 10 | 1 |
| 140 | 4 | 29 | 725 | 2135 | 4270 | 4 | 1 |
| 141 | 4 | 30 | 725 | 2135 | 4270 | 4 | 1 |
| 142 | 4 | 31 | 725 | 2135 | 4270 | 4 | 1 |
| 143 | 4 | 32 | 785 | 2456 | 4910 | 4 | 1 |
| 144 | 4 | 33 | 785 | 2456 | 4911 | 8 | 1 |
| 145 | 4 | 34 | 543 | 2135 | 4269 | 8 | 1 |
| 146 | 4 | 35 | 543 | 2135 | 4269 | 4 | 1 |
| 147 | 4 | 36 | 725 | 2135 | 4270 | 4 | 1 |
| 148 | 4 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 149 | 5 | 1 | 0 | 0 | 0 | 0 | 1 |
| 150 | 5 | 2 | 0 | 0 | 0 | 0 | 1 |
| 151 | 5 | 3 | 0 | 0 | 0 | 0 | 1 |
| 152 | 5 | 4 | 0 | 0 | 0 | 0 | 1 |
| 153 | 5 | 5 | 0 | 0 | 0 | 0 | 1 |
| 154 | 5 | 6 | 0 | 0 | 0 | 0 | 1 |
| 155 | 5 | 7 | 0 | 0 | 0 | 0 | 1 |
| 156 | 5 | 8 | 0 | 0 | 0 | 0 | 1 |
| 157 | 5 | 9 | 0 | 0 | 0 | 0 | 1 |
| 158 | 5 | 10 | 0 | 0 | 0 | 0 | 1 |
| 159 | 5 | 11 | 0 | 0 | 0 | 0 | 1 |
| 160 | 5 | 12 | 0 | 0 | 0 | 0 | 1 |
| 161 | 5 | 13 | 0 | 0 | 0 | 0 | 1 |
| 162 | 5 | 14 | 0 | 0 | 0 | 0 | 1 |
| 163 | 5 | 15 | 0 | 0 | 0 | 0 | 1 |
| 164 | 5 | 16 | 0 | 0 | 0 | 0 | 1 |
| 165 | 5 | 17 | 0 | 0 | 0 | 0 | 1 |
| 166 | 5 | 18 | 0 | 0 | 0 | 0 | 1 |
| 167 | 5 | 19 | 1873 | 53 | 106 | 8 | 1 |
| 168 | 5 | 20 | 2054 | 53 | 106 | 8 | 1 |
| 169 | 5 | 21 | 1390 | 533 | 1067 | 12 | 1 |
| 170 | 5 | 22 | 846 | 2135 | 4267 | 12 | 1 |
| 171 | 5 | 23 | 785 | 2135 | 4268 | 12 | 1 |
| 172 | 5 | 24 | 664 | 2135 | 4268 | 12 | 1 |
| 173 | 5 | 25 | 664 | 2135 | 4268 | 12 | 1 |
| 174 | 5 | 26 | 664 | 2135 | 4269 | 12 | 1 |
| 175 | 5 | 27 | 664 | 2135 | 4269 | 12 | 1 |
| 176 | 5 | 28 | 664 | 2135 | 4269 | 12 | 1 |
| 177 | 5 | 29 | 725 | 2135 | 4270 | 8 | 1 |
| 178 | 5 | 30 | 725 | 2135 | 4270 | 8 | 1 |
| 179 | 5 | 31 | 725 | 2135 | 4270 | 8 | 1 |
| 180 | 5 | 32 | 725 | 2135 | 4270 | 8 | 1 |
| 181 | 5 | 33 | 846 | 2669 | 5338 | 8 | 1 |
| 182 | 5 | 34 | 543 | 2135 | 4269 | 8 | 1 |
| 183 | 5 | 35 | 543 | 2135 | 4269 | 4 | 1 |
| 184 | 5 | 36 | 725 | 2135 | 4270 | 4 | 1 |
| 185 | 5 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5} ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 186 | 6 | 1 | 0 | 0 | 0 | 0 | 1 |
| 187 | 6 | 2 | 0 | 0 | 0 | 0 | 1 |
| 188 | 6 | 3 | 0 | 0 | 0 | 0 | 1 |
| 189 | 6 | 4 | 0 | 0 | 0 | 0 | 1 |
| 190 | 6 | 5 | 0 | 0 | 0 | 0 | 1 |
| 191 | 6 | 6 | 0 | 0 | 0 | 0 | 1 |
| 192 | 6 | 7 | 0 | 0 | 0 | 0 | 1 |
| 193 | 6 | 8 | 0 | 0 | 0 | 0 | 1 |
| 194 | 6 | 9 | 0 | 0 | 0 | 0 | 1 |
| 195 | 6 | 10 | 0 | 0 | 0 | 0 | 1 |
| 196 | 6 | 11 | 0 | 0 | 0 | 0 | 1 |
| 197 | 6 | 12 | 0 | 0 | 0 | 0 | 1 |
| 198 | 6 | 13 | 0 | 0 | 0 | 0 | 1 |
| 199 | 6 | 14 | 0 | 0 | 0 | 0 | 1 |
| 200 | 6 | 15 | 0 | 0 | 0 | 0 | 1 |
| 201 | 6 | 16 | 0 | 0 | 0 | 0 | 1 |
| 202 | 6 | 17 | 0 | 0 | 0 | 0 | 1 |
| 203 | 6 | 18 | 0 | 0 | 0 | 0 | 1 |
| 204 | 6 | 19 | 1571 | 533 | 1067 | 8 | 1 |
| 205 | 6 | 20 | 1450 | 533 | 1067 | 8 | 1 |
| 206 | 6 | 21 | 1027 | 1067 | 2135 | 8 | 1 |
| 207 | 6 | 22 | 785 | 2135 | 4267 | 12 | 1 |
| 208 | 6 | 23 | 725 | 2135 | 4268 | 12 | 1 |
| 209 | 6 | 24 | 664 | 2135 | 4268 | 12 | 1 |
| 210 | 6 | 25 | 664 | 2135 | 4269 | 12 | 1 |
| 211 | 6 | 26 | 664 | 2135 | 4269 | 12 | 1 |
| 212 | 6 | 27 | 664 | 2135 | 4269 | 12 | 1 |
| 213 | 6 | 28 | 664 | 2135 | 4269 | 12 | 1 |
| 214 | 6 | 29 | 664 | 2135 | 4270 | 8 | 1 |
| 215 | 6 | 30 | 725 | 2135 | 4270 | 8 | 1 |
| 216 | 6 | 31 | 725 | 2135 | 4270 | 8 | 1 |
| 217 | 6 | 32 | 725 | 2135 | 4270 | 8 | 1 |
| 218 | 6 | 33 | 906 | 2669 | 5338 | 8 | 1 |
| 219 | 6 | 34 | 604 | 2135 | 4270 | 8 | 1 |
| 220 | 6 | 35 | 483 | 2135 | 4269 | 4 | 1 |
| 221 | 6 | 36 | 725 | 2135 | 4270 | 4 | 1 |
| 222 | 6 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ $ft^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 223 | 7 | 1 | 0 | 0 | 0 | 0 | 1 |
| 224 | 7 | 2 | 0 | 0 | 0 | 0 | 1 |
| 225 | 7 | 3 | 0 | 0 | 0 | 0 | 1 |
| 226 | 7 | 4 | 0 | 0 | 0 | 0 | 1 |
| 227 | 7 | 5 | 0 | 0 | 0 | C | 1 |
| 228 | 7 | 6 | 0 | 0 | 0 | 0 | 1 |
| 229 | 7 | 7 | 0 | 0 | 0 | 0 | 1 |
| 230 | 7 | 8 | 0 | 0 | 0 | 0 | 1 |
| 231 | 7 | 9 | 0 | 0 | 0 | 0 | 1 |
| 232 | 7 | 10 | 0 | 0 | 0 | 0 | 1 |
| 233 | 7 | 11 | 0 | 0 | 0 | 0 | 1 |
| 234 | 7 | 12 | 0 | 0 | 0 | 0 | 1 |
| 235 | 7 | 13 | 0 | 0 | 0 | 0 | 1 |
| 236 | 7 | 14 | 0 | 0 | 0 | 0 | 1 |
| 237 | 7 | 15 | 0 | 0 | 0 | 0 | 1 |
| 238 | 7 | 16 | 0 | 0 | 0 | 0 | 1 |
| 239 | 7 | 17 | 0 | 0 | 0 | 0 | 1 |
| 240 | 7 | 18 | 967 | 533 | 1067 | 14 | 1 |
| 241 | 7 | 19 | 1329 | 533 | 1067 | 14 | 1 |
| 242 | 7 | 20 | 1208 | 533 | 1067 | 10 | 1 |
| 243 | 7 | 21 | 846 | 533 | 1067 | 10 | 1 |
| 244 | 7 | 22 | 725 | 533 | 1067 | 14 | 1 |
| 245 | 7 | 23 | 725 | 533 | 1067 | 14 | 1 |
| 246 | 7 | 24 | 664 | 1067 | 1067 | 14 | 1 |
| 247 | 7 | 25 | 664 | 2135 | 4269 | 14 | 1 |
| 248 | 7 | 26 | 664 | 2135 | 4269 | 14 | 1 |
| 249 | 7 | 27 | 664 | 2135 | 4269 | 12 | 1 |
| 250 | 7 | 28 | 664 | 2135 | 4270 | 12 | 1 |
| 251 | 7 | 29 | 664 | 2135 | 4270 | 12 | 1 |
| 252 | 7 | 30 | 725 | 2135 | 4270 | 12 | 1 |
| 253 | 7 | 31 | 725 | 2135 | 4270 | 12 | 1 |
| 254 | 7 | 32 | 725 | 2135 | 4270 | 8 | 1 |
| 255 | 7 | 33 | 846 | 2456 | 4911 | 8 | 1 |
| 256 | 7 | 34 | 967 | 2135 | 4270 | 8 | 1 |
| 257 | 7 | 35 | 483 | 533 | 1067 | 4 | 1 |
| 258 | 7 | 36 | 664 | 533 | 1067 | 4 | 1 |
| 259 | 7 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ $ft^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE (X $10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 260 | 8 | 1 | 0 | 0 | 0 | 0 | 1 |
| 261 | 8 | 2 | 0 | 0 | 0 | 0 | 1 |
| 262 | 8 | 3 | 0 | 0 | 0 | 0 | 1 |
| 263 | 8 | 4 | 0 | 0 | 0 | 0 | 1 |
| 264 | 8 | 5 | 0 | 0 | 0 | 0 | 1 |
| 265 | 8 | 6 | 0 | 0 | 0 | 0 | 1 |
| 266 | 8 | 7 | 0 | 0 | 0 | 0 | 1 |
| 267 | 8 | 8 | 0 | 0 | 0 | 0 | 1 |
| 268 | 8 | 9 | 0 | 0 | 0 | 0 | 1 |
| 269 | 8 | 10 | 0 | 0 | 0 | 0 | 1 |
| 270 | 8 | 11 | 0 | 0 | 0 | 0 | 1 |
| 271 | 8 | 12 | 0 | 0 | 0 | 0 | 1 |
| 272 | 8 | 13 | 0 | 0 | 0 | 0 | 1 |
| 273 | 8 | 14 | 0 | 0 | 0 | 0 | 1 |
| 274 | 8 | 15 | 0 | 0 | 0 | 0 | 1 |
| 275 | 8 | 16 | 0 | 0 | 0 | 0 | 1 |
| 276 | 8 | 17 | 0 | 0 | 0 | 0 | 1 |
| 277 | 8 | 18 | 1148 | 533 | 1067 | 14 | 1 |
| 278 | 8 | 19 | 1269 | 533 | 1067 | 14 | 1 |
| 279 | 8 | 20 | 1148 | 533 | 1067 | 10 | 1 |
| 280 | 8 | 21 | 725 | 533 | 1067 | 10 | 1 |
| 281 | 8 | 22 | 664 | 533 | 1067 | 14 | 1 |
| 282 | 8 | 23 | 664 | 533 | 1067 | 14 | 1 |
| 283 | 8 | 24 | 664 | 533 | 1067 | 14 | 1 |
| 284 | 8 | 25 | 664 | 533 | 1067 | 14 | 1 |
| 285 | 8 | 26 | 664 | 1067 | 2135 | 14 | 1 |
| 286 | 8 | 27 | 664 | 2135 | 4267 | 12 | 1 |
| 287 | 8 | 28 | 664 | 2135 | 4170 | 8 | 1 |
| 288 | 8 | 29 | 664 | 2135 | 4269 | 4 | 1 |
| 289 | 8 | 30 | 664 | 2135 | 4170 | 4 | 1 |
| 290 | 8 | 31 | 725 | 2135 | 4270 | 4 | 1 |
| 291 | 8 | 32 | 725 | 2135 | 4170 | 4 | 1 |
| 292 | 8 | 33 | 846 | 2135 | 4170 | 4 | 1 |
| 293 | 8 | 34 | 1027 | 2135 | 4171 | 4 | 1 |
| 294 | 8 | 35 | 483 | 533 | 1067 | 4 | 1 |
| 295 | 8 | 36 | 664 | 533 | 1067 | 4 | 1 |
| 296 | 8 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDICTIVITY LAYER 1 ($x10^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 297 | 9 | 1 | 0 | 0 | 0 | 0 | 1 |
| 298 | 9 | 2 | 0 | 0 | 0 | 0 | 1 |
| 299 | 9 | 3 | 543 | 533 | 1067 | 10 | 1 |
| 300 | 9 | 4 | 302 | 533 | 1067 | 10 | 1 |
| 301 | 9 | 5 | 48 | 74 | 149 | 10 | 1 |
| 302 | 9 | 6 | 24 | 42 | 85 | 10 | 1 |
| 303 | 9 | 7 | 12 | 32 | 64 | 15 | 1 |
| 304 | 9 | 8 | 6 | 32 | 64 | 17 | 1 |
| 305 | 9 | 9 | 24 | 42 | 85 | 10 | 1 |
| 306 | 9 | 10 | 30 | 74 | 149 | 10 | 1 |
| 307 | 9 | 11 | 30 | 106 | 213 | 10 | 1 |
| 308 | 9 | 12 | 60 | 106 | 213 | 10 | 1 |
| 309 | 9 | 13 | 60 | 106 | 213 | 15 | 1 |
| 310 | 9 | 14 | 181 | 106 | 213 | 17 | 1 |
| 311 | 9 | 15 | 483 | 106 | 213 | 25 | 1 |
| 312 | 9 | 16 | 483 | 106 | 213 | 25 | 1 |
| 313 | 9 | 17 | 362 | 533 | 1067 | 18 | 1 |
| 314 | 9 | 18 | 906 | 533 | 1067 | 10 | 1 |
| 315 | 9 | 19 | 725 | 533 | 1067 | 10 | 1 |
| 316 | 9 | 20 | 604 | 533 | 1067 | 10 | 1 |
| 317 | 9 | 21 | 543 | 533 | 1067 | 14 | 1 |
| 318 | 9 | 22 | 483 | 533 | 1067 | 14 | 1 |
| 319 | 9 | 23 | 604 | 533 | 1067 | 14 | 1 |
| 320 | 9 | 24 | 604 | 533 | 1067 | 14 | 1 |
| 321 | 9 | 25 | 604 | 533 | 1067 | 14 | 1 |
| 322 | 9 | 26 | 664 | 533 | 1067 | 14 | 1 |
| 323 | 9 | 27 | 664 | 533 | 1067 | 16 | 1 |
| 324 | 9 | 28 | 664 | 1067 | 2135 | 16 | 1 |
| 325 | 9 | 29 | 664 | 2135 | 4270 | 12 | 1 |
| 326 | 9 | 30 | 664 | 2135 | 4270 | 12 | 1 |
| 327 | 9 | 31 | 664 | 2135 | 4270 | 12 | 1 |
| 328 | 9 | 32 | 664 | 533 | 1067 | 12 | 1 |
| 329 | 9 | 33 | 664 | 533 | 1067 | 4 | 1 |
| 330 | 9 | 34 | 1027 | 1601 | 3203 | 4 | 1 |
| 331 | 9 | 35 | 664 | 533 | 1067 | 4 | 1 |
| 332 | 9 | 36 | 664 | 533 | 1067 | 4 | 1 |
| 333 | 9 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 335 | 10 | 2 | 604 | 533 | 1067 | 15 | 1 |
| 336 | 10 | 3 | 725 | 533 | 1067 | 15 | 1 |
| 337 | 10 | 4 | 604 | 533 | 1067 | 13 | 1 |
| 338 | 10 | 5 | 604 | 533 | 1067 | 10 | 1 |
| 339 | 10 | 6 | 483 | 320 | 640 | 10 | 1 |
| 340 | 10 | 7 | 60 | 213 | 427 | 13 | 1 |
| 341 | 10 | 8 | 60 | 85 | 170 | 17 | 1 |
| 342 | 10 | 9 | 60 | 106 | 213 | 13 | 1 |
| 343 | 10 | 10 | 60 | 106 | 213 | 10 | 1 |
| 344 | 10 | 11 | 60 | 106 | 213 | 10 | 1 |
| 345 | 10 | 12 | 60 | 106 | 213 | 10 | 1 |
| 346 | 10 | 13 | 60 | 106 | 213 | 15 | 1 |
| 347 | 10 | 14 | 181 | 106 | 213 | 15 | 1 |
| 348 | 10 | 15 | 181 | 106 | 213 | 18 | 1 |
| 349 | 10 | 16 | 181 | 106 | 213 | 21 | 1 |
| 350 | 10 | 17 | 241 | 106 | 213 | 16 | 1 |
| 351 | 10 | 18 | 362 | 106 | 213 | 10 | 1 |
| 352 | 10 | 19 | 362 | 106 | 213 | 8 | 1 |
| 353 | 10 | 20 | 362 | 106 | 213 | 5 | 1 |
| 354 | 10 | 21 | 423 | 106 | 213 | 8 | 1 |
| 355 | 10 | 22 | 362 | 106 | 213 | 10 | 1 |
| 356 | 10 | 23 | 241 | 106 | 213 | 10 | 1 |
| 357 | 10 | 24 | 302 | 533 | 1067 | 10 | 1 |
| 358 | 10 | 25 | 423 | 320 | 640 | 10 | 1 |
| 359 | 10 | 26 | 664 | 320 | 640 | 15 | 1 |
| 360 | 10 | 27 | 664 | 533 | 1067 | 12 | 1 |
| 361 | 10 | 28 | 664 | 1067 | 2135 | 12 | 1 |
| 362 | 10 | 29 | 664 | 533 | 1067 | 12 | 1 |
| 363 | 10 | 30 | 664 | 533 | 1067 | 12 | 1 |
| 364 | 10 | 31 | 664 | 533 | 1067 | 12 | 1 |
| 365 | 10 | 32 | 483 | 533 | 1067 | 12 | 1 |
| 366 | 10 | 33 | 483 | 533 | 1067 | 12 | 1 |
| 367 | 10 | 34 | 664 | 1067 | 2135 | 4 | 1 |
| 368 | 10 | 35 | 664 | 1067 | 2135 | 8 | 1 |
| 369 | 10 | 36 | 423 | 533 | 1067 | 4 | 1 |
| 370 | 10 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ $ft^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 372 | 11 | 2 | 604 | 533 | 1067 | 10 | 1 |
| 373 | 11 | 3 | 604 | 533 | 1067 | 10 | 1 |
| 374 | 11 | 4 | 725 | 2135 | 427 | 15 | 1 |
| 375 | 11 | 5 | 604 | 2135 | 427 | 13 | 1 |
| 376 | 11 | 6 | 604 | 1067 | 2135 | 10 | 1 |
| 377 | 11 | 7 | 483 | 1067 | 2135 | 10 | 1 |
| 378 | 11 | 8 | 120 | 533 | 1067 | 10 | 1 |
| 379 | 11 | 9 | 60 | 533 | 1066 | 10 | 1 |
| 380 | 11 | 10 | 60 | 533 | 1066 | 8 | 1 |
| 381 | 11 | 11 | 60 | 106 | 213 | 12 | 1 |
| 382 | 11 | 12 | 60 | 106 | 213 | 15 | 1 |
| 383 | 11 | 13 | 60 | 106 | 213 | 12 | 1 |
| 384 | 11 | 14 | 181 | 106 | 213 | 18 | 1 |
| 385 | 11 | 15 | 120 | 106 | 213 | 20 | 1 |
| 386 | 11 | 16 | 120 | 106 | 213 | 16 | 1 |
| 387 | 11 | 17 | 181 | 106 | 213 | 15 | 1 |
| 388 | 11 | 18 | 241 | 106 | 213 | 10 | 1 |
| 389 | 11 | 19 | 241 | 106 | 213 | 10 | 1 |
| 390 | 11 | 20 | 181 | 106 | 213 | 7 | 1 |
| 391 | 11 | 21 | 302 | 106 | 213 | 7 | 1 |
| 392 | 11 | 22 | 362 | 106 | 213 | 10 | 1 |
| 393 | 11 | 23 | 302 | 320 | 640 | 10 | 1 |
| 394 | 11 | 24 | 181 | 320 | 640 | 1 | 1 |
| 395 | 11 | 25 | 483 | 320 | 640 | 10 | 1 |
| 396 | 11 | 26 | 302 | 320 | 640 | 15 | 1 |
| 397 | 11 | 27 | 302 | 533 | 1067 | 12 | 1 |
| 398 | 11 | 28 | 123 | 533 | 1067 | 12 | 1 |
| 399 | 11 | 29 | 123 | 533 | 1067 | 12 | 1 |
| 400 | 11 | 30 | 123 | 533 | 1067 | 12 | 1 |
| 401 | 11 | 31 | 483 | 533 | 1067 | 12 | 1 |
| 402 | 11 | 32 | 483 | 533 | 1067 | 12 | 1 |
| 403 | 11 | 33 | 483 | 533 | 1067 | 12 | 1 |
| 404 | 11 | 34 | 483 | 533 | 1067 | 12 | 1 |
| 405 | 11 | 35 | 664 | 1067 | 2135 | 8 | 1 |
| 406 | 11 | 36 | 423 | 533 | 1067 | 8 | 1 |
| 407 | 11 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 (x10$^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 (X10$^{-5}$ft$^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE (X 10$^{-9}$ft/day/ft) | STORAGE COEFFICENT LAYER 1 (x10$^{-2}$) | LAYER 2 (x10$^{-5}$) |
|---|---|---|---|---|---|---|---|
| 408 | 12 | 1 | 0 | 0 | 0 | 0 | 1 |
| 409 | 12 | 2 | 483 | 2135 | 4269 | 10 | 1 |
| 410 | 12 | 3 | 604 | 2135 | 4270 | 10 | 1 |
| 411 | 12 | 4 | 604 | 2135 | 4270 | 13 | 1 |
| 412 | 12 | 5 | 725 | 2135 | 4270 | 17 | 1 |
| 413 | 12 | 6 | 604 | 2135 | 4270 | 12 | 1 |
| 414 | 12 | 7 | 483 | 2135 | 4269 | 10 | 1 |
| 415 | 12 | 8 | 241 | 2135 | 4267 | 10 | 1 |
| 416 | 12 | 9 | 120 | 533 | 4267 | 10 | 1 |
| 417 | 12 | 10 | 60 | 533 | 1066 | 6 | 1 |
| 418 | 12 | 11 | 60 | 533 | 1066 | 12 | 1 |
| 419 | 12 | 12 | 60 | 106 | 213 | 15 | 1 |
| 420 | 12 | 13 | 60 | 106 | 213 | 12 | 1 |
| 421 | 12 | 14 | 120 | 106 | 213 | 17 | 1 |
| 422 | 12 | 15 | 120 | 106 | 213 | 17 | 1 |
| 423 | 12 | 16 | 120 | 106 | 213 | 15 | 1 |
| 424 | 12 | 17 | 181 | 106 | 213 | 10 | 1 |
| 425 | 12 | 18 | 241 | 106 | 213 | 10 | 1 |
| 426 | 12 | 19 | 241 | 106 | 213 | 10 | 1 |
| 427 | 12 | 20 | 181 | 106 | 213 | 10 | 1 |
| 428 | 12 | 21 | 181 | 106 | 213 | 10 | 1 |
| 429 | 12 | 22 | 181 | 106 | 213 | 10 | 1 |
| 430 | 12 | 23 | 302 | 106 | 213 | 10 | 1 |
| 431 | 12 | 24 | 302 | 320 | 640 | 10 | 1 |
| 432 | 12 | 25 | 42 | 320 | 640 | 15 | 1 |
| 433 | 12 | 26 | 181 | 533 | 1067 | 12 | 1 |
| 434 | 12 | 27 | 362 | 533 | 1067 | 12 | 1 |
| 435 | 12 | 28 | 362 | 533 | 1067 | 12 | 1 |
| 436 | 12 | 29 | 362 | 533 | 1067 | 12 | 1 |
| 437 | 12 | 30 | 362 | 533 | 1067 | 12 | 1 |
| 438 | 12 | 31 | 362 | 533 | 1067 | 12 | 1 |
| 439 | 12 | 32 | 362 | 533 | 1067 | 12 | 1 |
| 440 | 12 | 33 | 30 | 53 | 106 | 2 | 1 |
| 441 | 12 | 34 | 30 | 53 | 106 | 1 | 1 |
| 442 | 12 | 35 | 664 | 961 | 920 | 16 | 1 |
| 443 | 12 | 36 | 362 | 533 | 1067 | 8 | 1 |
| 444 | 12 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 446 | 13 | 2 | 0 | 0 | 0 | 0 | 1 |
| 447 | 13 | 3 | 0 | 0 | 0 | 0 | 1 |
| 448 | 13 | 4 | 483 | 2135 | 4269 | 10 | 1 |
| 449 | 13 | 5 | 604 | 2135 | 4270 | 15 | 1 |
| 450 | 13 | 6 | 725 | 2135 | 4270 | 17 | 1 |
| 451 | 13 | 7 | 604 | 2135 | 4270 | 13 | 1 |
| 452 | 13 | 8 | 483 | 2135 | 4269 | 10 | 1 |
| 453 | 13 | 9 | 181 | 2135 | 4266 | 6 | 1 |
| 454 | 13 | 10 | 120 | 1067 | 2133 | 6 | 1 |
| 455 | 13 | 11 | 60 | 747 | 1493 | 12 | 1 |
| 456 | 13 | 12 | 120 | 533 | 1067 | 15 | 1 |
| 457 | 13 | 13 | 120 | 106 | 213 | 10 | 1 |
| 458 | 13 | 14 | 120 | 106 | 2131 | 13 | 1 |
| 459 | 13 | 15 | 181 | 106 | 213 | 15 | 1 |
| 460 | 13 | 16 | 181 | 106 | 213 | 11 | 1 |
| 461 | 13 | 17 | 181 | 106 | 213 | 10 | 1 |
| 462 | 13 | 18 | 241 | 106 | 213 | 10 | 1 |
| 463 | 13 | 19 | 241 | 106 | 213 | 10 | 1 |
| 464 | 13 | 20 | 181 | 106 | 213 | 10 | 1 |
| 465 | 13 | 21 | 181 | 106 | 213 | 10 | 1 |
| 466 | 13 | 22 | 181 | 106 | 213 | 10 | 1 |
| 467 | 13 | 23 | 181 | 320 | 640 | 10 | 1 |
| 468 | 13 | 24 | 42 | 320 | 640 | 10 | 1 |
| 469 | 13 | 25 | 302 | 320 | 640 | 10 | 1 |
| 470 | 13 | 26 | 302 | 533 | 1067 | 10 | 1 |
| 471 | 13 | 27 | 302 | 533 | 1067 | 10 | 1 |
| 472 | 13 | 28 | 302 | 53 | 1067 | 12 | 1 |
| 473 | 13 | 29 | 302 | 53 | 106 | 12 | 1 |
| 474 | 13 | 30 | 302 | 53 | 106 | 12 | 1 |
| 475 | 13 | 31 | 302 | 533 | 1067 | 12 | 1 |
| 476 | 13 | 32 | 302 | 533 | 1067 | 12 | 1 |
| 477 | 13 | 33 | 302 | 53 | 106 | 4 | 1 |
| 478 | 13 | 34 | 60 | 53 | 106 | 2 | 1 |
| 479 | 13 | 35 | 30 | 53 | 106 | 2 | 1 |
| 480 | 13 | 36 | 302 | 320 | 640 | 8 | 1 |
| 481 | 13 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ $ft^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE (X $10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 482 | 14 | 1 | 0 | 0 | 0 | 0 | 1 |
| 483 | 14 | 2 | 0 | 0 | 0 | 0 | 1 |
| 484 | 14 | 3 | 0 | 0 | 0 | 0 | 1 |
| 485 | 14 | 4 | 0 | 0 | 0 | 0 | 1 |
| 486 | 14 | 5 | 483 | 2135 | 4269 | 11 | 1 |
| 487 | 14 | 6 | 604 | 2135 | 4270 | 14 | 1 |
| 488 | 14 | 7 | 725 | 2135 | 4270 | 12 | 1 |
| 489 | 14 | 8 | 604 | 2135 | 4270 | 11 | 1 |
| 490 | 14 | 9 | 604 | 2135 | 4270 | 11 | 1 |
| 491 | 14 | 10 | 241 | 1067 | 2134 | 10 | 1 |
| 492 | 14 | 11 | 120 | 533 | 1067 | 10 | 1 |
| 493 | 14 | 12 | 30 | 533 | 1065 | 10 | 1 |
| 494 | 14 | 13 | 30 | 533 | 1065 | 10 | 1 |
| 495 | 14 | 14 | 30 | 533 | 1065 | 10 | 1 |
| 496 | 14 | 15 | 60 | 533 | 1066 | 10 | 1 |
| 497 | 14 | 16 | 60 | 106 | 213 | 10 | 1 |
| 498 | 14 | 17 | 90 | 106 | 213 | 10 | 1 |
| 499 | 14 | 18 | 181 | 106 | 213 | 10 | 1 |
| 500 | 14 | 19 | 181 | 106 | 213 | 10 | 1 |
| 501 | 14 | 20 | 181 | 106 | 213 | 10 | 1 |
| 502 | 14 | 21 | 120 | 53 | 106 | 10 | 1 |
| 503 | 14 | 22 | 120 | 53 | 106 | 10 | 1 |
| 504 | 14 | 23 | 30 | 53 | 106 | 10 | 1 |
| 505 | 14 | 24 | 30 | 53 | 85 | 10 | 1 |
| 506 | 14 | 25 | 302 | 53 | 64 | 10 | 1 |
| 507 | 14 | 26 | 302 | 53 | 106 | 8 | 1 |
| 508 | 14 | 27 | 302 | 53 | 106 | 8 | 1 |
| 509 | 14 | 28 | 483 | 53 | 106 | 12 | 1 |
| 510 | 14 | 29 | 604 | 53 | 106 | 12 | 1 |
| 511 | 14 | 30 | 362 | 53 | 106 | 12 | 1 |
| 512 | 14 | 31 | 362 | 53 | 106 | 12 | 1 |
| 513 | 14 | 32 | 362 | 53 | 106 | 12 | 1 |
| 514 | 14 | 33 | 181 | 53 | 106 | 12 | 1 |
| 515 | 14 | 34 | 181 | 53 | 106 | 12 | 1 |
| 516 | 14 | 35 | 30 | 53 | 106 | 12 | 1 |
| 517 | 14 | 36 | 60 | 320 | 639 | 4 | 1 |
| 518 | 14 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5} ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 520 | 15 | 2 | 0 | 0 | 0 | 0 | 1 |
| 521 | 15 | 3 | 0 | 0 | 0 | 0 | 1 |
| 522 | 15 | 4 | 0 | 0 | 0 | 0 | 1 |
| 523 | 15 | 5 | 483 | 2135 | 4269 | 8 | 1 |
| 524 | 15 | 6 | 604 | 2135 | 4270 | 8 | 1 |
| 525 | 15 | 7 | 604 | 2135 | 4270 | 8 | 1 |
| 526 | 15 | 8 | 604 | 2135 | 4270 | 12 | 1 |
| 527 | 15 | 9 | 604 | 2135 | 4270 | 12 | 1 |
| 528 | 15 | 10 | 60 | 2135 | 4256 | 12 | 1 |
| 529 | 15 | 11 | 30 | 320 | 640 | 8 | 1 |
| 530 | 15 | 12 | 30 | 320 | 640 | 8 | 1 |
| 531 | 15 | 13 | 30 | 320 | 640 | 8 | 1 |
| 532 | 15 | 14 | 30 | 320 | 640 | 8 | 1 |
| 533 | 15 | 15 | 30 | 320 | 640 | 8 | 1 |
| 534 | 15 | 16 | 30 | 106 | 213 | 4 | 1 |
| 535 | 15 | 17 | 30 | 106 | 213 | 4 | 1 |
| 536 | 15 | 18 | 30 | 106 | 213 | 4 | 1 |
| 537 | 15 | 19 | 30 | 106 | 213 | 4 | 1 |
| 538 | 15 | 20 | 30 | 106 | 213 | 4 | 1 |
| 539 | 15 | 21 | 30 | 53 | 106 | 4 | 1 |
| 540 | 15 | 22 | 30 | 53 | 106 | 4 | 1 |
| 541 | 15 | 23 | 60 | 53 | 106 | 4 | 1 |
| 542 | 15 | 24 | 60 | 53 | 106 | 4 | 1 |
| 543 | 15 | 25 | 60 | 53 | 106 | 4 | 1 |
| 544 | 15 | 26 | 302 | 53 | 106 | 4 | 1 |
| 545 | 15 | 27 | 302 | 53 | 106 | 4 | 1 |
| 546 | 15 | 28 | 725 | 53 | 106 | 4 | 1 |
| 547 | 15 | 29 | 30 | 53 | 106 | 2 | 1 |
| 548 | 15 | 30 | 30 | 53 | 106 | 2 | 1 |
| 549 | 15 | 31 | 123 | 53 | 106 | 4 | 1 |
| 550 | 15 | 32 | 483 | 53 | 106 | 12 | 1 |
| 551 | 15 | 33 | 181 | 53 | 106 | 12 | 1 |
| 552 | 15 | 34 | 30 | 53 | 106 | 12 | 1 |
| 553 | 15 | 35 | 241 | 53 | 106 | 4 | 1 |
| 554 | 15 | 36 | 60 | 533 | 1058 | 4 | 1 |
| 555 | 15 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE (X $10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 556 | 16 | 1 | 0 | 0 | 0 | 0 | 1 |
| 557 | 16 | 2 | 0 | 0 | 0 | 0 | 1 |
| 558 | 16 | 3 | 0 | 0 | 0 | 0 | 1 |
| 559 | 16 | 4 | 0 | 0 | 0 | 0 | 1 |
| 560 | 16 | 5 | 0 | 0 | 0 | 0 | 1 |
| 561 | 16 | 6 | 0 | 0 | 0 | 0 | 1 |
| 562 | 16 | 7 | 604 | 2135 | 427 | 8 | 1 |
| 563 | 16 | 8 | 604 | 2135 | 427 | 8 | 1 |
| 564 | 16 | 9 | 604 | 2135 | 427 | 8 | 1 |
| 565 | 16 | 10 | 604 | 2135 | 427 | 8 | 1 |
| 566 | 16 | 11 | 604 | 2135 | 427 | 8 | 1 |
| 567 | 16 | 12 | 604 | 2135 | 427 | 8 | 1 |
| 568 | 16 | 13 | 604 | 533 | 1067 | 8 | 1 |
| 569 | 16 | 14 | 604 | 533 | 1067 | 8 | 1 |
| 570 | 16 | 15 | 604 | 533 | 1067 | 8 | 1 |
| 571 | 16 | 16 | 604 | 533 | 1067 | 4 | 1 |
| 572 | 16 | 17 | 604 | 533 | 1067 | 4 | 1 |
| 573 | 16 | 18 | 120 | 533 | 1067 | 4 | 1 |
| 574 | 16 | 19 | 120 | 533 | 1067 | 4 | 1 |
| 575 | 16 | 20 | 120 | 53 | 106 | 4 | 1 |
| 576 | 16 | 21 | 120 | 53 | 106 | 4 | 1 |
| 577 | 16 | 22 | 120 | 53 | 106 | 4 | 1 |
| 578 | 16 | 23 | 120 | 53 | 106 | 4 | 1 |
| 579 | 16 | 24 | 120 | 53 | 106 | 4 | 1 |
| 580 | 16 | 25 | 183 | 53 | 106 | 4 | 1 |
| 581 | 16 | 26 | 183 | 53 | 106 | 4 | 1 |
| 582 | 16 | 27 | 604 | 85 | 107 | 4 | 1 |
| 583 | 16 | 28 | 1208 | 85 | 107 | 4 | 1 |
| 584 | 16 | 29 | 1208 | 85 | 107 | 4 | 1 |
| 585 | 16 | 30 | 1208 | 85 | 107 | 4 | 1 |
| 586 | 16 | 31 | 1208 | 85 | 107 | 4 | 1 |
| 587 | 16 | 32 | 1208 | 85 | 107 | 4 | 1 |
| 588 | 16 | 33 | 1208 | 85 | 107 | 4 | 1 |
| 589 | 16 | 34 | 543 | 53 | 106 | 4 | 1 |
| 590 | 16 | 35 | 120 | 53 | 106 | 4 | 1 |
| 591 | 16 | 36 | 604 | 533 | 1067 | 8 | 1 |
| 592 | 16 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ ft$^2$/s) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 593 | 17 | 1 | 0 | 0 | 0 | 0 | 1 |
| 594 | 17 | 2 | 0 | 0 | 0 | 0 | 1 |
| 595 | 17 | 3 | 0 | 0 | 0 | 0 | 1 |
| 596 | 17 | 4 | 0 | 0 | 0 | 0 | 1 |
| 597 | 17 | 5 | 0 | 0 | 0 | 0 | 1 |
| 598 | 17 | 6 | 0 | 0 | 0 | 0 | 1 |
| 599 | 17 | 7 | 604 | 2135 | 427 | 8 | 1 |
| 600 | 17 | 8 | 604 | 2135 | 427 | 8 | 1 |
| 601 | 17 | 9 | 604 | 2135 | 427 | 8 | 1 |
| 602 | 17 | 10 | 604 | 2135 | 427 | 8 | 1 |
| 602 | 17 | 11 | 604 | 2135 | 427 | 8 | 1 |
| 603 | 17 | 12 | 604 | 533 | 1067 | 8 | 1 |
| 604 | 17 | 13 | 604 | 533 | 1067 | 8 | 1 |
| 605 | 17 | 14 | 423 | 533 | 1067 | 8 | 1 |
| 606 | 17 | 15 | 423 | 533 | 1067 | 8 | 1 |
| 607 | 17 | 16 | 423 | 533 | 1067 | 4 | 1 |
| 608 | 17 | 17 | 604 | 533 | 1067 | 4 | 1 |
| 609 | 17 | 18 | 604 | 533 | 106 | 4 | 1 |
| 610 | 17 | 19 | 604 | 53 | 106 | 4 | 1 |
| 612 | 17 | 20 | 483 | 53 | 106 | 4 | 1 |
| 613 | 17 | 21 | 483 | 53 | 106 | 4 | 1 |
| 614 | 17 | 22 | 483 | 53 | 106 | 4 | 1 |
| 615 | 17 | 23 | 483 | 53 | 106 | 4 | 1 |
| 616 | 17 | 24 | 483 | 53 | 106 | 4 | 1 |
| 617 | 17 | 25 | 302 | 53 | 106 | 4 | 1 |
| 618 | 17 | 26 | 302 | 53 | 106 | 4 | 1 |
| 619 | 17 | 27 | 302 | 53 | 106 | 2 | 1 |
| 620 | 17 | 28 | 302 | 53 | 106 | 2 | 1 |
| 621 | 17 | 29 | 302 | 53 | 106 | 2 | 1 |
| 622 | 17 | 30 | 302 | 53 | 106 | 2 | 1 |
| 623 | 17 | 31 | 302 | 53 | 106 | 4 | 1 |
| 624 | 17 | 32 | 302 | 53 | 106 | 4 | 1 |
| 625 | 17 | 33 | 302 | 53 | 106 | 4 | 1 |
| 626 | 17 | 34 | 302 | 53 | 106 | 4 | 1 |
| 627 | 17 | 35 | 483 | 53 | 106 | 8 | 1 |
| 628 | 17 | 36 | 604 | 533 | 1067 | 8 | 1 |
| 629 | 17 | 37 | 0 | 0 | 0 | 0 | 1 |

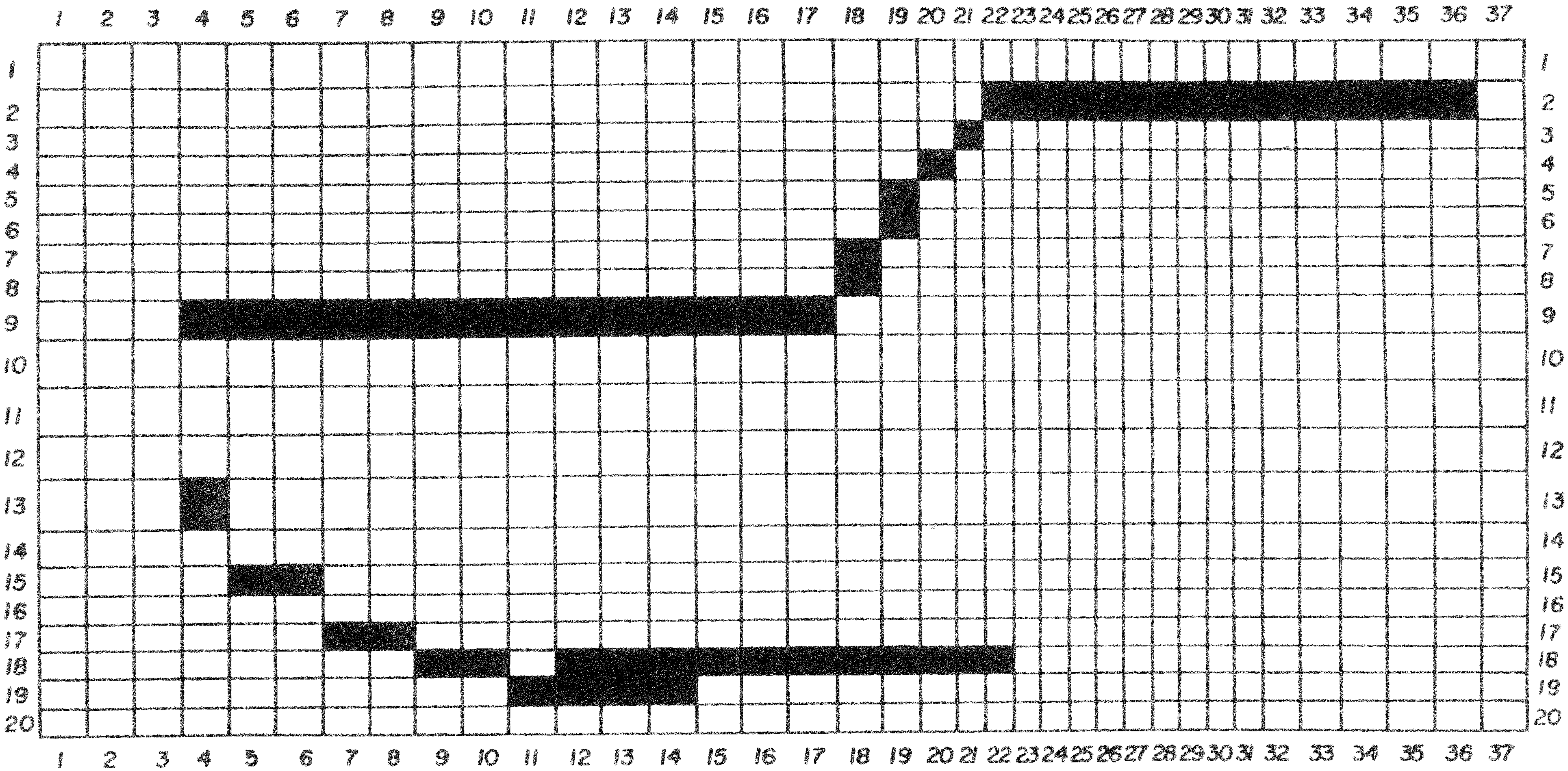
| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | STORAGE COEFFICIENT LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 630 | 18 | 2 | 0 | 0 | 0 | 0 | 1 |
| 631 | 18 | 2 | 0 | 0 | 0 | 0 | 1 |
| 632 | 18 | 3 | 0 | 0 | 0 | 0 | 1 |
| 633 | 18 | 4 | 0 | 0 | 0 | 0 | 1 |
| 634 | 18 | 5 | 0 | 0 | 0 | 0 | 1 |
| 635 | 18 | 6 | 0 | 0 | 0 | 0 | 1 |
| 636 | 18 | 7 | 0 | 0 | 0 | 0 | 1 |
| 637 | 18 | 8 | 0 | 0 | 0 | 0 | 1 |
| 638 | 18 | 9 | 302 | 2135 | 4268 | 8 | 1 |
| 639 | 18 | 10 | 120 | 533 | 1067 | 8 | 1 |
| 640 | 18 | 11 | 120 | 533 | 1067 | 21 | 1 |
| 641 | 18 | 12 | 120 | 533 | 1067 | 21 | 1 |
| 642 | 18 | 13 | 120 | 533 | 1067 | 8 | 1 |
| 643 | 18 | 14 | 120 | 533 | 1067 | 8 | 1 |
| 644 | 18 | 15 | 423 | 533 | 1067 | 8 | 1 |
| 645 | 18 | 16 | 423 | 533 | 1067 | 4 | 1 |
| 646 | 18 | 17 | 423 | 53 | 106 | 4 | 1 |
| 647 | 18 | 18 | 604 | 53 | 106 | 4 | 1 |
| 648 | 18 | 19 | 362 | 53 | 106 | 4 | 1 |
| 649 | 18 | 20 | 302 | 53 | 106 | 4 | 1 |
| 650 | 18 | 21 | 302 | 53 | 106 | 4 | 1 |
| 651 | 18 | 22 | 302 | 53 | 106 | 4 | 1 |
| 652 | 18 | 23 | 60 | 53 | 106 | 2 | 1 |
| 653 | 18 | 24 | 60 | 53 | 106 | 2 | 1 |
| 654 | 18 | 25 | 60 | 53 | 106 | 2 | 1 |
| 655 | 18 | 26 | 30 | 32 | 63 | 2 | 1 |
| 656 | 18 | 27 | 30 | 21 | 42 | 2 | 1 |
| 657 | 18 | 28 | 30 | 0 | 21 | 2 | 1 |
| 658 | 18 | 29 | 30 | 0 | 21 | 2 | 1 |
| 659 | 18 | 30 | 30 | 21 | 42 | 2 | 1 |
| 660 | 18 | 31 | 30 | 32 | 63 | 2 | 1 |
| 661 | 18 | 32 | 60 | 42 | 85 | 2 | 1 |
| 662 | 18 | 33 | 60 | 42 | 85 | 4 | 1 |
| 663 | 18 | 34 | 60 | 53 | 106 | 4 | 1 |
| 664 | 18 | 35 | 241 | 53 | 106 | 8 | 1 |
| 665 | 18 | 36 | 241 | 533 | 1067 | 8 | 1 |
| 666 | 18 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}$ $ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE ($X\ 10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 667 | 19 | 1 | 0 | 0 | 0 | 0 | 1 |
| 668 | 19 | 2 | 0 | 0 | 0 | 0 | 1 |
| 669 | 19 | 3 | 0 | 0 | 0 | 0 | 1 |
| 670 | 19 | 4 | 0 | 0 | 0 | 0 | 1 |
| 671 | 19 | 5 | 0 | 0 | 0 | 0 | 1 |
| 672 | 19 | 6 | 0 | 0 | 0 | 0 | 1 |
| 673 | 19 | 7 | 0 | 0 | 0 | 0 | 1 |
| 674 | 19 | 8 | 0 | 0 | 0 | 0 | 1 |
| 675 | 19 | 9 | 0 | 0 | 0 | 0 | 1 |
| 676 | 19 | 10 | 0 | 0 | 0 | 0 | 1 |
| 677 | 19 | 11 | 60 | 533 | 1066 | 21 | 1 |
| 678 | 19 | 12 | 60 | 533 | 1066 | 21 | 1 |
| 679 | 19 | 13 | 60 | 533 | 1066 | 12 | 1 |
| 680 | 19 | 14 | 60 | 533 | 1066 | 12 | 1 |
| 681 | 19 | 15 | 0 | 0 | 0 | 0 | 1 |
| 682 | 19 | 16 | 0 | 0 | 0 | 0 | 1 |
| 683 | 19 | 17 | 0 | 0 | 0 | 0 | 1 |
| 684 | 19 | 18 | 0 | 0 | 0 | 0 | 1 |
| 685 | 19 | 19 | 0 | 0 | 0 | 0 | 1 |
| 686 | 19 | 20 | 0 | 0 | 0 | 0 | 1 |
| 687 | 19 | 21 | 0 | 0 | 0 | 0 | 1 |
| 688 | 19 | 22 | 0 | 0 | 0 | 0 | 1 |
| 689 | 19 | 23 | 0 | 0 | 0 | 0 | 1 |
| 690 | 19 | 24 | 0 | 0 | 0 |  | 1 |
| 691 | 19 | 25 | 0 | 0 | 0 | 0 | 1 |
| 692 | 19 | 26 | 0 | 0 | 0 | 0 | 1 |
| 693 | 19 | 27 | 0 | 0 | 0 | 0 | 1 |
| 694 | 19 | 28 | 0 | 0 | 0 | 0 | 1 |
| 695 | 19 | 29 | 0 | 0 | 0 | 0 | 1 |
| 696 | 19 | 30 | 0 | 0 | 0 | 0 | 1 |
| 697 | 19 | 31 | 0 | 0 | 0 | 0 | 1 |
| 698 | 19 | 32 | 0 | 0 | 0 | 0 | 1 |
| 699 | 19 | 33 | 0 | 0 | 0 | 0 | 1 |
| 700 | 19 | 34 | 0 | 0 | 0 | 0 | 1 |
| 701 | 19 | 35 | 0 | 0 | 0 | 0 | 1 |
| 702 | 19 | 36 | 0 | 0 | 0 | 0 | 1 |
| 703 | 19 | 37 | 0 | 0 | 0 | 0 | 1 |

| GRID NO. | COL. | ROW | HYDRAULIC CONDUCTIVITY LAYER 1 ($x10^{-7}$ft/s) | TRANSMISSIVITY LAYER 2 ($X10^{-5}ft^2/s$) | VERTICAL HYDRAULIC CONDUCTIVITY ÷ THICKNESS = LEAKANCE (X $10^{-9}$ ft/day/ft) | STORAGE COEFFICIENT LAYER 1 ($x10^{-2}$) | LAYER 2 ($x10^{-5}$) |
|---|---|---|---|---|---|---|---|
| 704 | 20 | 1 | 0 | 0 | 0 | 0 | 1 |
| 705 | 20 | 2 | 0 | 0 | 0 | 0 | 1 |
| 706 | 20 | 3 | 0 | 0 | 0 | 0 | 1 |
| 707 | 20 | 4 | 0 | 0 | 0 | 0 | 1 |
| 708 | 20 | 5 | 0 | 0 | 0 | 0 | 1 |
| 709 | 20 | 6 | 0 | 0 | 0 | 0 | 1 |
| 710 | 20 | 7 | 0 | 0 | 0 | 0 | 1 |
| 711 | 20 | 8 | 0 | 0 | 0 | 0 | 1 |
| 712 | 20 | 9 | 0 | 0 | 0 | 0 | 1 |
| 713 | 20 | 10 | 0 | 0 | 0 | 0 | 1 |
| 714 | 20 | 11 | 0 | 0 | 0 | 0 | 1 |
| 715 | 20 | 12 | 0 | 0 | 0 | 0 | 1 |
| 716 | 20 | 13 | 0 | 0 | 0 | 0 | 1 |
| 717 | 20 | 14 | 0 | 0 | 0 | 0 | 1 |
| 718 | 20 | 15 | 0 | 0 | 0 | 0 | 1 |
| 719 | 20 | 16 | 0 | 0 | 0 | 0 | 1 |
| 720 | 20 | 17 | 0 | 0 | 0 | 0 | 1 |
| 721 | 20 | 18 | 0 | 0 | 0 | 0 | 1 |
| 722 | 20 | 19 | 0 | 0 | 0 | 0 | 1 |
| 723 | 20 | 20 | 0 | 0 | 0 | 0 | 1 |
| 724 | 20 | 21 | 0 | 0 | 0 | 0 | 1 |
| 725 | 20 | 22 | 0 | 0 | 0 | 0 | 1 |
| 726 | 20 | 23 | 0 | 0 | 0 | 0 | 1 |
| 727 | 20 | 24 | 0 | 0 | 0 | 0 | 1 |
| 728 | 20 | 25 | 0 | 0 | 0 | 0 | 1 |
| 729 | 20 | 26 | 0 | 0 | 0 | 0 | 1 |
| 730 | 20 | 27 | 0 | 0 | 0 | 0 | 1 |
| 731 | 20 | 28 | 0 | 0 | 0 | 0 | 1 |
| 732 | 20 | 29 | 0 | 0 | 0 | 0 | 1 |
| 733 | 20 | 30 | 0 | 0 | 0 | 0 | 1 |
| 734 | 20 | 31 | 0 | 0 | 0 | 0 | 1 |
| 735 | 20 | 32 | 0 | 0 | 0 | 0 | 1 |
| 736 | 20 | 33 | 0 | 0 | 0 | 0 | 1 |
| 737 | 20 | 34 | 0 | 0 | 0 | 0 | 1 |
| 738 | 20 | 35 | 0 | 0 | 0 | 0 | 1 |
| 739 | 20 | 36 | 0 | 0 | 0 | 0 | 1 |
| 740 | 20 | 37 | 0 | 0 | 0 | 0 | 1 |

# APPENDIX C

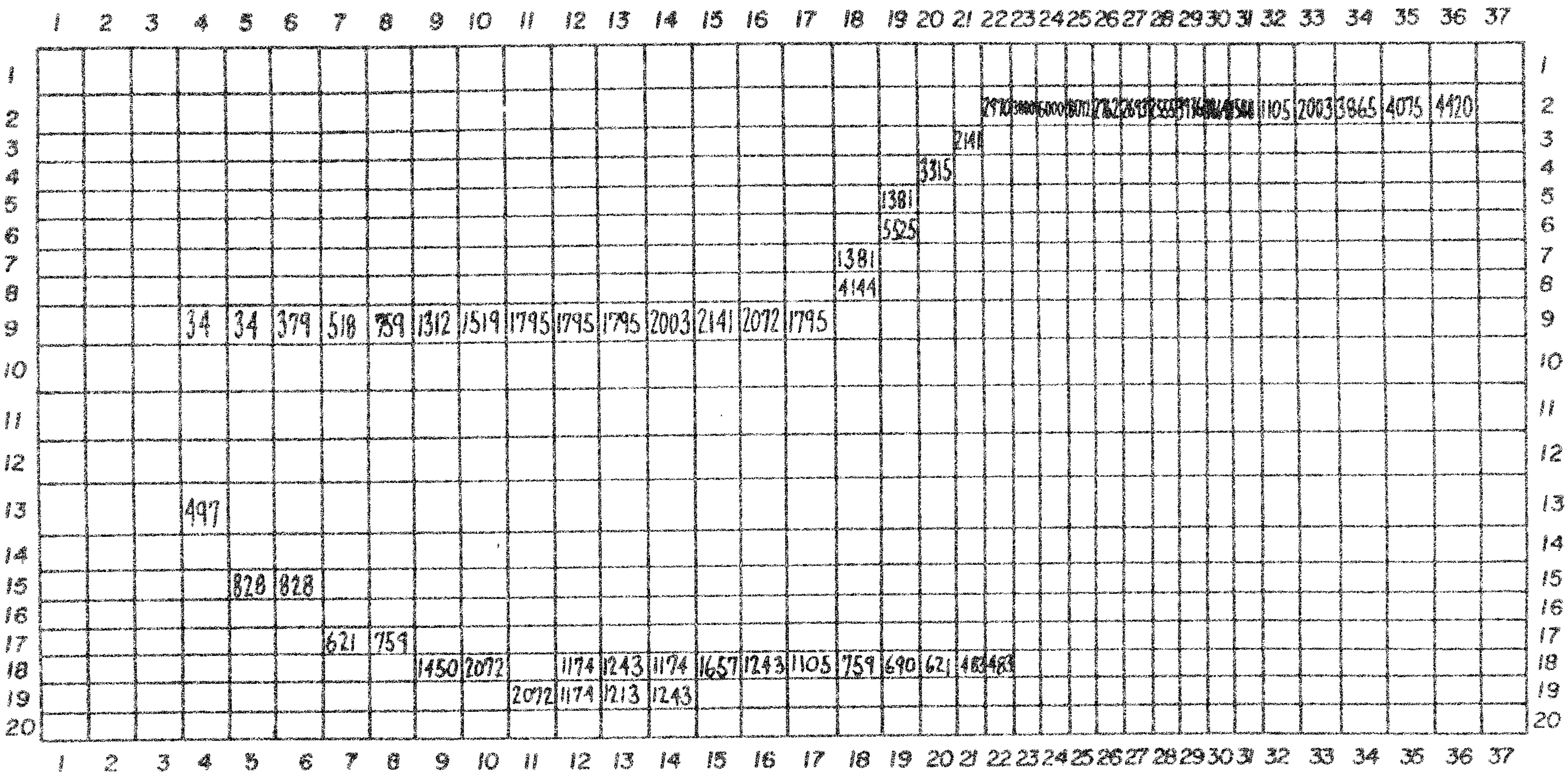
# MODEL STRESSES



SCALE = 1:210,000

MODEL RECHARGE NODE LOCATIONS

FIGURE C-1

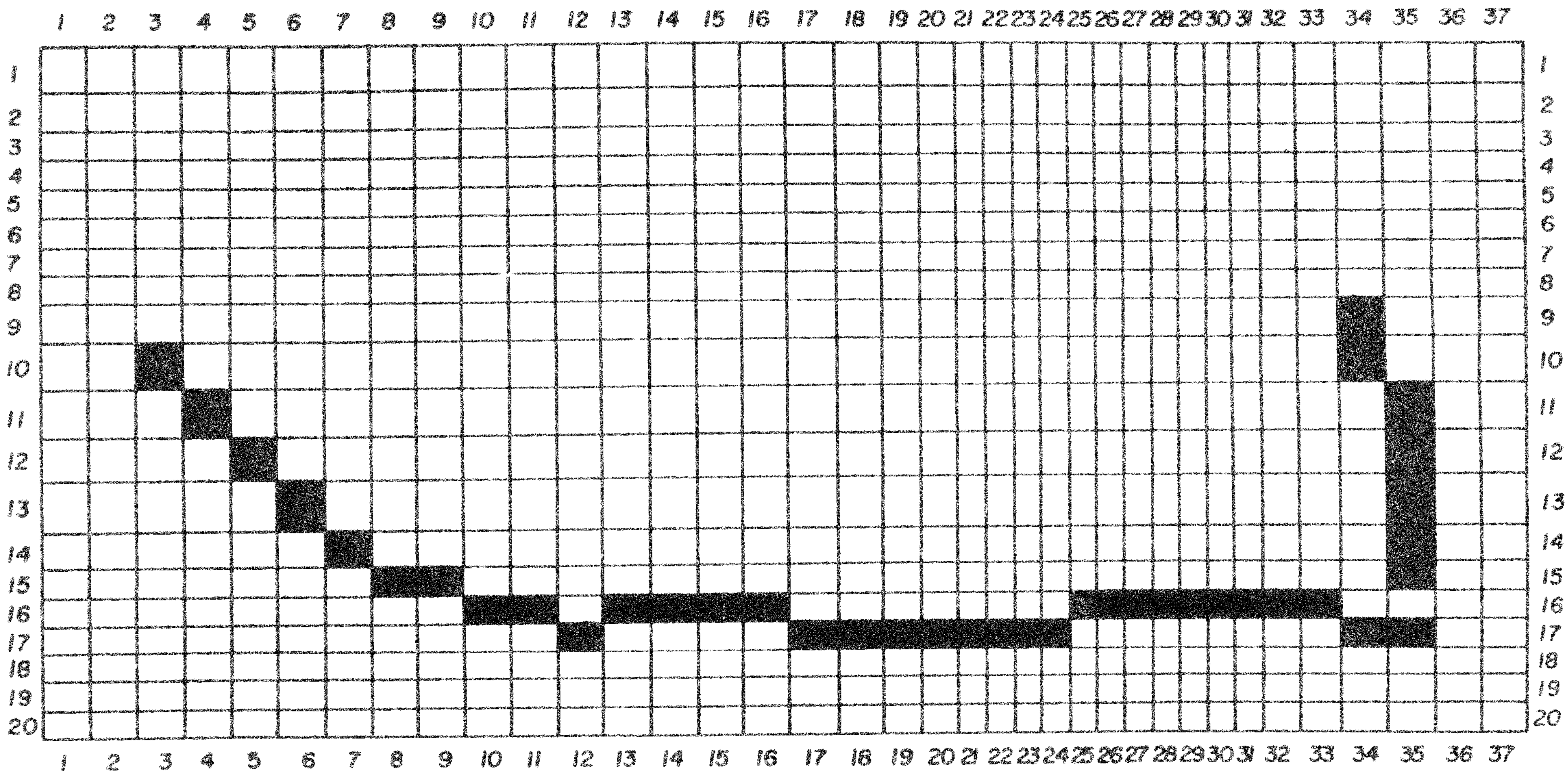



SCALE = 1:210,000

Model Recharge Rates From The Mountains

($x10^{-11}$ FT/S)

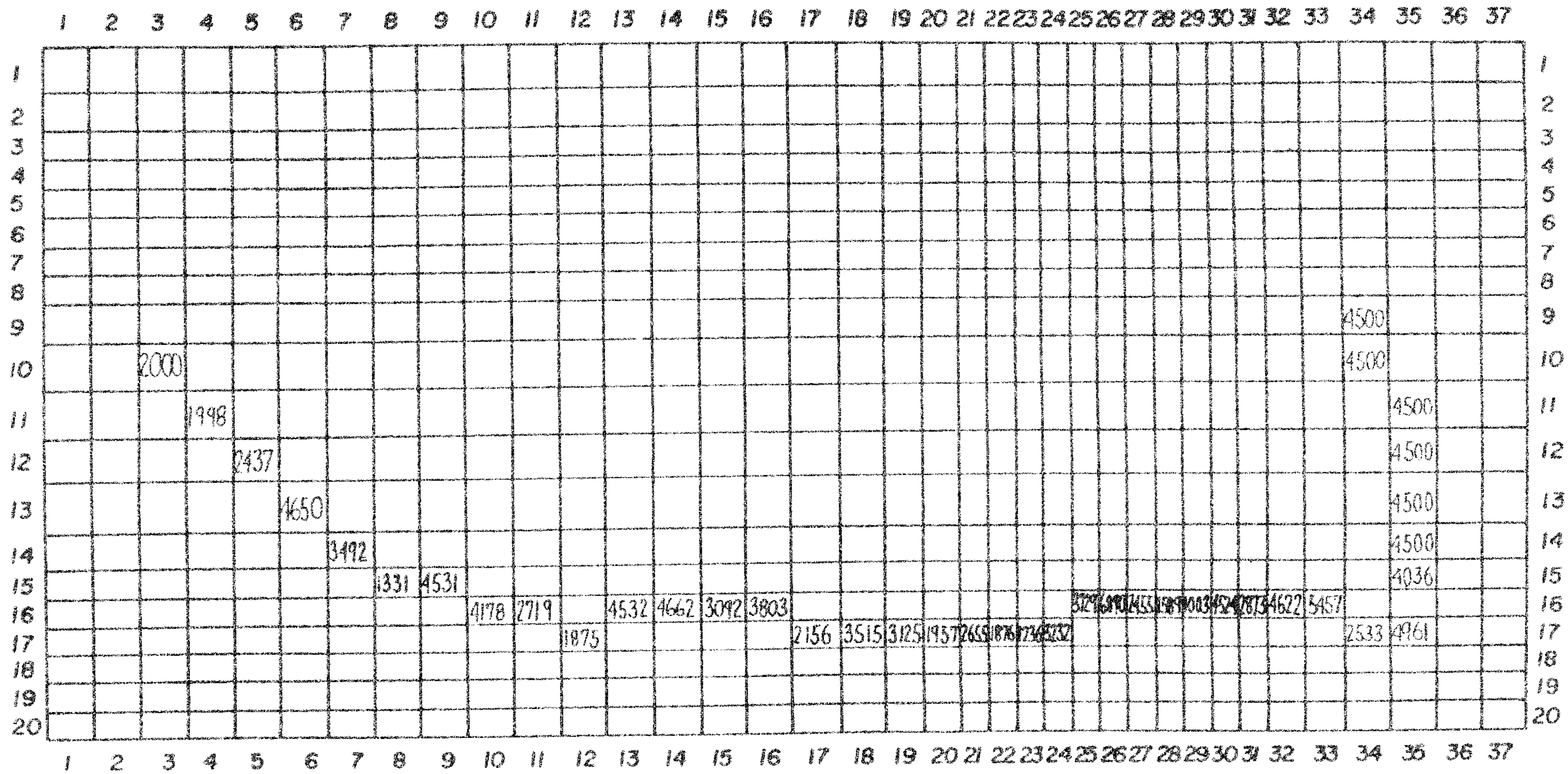
FIGURE C-2



SCALE = 1:210,000

MODEL EVAPOTRANSPIRATION NODE LOCATIONS

FIGURE C-3

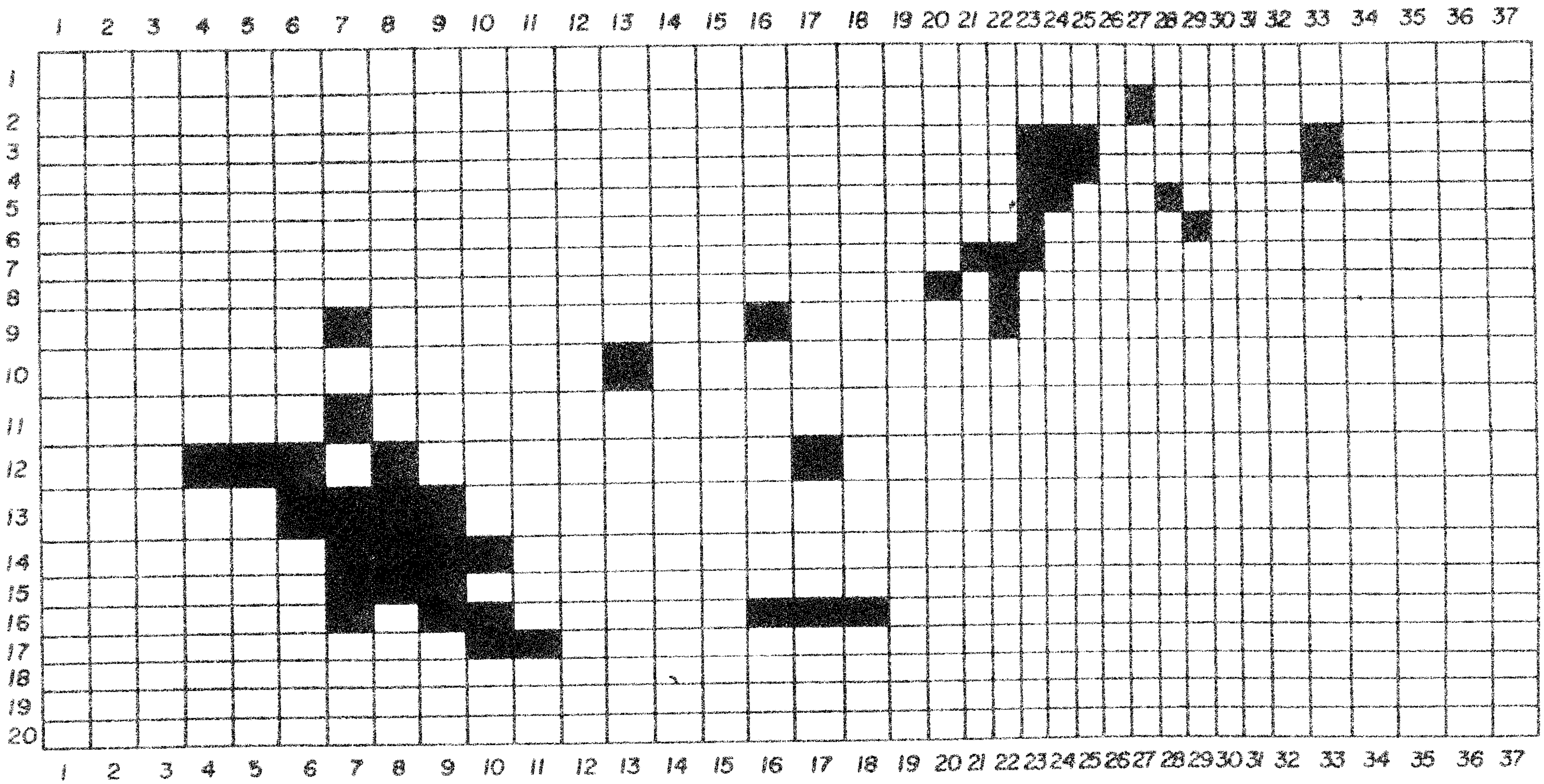



SCALE = 1:210,000

MODEL EVAPOTRANSPIRATION RATES

($x10^{-11}$ cfs)

FIGURE C-4




SCALE = 1:210,000

**_Model Well Locations_**
_(Dishorge Rates Shown In Table AI)_

FIGURE C-5

TABLE C1. Well Discharges for the Simulated Pumping Periods (cfs)

| ROW,COLUMN | PERIOD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | YEAR | 40-41 | 42-45 | 46-50 | 51-63 | 64-66 | 67 | 68 | 69-72 | 73-76 | 77 | 78 | 79,80 | 80-85 |
| 2,27 | | | | | 0.15 | 0.65 | 0.76 | 0.79 | 0.70 | 0.40 | 0.34 | 0.34 | 0.34 | 0.34 |
| 3,23 | | | | | | | 2.52 | 2.52 | 2.56 | 2.03 | 1.70 | 1.84 | 2.21 | 2.63 |
| 3,24 | | | | | | | 1.26 | 1.26 | 1.28 | 1.01 | .85 | .92 | 1.11 | 1.31 |
| 3,25 | | | | | | | .42 | .42 | .43 | .43 | .28 | .31 | .37 | .44 |
| 3,33 | | | | 0.01 | .05 | .09 | .12 | .13 | .16 | .20 | .20 | .19 | .15 | .14 |
| 4,24 | | | | | 1.07 | 1.12 | 1.30 | 1.36 | 1.20 | .71 | .60 | .64 | .58 | .58 |
| 4,25 | | 0.15 | 0.97 | | .41 | .57 | .67 | .70 | .62 | .31 | .31 | .30 | .27 | .27 |
| 4,33 | | | | .01 | .05 | .09 | .10 | .11 | .13 | .17 | .19 | .19 | .15 | .14 |
| 5,23 | | | | | .21 | .84 | .99 | .92 | .84 | .98 | 1.00 | .93 | .84 | .84 |
| 5,24 | | .15 | .97 | | .78 | .72 | .84 | .87 | .78 | .47 | .40 | .41 | .37 | .37 |
| 5,28 | | .15 | .97 | | .22 | .57 | .67 | .70 | .62 | .37 | .31 | .31 | .31 | .31 |
| 6,23 | | | | | | .01 | .04 | .06 | .11 | .22 | .35 | .32 | .18 | .18 |
| 6,29 | | | | | | | | | .32 | 1.04 | .88 | .86 | .88 | .88 |
| 7,21 | | | | | | | .18 | .18 | .32 | .38 | .15 | .70 | .92 | .96 |
| 7,22 | | | | | .03 | .10 | .14 | .05 | .11 | .22 | .35 | .32 | .18 | .22 |
| 7,23 | | | | | | .01 | .04 | .07 | .11 | .22 | .35 | .32 | .18 | .22 |
| 8,20 | | | | | | | | | | | .92 | .93 | .91 | .44 |

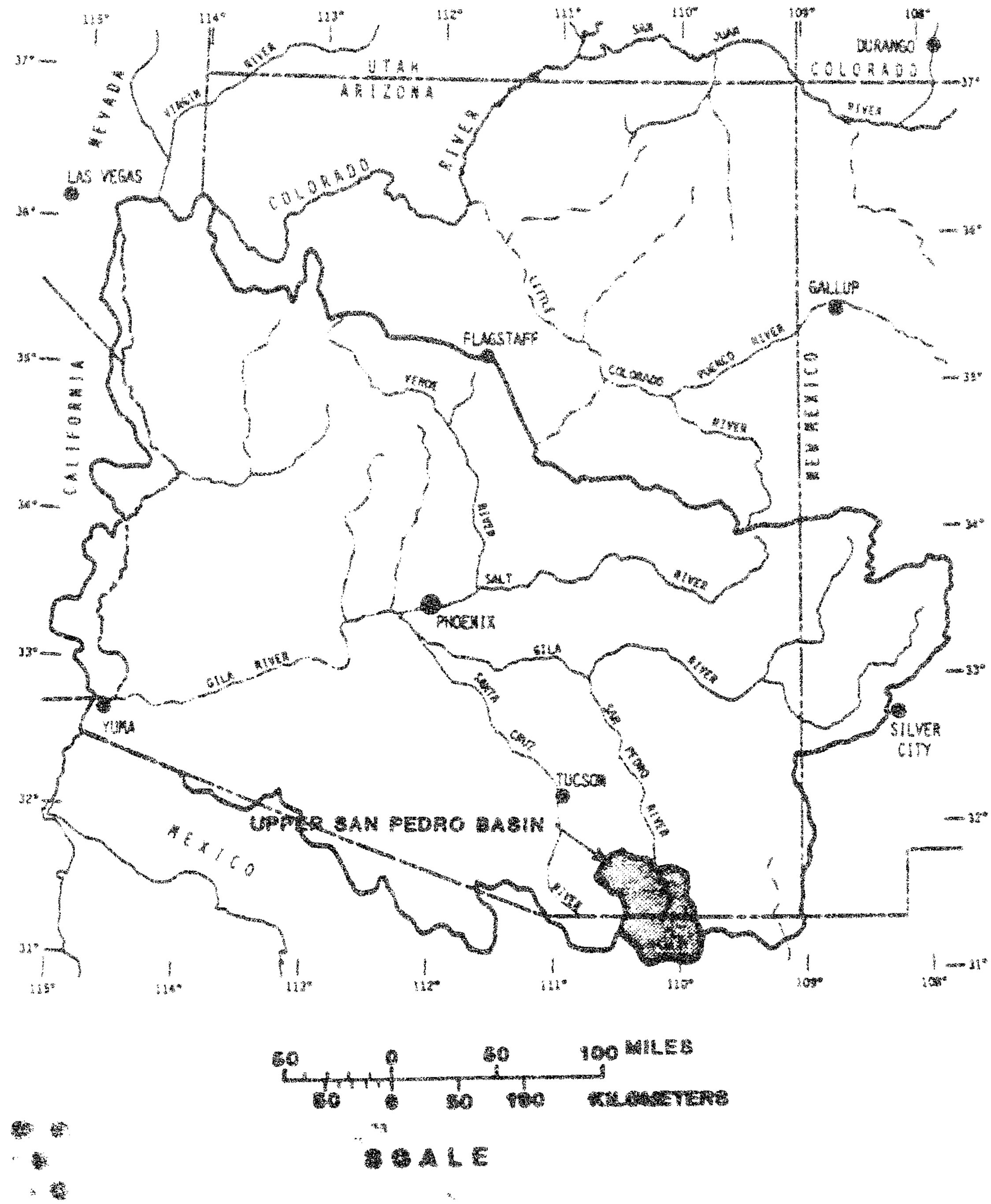
Table C1 (Continued)

| ROW, COLUMN | PERIOD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | YEAR | 40-41 | 42-45 | 46-50 | 51-63 | 64-66 | 67 | 68 | 69-72 | 73-76 | 77 | 78 | 79,80 | 80-85 |
| 8,22 | | | | | .04 | .16 | .15 | .46 | .32 | .50 | .50 | .66 | .37 | .45 |
| 9,6 | | | | | | | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .22 |
| 9,16 | | | | | | | | | | | | | | .10 |
| 9,22 | | | | | .04 | .16 | .15 | .05 | .22 | .25 | .25 | .38 | .21 | .26 |
| 10,13 | | | | | | | .43 | .26 | | | .27 | .27 | .28 | .28 |
| 11,7 | | | | | .16 | | | | | | | | | |
| 12,4 | | | | | .10 | .18 | .21 | .32 | .23 | .34 | .45 | .45 | .45 | .45 |
| 12,5 | | | | .05 | .22 | .36 | .31 | .48 | .34 | .51 | .68 | .68 | .68 | .68 |
| 12,6 | | | | .03 | .12 | .18 | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .22 |
| 12,8 | | | | | .02 | .07 | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .22 |
| 12,17 | | | | | | | .85 | .52 | | | | | | |
| 13,6 | | | | .07 | .22 | .36 | .31 | .48 | .34 | .51 | .68 | .68 | .68 | .68 |
| 13,7 | | | .07 | .15 | .28 | .50 | .42 | .64 | .46 | .67 | .97 | .97 | .97 | .97 |
| 13,8 | | | | | | .13 | .21 | .32 | .23 | .34 | .45 | .45 | .45 | .45 |
| 13,9 | | | | | | .13 | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .45 |
| 14,7 | | | .10 | .21 | .41 | .71 | .52 | .16 | .11 | .85 | 1.13 | 1.13 | 1.13 | 1.13 |
| 14,8 | | | | | | .27 | .21 | .80 | .57 | .34 | .45 | .45 | .45 | .45 |

Table C1 (Continued)

| ROW, COLUMN | PERIOD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | YEAR | 40-41 | 42-45 | 46-50 | 51-63 | 64-66 | 67 | 68 | 69-72 | 73-76 | 77 | 78 | 79,80 | 80-85 |
| 14,9 | | .14 | .14 | .15 | .28 | .50 | .31 | .48 | .34 | .51 | .68 | .68 | .68 | .68 |
| 14,10 | | | | | | .13 | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .22 |
| 15,7 | | | .08 | .10 | .22 | .36 | .21 | .32 | .23 | .34 | .45 | .45 | .45 | .45 |
| 15,8 | | .10 | .10 | .10 | .22 | .36 | .21 | .32 | .23 | .34 | .45 | .45 | .45 | .45 |
| 15,9 | | | | | .20 | .36 | .21 | .32 | .23 | .34 | .45 | .45 | .45 | .45 |
| 16,7 | | | | | | .18 | .10 | .16 | .11 | .17 | .22 | .22 | .22 | .22 |
| 16,9 | | .10 | .10 | .10 | .22 | .18 | .10 | .16 | .11 | .22 | .22 | .22 | .22 | .22 |
| 16,10 | | | | | | 1.03 | .96 | .69 | .11 | .17 | .22 | .22 | .22 | .22 |
| 16,16 | | | | | | .66 | .43 | .26 | | | | | | |
| 16,17 | | | | | | .66 | .43 | .26 | | | | | | |
| 16,18 | | | | | | .66 | .43 | .26 | | | | | | |
| 17,10 | | | | | .44 | .78 | .10 | | | | | | | |
| 17,11 | | | | | .46 | .78 | .43 | | | | | | | |

PLATES

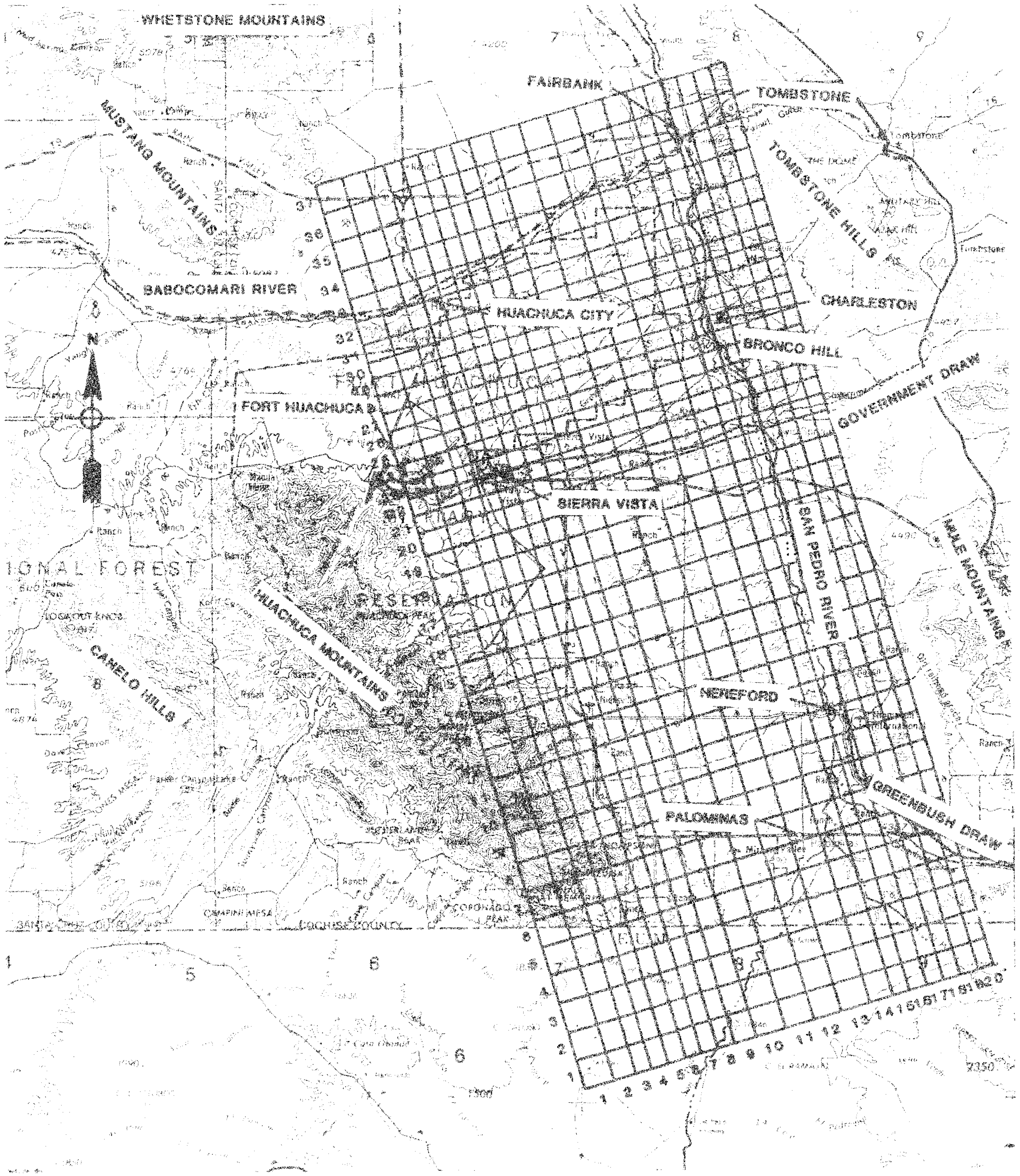



**UPPER SAN PEDRO RIVER BASIN, ARIZONA**

**STUDY AREA**

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

**PLATE 1**




## LEGEND

| | |
|---|---|
| ROW / COLUMN | MODEL NODE LOCATION |
| | RIVER |
| | FORT HUACHUA MILITARY RESERVATION BOUNDARY |

Base from U.S. Geological Survey 1:250,000
Nogales, 1969

0 5 10 MILES
0 5 10 15 KILOMETERS

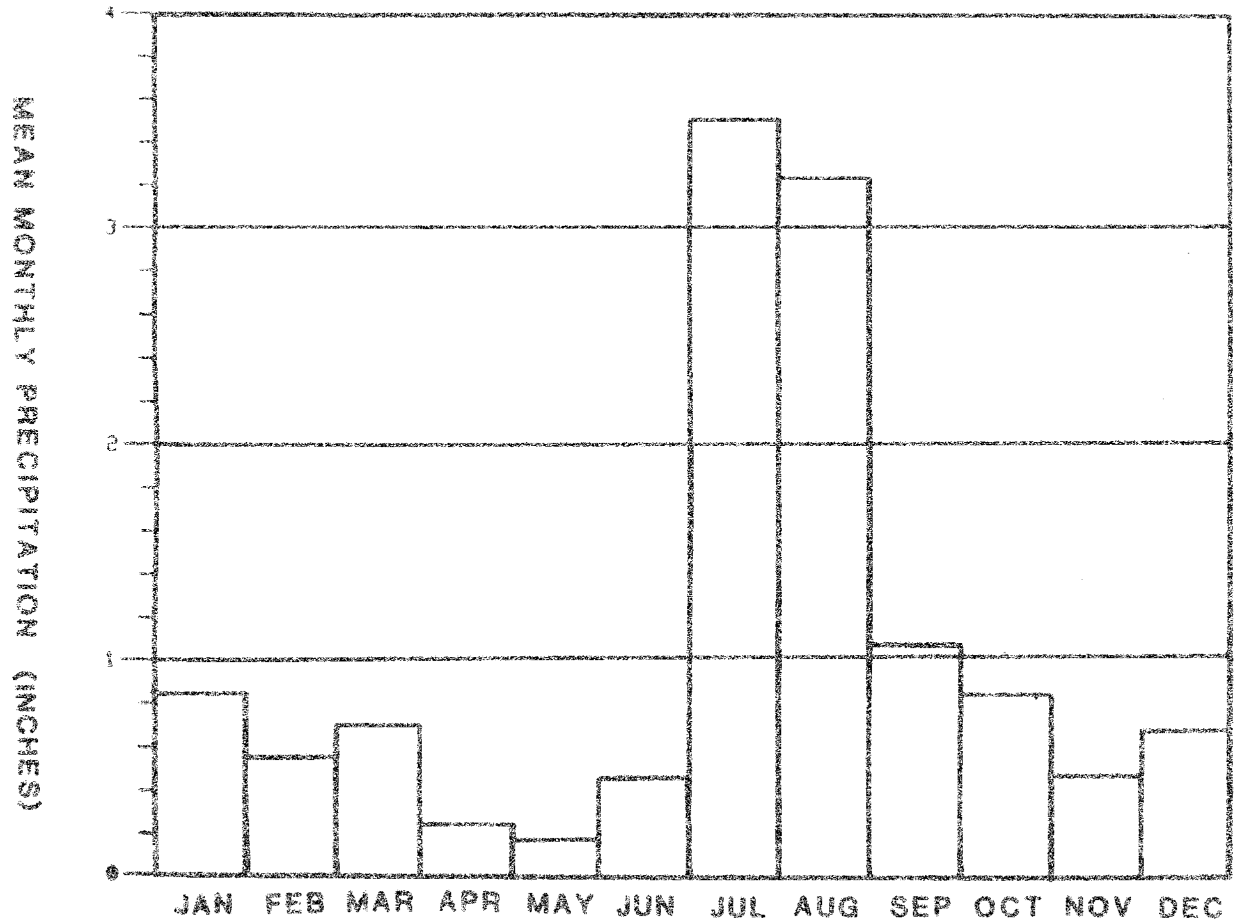
TOPOGRAPHIC CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UPPER SAN PEDRO RIVER BASIN, ARIZONA

**GEOGRAPHIC SETTING OF MODEL AREA AND GRID**

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 2




TOMBSTONE GAUGE
STA NO 8619
LAT 31 42 N
LONG 110 03 W

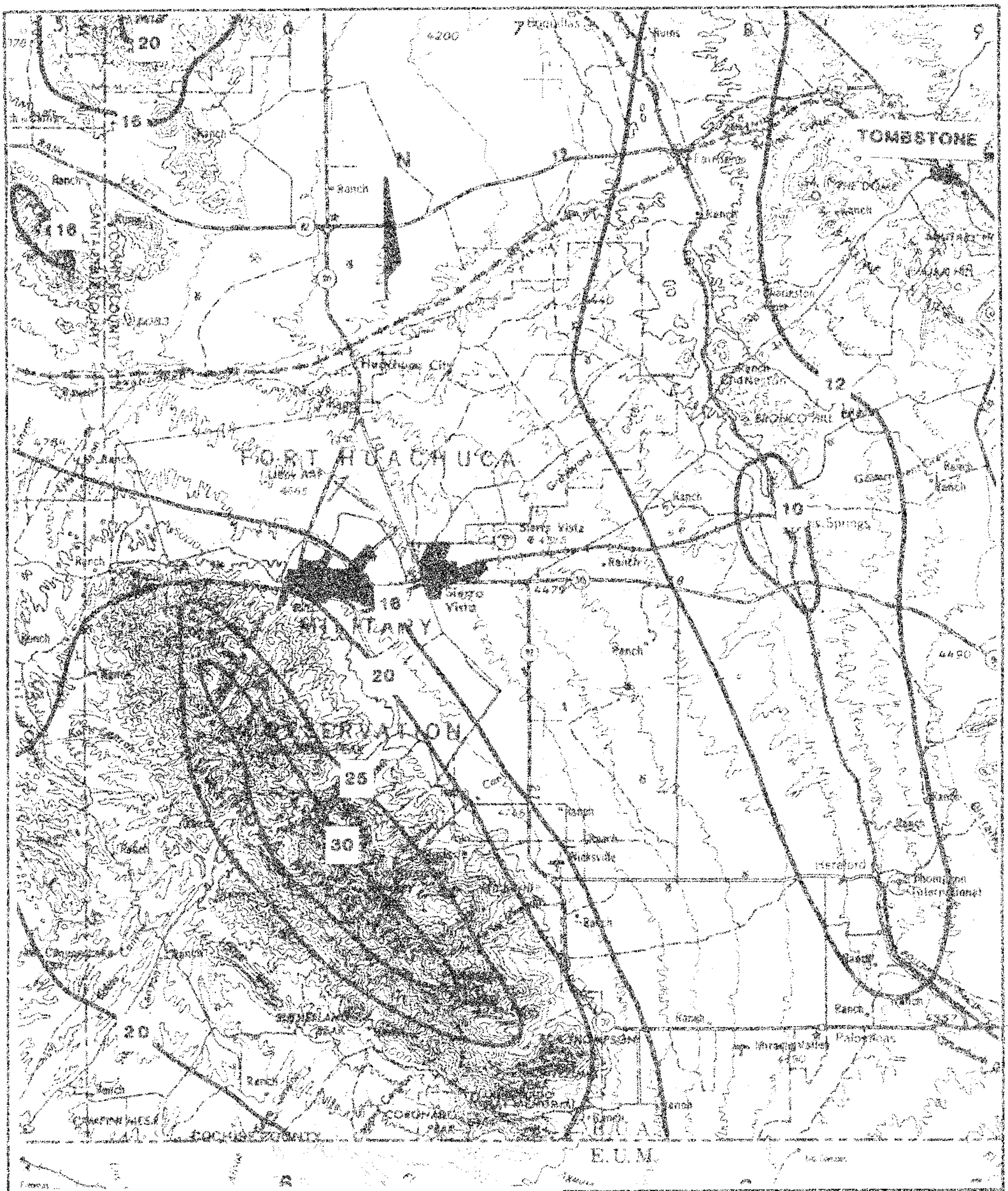
FROM NOAA CLIMAOLOGICAL
SUMMARY (REF. 10 )

UPPER SAN PEDRO
RIVER BASIN, AZ

MEAN MONTHLY PRECIPITATION
TOMBSTONE , AZ
(1951-1980)

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 3




UPPER SAN PEDRO
RIVER BASIN, ARIZONA

ISOLINES OF
NORMAL ANNUAL
PRECIPITATION (IN INCHES)

SCALE

MILES

0 5 10

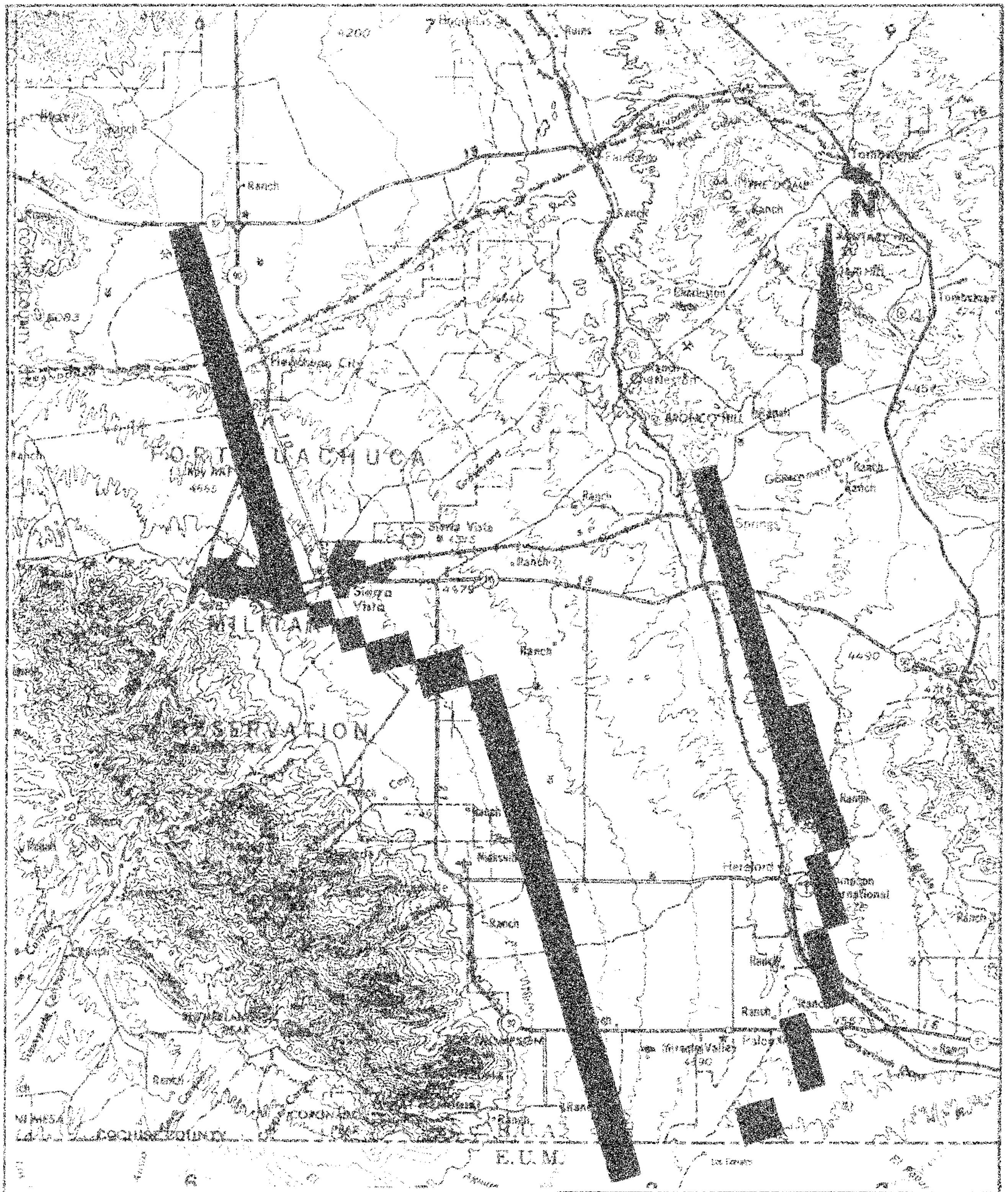
0 5 10 15

KILOMETERS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 4

USF200009929




SCALE

MILES

0 5 10

0 5 10 15

KILOMETERS

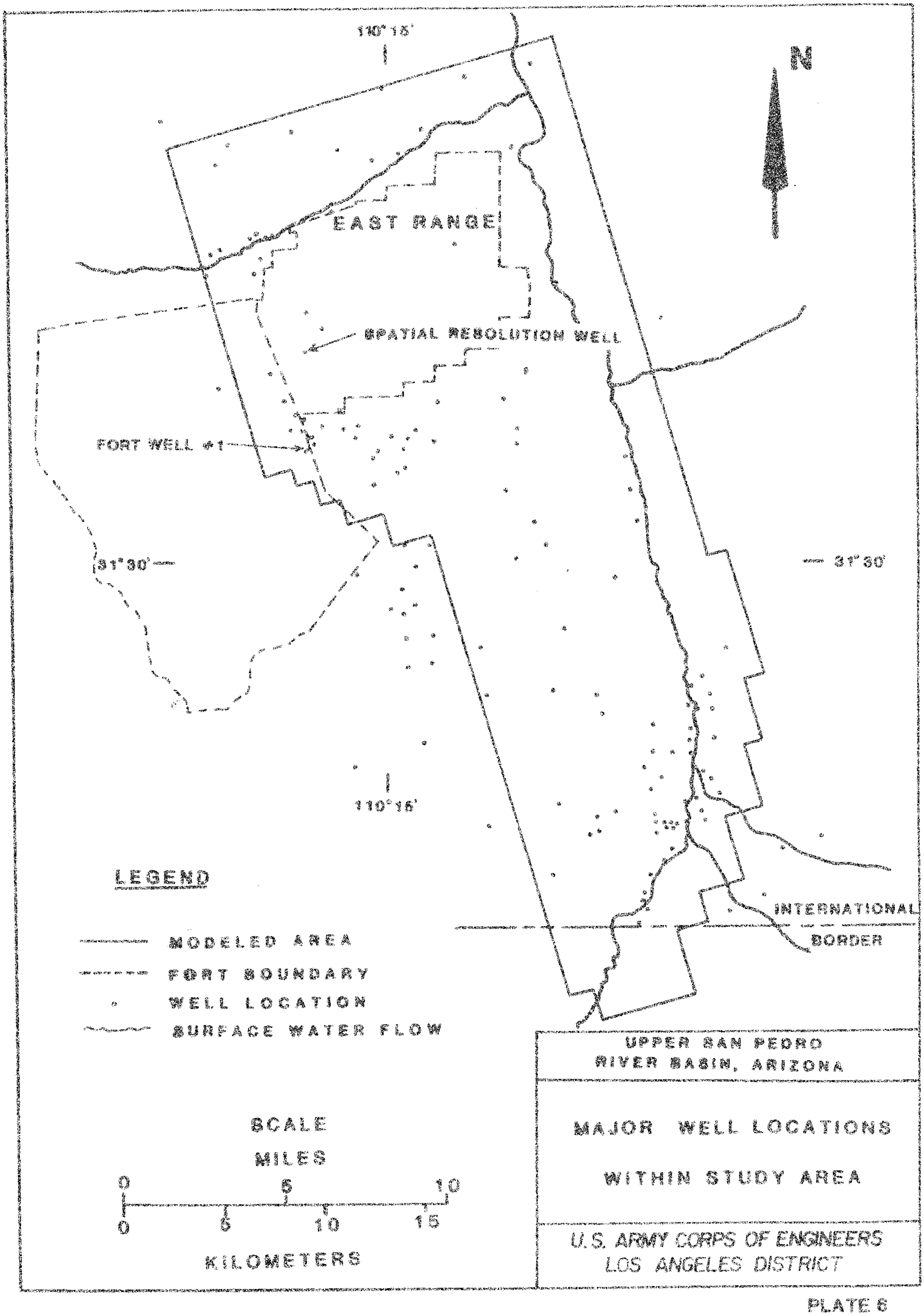
UPPER SAN PEDRO
RIVER BASIN, ARIZONA

SIMULATED ZONES OF

MOUNTAIN FRONT RECHARGE

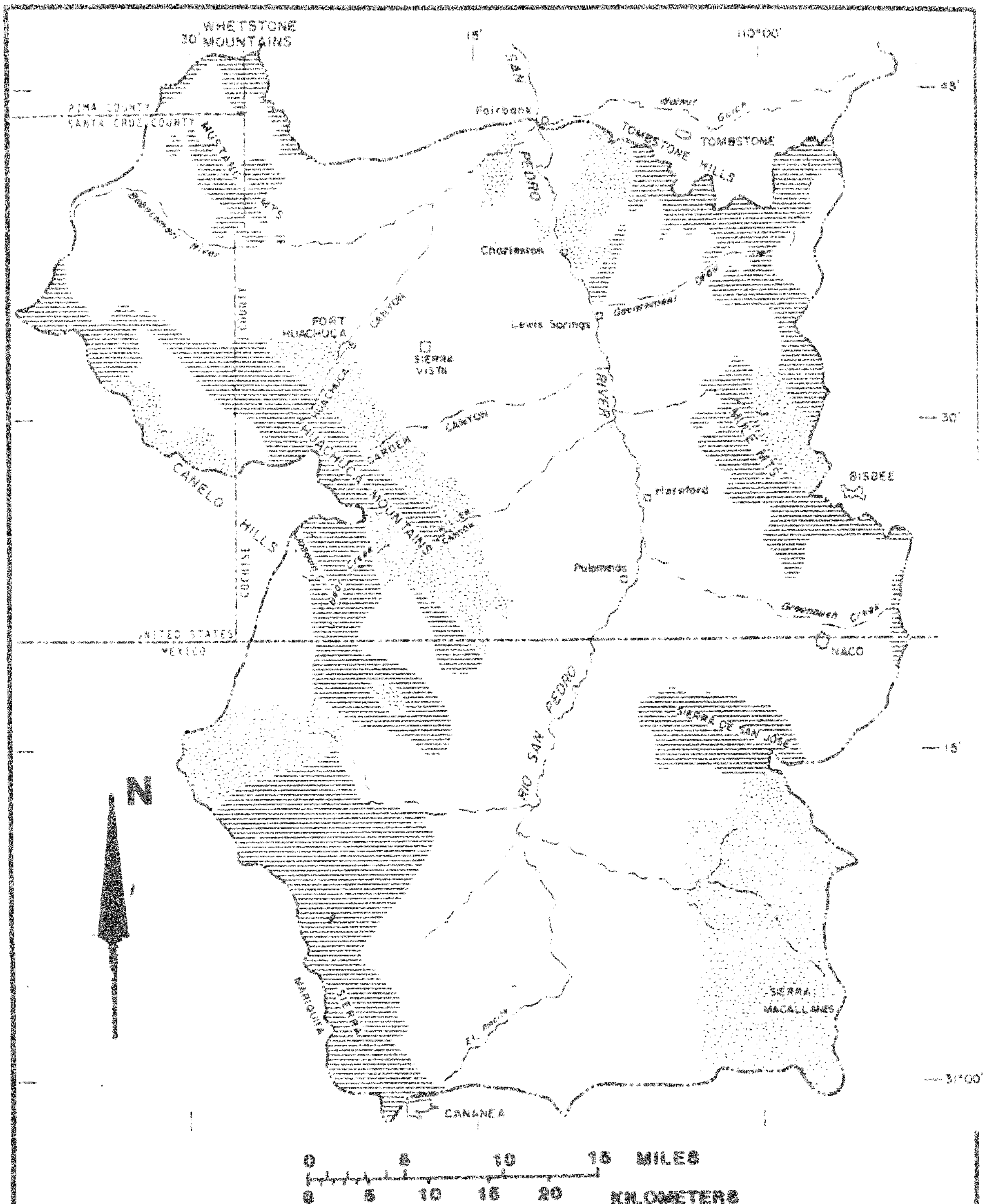
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 5



110°15'
N
EAST RANGE
SPATIAL RESOLUTION WELL
FORT WELL #1
31°30'
31°30'
110°15'
INTERNATIONAL
BORDER
LEGEND
MODELED AREA
FORT BOUNDARY
WELL LOCATION
SURFACE WATER FLOW
SCALE
MILES
0 5 10
0 5 10 15
KILOMETERS
UPPER SAN PEDRO
RIVER BASIN, ARIZONA
MAJOR WELL LOCATIONS
WITHIN STUDY AREA
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


PLATE 6




**LEGEND**

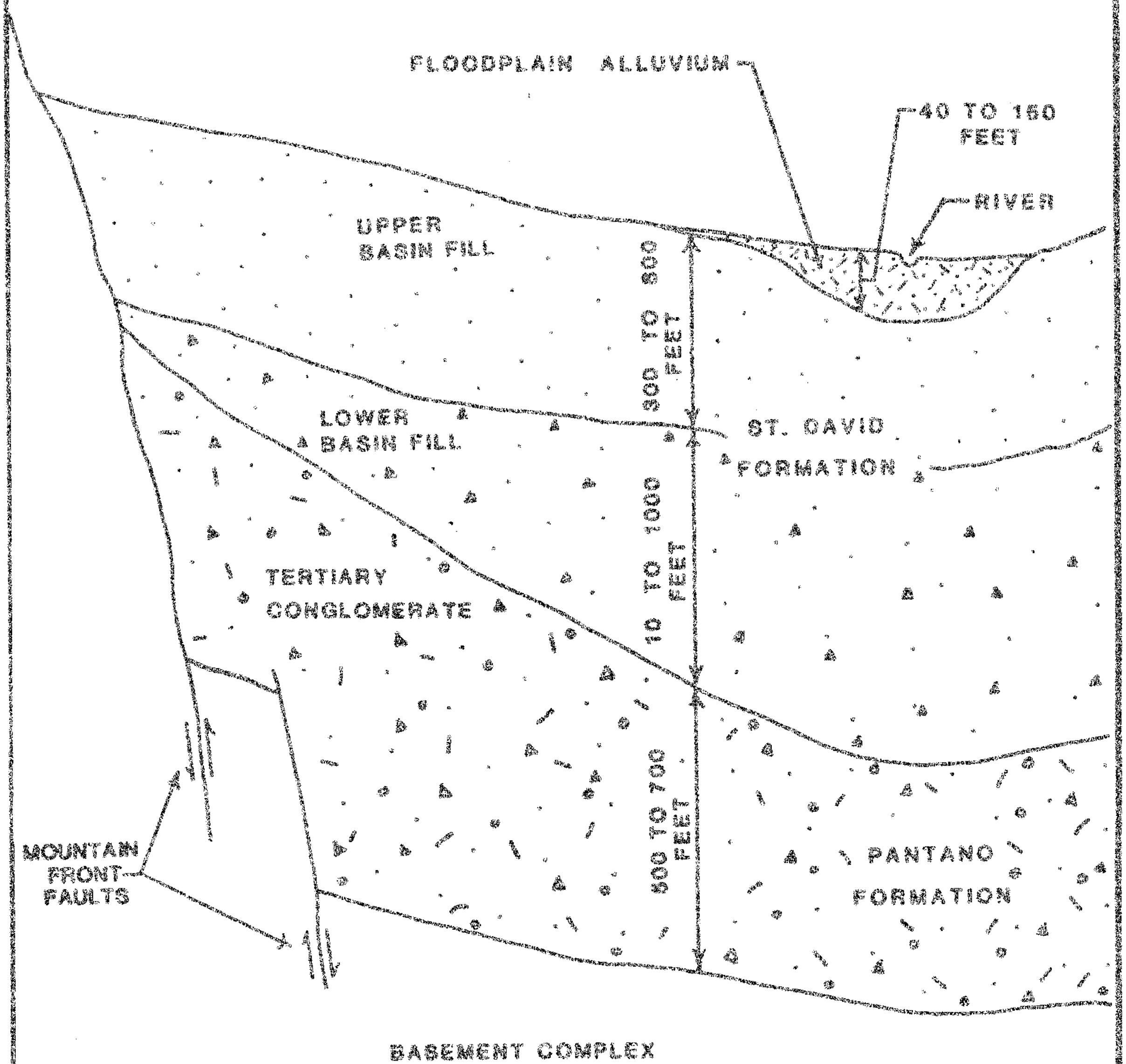
- BASIN BOUNDARY
- BASIN FILL
- SEDIMENTARY ROCKS
- IGNEOUS AND METAMORPHIC ROCKS

**UPPER SAN PEDRO RIVER BASIN, ARIZONA**

**GENERALIZED SURFICIAL GEOLOGY**

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

**PLATE 7**




(REF. 2)

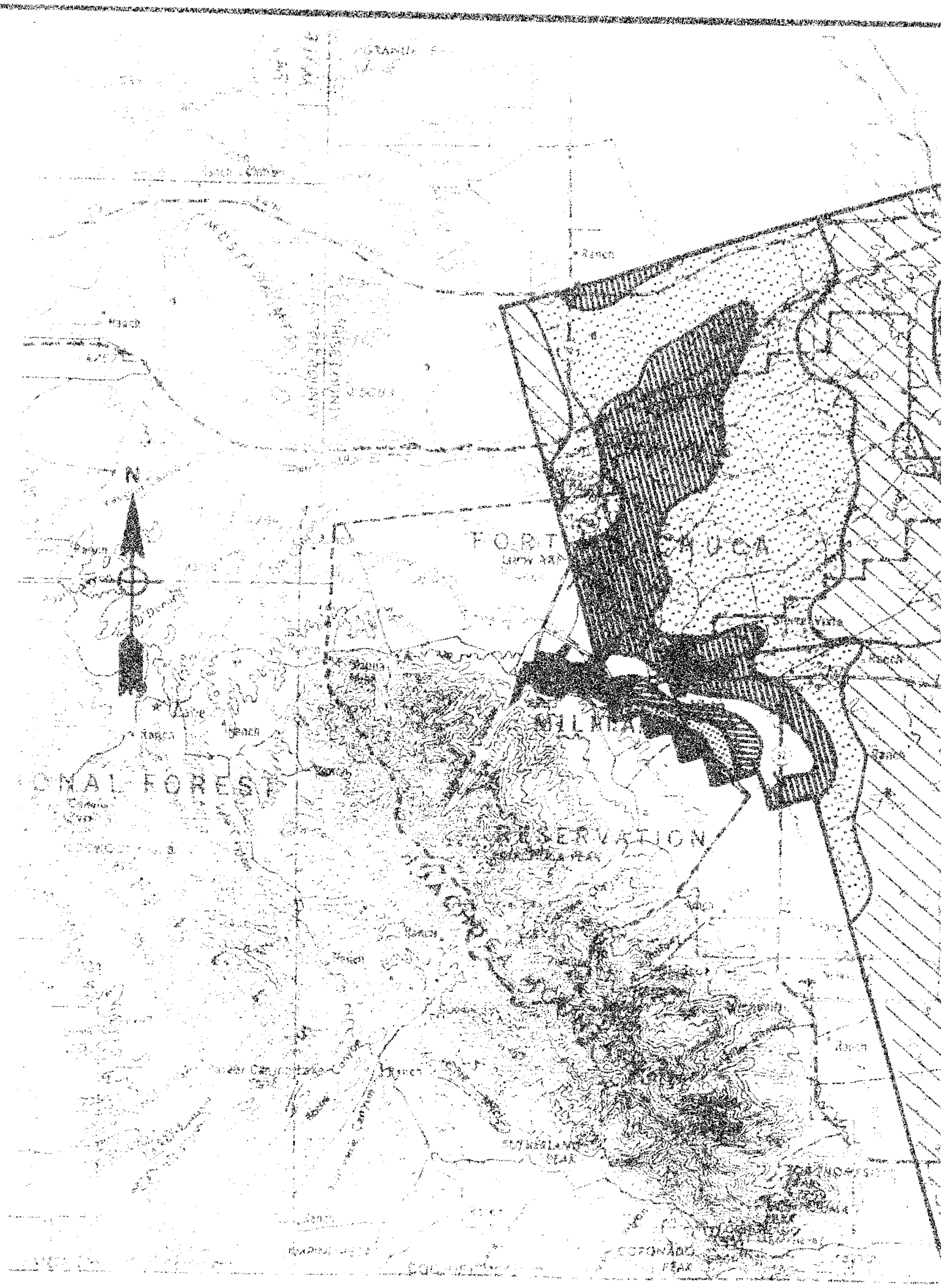
NOT TO SCALE

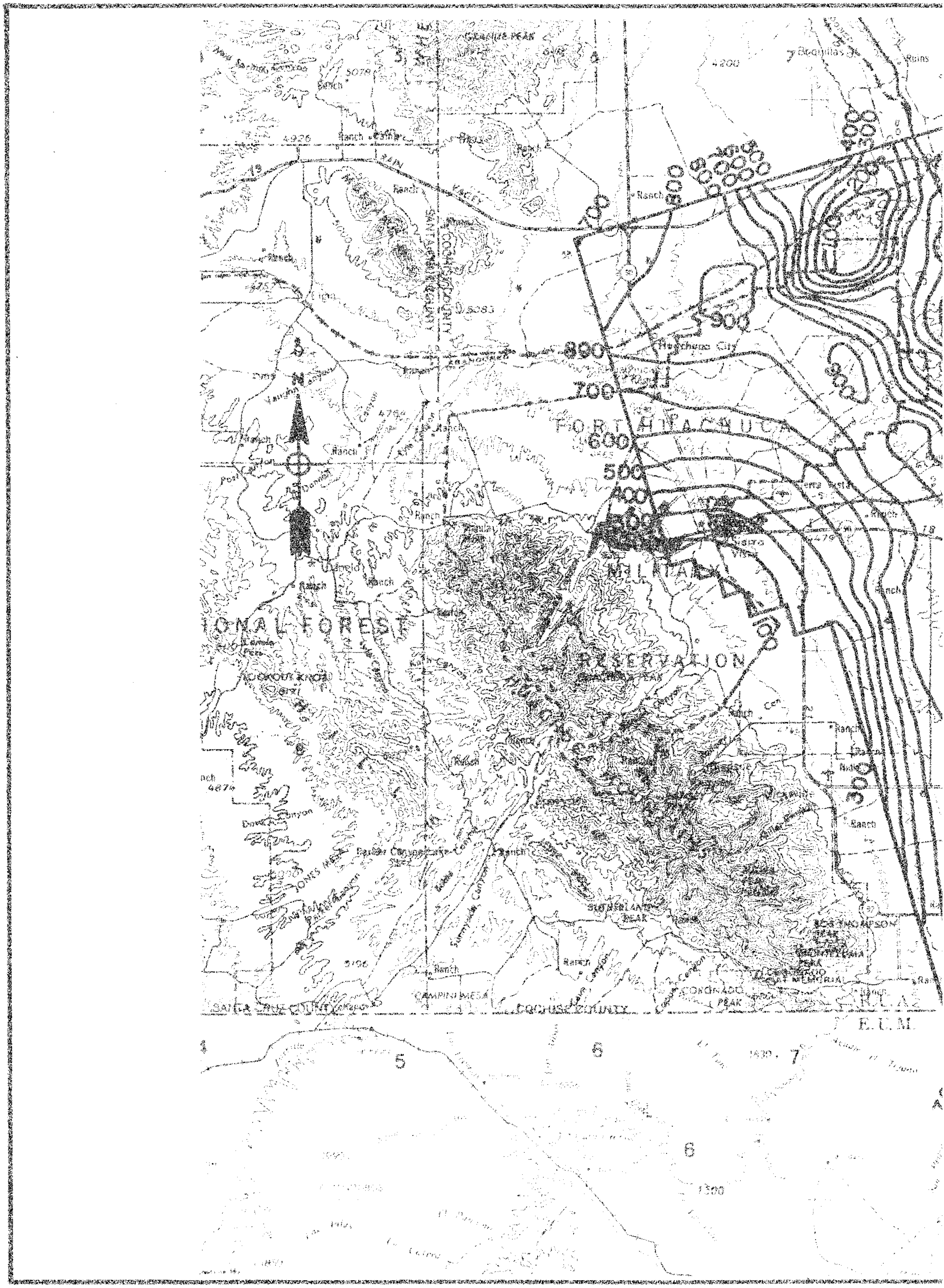
UPPER SAN PEDRO RIVER BASIN, ARIZONA

GENERALIZED GEOLOGIC RELATIONSHIPS

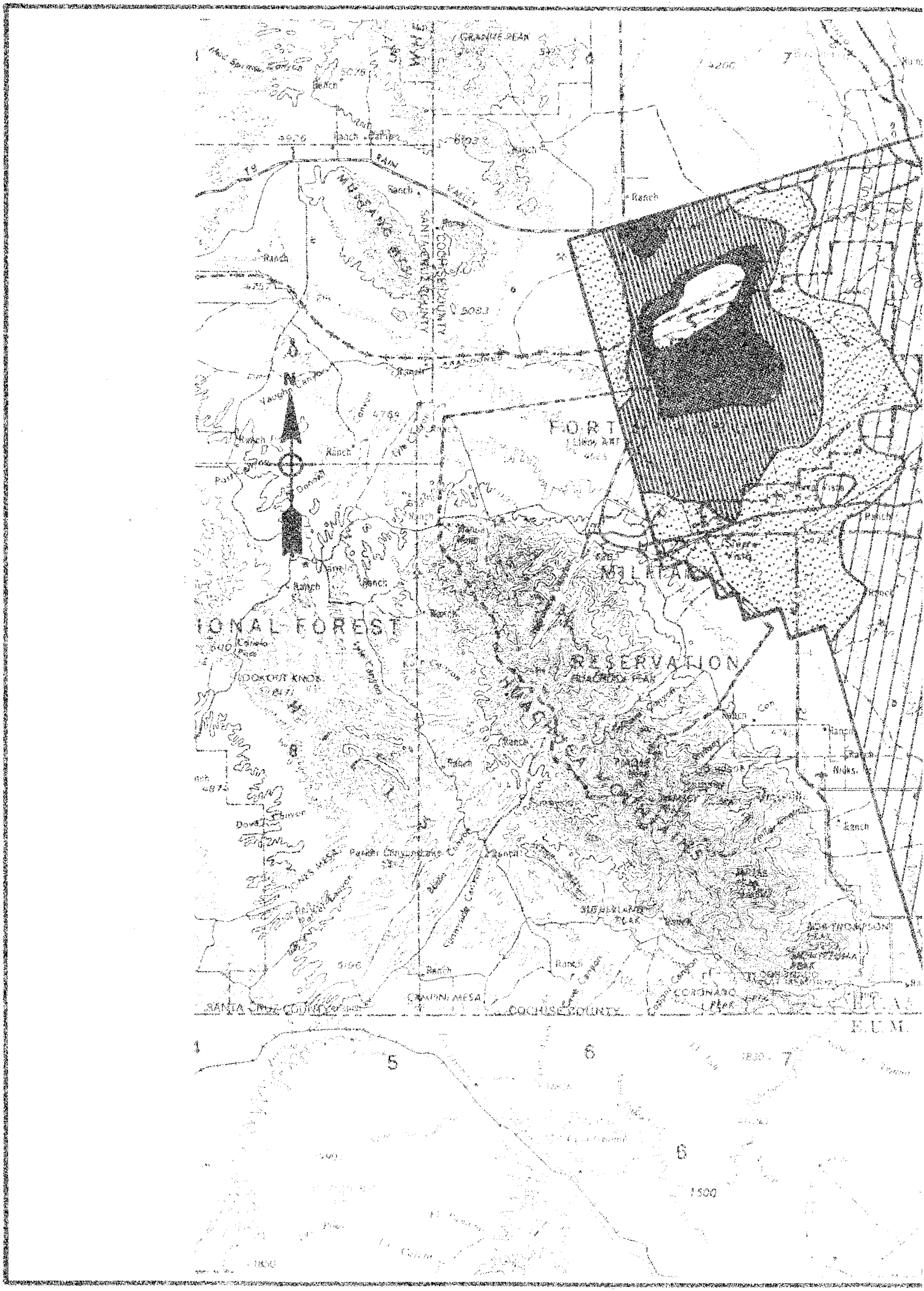
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 8

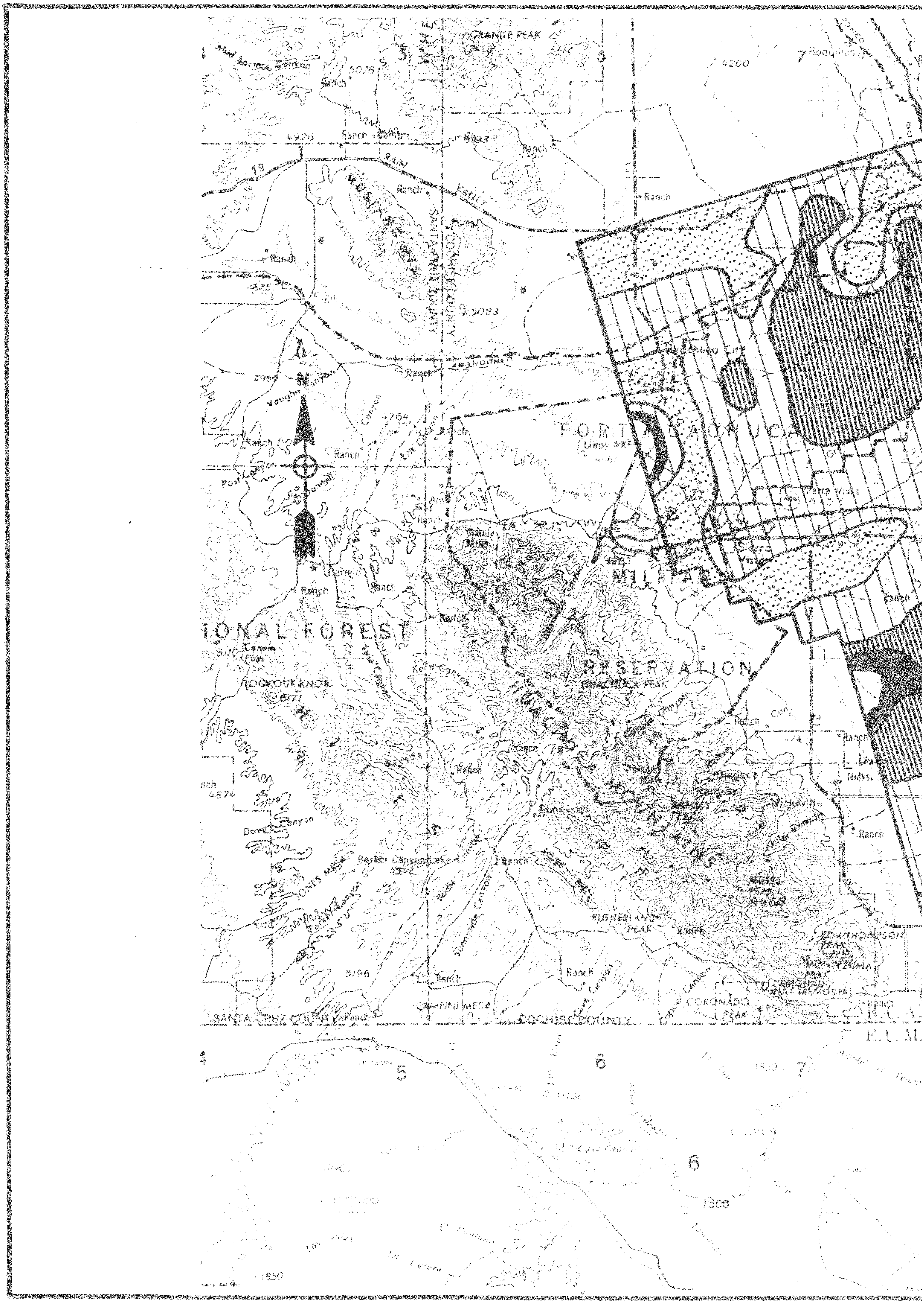

N
RESERVATION



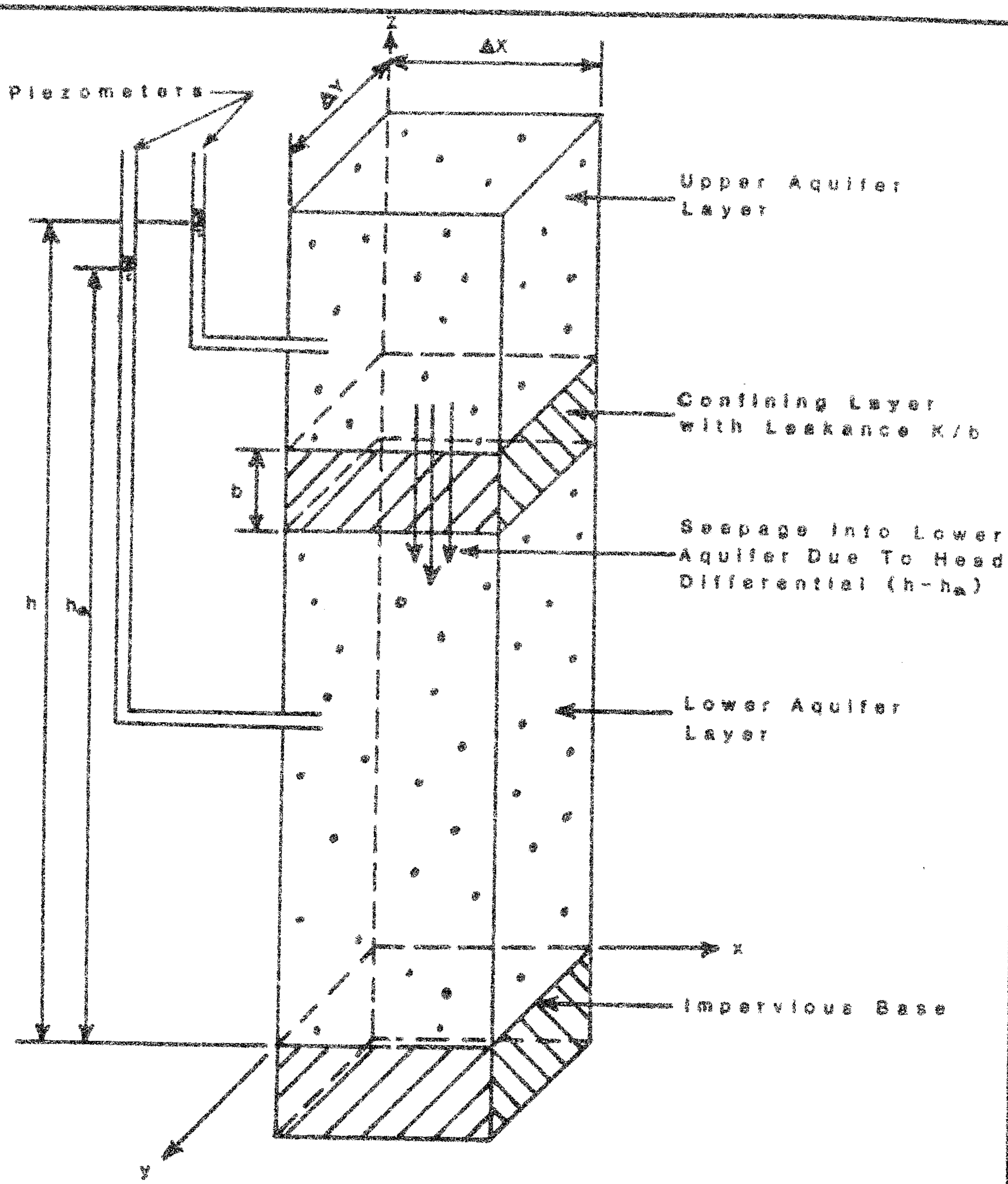
Huachuca City
FORT HUACHUCA
MILITARY
RESERVATION
IONAL FOREST
SANTA CRUZ COUNTY
COCHISE COUNTY
LOOKOUT KNOB
SUTHERLAND PEAK
CORONADO PEAK
CAMPINI MESA
Ranch
890
700
600
500
400
300
E.U.M.




USF200009936



GRANITE PEAK
SANTA CRUZ COUNTY
COCHISE COUNTY
FORT HUACHUCA
RESERVATION
IONAL FOREST
LOOKOUT KNOB
Parker Canyon Lake
CORONADO PEAK
SANTA CRUZ COUNTY
COCHISE COUNTY

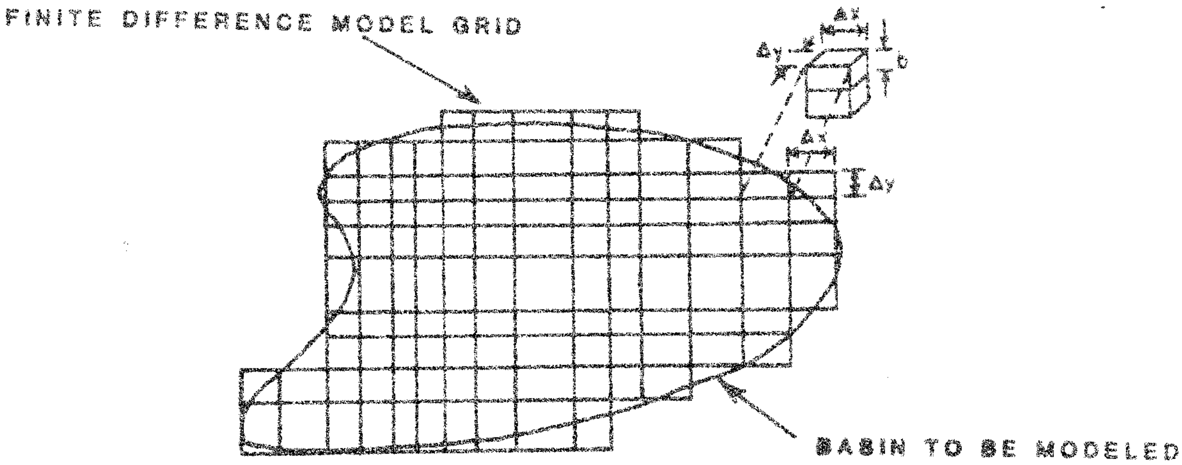



UPPER SAN PEDRO
RIVER BASIN, ARIZONA

**NON-EQUILIBRIUM FLOW THROUGH AN ELEMENTAL PRISM OF A TWO LAYER AQUIFER SYSTEM**

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 13

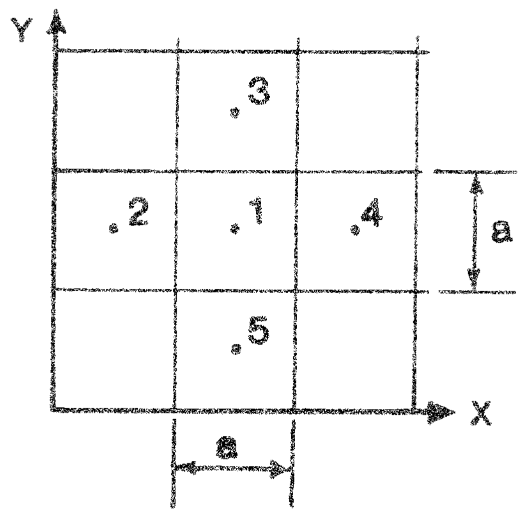



For the basic differential equation of ground water flow,

i.e.,

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{Sc}{T}\frac{\partial h}{\partial t}$$

the finite difference approximation is




$$\frac{h_2 + h_3 + h_4 + h_5 - 4h_1}{a^2} = \frac{Sc}{T}\frac{\partial h}{\partial t}$$

UPPER SAN PEDRO RIVER BASIN, ARIZONA

DESCRIPTION OF

MATHEMATICAL MODEL

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

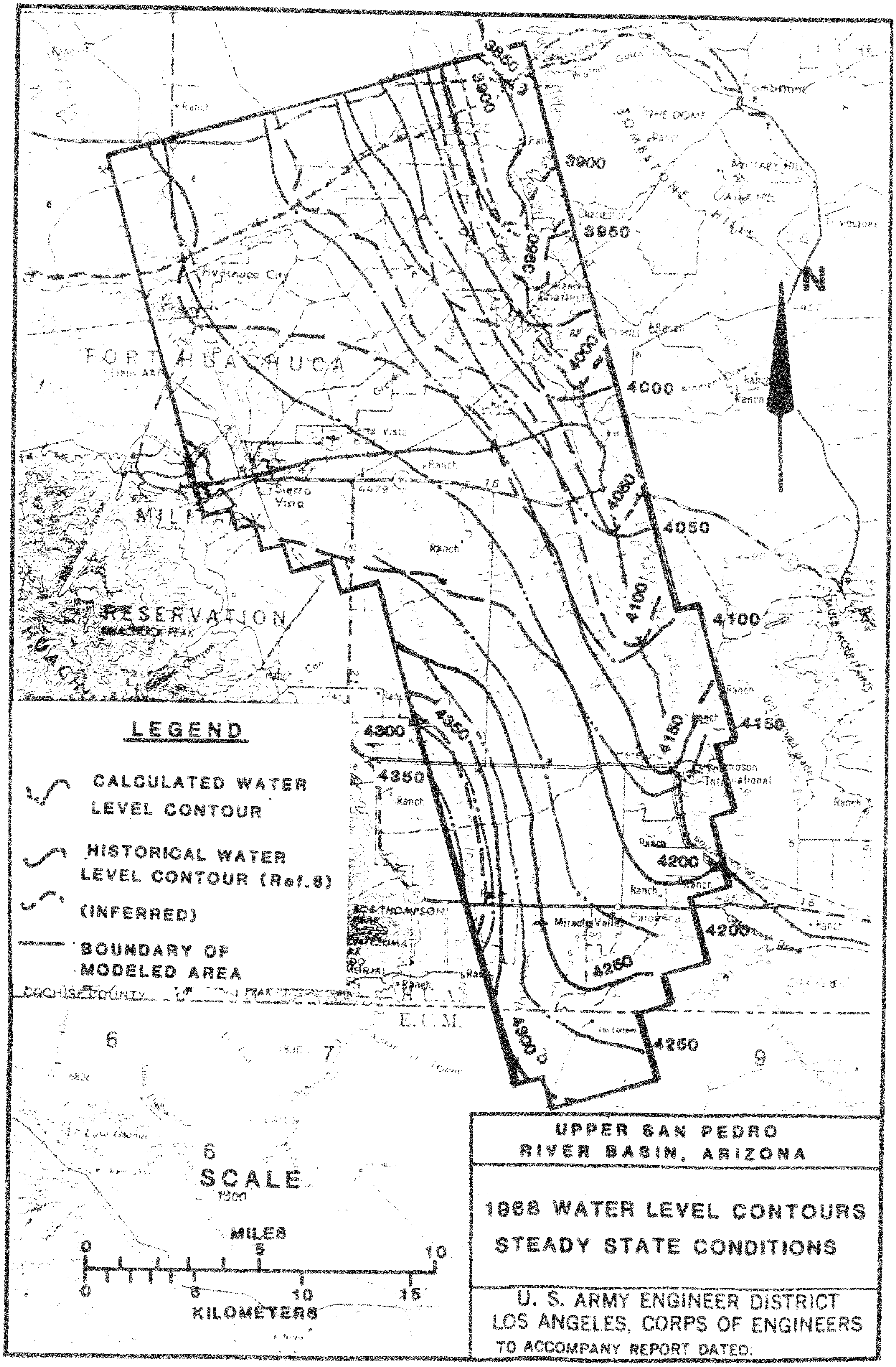
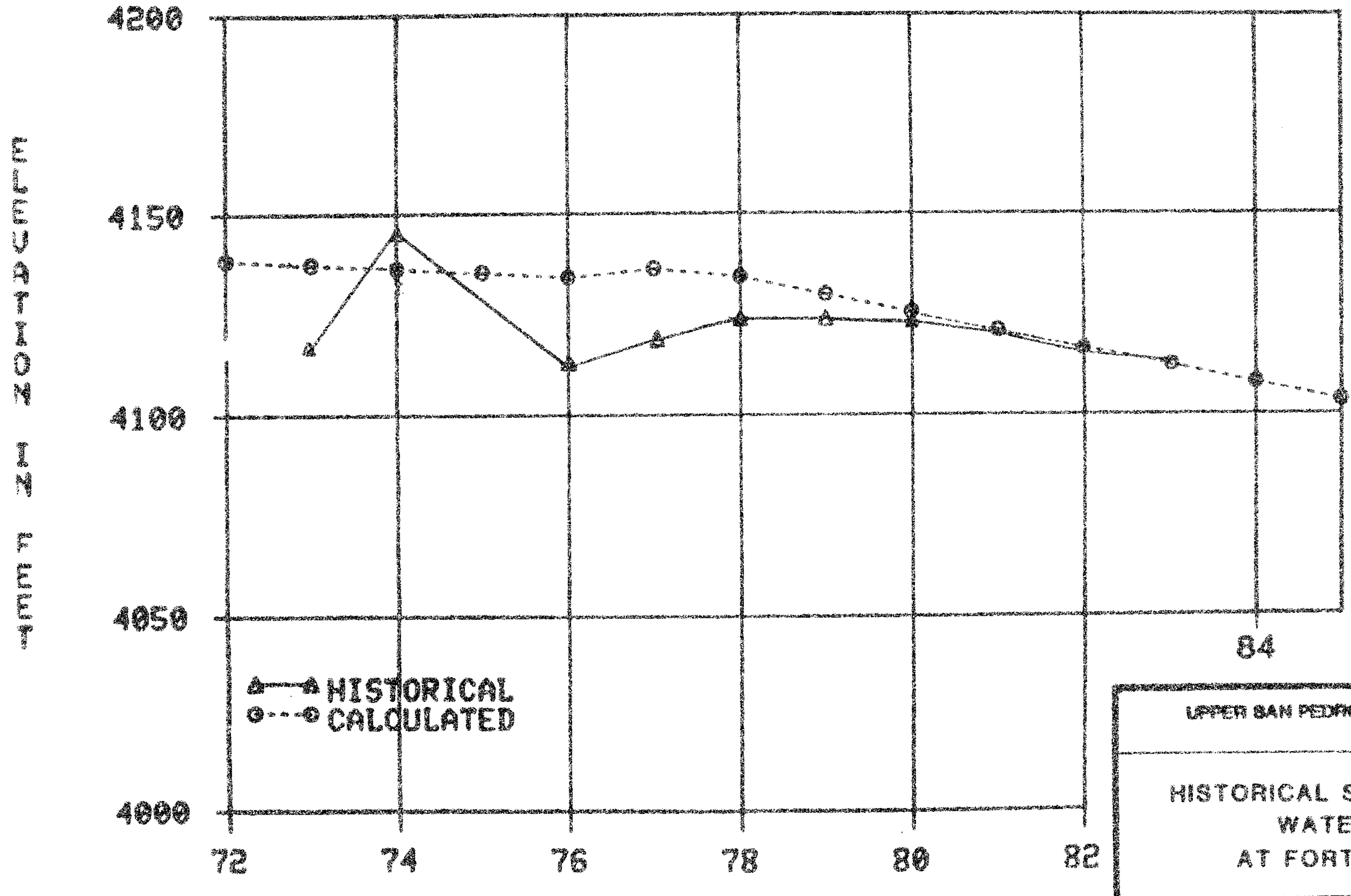

LEGEND
CALCULATED WATER LEVEL CONTOUR
HISTORICAL WATER LEVEL CONTOUR (Ref.8)
(INFERRED)
BOUNDARY OF MODELED AREA
FORT HUACHUCA
MILITARY
RESERVATION
Huachuca City
Sierra Vista
Miracle Valley
3850
3900
3950
4000
4050
4100
4150
4200
4250
4300
4350
N
SCALE
MILES
0
5
10
0
5
10
15
KILOMETERS
UPPER SAN PEDRO RIVER BASIN, ARIZONA
1988 WATER LEVEL CONTOURS
STEADY STATE CONDITIONS
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

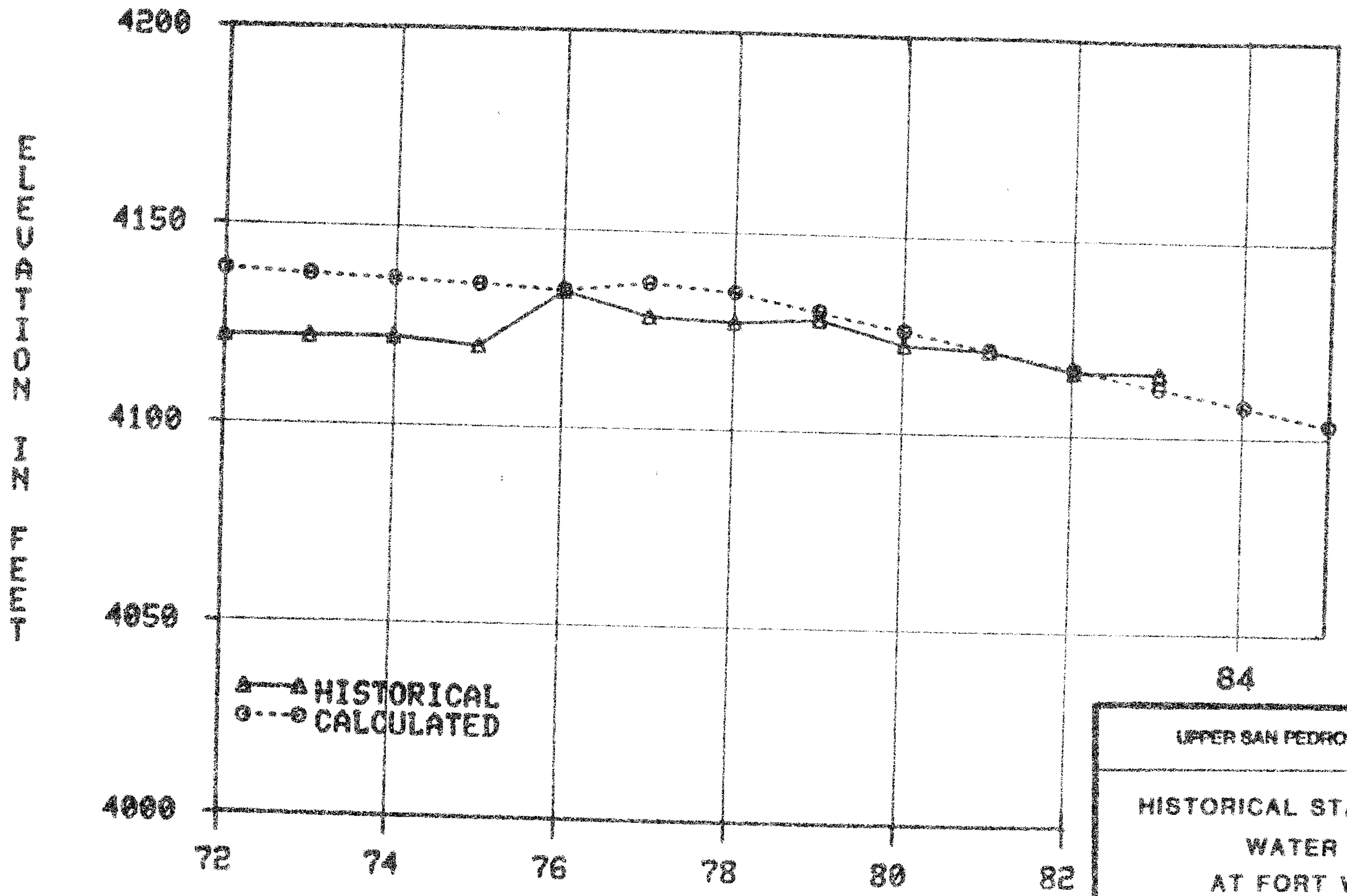
PLATE 15




UPPER SAN PEDRO BASIN, ARIZONA

HISTORICAL STATIC GROUND
WATER LEVEL
AT FORT WELL #1

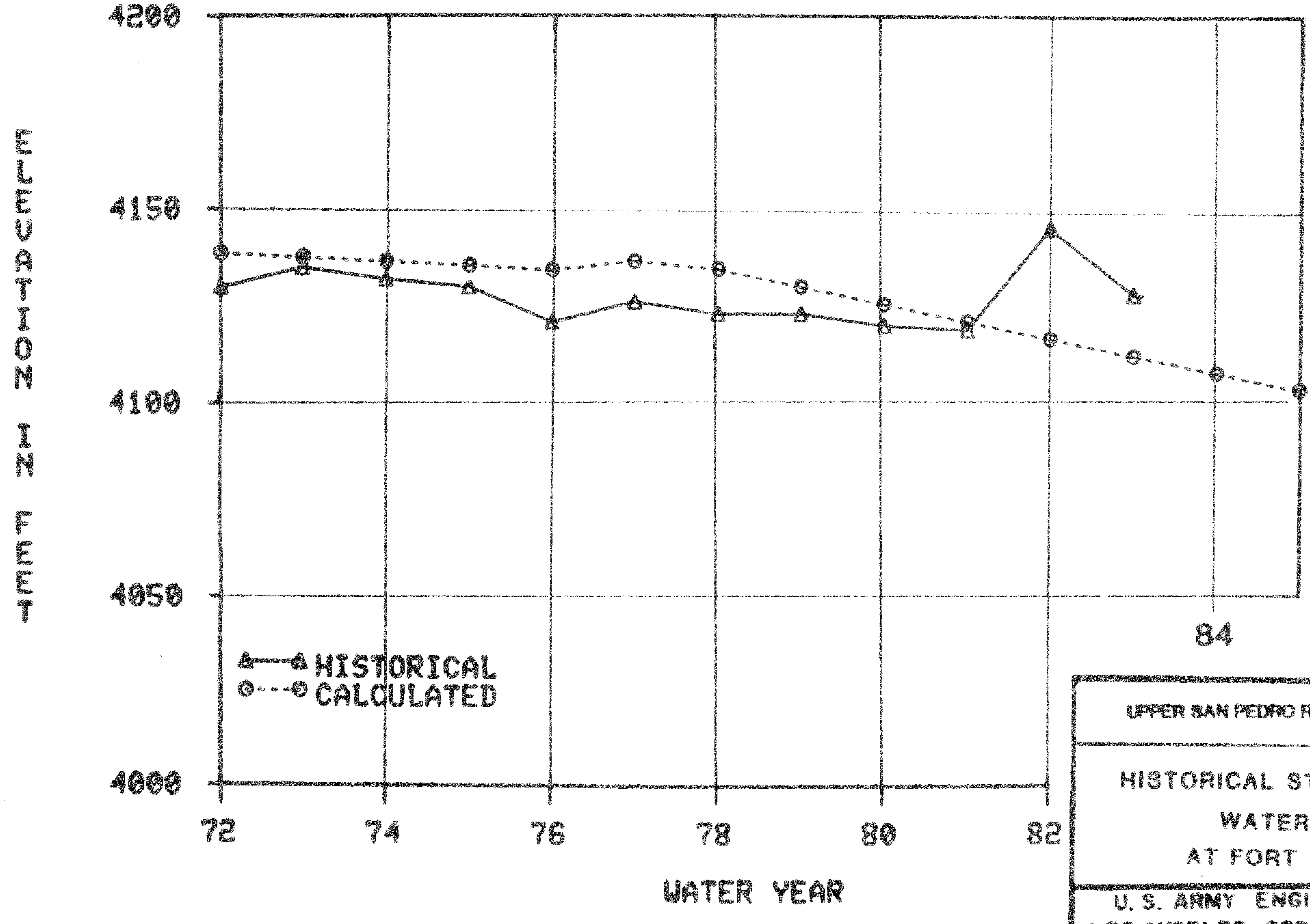
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:




UPPER SAN PEDRO BASIN, ARIZONA

HISTORICAL STATIC GROUND
WATER LEVEL
AT FORT WELL #2

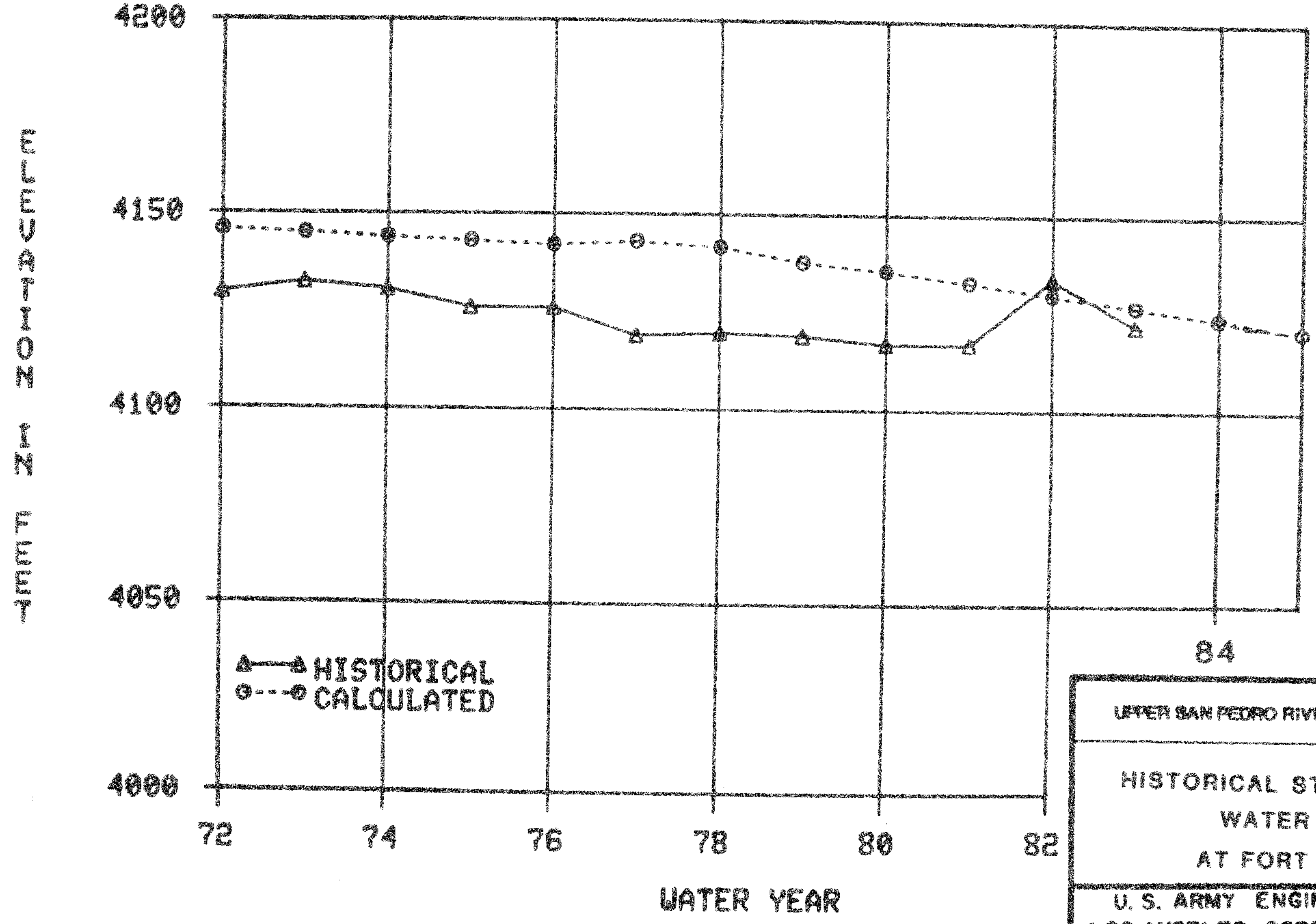
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:




UPPER SAN PEDRO RIVER BASIN, ARIZONA

HISTORICAL STATIC GROUND WATER LEVEL AT FORT WELL #3

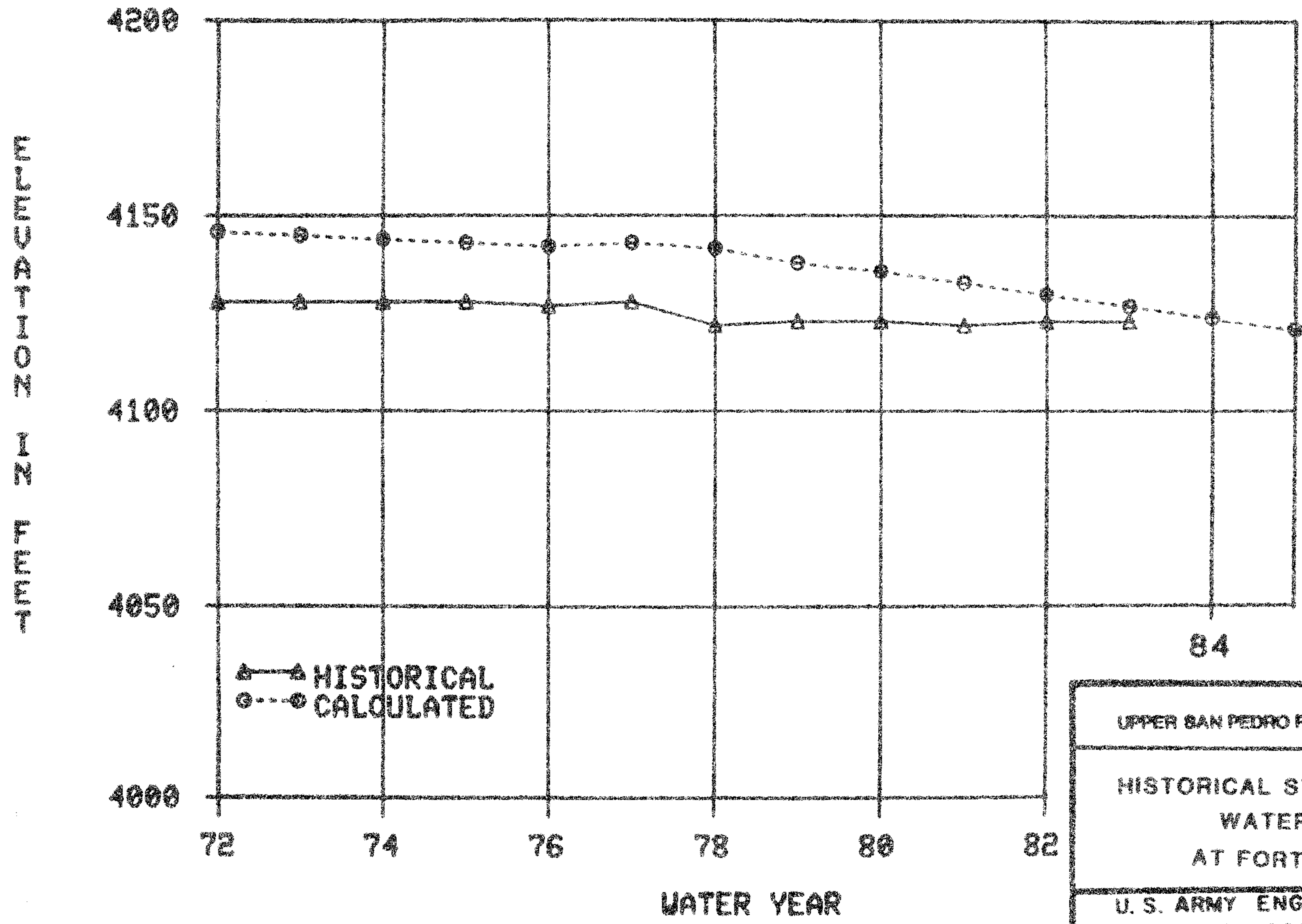
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:




UPPER SAN PEDRO RIVER BASIN, ARIZONA

HISTORICAL STATIC GROUND WATER LEVEL AT FORT WELL #4

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

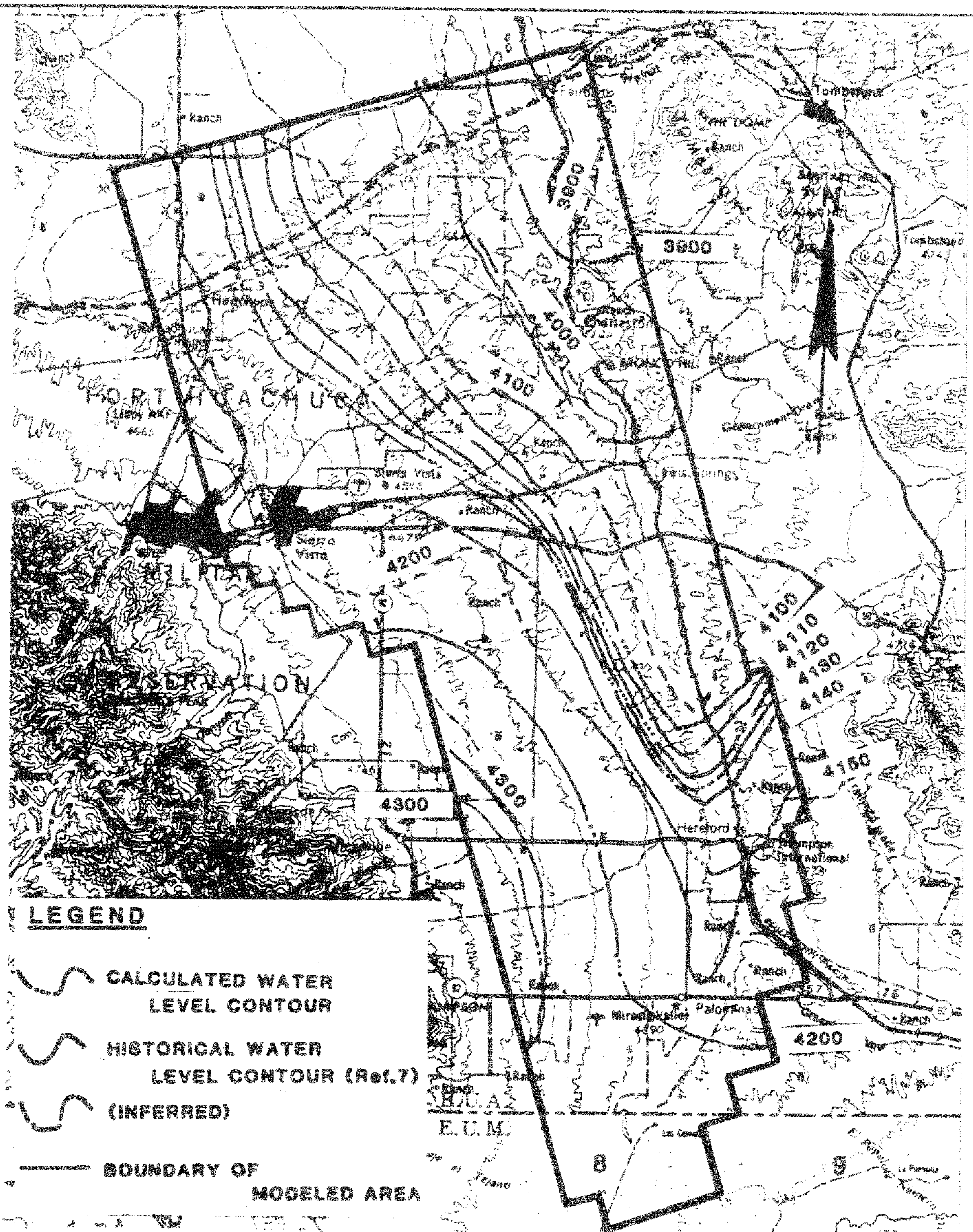



UPPER SAN PEDRO RIVER BASIN, ARIZONA

HISTORICAL STATIC GROUND
WATER LEVEL
AT FORT WELL #6

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 20




SCALE

MILES

0 5 10

0 5 10 15

KILOMETERS

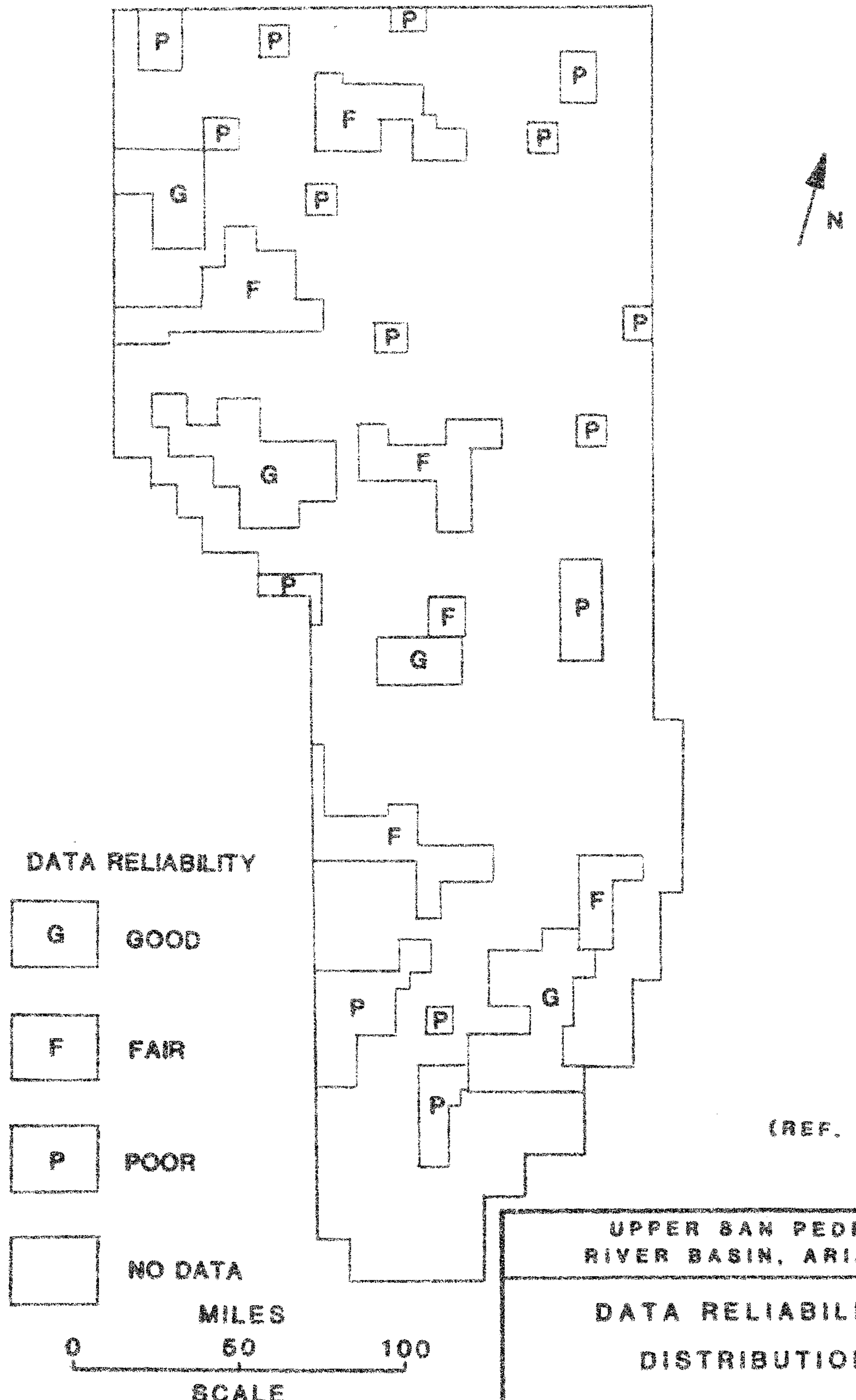
UPPER SAN PEDRO
RIVER BASIN, ARIZONA

1977 WATER LEVEL CONTOURS

TRANSIENT STATE CONDITIONS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 21



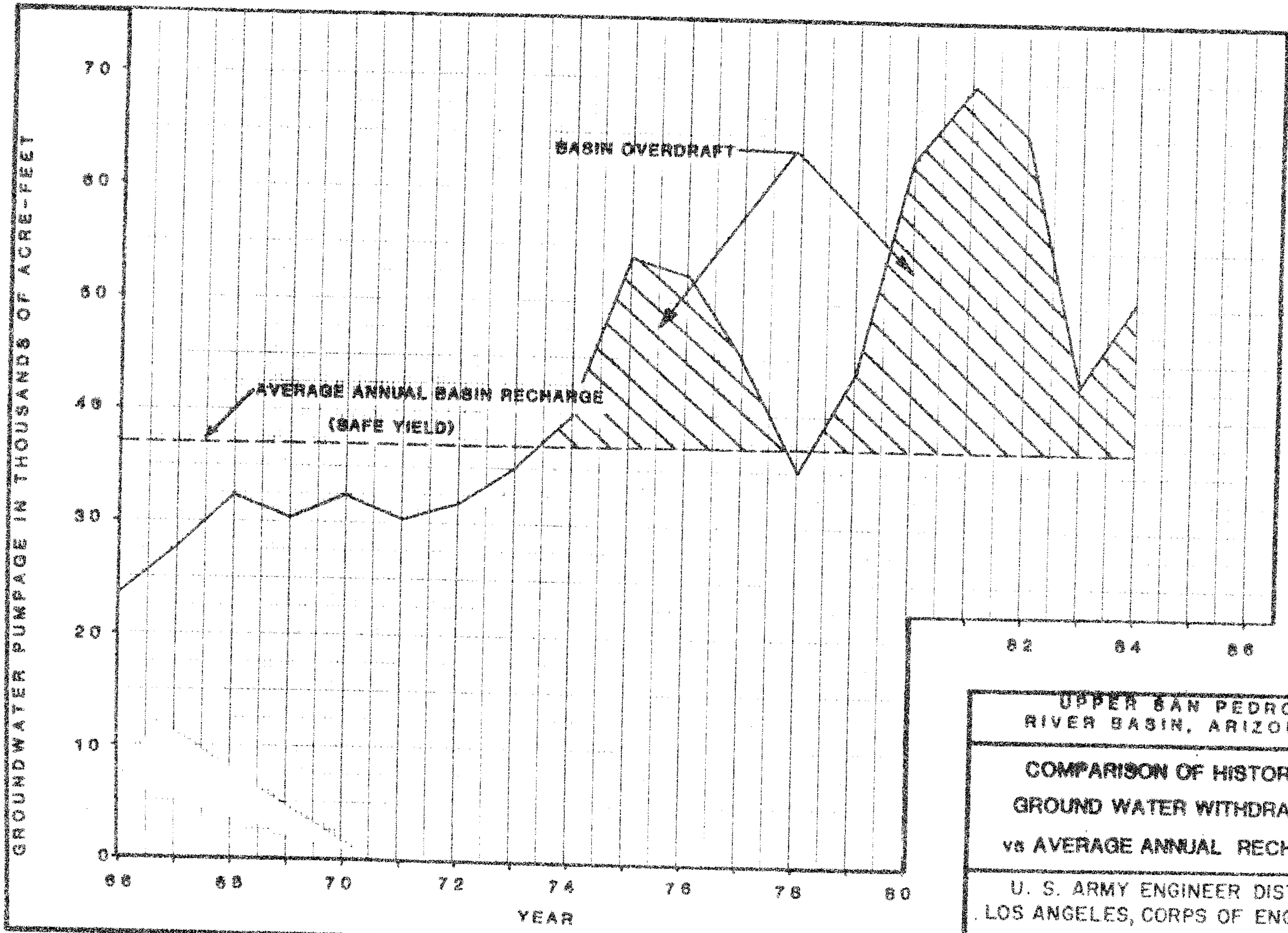

(REF. 5)

UPPER SAN PEDRO RIVER BASIN, ARIZONA

DATA RELIABILITY DISTRIBUTION

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 22




UPPER SAN PEDRO
RIVER BASIN, ARIZONA

**COMPARISON OF HISTORICAL GROUND WATER WITHDRAWALS vs AVERAGE ANNUAL RECHARGE**

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE 23

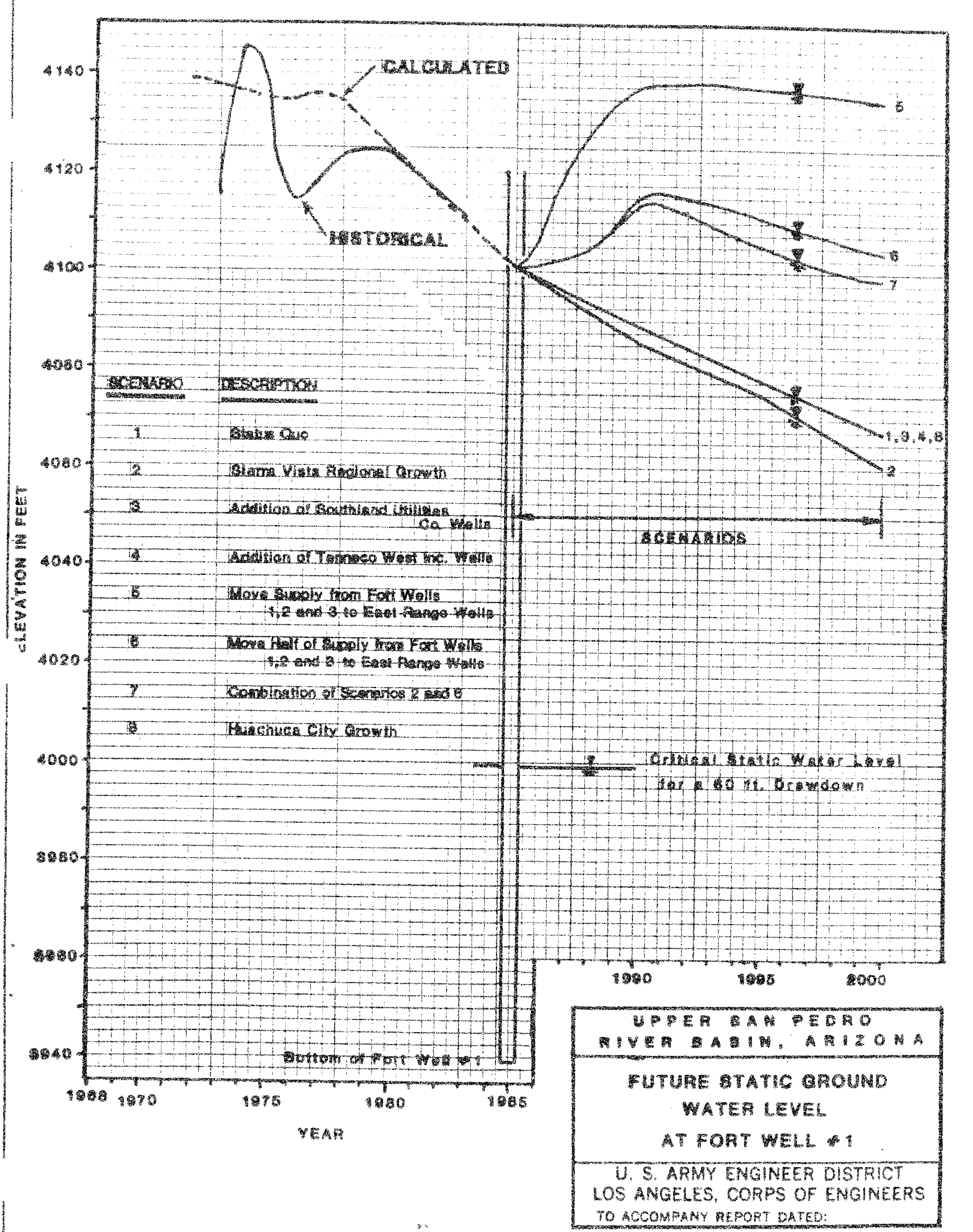
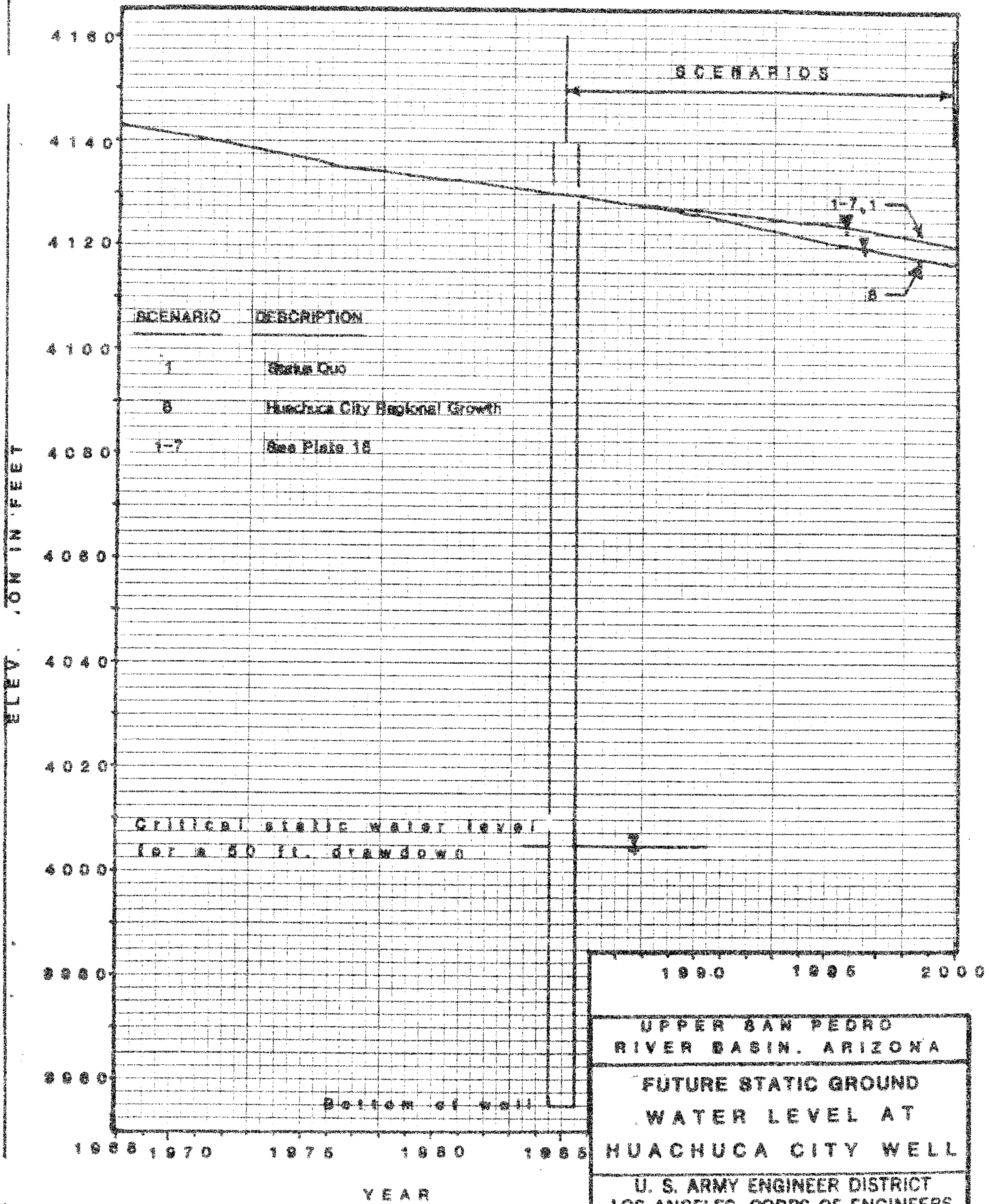



PLATE 24

USF200009949

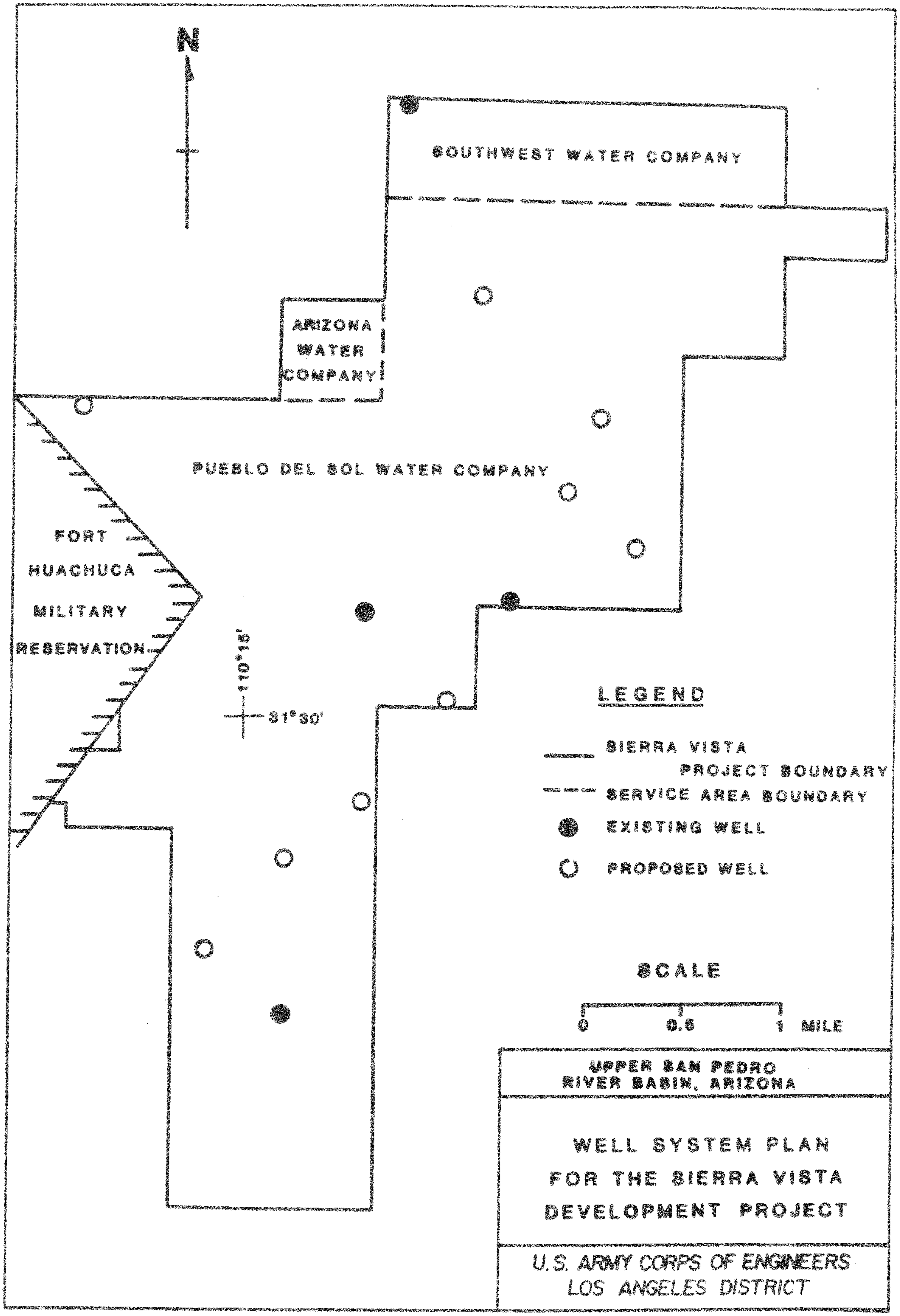



UPPER SAN PEDRO RIVER BASIN, ARIZONA

FUTURE STATIC GROUND WATER LEVEL AT HUACHUCA CITY WELL

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY REPORT DATED:

PLATE 25




UPPER SAN PEDRO RIVER BASIN, ARIZONA

WELL SYSTEM PLAN FOR THE SIERRA VISTA DEVELOPMENT PROJECT

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE 26