SIMULATED EFFECTS OF PROJECTED PUMPING ON THE AVAILABILITY OF FRESHWATER IN THE EVANGELINE AQUIFER IN AN AREA SOUTHWEST OF CORPUS CHRISTI, TEXAS

By George E. Groschen

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CONVERSION FACTORS

For use of readers who prefer to use System International units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
foot squared per day (ft^2/d)	0.0929	meter squared per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallons per minute (gal/min)	0.0630	liters per second
inch (in.)	25.40	millimeter
inch per year (in./yr)	25.40	millimeter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, called NGVD of 1929, is referred to as sea level in this report.

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ABSTRACT

This study is an investigation of the continued availability of freshwater in the Evangeline aquifer along the Texas Gulf Coast and the potential for degradation of the water quality by salinewater intrusion. Recharge to the aquifer occurs by the infiltration of precipitation in the outcrop area and by cross-formational flow from deeper aquifers. The predevelopment recharge rate is about 6 to 8 cubic feet per second. The predevelopment flow is toward the coast. The flow is semiconfined in the outcrop area and confined underneath the Chicot aquifer in the eastern two-thirds of the study area. Discharge, under natural conditions, is upward into the Chicot aquifer and to the Nueces River or Gulf of Mexico. Intensive pumping by irrigators, industries, and municipalities over the last 80 years has created a cone of depression as deep as 219 feet below sea level under the city of Kingsville in Kleberg County. The total rate of pumpage in 1982 was 29.6 cubic feet per second.

A mathematical model of the flow and water quality in the Evangeline aquifer was developed using available data to simulate the historical effect of pumping on the potentiometric surface and water quality, and to simulate the effect of projected pumping on the potentiometric surface and water quality to the year 2020. The water quality in the aquifer is only marginally suitable for drinking water. The chloride concentration before development in the 1930's and 1940's, ranged from 9 to 1,971 milligrams per liter. The mean chloride concentration was 353 (standard deviation 262) milligrams per liter. The potential sources of water-quality degradation on a regional scale are: Salinewater intrusion from under the Gulf of Mexico; movement of poor quality water within outlying sections of the aquifer; and downward leakage from the overlying Chicot aquifer. Leakage from the Chicot is the most likely to cause serious regional water-quality degradation. Other local potential sources of contamination are: Leaky well casings, oil-field brine disposal, water movement along faults, and in-situ uranium mining. These sources might create some local water-quality degradation. The results of the historical period simulation indicate, as do current field data, that little or no significant deterioration has occurred in the water quality of the Evangeline aquifer.

The simulations and the sensitivity tests of the aquifer properties, conditions, and assumptions indicate that vertical conductivity of the Chicot aquifer is the most sensitive and least well known part of the system. The storage coefficient of the Evangeline aquifer and the aggregate thickness of high-conductivity sand layers within the aquifer as well as the vertical distribution of these layers are also important properties that are not well known.

Two simulations of the projected pumping--a low estimate, as much as 46.2 cubic feet per second during 2011-20; and a high estimate, as much as 60.0 cubic feet per second during the same period--indicate that no further regional water-quality deterioration is likely to occur. Many important properties and conditions are estimated from poor or insufficient field data, and possible ranges of these properties and conditions are tested. In spite of the errors and data deficiencies, the results are based on the best estimates currently available. The reliability of the conclusions rests on the adequacy of the data and the demonstrated sensitivity of the model results to errors in estimates of these properties.

INTRODUCTION

History of Ground-Water Development

The Coastal Bend area (fig. 1) has a long history of ground-water development. The first wells that tapped the Evangeline aquifer were drilled prior to 1900. Most of these wells were for stock or domestic water supply on ranches. Many of these early wells flowed at rates of up to several hundred gallons per minute. By 1915, the potentiometric surface of the aquifer near these wells had dropped to the level where pumps had to be installed on many of the wells to maintain an adequate flow of water. An inventory of water wells made during 1932-33 shows that some of the large wells were still flowing, but at only a few gallons per minute. Currently (1982), only wells in the eastern and southeastern parts of the area have sufficient potentiometric head to flow. Irrigation of crops began near Falfurrias soon after the turn of the century by using flowing well water. Pumping equipment was installed as needed as potential heads dropped. Growth of irrigation in this area was steady until the late 1940's, when a severe winter seriously damaged the citrus crop. Ground-water use increased at a moderate rate, however, for irrigation of crops other than citrus fruit and for municipal water supply. The areas of intense irrigation spread from the Falfurrias district to southern Jim Wells and southern Duval Counties.

By 1968 there were about 60 irrigation wells in the southern ends of these two counties. This use of ground water has drawn the water levels down less than 50 ft over a wide area.

Meanwhile, municipal and industrial use of Evangeline ground water had been increasing steadily since the turn of the century. Most of the industrial use is related to oil and gas development. The increased pumping by municipalities and industry has resulted in large water-level drawdowns over much of the study area. The most notable area of drawdown is in the vicinity of the city of Kingsville. The water levels in this area have declined to as low as 219 ft below sea level. Other smaller depressions of potential head occur under Falfurrias and in an industrial area about 10 mi southwest of Kingsville. Withdrawals for municipal water supply in the city of Alice had produced a moderate cone of depression in that area by 1961. In 1964, the city of Alice started using surface water as the primary municipal supply. Currently, the water levels in the Evangeline aquifer around Alice have returned to the 1930's conditions.

The problems created by this intensive ground-water use are:

1. More energy is needed to pump from a lower static head;
2. More wells need to be drilled on a regular basis to replace old wells and to increase overall supply; and
3. There is an increasing potential for deterioration of water quality, by drawing water with high dissolved solids into the productive part of the aquifer.

The large water-level declines have reversed the natural Gulfward flow and the natural upward leakage in the cones of depression. Inferior water may flow into the productive part of the aquifer from the overlying formations, the Gulf Coast, or from other parts of the aquifer. The natural quality of the Evangeline water is marginal for drinking, according to the U.S. Environmental Protection Agency standards (1977). Therefore, any deterioration of the present

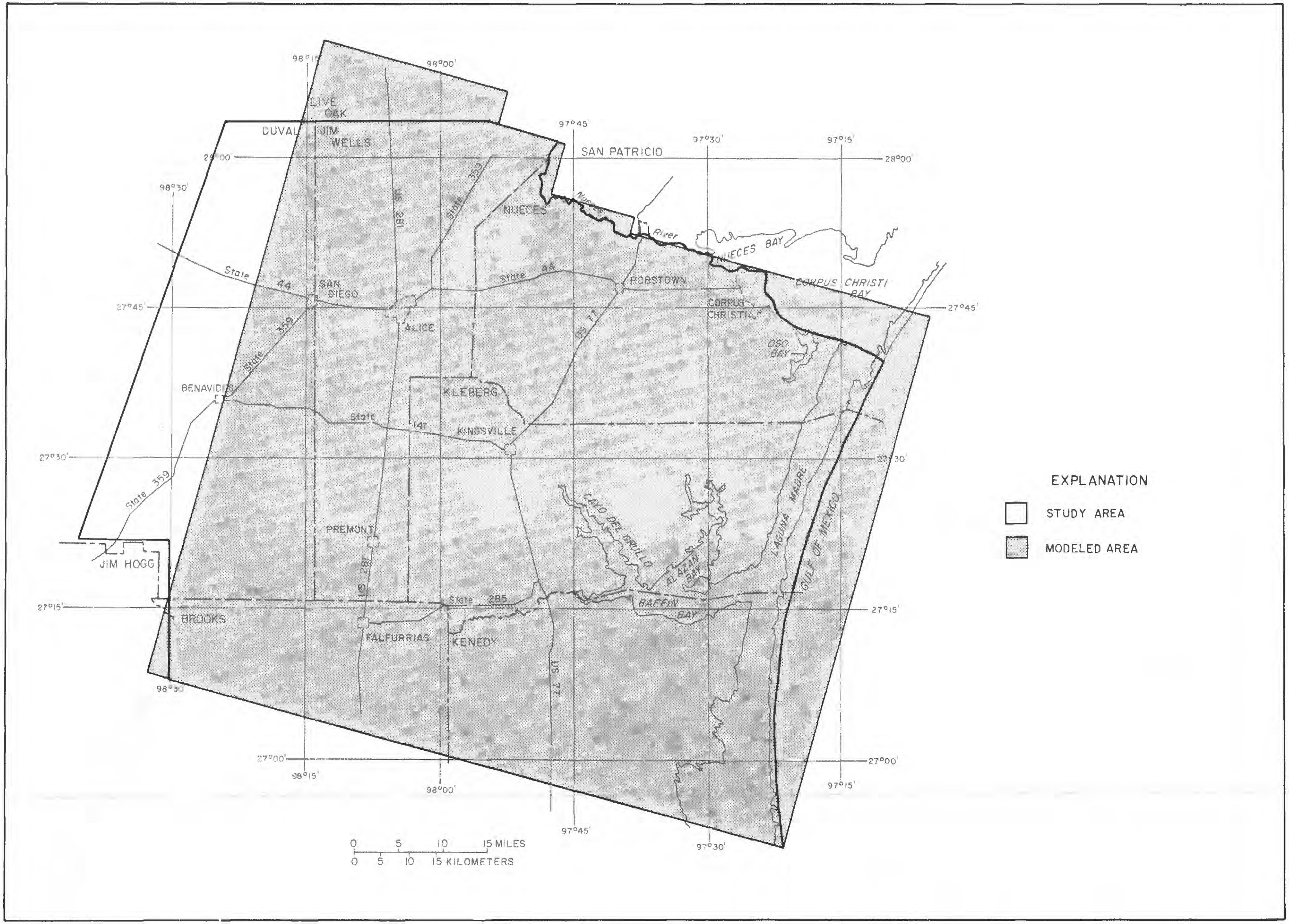

Figure 1.--Location of study and modeled areas.

quality, due to continued intensive pumpage, is of serious concern. What is needed is a study of the effect of historical water pumping on the present availability of freshwater and the effect of continued and increased pumpage on the occurrence and movement of salinewater in the Evangeline aquifer.

Purpose and Scope

This report is a summary of the second phase of a study to assess the potential for contamination of the Evangeline aquifer in south Texas. This study investigates the regional effects of historic and projected ground-water use on the occurrence and movement of salinewater in the Evangeline aquifer. Phase 1 objectives were to collect and compile data on the current (1982) water-level and water-quality conditions in the aquifer. These data are presented in a published report (Rettman, 1983). Phase 2 objectives are to assess the present availabilty of freshwater under present management conditions and to assess the continued availability of freshwater under projected increasing pumping. This second objective includes mathematical simulation of the potential for salinewater movement into the productive part of the aquifer.

Approach and Previous Investigations

A mathematical model is used to simulate ground-water flow and transport of solute in the Evangeline aquifer to determine the potential for salinewater movement into the aquifer. All the available historical and phase 1 data were compiled and used to construct the mathematical model of the aquifer system. This model is used to simulate the conceptual prototype of the aquifer system.

Many published data reports and investigations were reviewed for useful data and to help develop a concept of the flow system. Taylor (1907) briefly described wells in the area. Livingston and Bridges (1936) collected a large amount of ground-water data in Kleberg County. Sayre (1937) conducted a detailed investigation of the hydrogeology of Duval County. Well inventories for each county were compiled during the 1930's and 1940's (Lynch, 1934; Turner and Cumley, 1940a,b; White, 1940a,b,c). Barnes (1940) reported on the water supply of Falfurrias. Livingston and Broadhurst (1942) explored saltwater leaks in the wells on the King Ranch southeast of Kingsville. George and Cromack (1943) described the ground-water conditions at Kingsville. Cromack (1944) described, in general, the source and quality of the ground water in southern Jim Wells and northeastern Brooks Counties. Elling (1953) and Eskew (1958) collected large amounts of water-level data around Kingsville.

Detailed reports on the ground-water resources of each county have been published more recently. Myers and Dale (1967) reported on Brooks County, Shafer (1968) reported on Nueces and San Patricio Counties, and Mason (1963) summarized information on the ground water in the Alice area of Jim Wells County. Shafer and Baker (1973) reported on the ground-water quantity and quality in Kleberg, Kenedy, and southern Jim Wells Counties, and Shafer (1974) reported on recent data collected in Duval County. Solis (1981) investigated, in detail, the relationship between the lithology and the hydrology of the upper Tertiary and Quaternary deposits in the northern one-third of the study area. As part of a more general modeling study, Carr and others (1984) studied effects of pumping on water levels and land subsidence in the Coastal Bend area.

Using the data compiled from these reports and based on a conceptual prototype developed by these investigators, a mathematical model of the prototype was constructed. By calibrating the flow and solute transport model in accordance with the field data, new and modified concepts of the flow system and geochemistry emerge. When the model is considered sufficiently reliable, based on data availability and integrity, the calibrated model simulates the effect of projected pumping on the water levels and water quality.

Location of Study Area

Data collection for phase 1 and data compilation for phase 2 cover a rectangular 4,680-mi^2 area that extends inland about 65 mi from the Gulf of Mexico. Corpus Christi (population about 232,000) is located in the northeast corner of the area, and Kingsville (population about 29,000) is located in the center of the study area. The area includes all of Jim Wells, Nueces, and Kleberg Counties and parts of Kenedy, Duval, Brooks, Jim Hogg, San Patricio, and Live Oak Counties. The area modeled as part of this investigation is enclosed by a rectangle in figure 1. The area chosen for the model is described in more detail in the model section of this report.

Acknowledgments

This study was undertaken by the Water Resources Division of the Geological Survey with the cooperation of the Coastal Bend Council of Governments. William Sandeen helped in the phase 1 data collection and was of great assistance with compiling the water-use data. Paul Rettman did considerable work in compiling aquifer-test data, reformatting water-use information, and mapping. Fred Arteaga did the kriging of the chloride data.

HYDROGEOLOGY

Geologic Framework

The geologic formations that contain fresh to slightly saline water are, in order of decreasing age, the Catahoula Tuff, Oakville Sandstone, and Lagarto Clay of Miocene age, the Goliad Sand of Pliocene age, the Lissie Formation and Beaumont Clay of Pleistocene age, the south Texas eolian plain deposits of Pleistocene(?) and Holocene age, and the barrier island deposits and alluvium of Holocene age. All of these units except the Catahoula Tuff and Oakville Sandstone are exposed in the area of this study (fig. 2). A generalized cross section of the flow system is shown in figure 3.

The geologic formations, except the alluvium and the south Texas eolian deposits, crop out in belts that are nearly parallel to the Gulf Coast. Younger formations generally crop out close to the coast and successively older ones farther inland. Because of the different ages of the formations, the outcrops are progressively eroded and dissected inland. The Goliad Sand, the south Texas eolian deposits, and the alluvium transgress the other geologic formations. The Goliad Sand lies in contact with and on top of the Catahoula Tuff, the Oakville Sandstone, and the Lagarto Clay. The area where the Goliad lies on top of the Catahoula Tuff and the Oakville Sandstone is west of the areal model but in the area included in the cross-section model analysis.

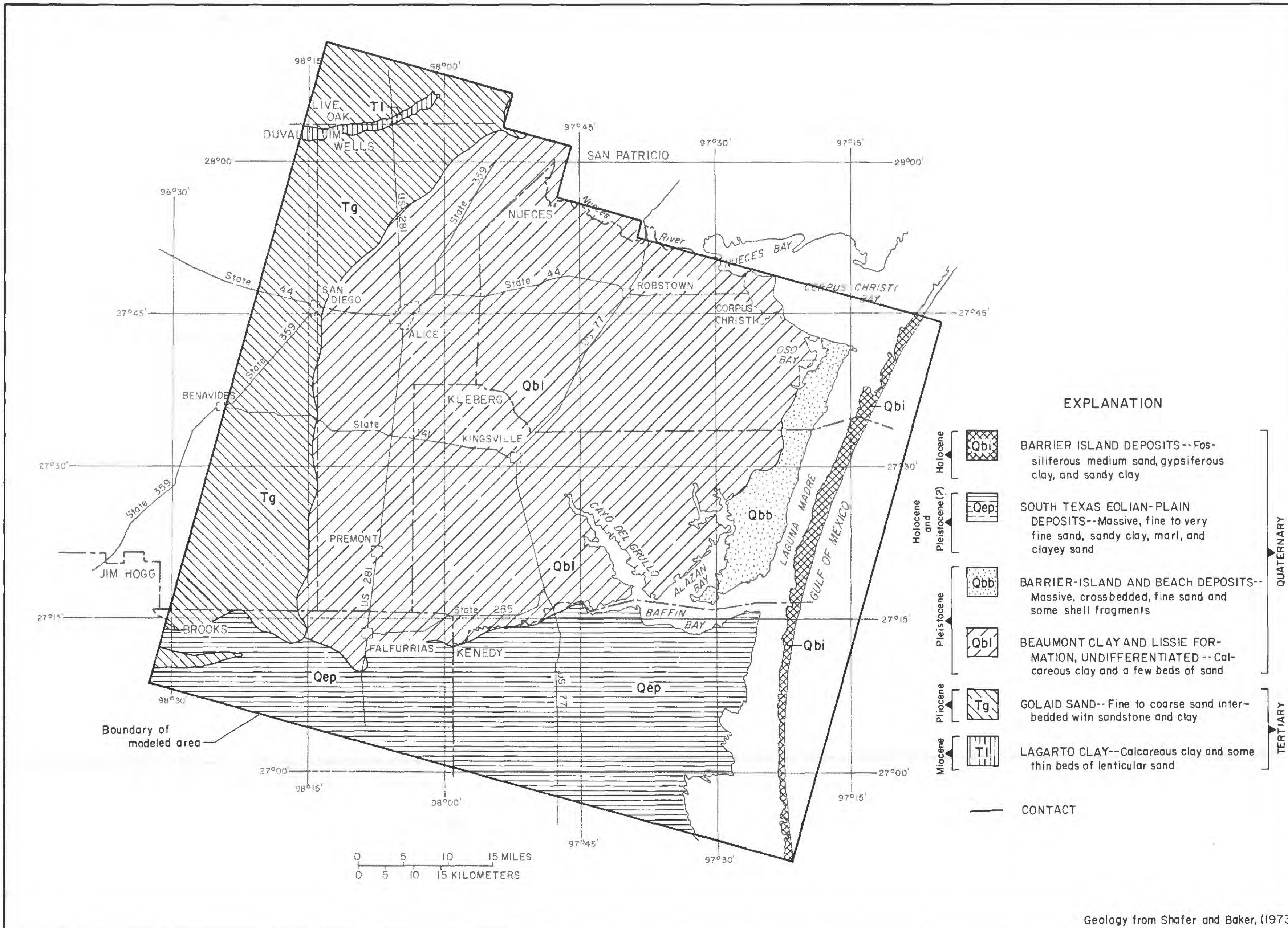

Figure 2.--Surface geology of modeled area.

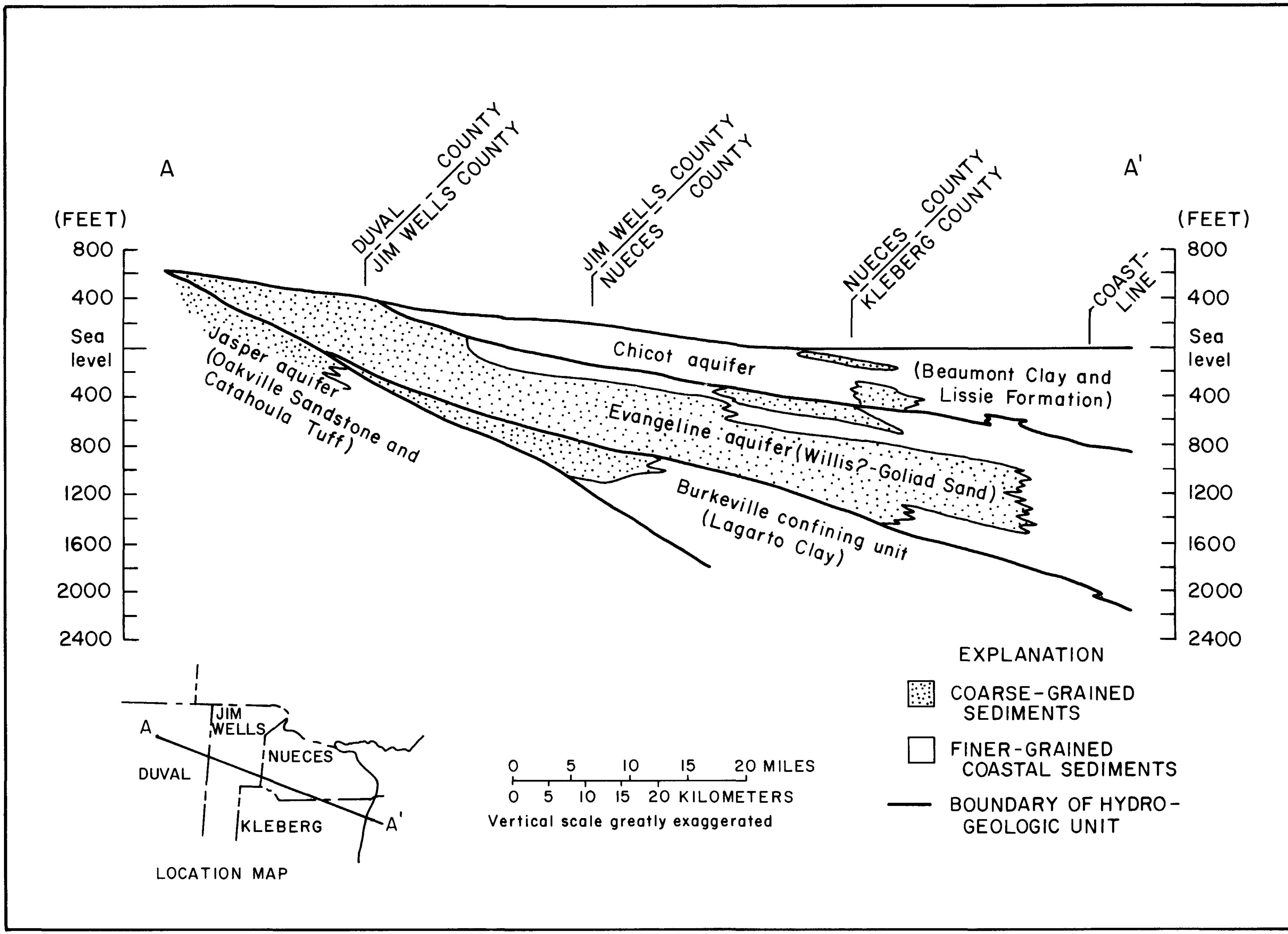

Figure 3.--Generalized hydrogeologic cross section of the aquifer system.

The lithology, dip, and thickness of many of the geologic formations change in the direction of the dip; the lithology and thickness also commonly change laterally along the direction normal to the dip. Sand beds may grade laterally into clay or silt over short distances. These sand beds and other beds containing water are interconnected with similar beds on a different level, so that a series of of water-bearing beds within a formation, or even within a group of formations, function as a single aquifer. The thicknesses of the formations increase toward the Gulf and the clastic sediments composing the geologic formations grade from fluvial and deltaic sand, silt, and clay in inland areas to predominantly finer sediments that interfinger with brackish and marine sediments near the Gulf Coast and offshore. Farther downdip of the study area, the dip becomes progressively steeper.

Geologic structure of the area is relatively simple. The water-bearing formations underlying the report area form a monocline that dips gently toward the coast. Although faults are fairly common in many of the deeply buried formations, none of the geologic formations discussed in this report are known to be significantly displaced by faults.

For this report, the definitions of the deepest aquifers of the area are based on Baker (1978; Baker defines the Fleming Formation as the unit equivalent to the Lagarto Clay and part of the Oakville Sandstone). Baker defines the Jasper aquifer as comprising the updip portions of the Catahoula Tuff and the Oakville Sandstone. The Catahoula is composed of tuffaceous clay, sandstone, and conglomerate. The Oakville Sandstone is composed of very fine to coarse sand and sandstone interbedded with silt and clay. The Burkeville confining unit overlies the Jasper aquifer and is comprised of what Shafer and Baker (1973) call the Lagarto Clay. The Lagarto Clay is calcareous and contains some thin beds of sand. The Burkeville confining unit underlies all of the aquifer in the areal model of this study.

The definition of the Evangeline and Chicot aquifers is a modification of Solis' (1981) definitions of four operational units. Solis (1981) defines operational units as:

> "...informal stratigraphic units that closely correspond to time-stratigraphic units."

The Evangeline aquifer, for the purpose of this report, consists of Solis' upper and lower Goliad-Willis operational units. The Willis Sand lies on top of the Goliad in other parts of the Texas Gulf Coast but probably does not exist as a distinct formation in the study area. Solis uses Goliad-Willis operational units for uniformity along the Gulf Coast. The Goliad Sand consists of fine to coarse, mostly gray, calcareous sand interlayered with sandstone and variously colored calcareous clay. Interpretations of the geology from well electric logs indicate that 40 to 60 percent of the formation thickness is sand; the rest is finer-grained sediments. The aquifer might better be defined as the group of sand lenses and layers that are tapped by wells in the area within 300 ft above or below the centerline of the Goliad Sand. Solis' two operational units include all of the major sand bodies that fit into this criterion. The Chicot aquifer is defined as Solis' Lissie and Beaumont operational units. The Beaumont Clay and Lissie Formation (undifferentiated) are composed of calcareous clay and a few thin beds of sand. Solis (1981) describes his operational units in detail in his report. The Evangeline aquifer underlies all of the study area shown in figure 2. The sand thickness ranges from less than 50 ft in the outcrop of the Goliad Sand to greater than 360 ft in the thickest part of the aquifer.

Aquifer Conditions

Predevelopment Flow System

The equipotentials of the natural flow system were parallel to the Gulf Coast. Thus, the general direction of flow was toward the Gulf. The upper one-third of the Evangeline aquifer is unconfined in the shallow subsurface in Duval and northwestern Brooks Counties. The deeper two-thirds of the Evangeline aquifer is confined in the deep subsurface in the outcrop area. The entire thickness of the aquifer is confined where it is overlain by the Chicot aquifer. The Evangeline aquifer (Goliad Sand) is at the surface in Duval and northern Brooks Counties. Because the aquifer in this area consists of several distinct sand layers (Sayre, 1937) and most of the production wells are screened in the deeper sands, the aquifer exhibits confined conditions rather than water-table conditions. Many of the water levels measured in this area represent a composite water level which may not be indicative of the potentiometric head in any one sand layer. It is assumed that the water levels in the shallow wells are representative of the head in the topmost sand layer and this is considered the water table.

The water-table altitude in the Chicot and the Evangeline aquifer is estimated from historic water levels published in the county reports and is assumed to have been constant since 1901 and to remain constant through the period studied. The potentiometric surface in the eastern half of the Evangeline aquifer was not measured prior to development so it was estimated from estimations of flow from wells and potential head constraints of a hypothetical freshwater-saltwater interface assumed to be about 5 to 10 mi east of the coast. The head in the Evangeline aquifer near the edge of the Chicot aquifer is not measured, but it is assumed that the head in the confined portion is about equal to the water-table altitude in the unconfined portion at this boundary. The water table in the Chicot and Evangeline aquifers is shown in figure 4. The estimated initial potentiometric surface of the Evangeline aquifer is shown in figure 5.

Where the Nueces River crosses the Goliad Sand outcrop it receives discharge from local, intermediate, and regional ground-water flow systems. The river is a regional discharge zone for the Evangeline aquifer where it crosses the Chicot aquifer. Where the river crosses the Chicot aquifer is a regional discharge zone for both the Chicot and Evangeline aquifers. This is because the river is the point of lowest head in the Chicot aquifer in the area. The upward gradient from the Evangeline to the Chicot is greatest under the river, thus creating a lateral flow-system boundary. A no-flow boundary is assumed underneath the river in the Evangeline aquifer because of this discharge zone. This no-flow zone is chosen for the northern boundary of the investigation.

The Evangeline aquifer lies on top of the Burkeville confining unit in the model area. The assumption that this unit forms an impermeable base is tested in the cross-section model.

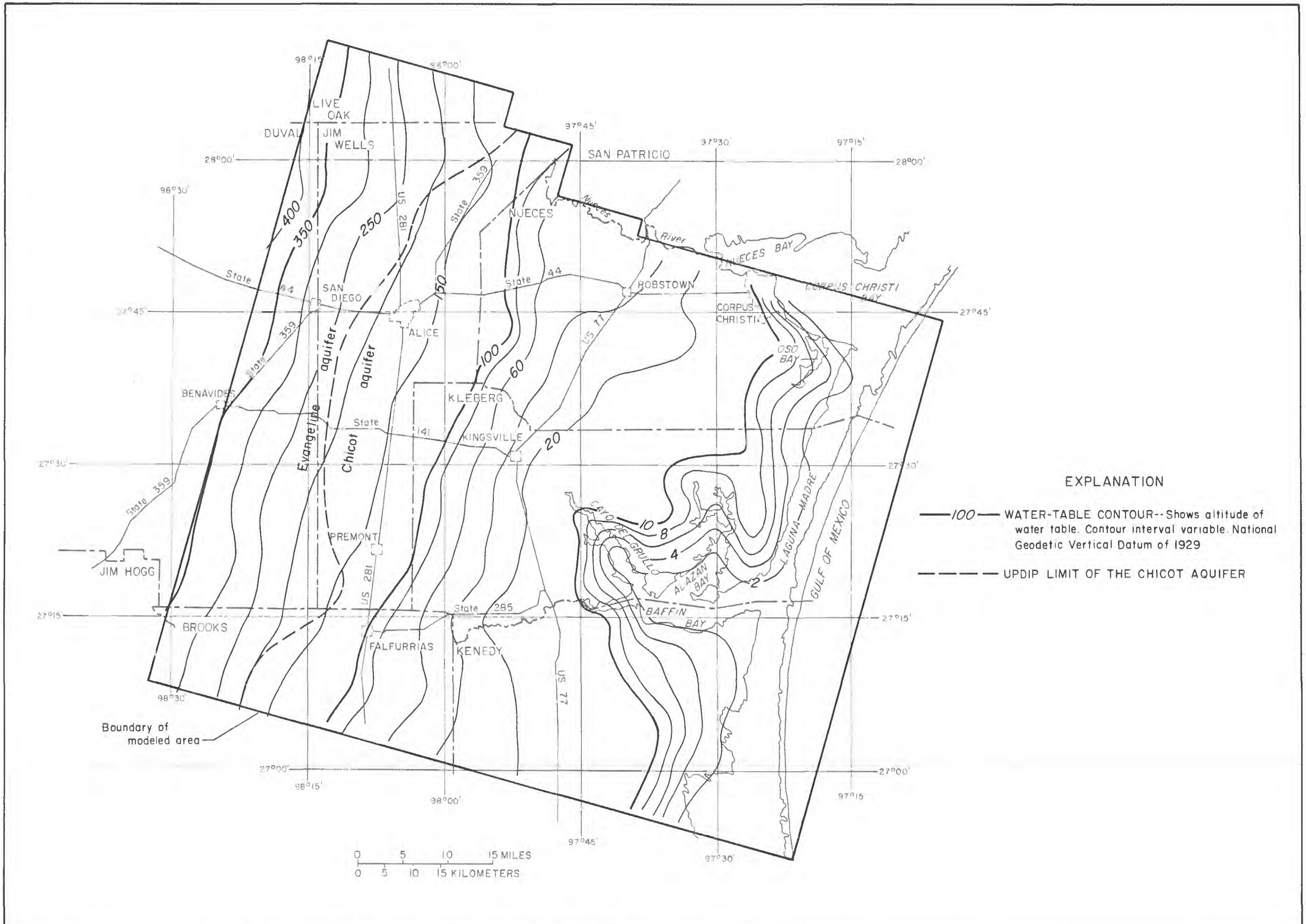

Figure 4.--Steady-state water-table altitude in the Chicot and Evangeline aquifers.

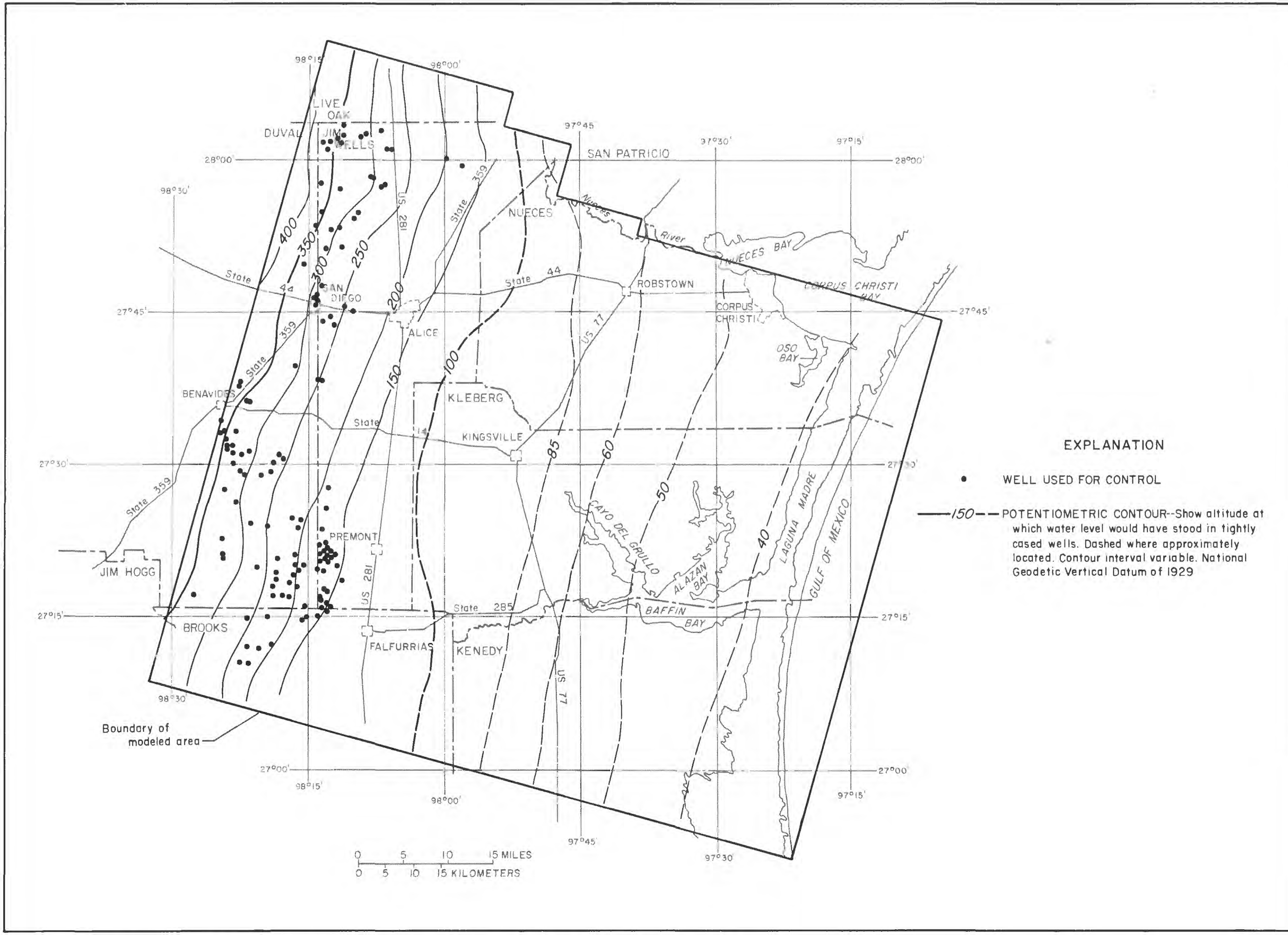

Figure 5.--Potentiometric surface of the Evangeline aquifer prior to development.

Recharge and Discharge

Before pumping began, it was assumed that the regional flow direction was from the west-northwest recharge zone to the east-southeast and generally perpendicular to the Gulf Coast. The outcrop of the Goliad Sand in Duval and part of Jim Hogg Counties is the recharge zone for the Evangeline aquifer. The amount of recharge from rain in this area is uncertain and probably is small. The assumption that there is little recharge from rainfall is based on a consideration of climate and the work of Sayre (1937), Rightmire (1967), and Thomas and others (1963).

The normal rainfall in the recharge area, based on 1941-70, is approximately 24 in. The normal precipitation deficit (defined as the average annual precipitation minus the potential evapotranspiration calculated by the Thornthwaite method) ranges from -18 to -28 in. (State climatologist, 1969). The maximum deficit occurs in the western part of the study area. Except for the Nueces River, there are no major perennial streams in the study area. This indicates not only that recharge is limited, but also that discharge must occur either directly into the Gulf of Mexico or through evapotranspiration from the Chicot aquifer. Sayre (1937) found relatively impermeable caliche in the Goliad outcrop in Duval County except in depressions (sinks) and creeks. He also measured water levels in over 200 water-table wells and found no clear relationship between rain storms and ground-water levels. He found that the chloride concentrations in these wells also showed no clear relationship to rain storms. This lack of correspondence of rainfall and recharge was found in areas with extensive caliche and in areas where the caliche is discontinuous. Rightmire (1967) infers that the caliche of South Texas formed under a more humid climate than present conditions. Thomas and others (1963) found no relationship between the severe drought of 1942-56 and water levels in the Evangeline aquifer.

Shafer and Baker (1973) estimated recharge using estimates of transmissivity, hydraulic gradient, and size of the aquifer. Their estimate is most likely high because they used the maximum transmissivity value calculated from the few pumping tests made on the aquifer. Their estimate is also much higher than the natural recharge since they estimated the gradient from potentiometric-surface maps constructed from data collected during the late 1960's. The gradient from recharge area to discharge was much greater in the 1960's, due to pumping, than under predevelopment conditions. This larger gradient, in Shafer and Baker's calculation, yields a larger value for recharge than if they used the smaller predevelopment gradient.

Most recharge, in the present climate prior to development, is most likely cross-formational flow from the underlying Jasper aquifer. This aquifer is in hydraulic connection with the base of the Goliad Sand at the west edge of the Goliad outcrop. West of this contact, the Jasper has higher potential head than the Evangeline aquifer. The water quality in the Jasper, in this area, is similar to that of the Evangeline (Myers and Dale, 1967; Shafer, 1974).

Under natural conditions, the discharge is equal to the recharge. Most of the discharge is into the Chicot aquifer under predevelopment conditions, although there is some direct discharge from the Evangeline aquifer to the Nueces River and streams in the area. The discharge to these zones decreases and stops when well discharge exceeds the recharge rate; however, this is dependent on the distribution of the wells and may not be true for the entire modeled area.

Carr and others (1984) conceptually divide the Evangeline and the overlying Chicot into distinct aquifers based on differences in overall hydraulic conductivity and head. In this analysis, the Chicot aquifer is assumed to act as a leaky layer on top of the Evangeline. Under predevelopment conditions, discharge of water from the Evangeline is upward into the Chicot. Under pumping conditions, the salinewater in the Chicot flows downward into the Evangeline over most of the study area. This reversal of the natural flow direction is due to the declines of the potential head in the Evangeline aquifer. The analytical separation of these two flow systems is different in this study for the following reasons:

1. The Chicot, except for small areas near Corpus Christi Bay, is not intensively pumped;
2. The dissolved-solids concentration of the Chicot water generally is much greater than the dissolved-solids concentration of the Evangeline; and
3. The Chicot generally is finer grained, consisting mainly of the Beaumont Clay--so it acts as a leaky confining layer relative to the Evangeline aquifer.

Position of the Freshwater-Saltwater Interface

According to theory, a state of equilibrium exists under natural steady-state conditions at the interface between fresh or slightly saline ground water and salinewater that underlies the Gulf Coast. The potential head of the freshwater at the interface is the same as the head of sea water; thus, there is no horizontal flow at this boundary. In actuality, there is upward discharge of the less dense freshwater and circulation of the salinewater due to dilution through diffusion (Henry, 1964).

In south Texas, the existence of this interface is conjectural because no reliable borehole data are available to confirm or define it. Furthermore, the concentration of dissolved solids in the Evangeline increases gradually from west to east over most of the area of this study. The interface between slightly saline and dense saline water is assumed to exist in the aquifer 5-10 mi offshore and even under intensive pumping at Kingsville, it has not moved in historic time and will not move under the projected pumping stress. The predevelopment freshwater head in the aquifer was also assumed to be sufficient to maintain the interface at this position. Using the Badon Ghyben-Herzberg relationship (Bear, 1979), the vertical average head in the aquifer directly under the coastline should have been at least 40 ft above sea level. No water levels were measured in the eastern one-half of the study area prior to 1940. It is nessesary to interpolate between actual measurements in the western area and the presumed head at the interface. There are a few visual estimates of well flow in the area (Taylor, 1907), but these are too crude to verify potential heads.

Ground-Water Withdrawals

Historically, irrigation and stock supplies have been a significant use of ground water. Except for areas within the Corpus Christi utility service area, the Evangeline aquifer has been the primary water source for all water uses. Recently, the primary use of Evangeline water was for municipal, industrial, and domestic supply. The primary use of water by industry is for oil refineries and petrochemical plants. Carr and others (1984, fig. 11) list the water use of the Evangeline aquifer in this area by county for 1900 through 1982.

The first period for approximating the ground-water withdrawals is 1901 through 1935. This period has a small total rate of pumping; most water use was small-scale irrigation and small municipality water supply. The combined pumping rate for this period was about 3.1 ft^3/s. From 1936 through 1949, more irrigation wells were pumping and old wells were pumped more. In addition, municipal water use continued at a higher rate. The total rate of pumpage during this period was about 10.0 ft^3/s. In 1949, a severe frost destroyed citrus and other crops and irrigation was drastically cut back in the following years. The pumpage during 1950 through 1963 increased primarily because of expanding industrial and municipal use. Because the irrigation wells that ceased or curtailed pumpage were widely spaced, the recovery went largely unnoticed. The increased pumpage in the municipal areas tended to focus the intensive pumping into smaller areas and concentrate the effects on the system. The total rate of pumping during this period was about 21.8 ft^3/s. In 1964, the city of Alice in Jim Wells County--a major ground-water user until that time--began using surface water as their main source of water and ceased pumping their wells. From 1964 through 1970, the total pumpage was only slightly greater than the previous period, but it was further concentrated in the Kingsville area. The total pumpage was about 26.8 ft^3/s during this period. During 1971 through 1982, the last pumping period for which data are available for this study, pumpage was about 29.6 ft^3/s.

Aquifer Properties

Transmissivity

Published data on the transmissivity of the Evangeline aquifer in this area range from 2.7 ft^2/d in northeastern Duval County to 5,200 ft^2/d (Shafer and Baker, 1973; Shafer, 1974). Shafer and Baker (1973) estimate that the transmissivity of the aquifer is about 13,000 ft^2/d in western Kenedy County.

Aquifer Thickness and Porosity

The aquifer thickness ranges from zero at the edge of the outcrop in Duval and Jim Hogg Counties to over 600 ft. Figure 6 is a map of the aquifer thickness which was constructed from information published in Carr and others (1984). There are few data on the porosity of the aquifer and it is assumed to be a uniform 30 percent--typical of an unconsolidated sand (Freeze and Cherry, 1979).

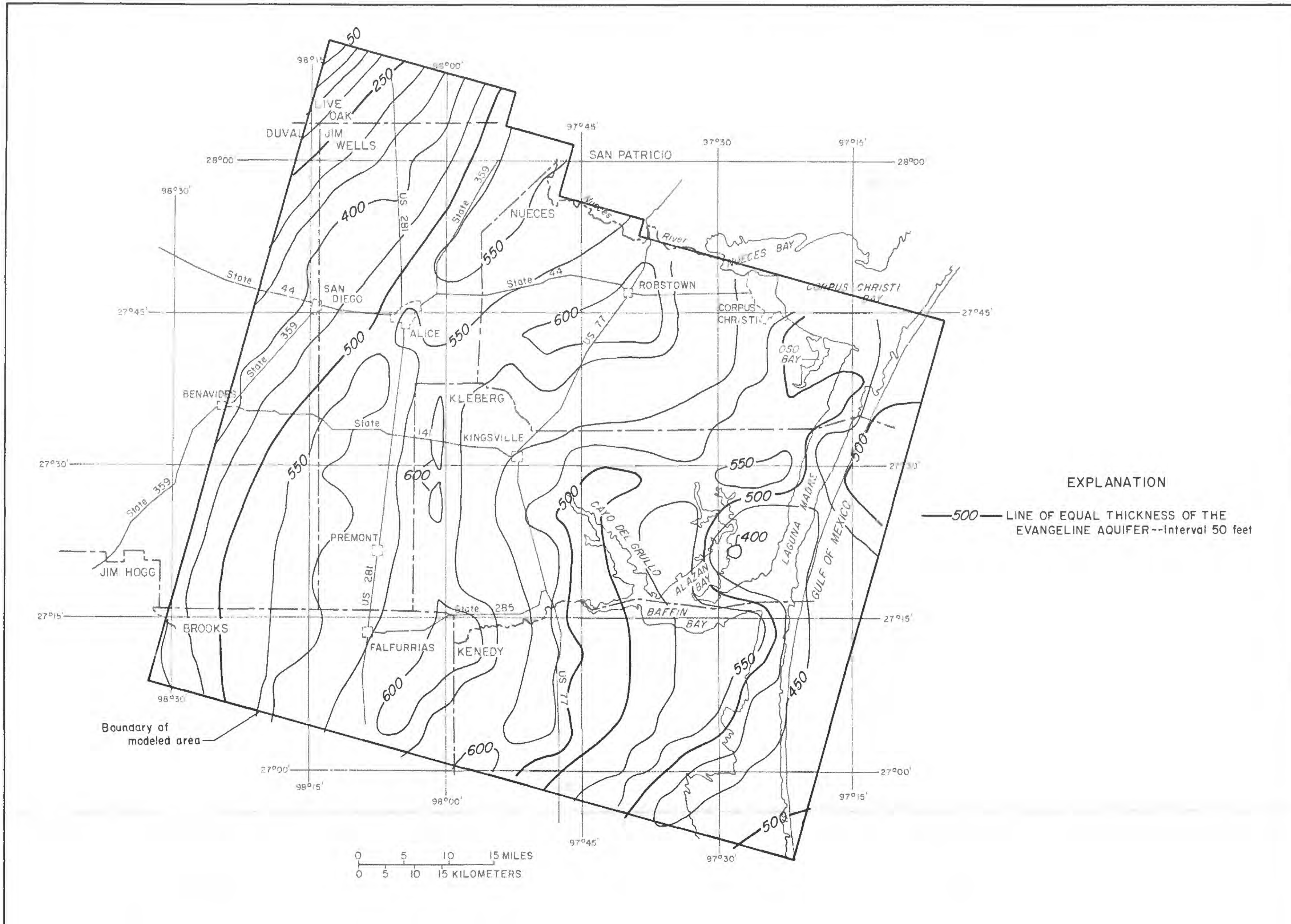

Figure 6.--Thickness of the Evangeline aquifer.

Storage Coefficient

Published data on the storage coefficient range from 6.2 x 10^{-5} to 0.0007. The smallest storage coefficient was calculated for a well in Duval County in the outcrop of the Goliad Sand (Shafer, 1974). Based on their modeling study, Carr and others (1984) estimated that the storage coefficient ranges from 0.0005 near the coast to 0.1 at the western edge of the outcrop. The high storage coefficients in the outcrop area are consistent with unconfined conditions, but most wells in the Evangeline in Duval County produce from deep, probably semi-confined sand layers.

WATER QUALITY

Relationship Between the Flow System and Quality

There is a relationship of the overall water quality in the aquifer to the regional flow system. A general relationship between ground-water flow systems and general water chemistry is discussed by Freeze and Cherry (1979), Drever (1982), and Hem (1970). The amount and relative proportions of major ions dissolved in any ground water depends on the following:

1. The minerals in the formation and their respective solubilities - this determines how fast the minerals dissolve and what constiuents they yield;
2. Velocity of flow - this determines the length of time the water is in contact with the minerals (residence time);
3. The amount of dissolved oxygen and carbon dioxide in the water - these affect the type of mineral that will dissolve or react;
4. The amount of organic matter - this consumes oxygen and makes certain trace elements more soluble;
5. The various reactions between the minerals and pore water, such as ion exchange, precipitation, and sorption;
6. Discharge of water from deeper formations (along faults) that generally have higher dissolved-solids concentrations and are potentially reactive when mixed with aquifer water; and
7. Soil zone processes - such as evaporation and transpiration that tend to concentrate ions during infiltration to ground water.

All these factors have effects on the ground water of the Evangeline aquifer. In the study area, the dissolved-solids concentrations range from 628 to 2,000 mg/L (milligrams per liter) in the freshwater part of the aquifer. For the purposes of this report, 2,000 mg/L is considered the upper limit of freshwater. The concentrations generally increase with distance from the recharge area and grade into slightly saline water near the coast.

Dissolved-solids concentration is the preferred measure of water salinity. These data do not exist for the period prior to 1960. Chloride concentration is a useful measure of water salinity for this study. The reasons for this follow:

1. Chloride is not chemically reactive under aquifer conditions; only the physical processes of mixing, evaporation, and dissolution of evaporite minerals exert signicant control over its concentration;
2. Chloride determinations are the most accurate historical data available;
3. During the period of ground-water development, a large number of well samples were analyzed for chloride;

4. There are no other useful water-quality data for most of the period prior to 1960; and

5. Chloride is the most abundant ion in sea water (Cl = 19,000 mg/L), therefore, intrusion of sea water into the aquifer would be marked by a steep chloride concentration gradient.

For these reasons, chloride concentration is chosen as the measure and index of water salinity for the remainder of this report. The major point of error with this choice is in those local areas in which the aquifer has sulfate concentrations greater than 250 mg/L or the sulfate concentrations exceed those of chloride. In these areas, the dissolved-solids concentration will be underestimated.

Natural Distribution of Chloride

In general, the magnitude and pattern of distribution of chloride concentration is the result of past and present climatic conditions. As noted above, the study area now has a subarid climate, based on precipitation deficiency, and may have been more humid in the past. The distribution of chloride in the aquifer prior to development is unknown. It is assumed that there have been no significant changes in the chloride distribution between 1900 and 1940. Pumping was relatively minor during that period. The chloride-concentration data compiled in the county well inventories and the early reports are used to construct a map of the approximate chloride distribution of predevelopment conditions (fig. 7). After eliminating all wells for which casing construction information was incomplete or uncertain, 1,240 chloride values remained. For all of the wells except those in Duval County, an arbitrary upper limit of 1,000 mg/L is used to eliminate data for wells that probably were contaminated by cross-formational flow through leaky well casings. Leaky well casings are discussed further in a following section. In Duval County, the Evangeline aquifer is unconfined. The well casings pass only through the aquifer itself. There is no reason to suspect that most of the high chloride concentrations found in wells in Duval County are caused by contamination.

The remaining 836 chloride values range from 9 to 1,971 mg/L and the mean is 353 mg/L (standard deviation = 262 mg/L). Because the chloride distribution is so complex and there are many values, the data were processed statistically by computer to construct the map. The kriging procedure (Skrivan and Karlinger, 1980) as modified by Spinazola (U.S. Geological Survey, oral commun., 1984) is used to process the data (Arteaga and Groschen, 1985, written commun.). This procedure not only yields a much better map than hand contouring, but also yields an areal distribution of error for the estimation process and can interpolate chloride concentrations for input to the mathematical simulation. Figure 7 is a map of the data (742 values) for all counties except Duval.

Duval County chloride values are too variable to be able to map them with reasonable accuracy. This may be due in part to strong vertical variations in the chloride distribution in the recharge area. Sayre (1937, p. 54-55) describes three distinct "sand" layers that yield water to wells in this area. He says the shallow layer, 30-50 ft deep, yields poor quality water, the middle sand layer yields less saline water, but the deepest layer, about 150 to 250 ft deep, yields drinkable freshwater. These two lower layers also are under artesian pressure, and the water levels in the wells rise well above the tops of the

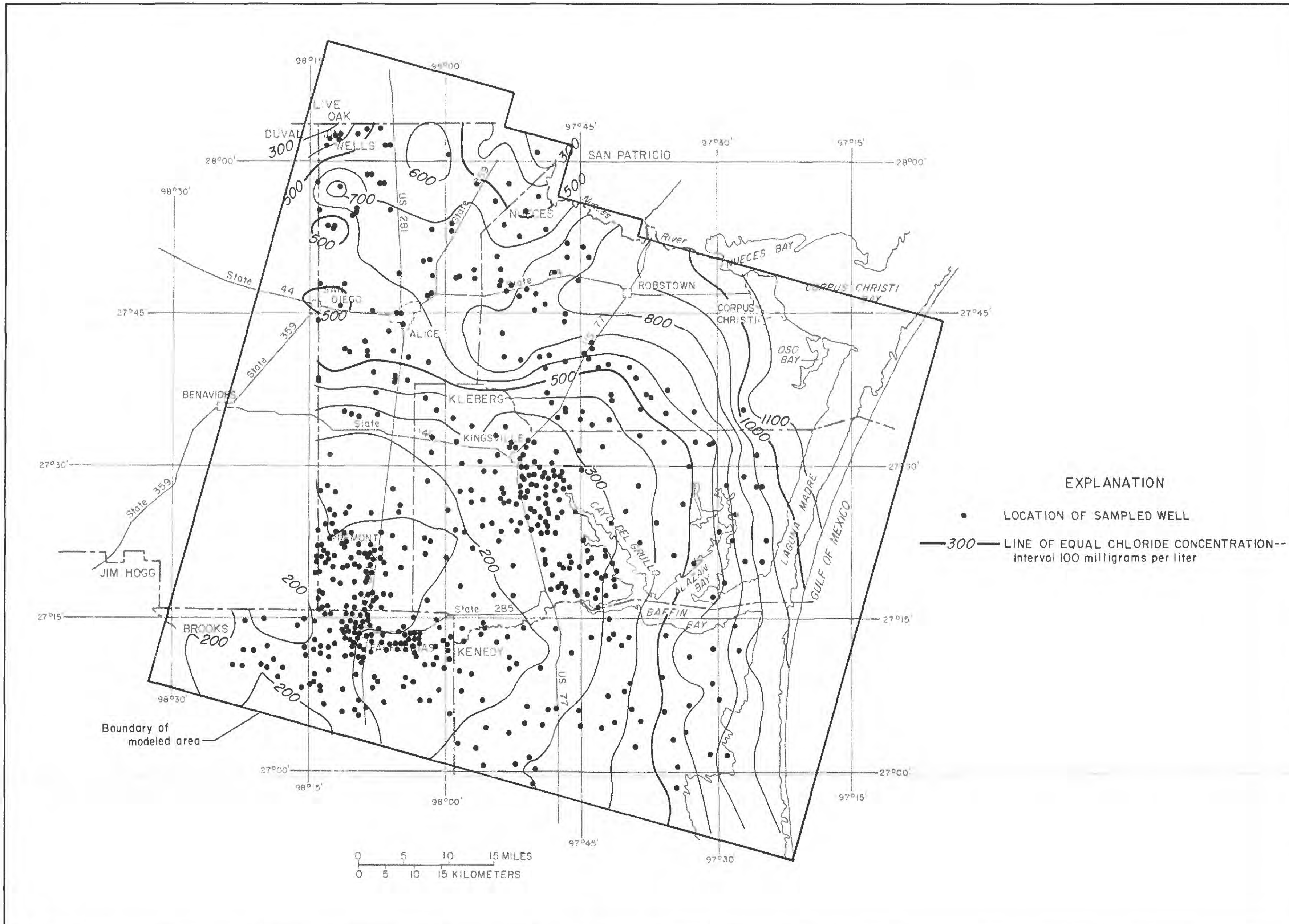

Figure 7.--Chloride concentration in the Evangeline aquifer prior to development.

sands. The quality of water in this area was estimated from data to the east and south by kriging. This estimate is considered to be an average of all three layers.

Under current climatic conditions, recharge-water dissolved solids probably increases through land-surface and soil-zone evaporation before it infiltrates to those areas where caliche is absent. The variations in chloride concentrations are due, in part, to local flow systems that developed where significant recharge occurs. This recharge water can vary in concentration from very fresh to saline depending upon the amount of evaporation it is subjected to before it infiltrates to the water table. Sayre (1937) measured chloride concentrations in presumed recharge water and found no relationship between chloride concentration changes and rain storms. Some water levels in wells fluctuated widely where the caliche was discontinuous but the chloride concentrations in these same wells showed no response to storms. He assumed that recharge water would have the lowest chloride concentrations and would dilute the concentrations in the ground water sampled after a heavy rain.

In northern Jim Wells and in most of Nueces Counties, the natural chloride concentrations in the confined part of the aquifer are widely variable and have a greater average than chloride concentrations in the rest of the confined aquifer within the study area. This is most likely due to the slower flushing of saline formation water from the aquifer in this area caused by the low transmissivity. The river is a local and regional discharge area. The small local flow systems superimposed on the regional flow system have relatively shorter flow paths and thus shorter residence times than the regional system and, therefore, lower chloride concentrations. According to Solis (1981) the Goliad-Willis sediments beneath Corpus Christi Bay are fine-grained bay and lagoon deposits. These sediments have a much lower hydraulic conductivity relative to the sediments in the rest of the aquifer. Generally, the higher chloride concentrations are due primarily to the long residence time of water in this low-conductivity zone, but the low concentrations are caused by the local flow systems.

Poor water quality (chloride concentration greater than 500 mg/L) existed in the aquifer under most of eastern Nueces and extreme eastern Kleberg and Kenedy Counties. In contrast, the chloride concentration was lowest and least variable in the west-central and southern parts of the aquifer in the study area. Kingsville lies approximately in the center of the study area within but near the northeastern boundary of the area with good water quality. From Kingsville to the north and east, the chloride concentrations increased in average and in variability from well to well.

Present (1982) Water Quality

The regional water quality in the Evangeline aquifer has not changed significantly since before development began. Figure 8 is a map of the chloride distribution in the aquifer in 1982. The map is a modification of Rettman's (1983) map of specific conductance. A linear regression of chloride on specific conductance is used to estimate chloride concentrations from the specific conductance values listed in Rettman (1983). The regression equation is:

$$\text{chloride (mg/L)} = 0.27 \text{ specific conductance } (\mu S) - 209.$$

The correlation coefficient (r^2) is 0.95 at the 0.0001 significance level.

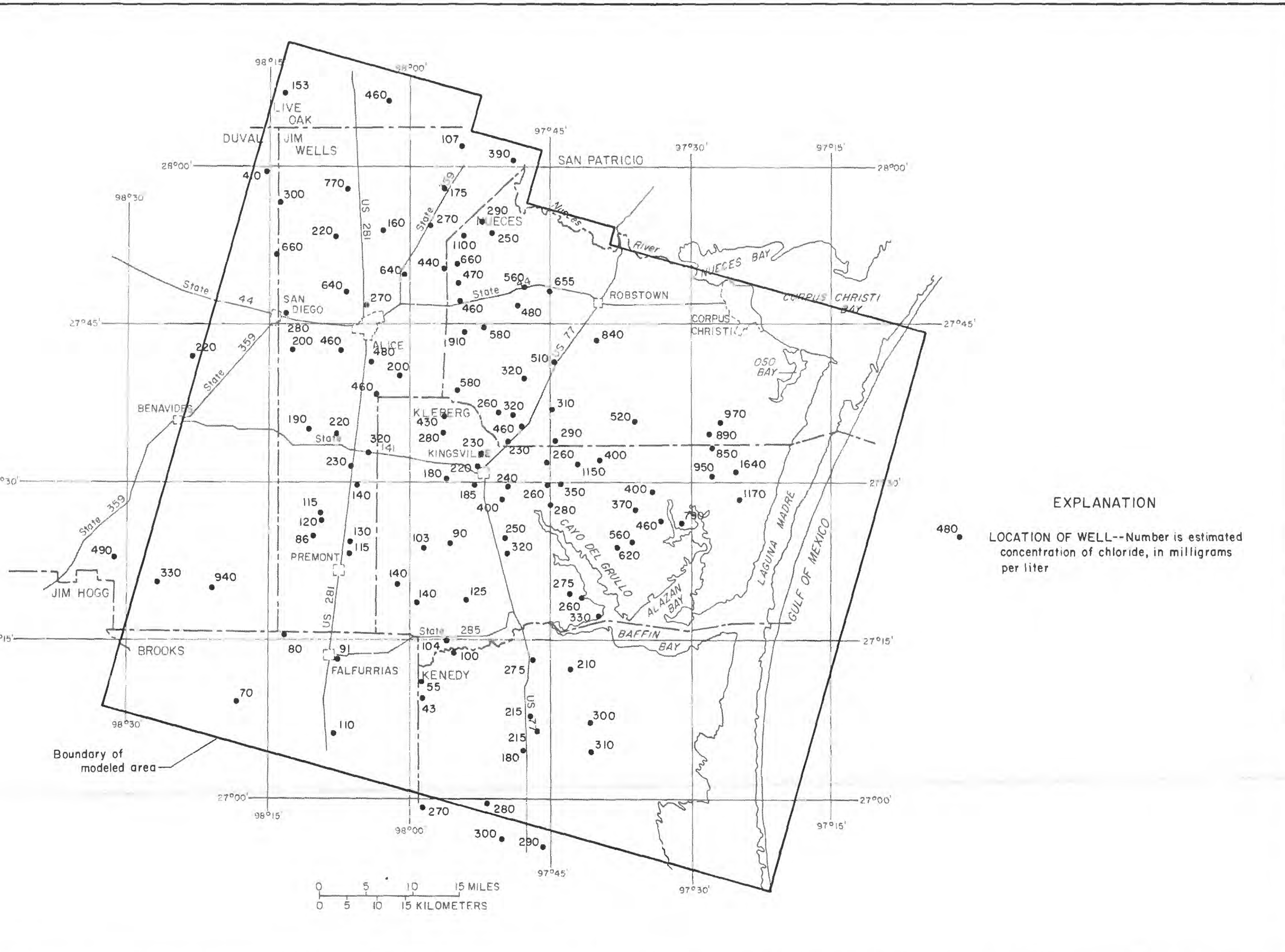

Figure 8.--Chloride concentration in the Evangeline aquifer in 1982.

Even though there are large water-level declines in the Evangeline over much of the study area (fig. 9), the map of the 1982 chloride distribution is similar to the map of the predevelopment distribution shown in figure 7. There are noticeable differences between the maps at specific wells. This is particularly true in the area in northern Jim Wells County. The chloride concentrations in many of the wells sampled by Rettman (1983) are considerably lower than are indicated by the map in figure 7 of the predevelopment chloride distribution. This is due to several things. The first is that the chloride in 1982 is estimated from a presumed linear relationship between specific conductance and chloride. This equation is most accurate for moderate to high chloride concentrations where chloride makes up a considerable fraction of the total ion concentration. It is least accurate for low chloride concentrations or other water samples where other ions such as sulfate make up a greater relative proportion of the total ion concentration. Second, the set of wells sampled by Rettman is biased toward wells that have good quality water. This is due to a normal process of abandoning poorly constructed wells and wells with marginal water quality and drilling new and replacement wells in areas known to produce only good quality water. Over the years, the number of wells decreased because irrigation became less important and good quality became more important because the principal uses are domestic, municipal, and industrial supplies. Thus, the older wells that are more widely and uniformly distributed probably are more representative of the average quality of the water in the aquifer.

The high chloride concentrations for wells listed in the reports published prior to 1960 are attributable to one of two causes or both. These are: Wells which tap naturally occurring, discontinuous lenses of high chloride water (particularly in the outcrop area); or wells through which salinewater flows from the Chicot aquifer into the Evangeline because of defective casing.

Apparent vertical stratification of the dissolved solids in the outcrop area adds to the complexity of the chloride distribution. Water from wells that tap the deep extensive sands in the Evangeline have less variable and usually lower chloride concentrations than water from wells that tap the shallow sands. Also, several of these deep wells in extreme southern Duval County (within the outcrop area) flowed when drilled (Taylor, 1907; Sayre, 1937). The flow system and the vertical chloride distribution in southern Duval County are more complex than assumed for this study. The existing hydrogeologic data are insufficient to define the flow system in more detail than already described above. The error associated with this simplification of the system is considered to be only locally important and is therefore not investigated for this study.

Potential For Degradation

This is not an exhaustive analysis of all possible contamination sources to the aquifer but a discussion of the major sources of potential degradation of regional importance. Furthermore, as noted above, areas of the aquifer have widely variable natural chloride concentrations. In many cases, it is difficult to distinguish between increases in salinity due to natural variations and those created by contamination. A regional increase is defined as one that affects a number of wells in an area greater than 16 mi^2 (the size of four model cells). It is not possible, using this study, to predict which individual wells may become contaminated. It is useful to delineate areas where a

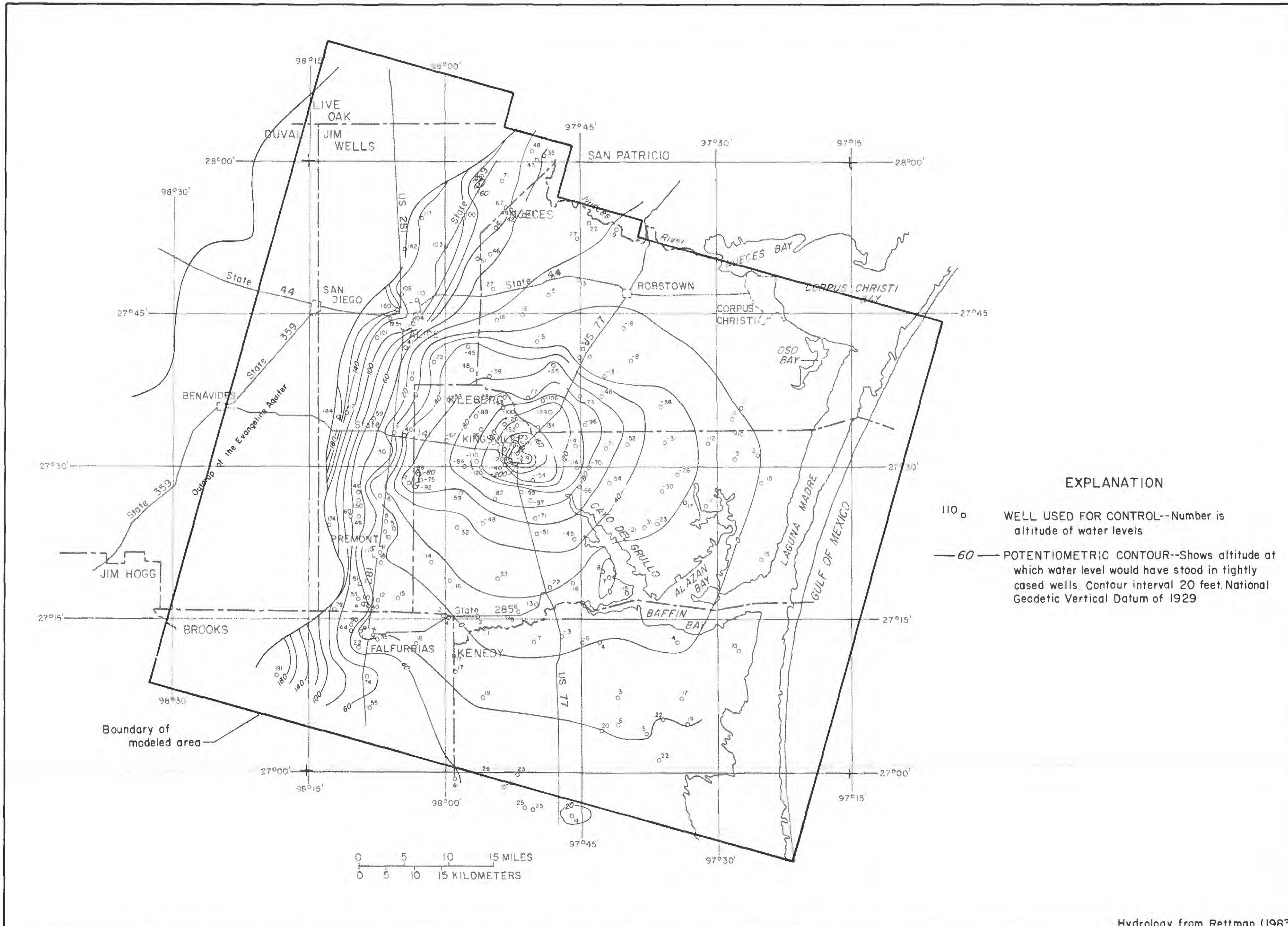

Figure 9.--Potentiometric surface in the confined portion of the Evangeline aquifer in 1982.

significant potential exists for contamination and to test, using the model developed as part of this study, if the continued pumping of water from the aquifer will increase the potential for contamination or actually cause contamination.

Leaking Well Casings

Well casings can be defective either by poor design and construction or through corrosive attack by salinewater. Leaky casings act like "short circuits" for interaquifer water flow. Wells that tap the Evangeline freshwater are cased through the entire thickness of the Chicot. The salinewater of the Chicot leaks through poorly constructed joints and attacks and perforates the metal of unprotected casing. Only cement grout around casing is unaffected by corrosion. Water can also migrate between the borehole and the casing (annulus) in ungrouted or improperly grouted wells.

Before water levels declined in the Evangeline, its higher potential head would force water to flow upward, out of the casing and into the Chicot in unused wells. When the Evangeline head was drawn below that of the Chicot, the flow reversed causing salinewater to flow directly into the casing and out into the Evangeline through the screen. As the head in the Evangeline declines further, the flow of salinewater increases. Livingston and Broadhurst (1942) investigated just such leaky well casings in Kleberg and Kenedy Counties. They located saltwater leaks using a qualitative electrical conductivity sensor. Shafer and Baker (1973) report that some of the oil and gas exploration wells in Jim Wells and Kleberg Counties were improperly cased thereby creating conditions for interaquifer flow within the wells. They also report that no conclusive evidence existed, at that time, of regionally significant increases in dissolved solids resulting from improperly cased wells. The problem of leaky well casings is assumed to be only locally important. However, if interaquifer well leakage is allowed to continue unabated, there is some potential for serious regional water-quality deterioration.

The high chloride water that exists in the aquifer under Nueces, Jim Wells, and eastern Kleberg and Kenedy Counties, has a potential to move laterally to the south and west into the area of intensive pumping.

Discharge of Deep Salinewater

The assumption that there is insignificant upward flow of salinewater from beneath the aquifer is in accord with the assumption made previously that the Burkeville confining unit is relatively impermeable. Solis' (1981) cross sections show faults that cut through beds including the Goliad-Willis units. Galloway (1982) concludes that fault discharge from deeper formations is geochemically important for the genesis of uranium ore deposits in the Oakville Sandstone that underlies the Burkeville. A deposit of uranium exists in the Goliad Sand in Duval County (Eargle and others, 1975). There are potentially economic deposits of uranium in the Evangeline near Cayo del Grullo (Mark Pelizza, Uranium Resources, Inc., oral commun., 1984). Therefore, according to Galloway's theory of uranium emplacement, fault discharge of salinewater from formations underlying the Burkeville into the Evangeline aquifer, must have occurred during recent geologic time. There is no evidence that this is occurring now, even though large water-level declines in the aquifer should increase the likelihood for upward discharge of salinewater through faults.

Leakage from the Chicot Aquifer

The most important source of salinewater, outside the aquifer, is the overlying Chicot aquifer. As discussed above, the natural, prepumping water flow in the Evangeline discharged upward into the Chicot. In about one-half of the study area, the large water-level declines have reversed the gradient and thus the flow direction between the aquifers. Salinewater flows downward from the Chicot into the Evangeline where this reversal occurs.

The wells in the Chicot aquifer that were sampled through the period studied had chloride concentrations ranging from 144 to 2,250 mg/L. The mean from 29 samples is 740 mg/L. These wells are primarily domestic wells that tap discontinuous fresh to slightly saline water within the Chicot. It is assumed that the general water quality of the Chicot aquifer is much more saline than is indicated by the sampled wells. This is based on geophysical logs of wells that indicate relatively high salinity in the Chicot with respect to the Evangeline aquifer. It also represents the worst possible situation for this boundary condition in the model.

Irrigation Return Flow, Oil-Field Brine Disposal, And In-Situ Uranium Mining

There are other man-made, direct or indirect sources of contamination to the aquifer. These include:

1. Irrigation return flow;
2. Oil-field brine disposal practices and;
3. Uranium mining, both in the Oakville Sandstone and the Goliad Sand.

A detailed investigation into the impact of each of these sources is beyond the scope of this report. They are briefly discussed here because they have caused and will most likely continue to cause some small-scale water-quality degradation, and, if unchecked, can become a regional problem.

Although irrigation in the study area has never been extensive, several areas have had relatively intensive irrigation that peaked at various times through the period studied. The addition of soluble salts to the unsaturated zone and the water table in irrigated areas probably is insignificant on a regional scale. Furthermore, most irrigation occurred before the wide-spread use of chemical fertilizers and pesticides. Irrigation is not an important water use at present.

Until 1970, oil-field brine was disposed of in pits and surface-water courses (Shafer, 1974). Many of these pits were unlined and allowed seepage into the aquifer, and the surface channels are probaby areas of recharge to the aquifer--particularly in the outcrop area. Seepage of brine into the aquifer is not known to have affected any wells that have been sampled. The extent of contamination due to oil-field brines is therefore unknown, but, if it exists, it probably is only locally significant at present.

Contamination of the aquifer by in-situ mining of uranium is possible if adequate care is not taken in designing and installing well networks. Henry and others (1982) discuss, in detail, the problems associated with this type of mining operation with respect to the Oakville Sandstone. The general points of their study can be applied to the mining that is likely to occur in Kleberg County within the aquifer. The potential for significant regional water-quality degradation by improper in-situ mining practices is small.

SIMULATION MODEL OF THE AQUIFER

Description of the Mathematical Model

The mathematical model used in this study was developed by Konikow and Bredehoeft (1978). The equation of ground-water flow is approximated by finite-difference equations for each node. The flow equation for two dimensions is:

$$\frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial h}{\partial x_j}\right) = s\frac{\partial h}{\partial t} + w(x,y,t), \quad i,j = 1,2$$

where:
T_{ij} = transmissivity tensor (L^2/T);
h = hydraulic head (L);
s = storage coefficient (L^0);
t = time (T); and
w = volumetric flux per unit area (L/T) as:

$$w(x,y,t) = Q(x,y,t) - \frac{K_z}{m}(H_s - h)$$

where:
Q = rate of withdrawal (+) or recharge (-) (L/T);
K_z = vertical hydraulic conductivity (L/T);
m = saturated thickness (L); and
H_s = head in the source bed (L).

A uniform rectangular grid was superimposed on the area to be modeled. Within the area divided into these cells, flow-system boundaries are designated and the cells within these boundaries are assigned values for certain terms of the finite-difference equation at those nodes.

The average seepage velocity (Lohman, 1972) is defined, using Darcy's Law as:

$$V_i = -\frac{K_{ij}}{n}\frac{\partial h}{\partial x_j}$$

where:
V_i = seepage velocity in the X_i direction (L/T);
K_{ij} = hydraulic conductivity tensor (L/T); and
n = effective porosity of the aquifer.

The average velocity is calculated in the model and used for the computation of the transport of solute. The equation of transport (Bredehoeft and Pinder, 1973) is:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x_i}\left(D_{ij}\frac{\partial C}{\partial x_j}\right) - \frac{\partial}{\partial x_i}(CV_i) - \frac{C'W}{nb} + \sum_{k=1}^{s} R_k, \quad i,j = 1,2$$

where:

C = the concentration of dissolved species (M/L^3);
D_{ij} = dispersion tensor (L^2/T);
b = saturated thickness of the aquifer (L);
c' = concentration of dissolved species in a source fluid (M/L^3); and
R_k = rate of production of the chemical species in reaction k of s possible reactions (M/L^3T).

The first term on the right side of this equation represents the change in concentration in the water due to hydrodynamic dispersion. Hydrodynamic dispersion is assumed to be proportional to the concentration gradient (Scheidegger, 1961). The second term on the right side of the equation represents convective mass transport due to fluid movement. The third term represents the concentration changes that occur due to fluid sources or sinks. The last term on the right side of the equation describes the changes in concentration resulting from chemical reactions involving the chemical species of interest. The model is not set up to use this term of the equation, and the chemical species of interest in this study is chloride. Chloride does not take part in any reactions under the conditions found in the Evangeline aquifer, therefore, there is no loss of accuracy in ignoring the term relating to chemical reactions.

There are no data from which to accurately define the dispersion coefficient for the Evangeline aquifer. For the model calibration, it was assumed that this coefficient is so small as to be negligible. A later simulation tests the significance of this assumption.

The flow equation is solved using the strongly implicit procedure (Stone, 1968) as adapted by R. Healey (L. Konikow, written commun., 1983). After the head distribution is computed, the fluid velocities at node centers and cell boundaries in the X-direction are computed using the following modified equation:

$$V_x(i,j) = \frac{T_{xx(i,j)}}{nb_{(i,j)}} \frac{h_{i-1,j,k} - h_{i+1,j,k}}{2\Delta x} .$$

A similar equation is used for the Y-direction velocities.

The solute transport equation is then solved using the method of characteristics (or particle-in-a-cell) of Garder, Peaceman, and Pozzi (1964). Konikow (1977, p. 9) describes this method:

> "The numerical solution is achieved by introducing a set of moving points that can be traced with reference to the stationary coordinates of the finite-difference grid. Each point has a concentration associated with it and is moved through the flow field in proportion to the flow velocity at its location. The moving points simulate convective transport because the concentration at each node of the finite-difference grid changes as different points enter and leave its area of influence. Then, additional change in concentration due to dispersion and to fluid sources is computed by solving an explicit finite-difference equation."

In this study, four points were initially distributed in each cell of the grid.

Application of the Mathematical Model

Assumptions

Many assumptions about the flow system and boundaries are necessary for any hydrologic-system analysis. Some of these have been described above in the description of the hydrogeology. The ability of a mathematical model to accurately and reliably simulate the behavior of an aquifer under pumping stress depends on the following:

1. A thorough understanding of the aquifer hydrology including the boundary conditions;
2. The validity of the underlying assumptions;
3. The availabilty and accuracy of data; and
4. The ability of the investigator to translate this information into the mathematical scheme.

This section explains the assumptions made in order to study the Evangeline aquifer, how these assumptions affect each property or boundary condition, and the data required for each property or condition in the mathematical model.

The major assumptions with respect to ground-water flow in the aquifer that are not specifically mentioned in the hydrogeology section are:

1. Ground-water movement is primarily horizontal within the Evangeline;
2. No significant changes in head occur in the Chicot aquifer over the period simulated (the aquifer is at steady-state);
3. The potentiometric head in the Chicot aquifer is the water-table altitude;
4. Fluctuations in the water table in the Evangeline aquifer are too small to significantly affect the transmissivity;
5. Properties or conditions other than the rate and pattern of pumping do not vary during the simulation;
6. The aquifer is isotropic; and
7. The faults do not significantly affect the movement of water in the aquifer.

Assumptions that primarily affect the solute-transport model of the study are:

1. The porosity is constant over the entire modeled area;
2. No chemical reactions occur in the aquifer to change the concentration of the solute;
3. Gradients of fluid density, viscosity, and temperature do not affect the velocity distribution;
4. Ionic and molecular diffusion contribute no significant effect on the solute dispersion;
5. Vertical variations in concentration are negligible; and
6. The aquifer is isotropic with respect to dispersion.

Cross-Sectional Model

A course-grid cross-sectional flow and solute transport model (fig. 10) was constructed to help test certain aquifer conditions and assumptions used in the areal predevelopment steady-state (PDSS) model. The model is based on the dip cross-section number 1 of Solis (1981, fig. 5, p. 10). This hydrogeologic slice runs from a point in north-central Duval County through the coast-

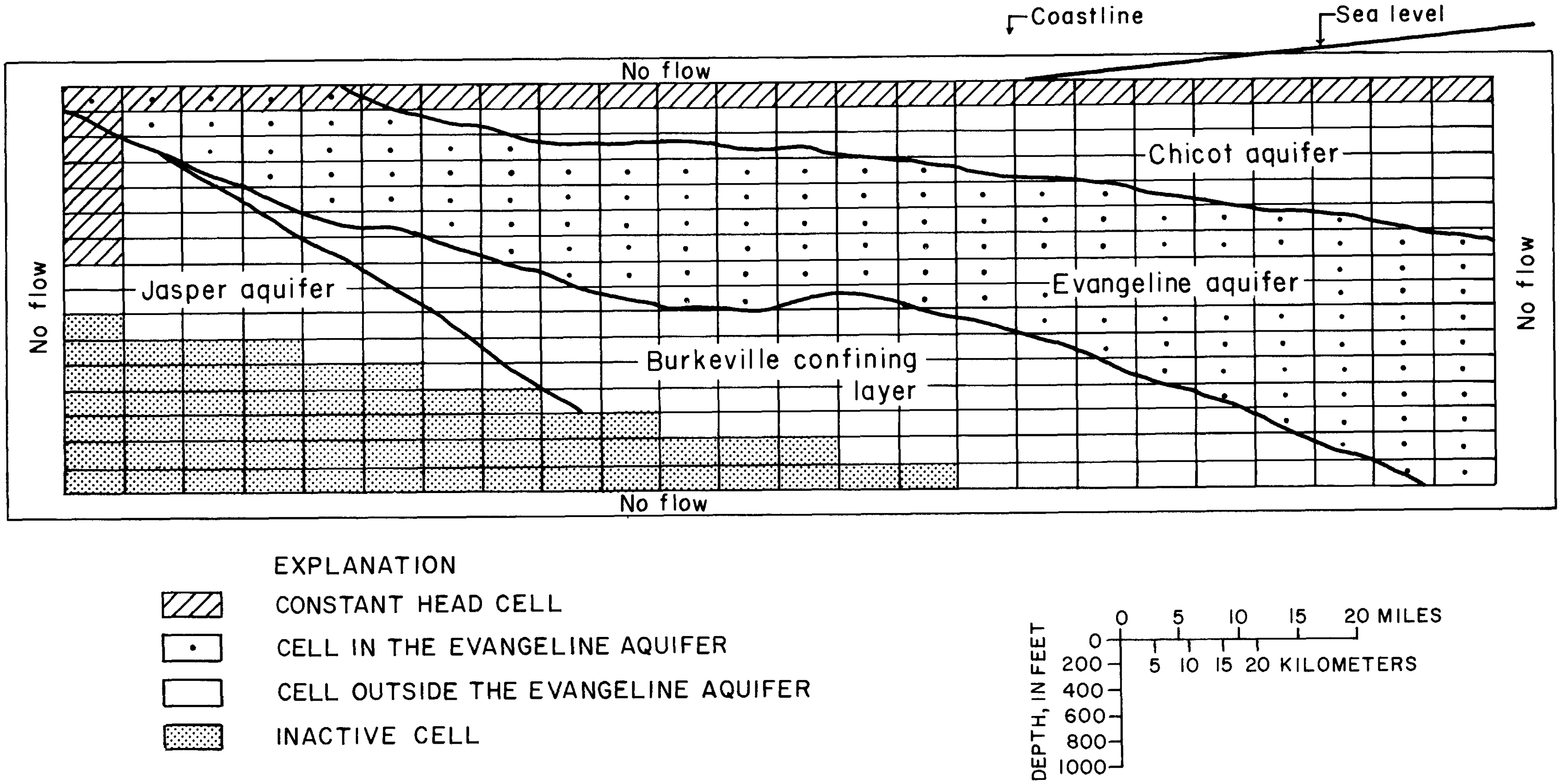

Figure 10.--Finite-difference grid superimposed on the generalized hydrogeologic cross section.

line near the border of Nueces and Kleberg Counties (fig. 3). The slice runs along a flowpath from the recharge area to the discharge area of the PDSS system. The model stretches beyond the east and west boundaries of the areal model. The cell size is 200 ft high by 26,400 ft long in 26 columns and 18 rows. The vertical section modeled includes the saturated interval extending from the water table to as deep as 2,000 ft below sea level. This design allows testing of the Chicot aquifer and the Burkeville confining unit as aquifer boundaries.

No attempt was made to rigorously adjust this model since accurate detailed information is lacking and the model's only purpose is to test assumptions about vertical flow and the east and west boundaries. The hydraulic conductivity is estimated from the sediment facies of Solis' cross section using the range of published data.

The assumption that upward movement of water from the Burkeville confining unit is insignificant is tested by representing it as a low conductivity layer. Because no reliable data exist on the vertical or horizontal conductivity of the confining unit, it was assumed that they are 0.1 to 0.01 times the respective conductivities of the Evangeline aquifer based on the greater clay content of the Burkeville. Model results indicate that the layer has little or no effect on the head in the Evangeline aquifer under these conditions.

There are published data on the vertical and horizontal conductivity of the Chicot aquifer (Carr and others, 1984). These data are of limited transferability to the study area. Solis (1981) shows that there is a trend to finer grained sediments and different depositional environments from northeast to southwest along the Texas Gulf Coast. Therefore, the data obtained in the Houston, Texas, area may not be applicable to the study area. However, these data are useful in testing the assumptions in the cross-sectional model. In modeling the vertical flow between the Chicot and the Evangeline aquifers, the relative difference between the vertical conductivities in the two aquifers is important. The vertical conductivity of the Evangeline aquifer is estimated to be at least 100 times lower than the horizontal conductivty. The vertical conductivity is actually computed using the input horizontal conductivity multiplied by a factor for anisotropy. The range of horizontal conductivity is 10^{-4} to 10^{-6} ft/s. The range of vertical conductivity for the Evangeline is therefore calculated to be 10^{-6} to 10^{-8} ft/s. The range of vertical conductivity tested is 10^{-8} to 10^{-12} ft/s for the Chicot aquifer. This range lies within the range estimated by Carr and others (1984). An average value of 1.4 X 10^{-9} is adequate to reproduce the head gradient assumed to exist between the two aquifers before development.

The sources and quantity of recharge could only be tested at a cursory level because the Jasper and Evangeline aquifers pinch out at the western end of the model. The thin section is difficult to simulate with the finite-difference grid. The results do indicate that there is cross-formational flow from the underlying Jasper aquifer to the Evangeline aquifer where the Burkeville confining unit pinches out.

The major constraints used in this modeling procedure are the presumed steady-state vertical head distribution, the presumed equilibrium at the saltwater interface under the Gulf, and the requirement that the properties and conditions agree with those of the areal modeling. This is especially important in testing the saltwater-interface boundary.

Based on the Badon Ghyben-Herzberg relationship (Bear, 1979), the freshwater head can be estimated at this boundary at depth. At the center of the aquifer underneath the coastline, about 1,300 ft below sea level, the freshwater head should be no less than 32.5 ft above sea level. By trial and error, the ratio of horizontal to vertical conductivity is adjusted until the resultant head distribution matches the presumed predevelopment head distribution within the constraints listed above. A ratio of 1,500:1 reproduces the head distribution adequately. This interface is a no-flow boundary, and thus, the saline-water nodes are outside the aquifer and were changed to no-flow nodes. This test helps define the probable location of the freshwater-saltwater interface based on theory and the presumed potentiometric head distribution in the Evangeline aquifer. The results are consistent with the earlier assumption that the interface is at least 5 to 10 mi offshore and therefore far enough from the pumping center at Kingsville that it can be modeled by a no-flow boundary at the eastern end of the areal model. The information gained from these tests of assumptions and boundaries is used to refine the predevelopment areal model and the transient-state model.

Areal Model and Input Data

The area modeled is divided into a 38 by 38 square grid with sides 2 mi long (fig. 11). The head and concentration of solute are solved at the center of each of these cells (nodes). A value for transmissivity, storage coefficient, vertical leakage, aquifer thickness, initial head, and water table are coded for each node in the transient model. Maps of most of these properties and conditions were given earlier. The predevelopment model uses zero for the storage coefficient value. Aquifer properties that are constant over the entire model are: Effective porosity, characteristic length of dispersion, and a factor of anisotropy. Because the aquifer is assumed to be isotropic, this value is set to 1.

Vertical leakance is used in the mathematical formulation and is computed from the vertical hydraulic conductivity divided by the thickness of the Chicot aquifer. The model input is set up for a limited number of leakance "areas" so the leakance actually is divided into seven areas as shown in figure 12. This artifact of the program has little effect on the quality of the computations. The leakage computation also requires a value for the head and concentration in the Chicot aquifer be entered at each node where this aquifer exists.

To simulate aquifer-boundary conditions such as recharge-discharge possibilities, the options include: Vertical-leakage, recharge, no-flow, constant-head, or constant-flux constraints. The western boundary is set as a constant head in the left column because the aquifer continues to the west, and the head is assumed to remain relatively constant during the period simulated. The eastern boundary is marked by the Gulf of Mexico and is set as a no-flow boundary. This boundary was explained earlier in the sections on hydrogeology and cross-sectional model.

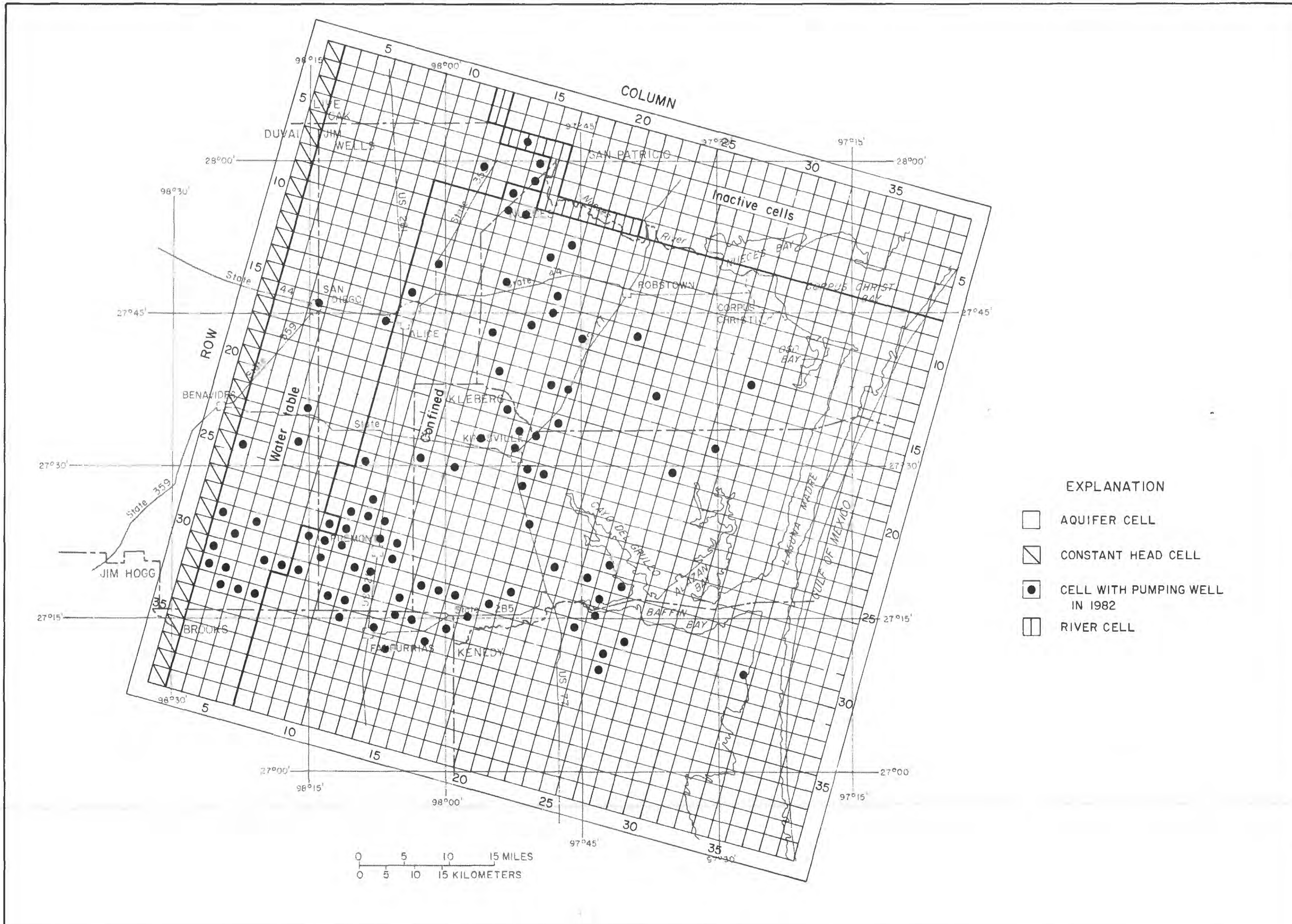

Figure 11.--Finite-difference grid superimposed on the modeled area.

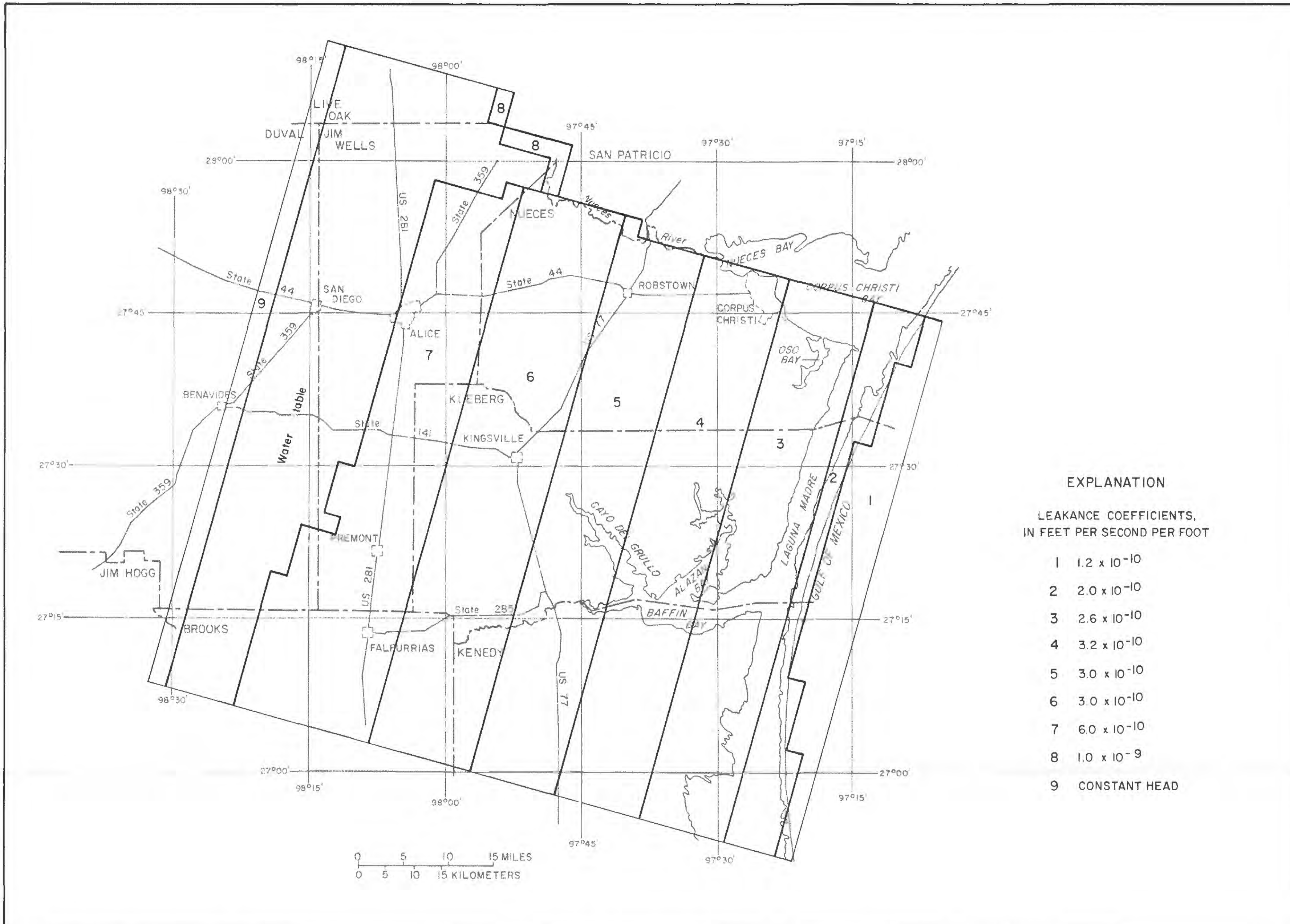

Figure 12.--Simulated leakance coefficient distribution of the Chicot and Evangeline aquifers.

The northern and southern boundaries are also set as no-flow boundaries. The northern boundary lies underneath the Nueces River and Corpus Christi Bay, which are regional discharge areas. The southern boundary is an area where the equipotentials of the potentiometric surface are subparallel to the coastline. There is no significant north-south flow across this boundary under steady-state conditions. This assumption is not accurate for the transient simulation because it assumes that the water pumpage to the south of this boundary is a mirror image of the water pumpage north of the boundary. This is somewhat true for the pumpage in Brooks and Kenedy Counties where pumping wells are fairly uniformly dispersed. There is no mirror-image of the intense pumpage of the Kingsville area in Kenedy or Brooks Counties. The water levels in the southwest corner of the modeled area do not change significantly over the time period simulated, so the assumption creates no obvious error in this area. The area of largest potential error, primarily in computed head, is that area in northern Kenedy County. This is discussed further in the section on uncertainty.

Ground-Water Withdrawals

Ground-water pumpage is not known exactly and is estimated by a step function. The data used in this study is modified from that estimated in the report by Carr and others (1984). The data had to be reformatted from the grid design of that study to the grid used here.

The time (1901-82) of the calibration simulation is broken into five pumping periods. During each period, the estimated pumpage is constant.

Projected Pumpage to the Year 2020

Two projections, a low estimate and a high estimate, are used in this study for the projected stress on the aquifer. Both are based on Texas Department of Water Resources (1981) and U.S. Bureau of Reclamation (1983) projections. Modifications to the low estimate are made to include the changes in pumping by Kingsville and the other municipalities that are scheduled to switch to surface water.

The first period of the projected pumping is 1983-84. The Kingsville area, center of most of the pumping through the historical period, had planned to cease or curtail pumping and begin using surface water supplies in mid-1984. A new surface-water reservoir did not fill as expected due to the long drought in South Texas and thus the planned diversion was delayed. At this writing, it is not known how long the delay will be. It is assumed to end by 1985. The projected pumpage for this period is 28.6 ft^3/s, or no increase for the low estimate, and 31.5 ft^3/s, a 10-percent increase for the high estimate.

The pumpage for 1985-2020 is estimated assuming that, in addition to Kingsville and other small municipalities discontinuing pumping their wells and using surface water as their main water source, other private and industrial wells continue production at slightly higher rates.

The pumpage for 1985-90 is 29.6 ft^3/s, an increase of 3.5 percent over that in 1982. The high estimate of this period is 34.3 ft^3/s, an increase of 20 percent over the pumpage in 1982. The pumpage in 1982 is increased 18 percent (33.7 ft^3/s) for 1991-2000; 30 percent (37.2 ft^3/s) for 2001-10; and 40 percent (42.6 ft^3/s) for 2011-20 for the low estimate. The 1982 pumpage is increased 54 percent (44.0 ft^3/s) for 1991-2000; 77 percent (50.6 ft^3/s) for 2001-10; and 110 percent (60.0 ft^3/s) for 2011-20 for the high estimate of pumpage.

Model Adjustments

Field data on the hydrogeology of the Evangeline aquifer, other than water-level measurements, are few and of limited accuracy. Assessing the potential deterioration of the freshwater in the aquifer is a two-pronged problem. The spatial distribution of hydrologic properties, particularly transmissivity, needs to be determined and then the effect of the distribution of these properties on the transport of salinewater can be estimated.

The most detailed aquifer-conditions data are head distribution and chloride-concentration distribution. The steady-state, predevelopment flow-system head distribution is based on historic observed water levels and contours drawn to estimate the data between wells. As explained in the section on hydrogeology, the head in the eastern half of the aquifer was not measured prior to intense pumping. Estimating the potential head that existed in the aquifer before development is constrained by the assumption concerning the equilibrium at the saltwater interface, the visual estimates of well flow by Taylor (1907), and the heads actually measured in some artesian wells near Kingsville. Accordingly, at the mean aquifer depth of 1,300 ft below sea level at the coastline, the head must have been greater than 35 ft above sea level to maintain the saltwater interface east of the coast. A similar value was calculated from the discharge data of several flowing wells given by Taylor (1907). This was estimated by calculating the drawdown expected in a well with an estimated transmissivity, a known discharge, and a few assumptions concerning the well screen and well efficiency. Head values are linearly interpolated between the coast and the measured values to the west.

Carr and others (1984) estimated regional transmissivity and storage coefficients in their study of the Texas Gulf Coast aquifers. Their estimates are used as the first approximation in this study. There are some aquifer-test data that, because of the low quality, are used only as constraints in the process of transmissivity estimation. Most of these aquifer tests were not set up according to accepted procedure (Ferris and others, 1962), and the data is of limited value. The major flaw in most of the tests is that the well screen does not penetrate the entire aquifer thickness, therefore, the data represent minimum values of transmissivity at best.

The process of adjusting the flow part of the model is essentially modifying the transmissivity distribution by trial and error until a satisfactory match is obtained between the presumed steady-state flow head distribution and the computed head. The process is repeated in the transient simulation to match historical observed heads with the computed head obtained by simulating the pumping stress.

Transmissivity and vertical leakage (vertical-leakance coefficient) have similar relative effects on the computed head in the model. The average of the vertical-hydraulic conductivities determined by Carr and others (1984) (1.4 X 10^{-9} ft/s) was used to determine the distribution of vertical leakance over the confined area. In the steady-state simulations, an estimate of the flow volume is used as a constraint on both the vertical leakage and the transmissivity.

An estimate of the natural flow through the aquifer is based on calculations made by Shafer and Baker (1973). They estimated that about 29 ft^3/s of water flowed through the aquifer at that time. Their value is high because it is based on a large estimate for transmissivity and they used the steep gradient that had developed in the 1960's from the intensive pumping.

The transient simulations, in which the pumping stress is simulated, impose an additional constraint on the magnitude of the transmissivity and leakance values. With the constraints imposed by estimates of volume of flow in the steady-state predevelopment simulations and the large changes in water levels in the transient simulations, a compatible and reasonable regional pattern of transmissivity and leakance can be determined.

Predevelopment steady-state simulations were done first to develop the correct ratio of transmissivity to leakance. The next step was, assuming a limited range for vertical hydraulic conductivity (from Carr and others 1984), to use the transient simulations to estimate the pattern of transmissivity distribution by trial and error. The transient simulations indicate that the actual transmissivity over much of the area is higher than the limited field data indicate. It is close to the estimates of transmissivity made by Shafer and Baker (1973). The final estimate for the transmissivity distribution is shown in figure 13.

All of the transmissivity values used in the adjusted model fall within the range of published data. The pattern of the distribution is close to that estimated in the various county reports. A notable exception is the area near Kingsville. Published estimates of the transmissivity made from specific capacity tests on the municipal wells at Kingsville range from 3,600 to 5,200 ft^2/d. The transmissivity used for this area in the model is 2,100 ft^2/d, significantly lower than the published estimates.

A map of the simulated storage coefficient used in the transient simulations is shown in figure 14. Because no reliable data exist for the storage coefficient and no data exist for the specific yield in the unconfined portion of the aquifer, adjustments to the storage values were kept to a minimum. An attempt was made to readjust the model using a water-table specific yield, but it was impossible to readjuste to achieve agreement with the data; this and field information led to a significant change in the concept of the flow system. The presumed "water-table" area does not respond like a free surface, and the large wells produce from the deepest of the three sand beds. These sand beds have water levels above the top of the sand. Shafer (1974) determined a storage coefficient of 0.000062 for a municipal well in this area. The area that required most adjustment of the storage-coefficient value is in the southwest quadrant of the modeled area. The value in this area was increased, and the best fit value is about 0.1--near what would be expected for an unconfined sandstone aquifer (Freeze and Cherry, 1979).

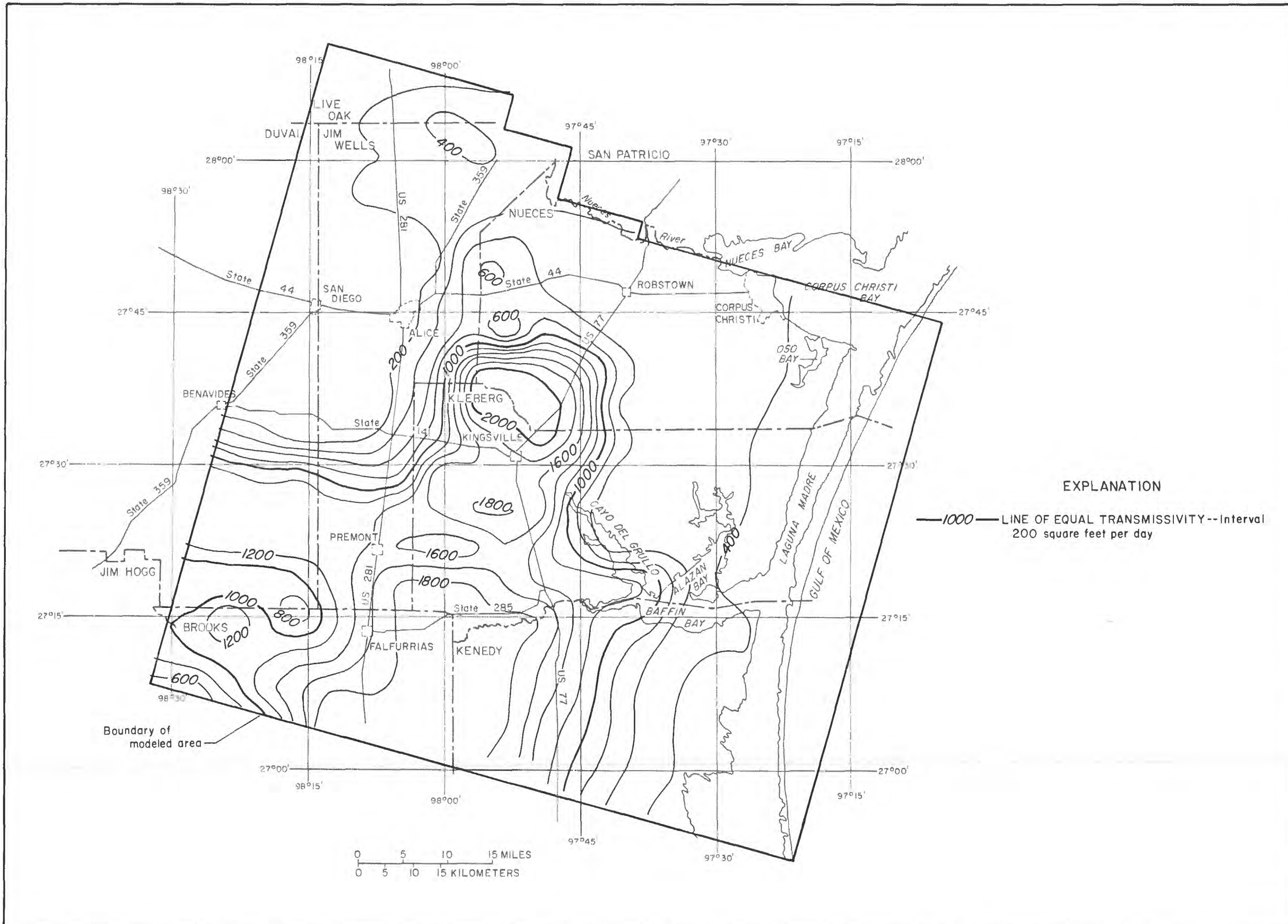

Figure 13.--Simulated transmissivity of the Evangeline aquifer.

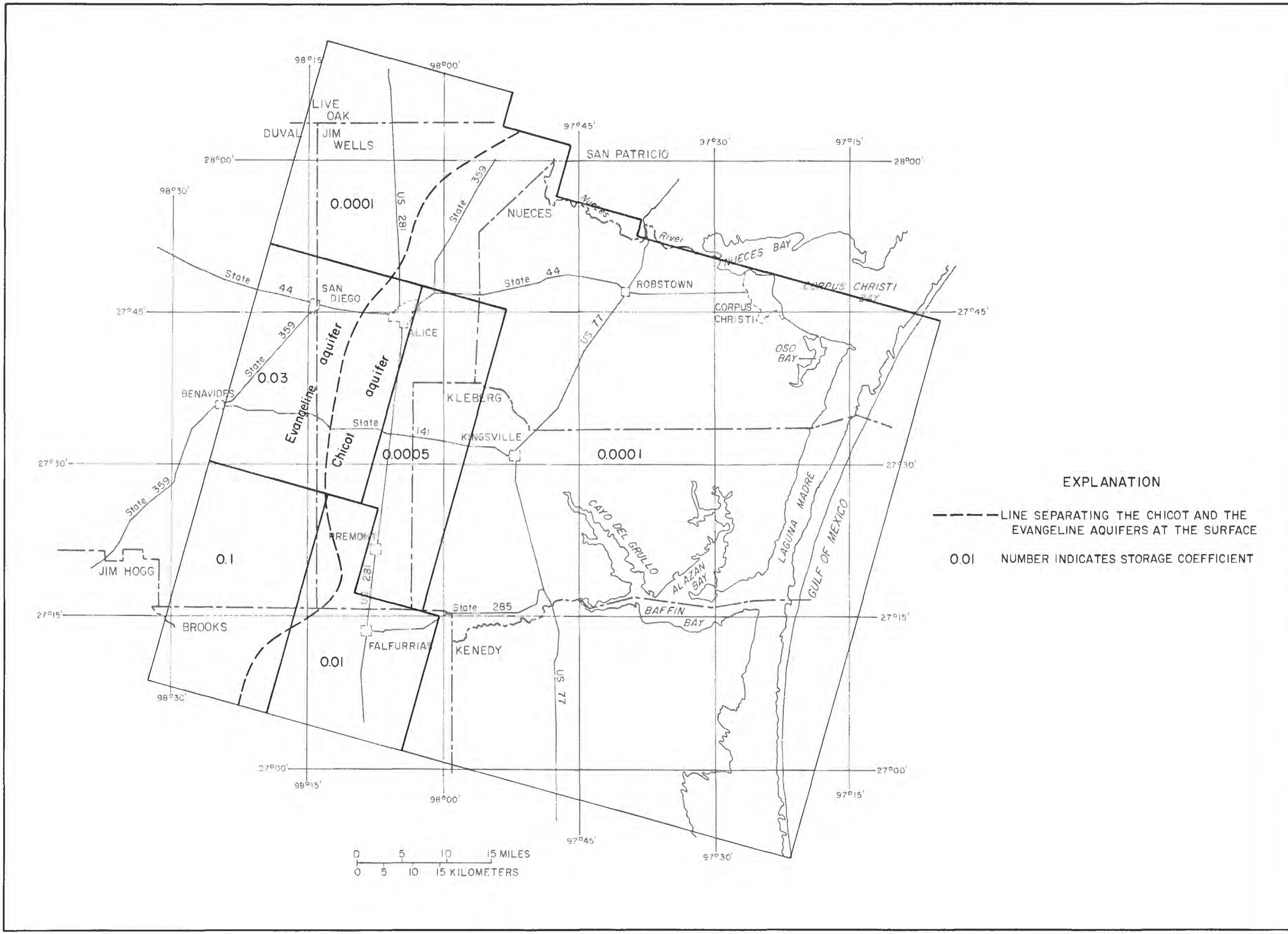

Figure 14.--Simulated storage coefficient of the Evangeline aquifer.

This high value is consistent with the original idea that the aquifer is under water-table conditions in the outcrop. In light of the reinterpretation of the aquifer conditions in the outcrop, this value is high. An explanation for this is that the wells that produce from the Evangeline in this area draw water from the deep sand layers within the aquifer. The decline in head due to this pumping causes water to leak downward from the overlying clay and sand beds within the Evangeline aquifer. The digital model cannot accurately simulate this kind of intra-aquifer leakage. Another possible explanation is that there is a relatively good hydraulic connection between the Evangeline and Jasper aquifers in this area. Water from the Jasper could be drawn upward into the Evangeline because the Burkeville confining bed pinches out underneath the Evangeline in this area. In either case, a high storage coefficient yields a similar effect--a larger amount of water released for a given decline in head. This artifact of the model, for this problem, results in computed head and solute concentration that would be expected from any of the three alternative causes (water-table conditions, intra-aquifer leakage, or upward leakage from the Jasper aquifer), but there is an unknown amount of error associated with it.

The transmissivity and leakage were adjusted first because they are both included in the transient and steady-state simulations. The transmissivity and leakage were adjusted during the estimation process to achieve the best match between computed and observed head. Because adjustment of transmissivity and leakage alone could not achieve a satisfactory match over the entire area, it was decided late in the modeling to use an array of storage coefficient values rather than one value. Thus, the original estimate of the storage coefficient was adjusted only in the areas where it was needed and not in the areas where an adequate fit had already been found. Since field data for storage are limited and time for adjustments was short, it was decided that any more "fine-tuning" of the properties would not yield any new useful insight.

The model was adjusted after comparing head and concentrations in observation wells that are as near the center of nodes as possible. Only a few wells meet these qualifications, even though there is a large amount of data available for over 800 wells in the area. There are several reasons for this apparent disparity. First, accurate representation of the lateral and vertical boundary conditions and alignment of the principal flow direction with the X-direction of the model grid took precedence over locating wells in the center of nodes in the positioning of the finite-difference grid on the study area map. Second, a large portion of the wells that were measured for water levels, and especially for chloride concentration, in the first half of this century were abandoned and sometimes replaced at a new location or were destroyed. A large number of the wells that were used to develop the original chloride distribution could not be tested again in 1982. Third, the majority of the wells for which data exist are not regularly spaced over the area. Most are located in the area around Kingsville and the area between Kingsville and Falfurrias in Kleberg, southern Jim Wells and Duval, and northern Brooks and Kenedy Counties. These wells are closely spaced so that a number may lie within one node. Finally, most of the wells were measured only once or twice for water levels.

The wells chosen for testing the goodness-of-fit of the model are listed in table 1 along with the measured water level and computed water level. Also shown in this table are the measured chloride values and the respective com-

Table 1.--Comparison of 1982 observed water levels and chloride concentrations and the computed values for 1982

Texas Department of Water Resources well number*	Node coordinates		Altitude (feet)		Concentration (milligrams per liter)	
	Column	Row	Observed head	Computed head	Observed chloride	Computed chloride
JB-84-30-301	6	21	242	236	--	720
37-901	4	29	285	287	--	9
45-304	4	31	314	285	--	1,740
RD-83-50-307	25	30	-6	-6	270	210
59-501	28	34	6	7	310	430
60-101	30	33	22	4	--	460
501	32	33	19	3	--	830
88-02-103	23	38	23	24	280	350
RR-83-25-301	17	18	-93	-83	--	280
26-401	18	19	-152	-123	--	350
29-404	30	16	-10	-10	850	750
35-201	24	21	-54	-60	--	310
UB-83-03-702	19	7	22	16	600	600
09-205	14	10	46	56	660	660
29-201	30	15	11	-6	970	870

* See Rettman (1983).

puted chloride concentrations. All the values for both water levels and chloride concentration lie within error limits for these conditions with a few exceptions. The computed potentiometric head for 1982 is shown in figure 15.

Figure 16 shows the departure of computed head from the observed heads as interpolated from the map of the potentiometric head (fig. 9). All the heads in these profiles agree with an error range of less than ± 40 ft. This agreement indicates that the model is sufficiently adjusted. Furthermore, the errors of the computed mass balances are less than 0.5 percent for the flow model (water mass) and less than 0.2 percent for the solute transport model (chloride mass). These small mass balances errors indicate the model solution is not an artifact of numerical error.

SENSITIVITY OF THE MODEL

Because it is impossible to know everything about the aquifer with a reasonable amount of certainty, the sensitivity of the model to the vagaries of the data and underlying assumptions must be assessed. These sensitivities reflect the overall reliability of the model (Konikow, 1978). Errors associated with each property or condition vary not only in range and absolute value, but also in the magnitude of the effect each has on the computed head and chloride distributions.

In this section, the uncertainty of each property and condition and the effect of the uncertainty on the head distribution is discussed first, then the effects of the uncertainty on the computed chloride distribution is discussed. This discussion focuses on gross regional changes or effects on the head and chloride; local effects (those that affect an area of less than 4 grid cells--16 mi^2) are beyond the scope of the available data. The adjusted model is the unperturbed, or base, simulation. The simulations discussed in this section have aquifer properties or conditions that have imposed changes to simulate the effect of errors in those properties or conditions.

Sensitivity of the head distribution to properties and conditions in the predevelopment simulations is not as great as in the transient simulations. Only those uncertainty effects that are common to both the predevelopment and transient simulations or only transient sensitivities where the predevelpment simulations yield dissimilar or inconclusive results are addressed.

Sensitivity of the Computed Head to Uncertainty in Aquifer Properties and Conditions

Error Associated with Aquifer Properties

Transmissivity

Properties of the aquifer have an important effect on the computed head. Transmissivity is the most important of these properties. The lack of accurate, well-distributed transmissivity data is the most important source of uncertainty in this study.

There is no way to formally measure the amount of error associated with these estimates or the fitted transmissivity distribution in the model. A conservative range of the uncertainty is ±50 percent of the value. Two runs

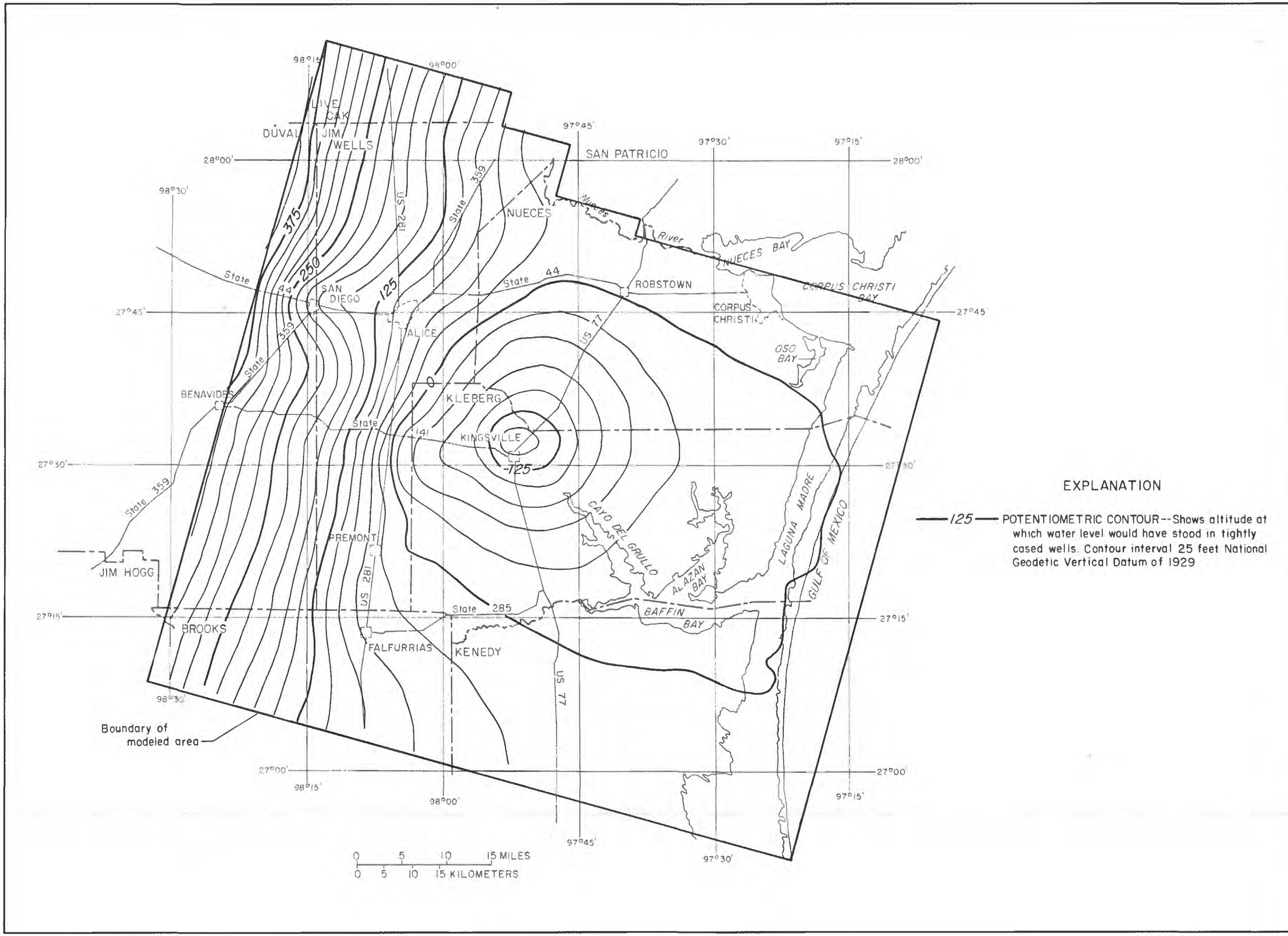

Figure 15.--Computed potentiometric surface of the Evangeline aquifer for 1982.

page 44 follows

of the model were made to test the effect of this range of transmissivities. Figure 16 is a graph of the head in rows 10, 20, and 30 from west to east. The three lines show the simulated head and the result of increasing and decreasing the transmissivity over the entire model grid. The increase in transmissivity has a pronounced effect over the head profile in rows 20 and 30. The relative insensitivity of computed head in row 10 is due primarily to the absence of drawdown by pumping. Note the difference in scale between the rows in the figures. Rows 20 and 30 are located in the area either where large declines in head have occurred or where there is substantial historic pumpage or both. Also note, that in row 20, the head at the ends of the row are slightly higher for reduced transmissivity and slightly lower for increased transmissivity. This indicates that relative radius of influence of the pumping center varies with the overall transmissivity. In the center of row 20 and over most of row 30, the heads are lower for reduced transmissivity and higher for increased transmissivity. From column 2 through column 8 in both rows 20 and 30, the outcrop area shows less sensitivity than the area where the Evangeline is overlain by the Chicot aquifer.

Aquifer thickness and porosity

The thickness of the aquifer is known with some certainty to about ±10 percent over most of the area. The uncertainty of aquifer thickness lies not only in estimating the upper and lower limits of the aquifer, but also in estimating the aggregate thickness of the sand layers that conduct the majority of the water in the aquifer. The total thickness of the aquifer includes relatively nonconductive silt and clay layers--as much as 70 percent of the total aquifer thickness could be silt and clay. Porosity has a similar relative amount of uncertainty. These properties are not used for the flow model but are critical to the solute transport model and are discussed further in that section.

Storage coefficient

The error associated with the storage coefficient is great and could be as much as a factor of 10. The range used in the adjusted model is from 0.0001 in the eastern and northern areas to 0.1 in the southwestern area. A conservative range of uncertainty is ±50 percent. Two simulations were run using these error bounds. Figure 16 shows the head profile in the three rows. The storage coefficient has a much smaller effect on the computed head relative to the transmissivity. Note that the relative effect of increasing the storage coefficient is greatest near the center of row 10, but in row 20, the departure is greatest in the outcrop area (columns 2-8). In row 30, the changes in storage coefficient affects the computed head in the outcrop area--the opposite of the rest of the modeled area. The computed head, in columns 2-7, is increased for decreased storage coefficient and decreased for increased storage coefficient. This effect is most likely the result of using a large storage coefficient to simulate intra-aquifer leakage. This area has the highest storage coefficient.

Error Associated with the Aquifer Boundary Conditions and Assumptions

The freshwater-saltwater interface

The flow model is relatively insensitive to transmissivity perturbations in the downdip half of the modeled area. The base simulation was run with the transmissivities in columns 25 through 39 halved. The resultant head distribution is only slightly different from the unperturbed model results. This insensitivity of the computed potentiometric head at this boundary is due to the flat head gradient and absence of pumping wells in the area.

The eastern boundary condition was tested to determine the significance of the uncertainty about the nature of the saltwater interface. The leakance value of this boundary was increased to 2.8×10^{-7} to act, as closely as possible in the model, as though there were no interface and that the aquifer continued under the Gulf and maintained a constant head to the east of the boundary. The results of this run are insignificantly different from the unperturbed simulation for both head and chloride distribution.

The water table in the Evangeline aquifer

The water table in the Evangeline aquifer changes insignificantly over the period simulated. The effect of changing this condition has little or no effect on the computed head because the PDSS model is adjusted in all properties and conditions to simulate the observed head distribution. A change in the input starting head for the Evangeline aquifer would not result in a different computed head.

The southern no-flow boundary

As noted above, the no-flow condition used at the southern boundary of the modeled area is not justifiable under transient-state conditions. A test of this boundary was done by changing it to a constant-head boundary similar to that on the western edge of the model. This is justifiable in the southwest area because no significant observed water-level changes occured in this area during the period simulated. The results of this sensitivity test indicate that the computed head is not significantly different anywhere in the modeled area between these two boundary conditions. It is concluded, therefore, that the assumption of no flow at this boundary is sufficiently accurate for this study.

Recharge

The estimation of the predevelopment system properties using a constant head boundary on the west avoids the problem of an unknown recharge rate. The boundary acts as though the aquifer continues indefinitely to the west and "leaks" in enough water to maintain a constant head along the nodes at the boundary. The amount of water that is "leaked in" (recharge in this case) is dependent on the transmissivity of the boundary and nearest neighbor nodes and the head gradient at the boundary. The amount of water that flows into the aquifer in the adjusted predevelopment model is 7 ft^3/s. This rate is equivalent to about 0.06 in./yr of recharge over the water-table area. The error associated with this estimate of the recharge is difficult to quantify but, is likely of greater magnitude than the actual rate. The error of measurement in any attempt to measure recharge would be much greater than 0.06 in.

In the transient model, the rate of flow across this boundary should remain about the same because it is assumed that the water table in the Evangeline does not change significantly. In actuality, there are some local significant changes in the water levels in this area, and some of these show up in the computed head. This is obvious in the area around San Diego and Benavides. These local depressions in the water table surface have a small effect on the total flux across the boundary.

Discharge

The vertical leakance rates are estimated, and there are no means to formally calculate the amount of uncertainty of these values. The values used in the mathematical model are computed from vertical-hydraulic conductivity divided by the thickness of the Chicot aquifer. The thickness of the Chicot aquifer is accurate to ±50 ft over most of the study area. The estimated vertical conductivity has an unknown amount of uncertainty. A conservative estimate of the uncertainty is ±50 percent. The results are shown in figure 16 for head in rows 10, 20, and 30 for varying the vertical conductivity ±50 percent. The head distribution is sensitive to these perturbations. In all the rows, the increase in the vertical conductivity has a greater effect on computed head than the equivalent decrease. For rows 10 and 30, this is the property or condition that exhibits the greatest sensitivity. For row 20, it is one of the least sensitive perturbations. By comparing the effects of perturbed transmissivity and vertical conductivity, it is clear that even though both of these parameters show large departures from observed head, the transmissivity around the pumping center is more important than vertical conductivity. The ability of the Evangeline aquifer to transmit water to the pumping wells has a greater effect on the computed head than the ability of the Chicot to leak water downward, but only within the radius of influence of the pumping around Kingsville and to the area southwest of it. Over the rest of the modeled area, the vertical conductivity is relatively more important.

The water table in the Chicot aquifer

The water table in the Chicot aquifer is, by assumption, the head in the leaky saline layer overlying the Evangeline aquifer. The mathematical model multiplies the leakance coefficient by the difference in head between the Evangeline and Chicot aquifers. Assuming there is no error in the Evangeline head, the head difference has an uncertainty of about ±10 ft due to the estimate of the head in the Chicot aquifer. The water-table altitude in the Chicot aquifer is known with less certainty than the water-table altitude in the Evangeline aquifer. The water table in the Chicot aquifer is near land surface close to the Gulf of Mexico and is probably within 40 ft of land surface over most of the area. The error associated with this estimate of the head in the Chicot is no more than ±10 ft. The effects of increasing and decreasing the water-table altitude by 10 ft are shown in figure 16. Relative to the perturbations in other properties and conditions, the changes in the water table are least sensitive. The effects are fairly uniform over the entire modeled area. Note that this is the only condition or property that significantly affects the computed head at the lateral boundaries. These boundaries are where the errors of measurement or estimation are smallest. Also, the changes in the Chicot water-table altitude cause a similar increase or decrease in the computed Evangeline water-table altitude. This is because the potentiometric head in the Evangeline, where it is overlain by the Chicot, has a direct influence on the head in the outcrop area.

Pattern and rate of withdrawals

As stated earlier, the pumping rates are modified from the estimates made by Carr and others (1984). W. Sandeen (U.S. Geological Survey, oral commun., 1984) estimates that the error associated with municipal well pumpage rates is on the order of 10 percent. These wells also are located accurately so the pattern of pumping from these wells can be simulated accurately. Sandeen also estimates the error associated with the stock wells and irrigation wells is much higher--as much as 50 percent. This is especially true for flowing wells. However, the relative proportion of the total pumpage from these privately-owned wells is rather small. Many of these private wells are difficult to locate accurately on a map because they have since been destroyed or are situated in an area with no landmarks and little survey control. The uncertainty of the location of the wells is further increased because well discharge is averaged over the area of the cell in the model, but the head is computed for the node. This affects the overall pattern of drawdown to an uncertain extent. Other aquifer properties, such as transmissivity, obscure the inaccurate pattern of pumping. A conservative estimate of the overall error of the pumping rates is ±25 percent.

The pumping rate has a significant effect on the head distribution. This is shown in figure 16. The greatest effect, as expected, is near the pumping centers. The difference in computed water levels between each of the perturbed simulations and the unperturbed run is about 50 ft maximum. The perturbations in pumping show relatively great effects on the computed head for row 30 compared with other sensitivities. Row 20 shows a relatively small sensitivity.

Sensivitity of Computed Chloride Concentration to Uncertainty of Aquifer Properties, Conditions, and Assumptions

Due to the nature of the problem, it is difficult to define the effects of aquifer property and condition uncertainty on the computed chloride concentration. Attempts to formally address the sensitivity of chloride to the properties and conditions of the aquifer is made difficult, if not impossible, by several factors. The first is that no significant regional degradation of water quality has been found in the study area. Second, the field data used to define several of these properties and conditions are extremely limited or nonexistent. Third, the analytical error of the historical chloride concentration determinations is most likely about 10 percent. This means that over most of the area, the error range for observed chloride concentrations is ±25-50 mg/L. The model-computed changes in chloride concentration are all smaller than these analytical errors. Finally, there is a larger error associated with the kriging process used to make the map of the original chloride distribution and estimate the nodal chloride concentrations. The standard deviations of the chloride estimates (fig. 17) are all greater than 90 mg/L. This is far greater than any computed changes in concentration. Even with

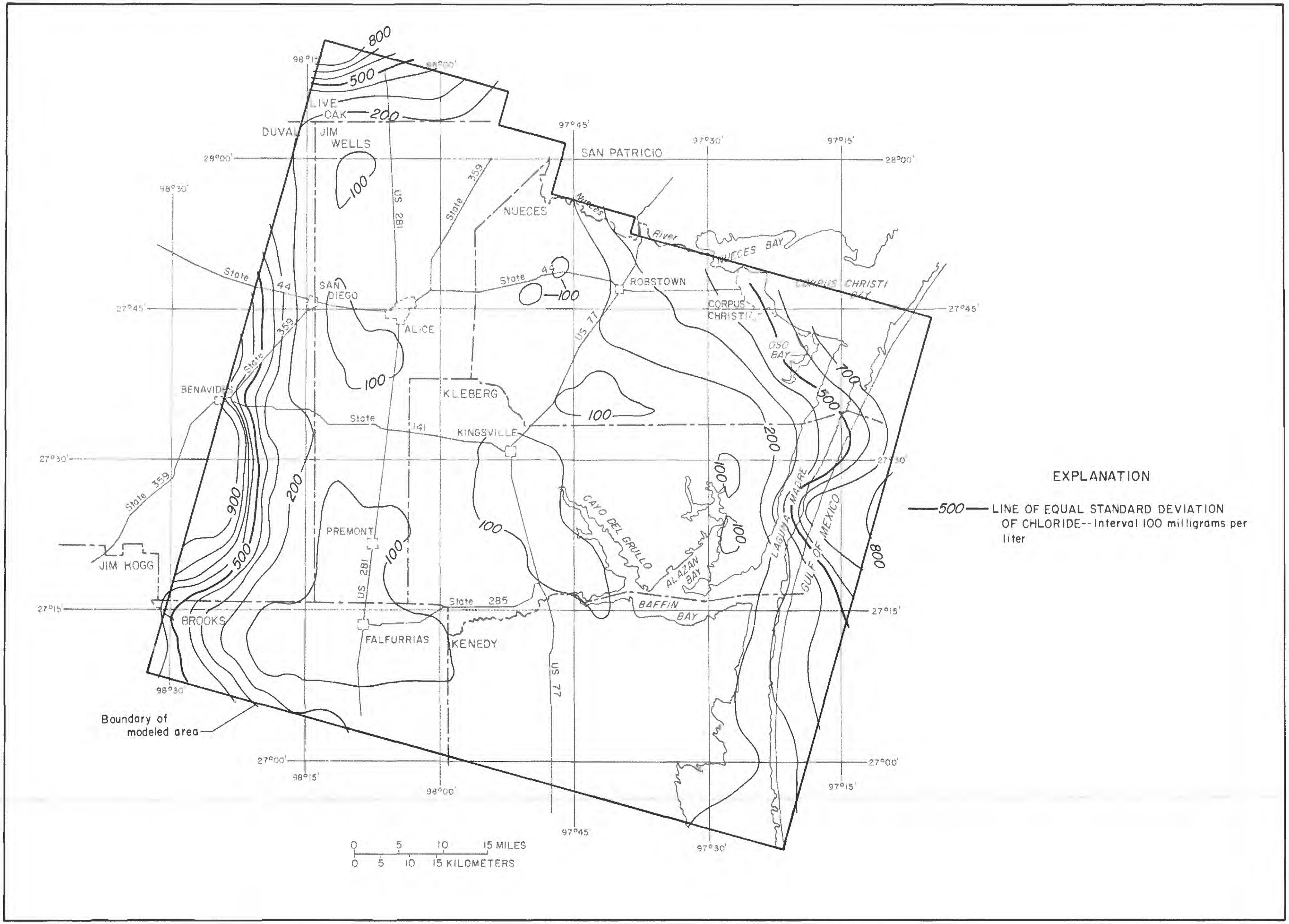

Figure 17.--Standard deviation of cholride concentration in the Evangeline aquifer derived by kriging.

this amount of uncertainty, it is possible to identify--based on relative changes in concentration computed by the model--potential problems by area and aquifer property or condition.

Error Associated with Aquifer Properties

Transmissivity

Although the chloride distribution is relatively insensitive to the imposed perturbations in transmissivity, it is still indirectly sensitive to the actual vertical distribution of the highly transmissive layers within the aquifer. The salinewater that lies within the aquifer should be transported more quickly in the sand layers than in the silty layers. The areal model uses a vertically integrated transmissivity in the computations even though most of the water is conveyed in the sand layers. The effect this has on the transport of solute is that it increases the apparent solute dispersion (Schwartz, 1977; Guven and others, 1984). The increased solute dispersion occurs because the highly conductive but thin sand layers will transmit solute faster than the equivalent transmissivity in a thick layer. This is shown in the next section on sensitivity of chloride to aquifer thickness.

Aquifer thickness and porosity

The actual thicknesses of the sand layers within the the aquifer vary over the area modeled. At the outcrop, as much as 60 percent of the Goliad-Willis operational units are sand (Solis, 1981). The average over the confined area is about 30 percent. A simulation using an aquifer thickness of 0.3 times the total base run thickness shows that the chloride is more sensitive to this perturbation than most others. The same change in computed chloride occurs if the effective porosity is decreased to 10 percent from 30 percent used in the unperturbed model. These changes are due to the increase in computed velocities. The maximum velocity increases, as expected, by a factor of 3. The chloride changes that result from decreasing the aquifer thickness or porosity input data affect the same area shown in the map of computed chloride changes in figure 18.

The amount of change in concentration for the run with decreased aquifer thickness is 2 to 3 times greater than the respective change in the unperturbed run in most of the same nodes. In addition, the area of Brooks, southern Duval, and extreme southern Jim Wells Counties shows changes in chloride that the unperturbed run did not. If the aquifer thickness or porosity varies significantly from what was used in the model, water-quality degradation would be indicated by the model to occur in this portion of the aquifer.

Dispersion coefficient

The literature on solute transport modeling contains many criticisms and cautions about the applicability of and reliability of simulating solute dispersion in ground-water flow (Anderson, 1979). Because the transport of solutes is primarily dependent upon accurate velocity determinations, the need for detailed and extensive field data on conductivities and heterogeneities of the aquifer overshadows the importance of the dispersion coefficient. This, and the difficulty of obtaining any meaningful dispersion coefficient data in

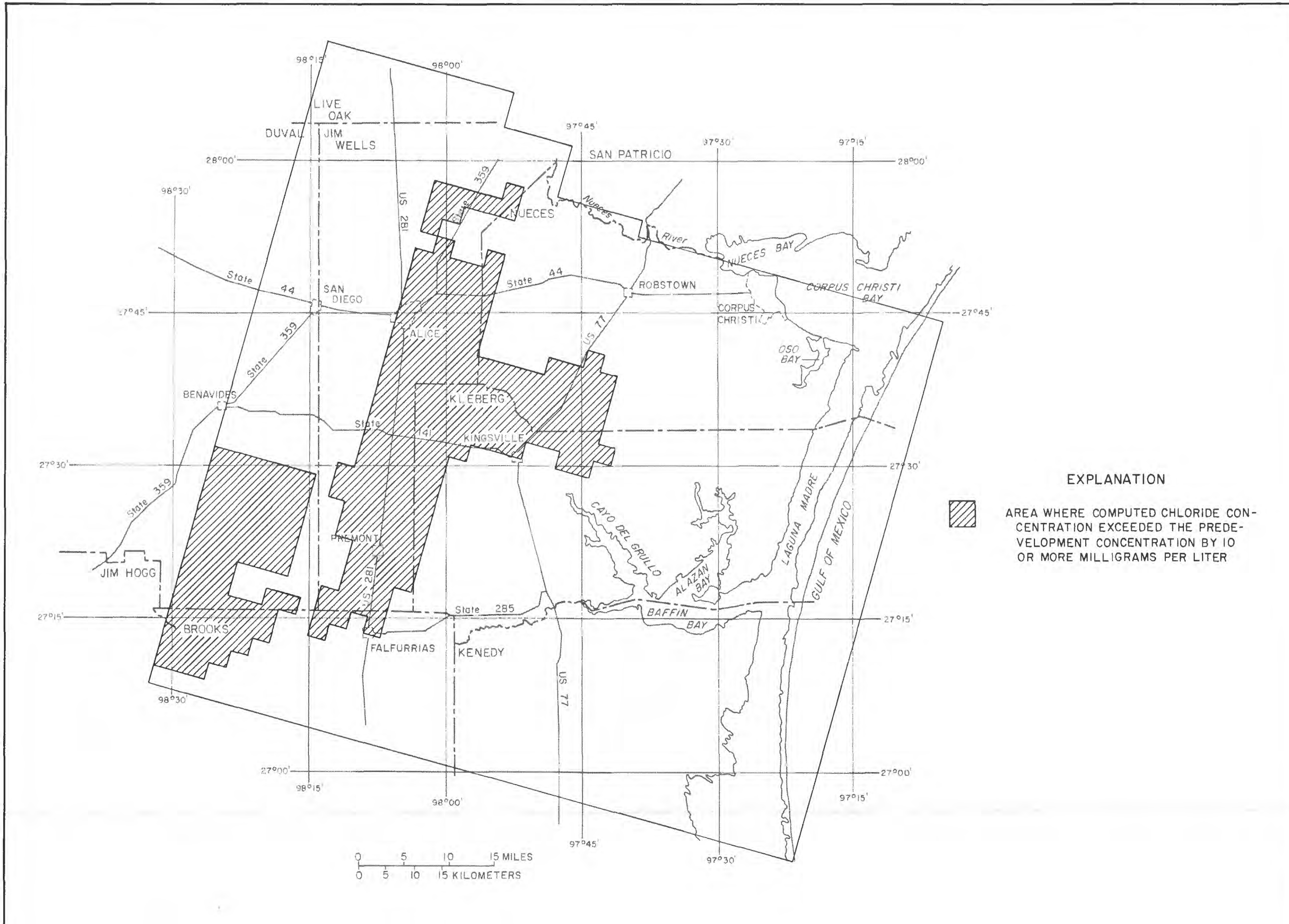

Figure 18.--Effect of imposed decrease in aquifer thickness on computed chloride concentration in the Evangeline aquifer for 1901-82.

the field are why emphasis is placed on estimating transmissivity. The dispersion coefficient is taken into account only in this section.

The characteristic length (a measure of dispersion coefficient) is set to 1 ft for the adjustments to the solute transport model. A value of 5,000 ft, approximately one-half of a grid cell, is used to test the effect of the uncertainty associated with the dispersion coeffecient. The resultant chloride distribution is identical to the unperturbed model distribution, considering the analytical error. Under the assumed conditions and the properties as they are estimated, the transport of chloride over the period simulated is insensitive to the dispersion coefficient.

Error Associated with Boundary Conditions

Concentration of chloride in the Chicot aquifer

The other condition that has an important effect on the chloride distribution is the chloride concentration of the water that leaks into the Evangeline aquifer from the Chicot aquifer. For this sensitivity run, the concentration range assigned to the leakage is increased from 2,500-10,000 mg/L to 4,000-10,000 mg/L. The lower range values were used in the unperturbed model and are estimated. The average concentration of chloride from wells that tap the Chicot aquifer in the study area is much lower--about 500 mg/L. This is a biased sample since most of these wells are set in freshwater lenses within the Chicot and are not representative of the water that leaks downward. Electric logs give a better idea of the average concentration of water in the Chicot aquifer. The error associated with using electric logs to estimate the chloride concentrations could be as much as 2,000 mg/L.

The resultant changes in concentration as computed by the model using the high estimate of the Chicot aquifer concentrations are relatively greater than those computed by the unperturbed model but are still lower than 50 mg/L.

The freshwater-saltwater interface

An unexpected result of these sensitivity tests and of the study is that the salinewater interface at the eastern boundary has little effect on the head or chloride distribution. The test run of the uncertainty of this boundary condition, when the no-flow condition was replaced by a leakage condition, has the same resultant chloride distribution as the base simulation.

The Significance of the Sensitivity Analysis

Table 2 is a summary of the sensitivities of computed head and concentration to the aquifer properties and conditions tested. For all of the computed potentiometric head sensitivities, only the area in the cone of depression showed sensitivities that are greater than the model-fitting criterion for head. In figure 16, only row 20 departures exceed ±50 ft of the observed head. For the changes in properties and boundary conditions in areas that showed little sensitivity in computed head or chloride, more data would probably not help refine the model. The properties that need to be better defined to refine the flow model are Evangeline transmissivity, the vertical-hydraulic conductivity in the Chicot aquifer, and pattern and rate of pumping. The computed head showed significant sensitivity to changes in these properties. Vertical con-

Table 2.--Summary of the relative sensitivities of computed potentiometric head and solute concentration to uncertainty of aquifer properties and conditions

Aquifer property or condition	Relative quality of field data	Effect on head	Effect on solute
Transmissivity	Fair	Significant	Significant
Storage coefficient	Poor	Significant	Slightly significant
Vertical conductivity	Poor	Significant	Significant
Constant head boundary			
a. Head	Good	Insignificant	Insignificant
b. Transmissivity	Fair	Locally significant	Locally significant
Pumpage	Very good	Significant	Significant
Thickness	Good	None	Locally significant
Porosity	Poor	None	Locally significant
Head in source bed	Good	Significant in confined portion	Insignificant
Concentration in source bed	Fair	Insignificant	Significant

ductivity is one of the most poorly defined properties. The solute-transport model can be refined by new data on the aggregate thickness of the highly conductive (sand) layers. Guven and others (1984) have shown that the vertical distribution of conductivity within an aquifer is a major component of the apparent solute dispersivity in an aquifer. Porosity also needs to be measured in the aquifer to refine the solute transport model. Both vertical-hydraulic conductivity of the Chicot aquifer and, indirectly, the storage coefficient, need better definition for the solute transport model. The vertical conductivity directly affects how fast salinewater will move downward. The storage coefficient, by definition, is the volume of water released by a unit volume times the thickness of the aquifer per foot of drawdown. The amount of water that can be withdrawn by wells from the Evangeline aquifer before drawdown reverses the natural gradient and causes downward migration of salinewater is affected by the storage coefficient.

The best estimates of all aquifer properties and conditions obtained from the model-fitting process are those in the area in and around the cone of depression. The properties and conditions in the areas outside of the cone are the least well-estimated due to the flat gradients or the lack of historic water-level and chloride concentration changes. Because of the assumed vertical uniformity of the aquifer properties and quality in the outcrop area, and especially in Duval County, the model results probably are less accurate here than elsewhere in the modeled area. In this area, the results shown are more applicable to the deepest sand layer since it is pumped more and the water quality is more consistent from well to well.

SIMULATED EFFECTS OF PROJECTED PUMPING ON POTENTIOMETRIC SURFACE AND WATER QUALITY

Results of the Low Estimate of Pumping

The computed head for the year 2020 is shown in figure 19 for the low estimate of pumpage and in figure 20 for the high estimate of pumpage. The drawdown of the low estimate is not much greater than the drawdown of the base period. This small change in potentiometric surface is reflected in the change in the concentration map shown in figure 21. The concentration of chloride does not change significantly under this projected pumping stress.

Results of the High Estimate of Pumping

The potentiometric surface computed at the end of the high estimated pumpage through 2020 does show significantly more drawdown over most of the area with respect to the surface of 1982. The deepest water level is about 400 ft below sea level. This water level would be located under Kingsville. At this location, -400 ft is still about 200 ft above the top of the aquifer; thus dewatering of the aquifer does not occur, although actual drawdowns in wells would exceed this depth. The increased downward gradient does cause an increase in the amount of water that flows from the Chicot aquifer to the Evangeline aquifer.

The change in chloride concentration for the high estimate of pumpage is shown in figure 22. There still are no nodes where the change in concentration exceeds the error of interpolation, so it is not possible to conclude that

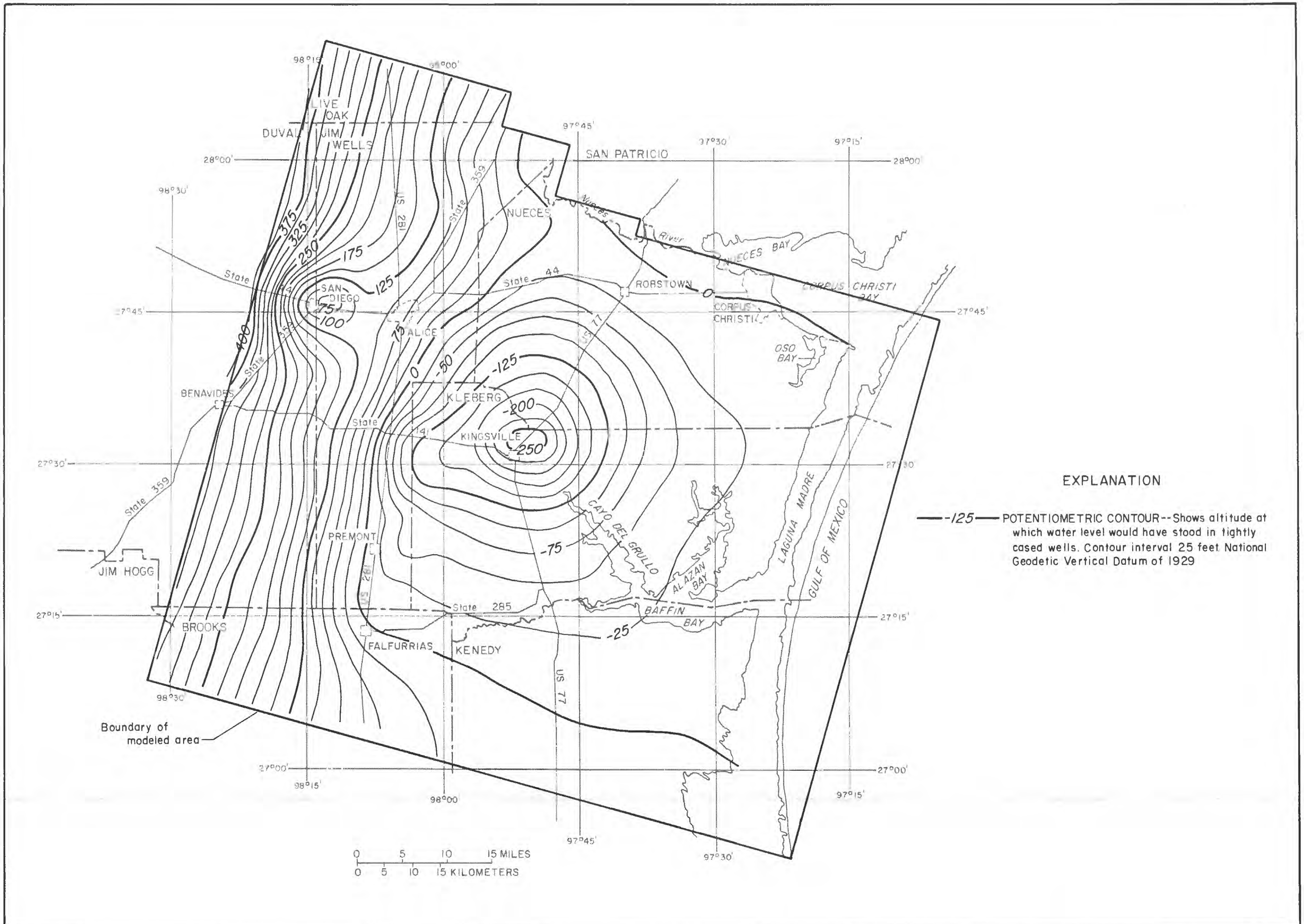

Figure 19.--Computed potentiometric surface of the Evangeline aquifer for 2020, using the low estimate of pumpage for 1983-2020.

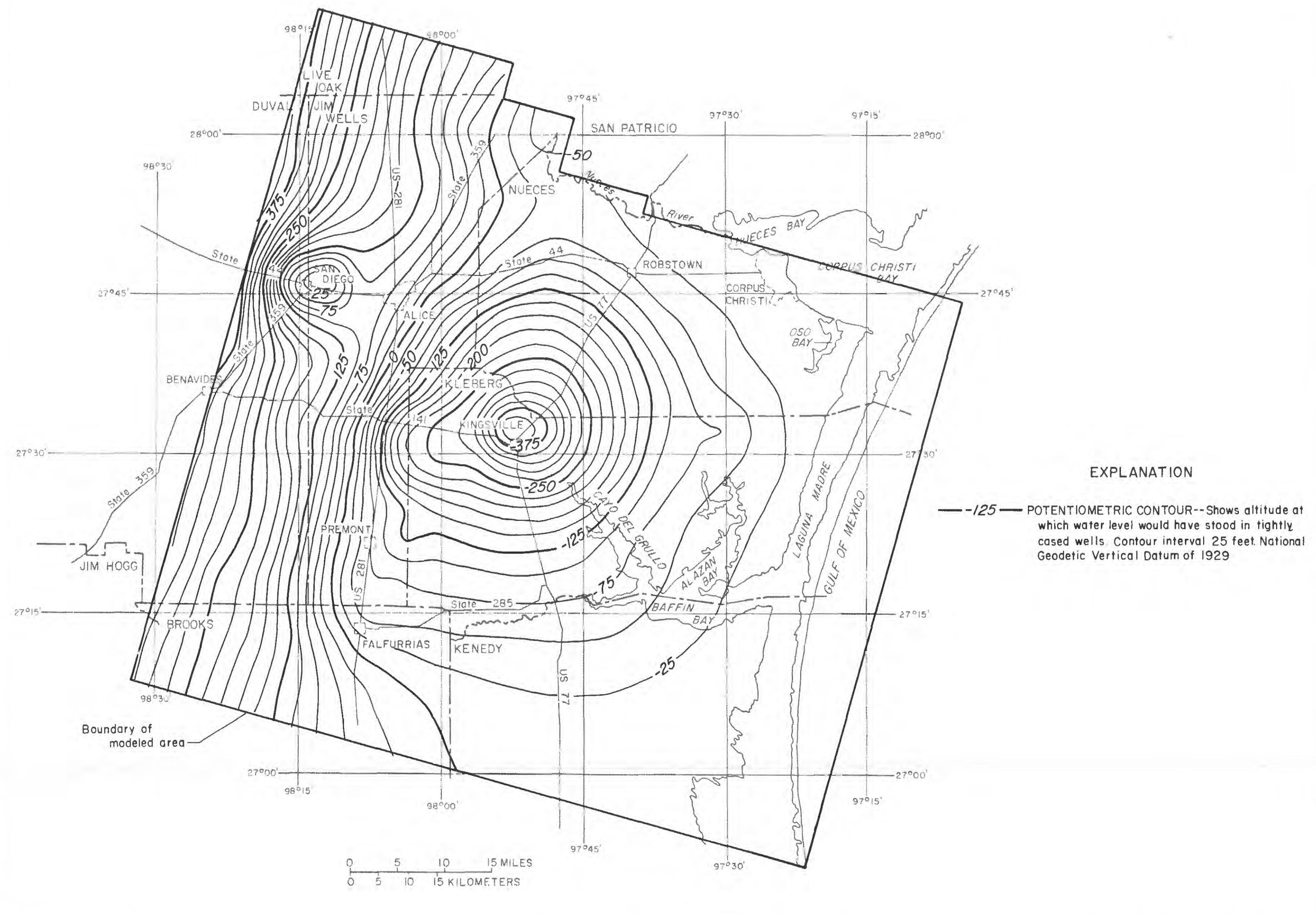

Figure 20.--Computed potentiometric surface of the Evangeline aquifer for 2020, using the high estimate of pumpage for 1983-2020.

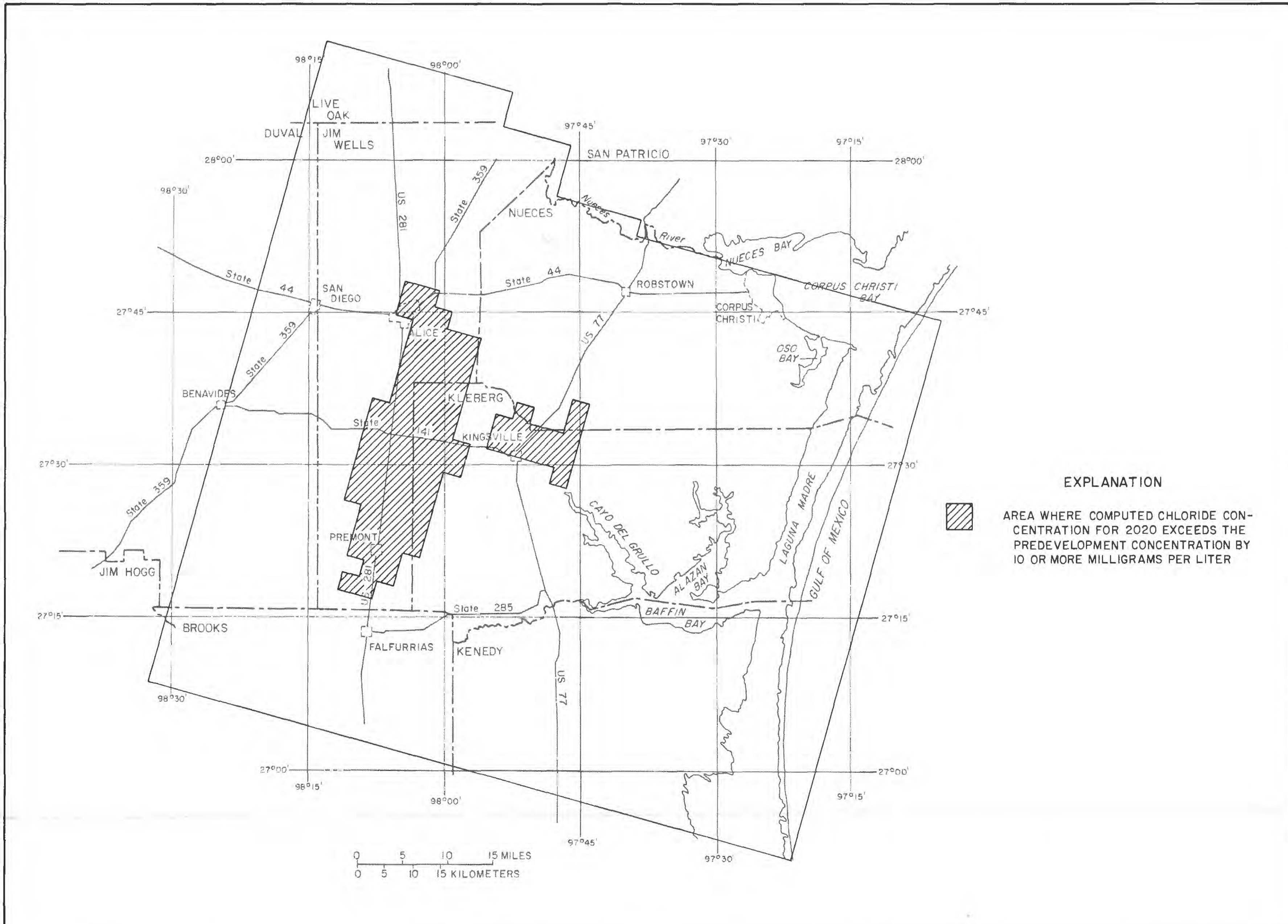

Figure 21.--Effect of the low estimate of pumpage on the computed chloride concentration in the Evangeline aquifer for 2020.

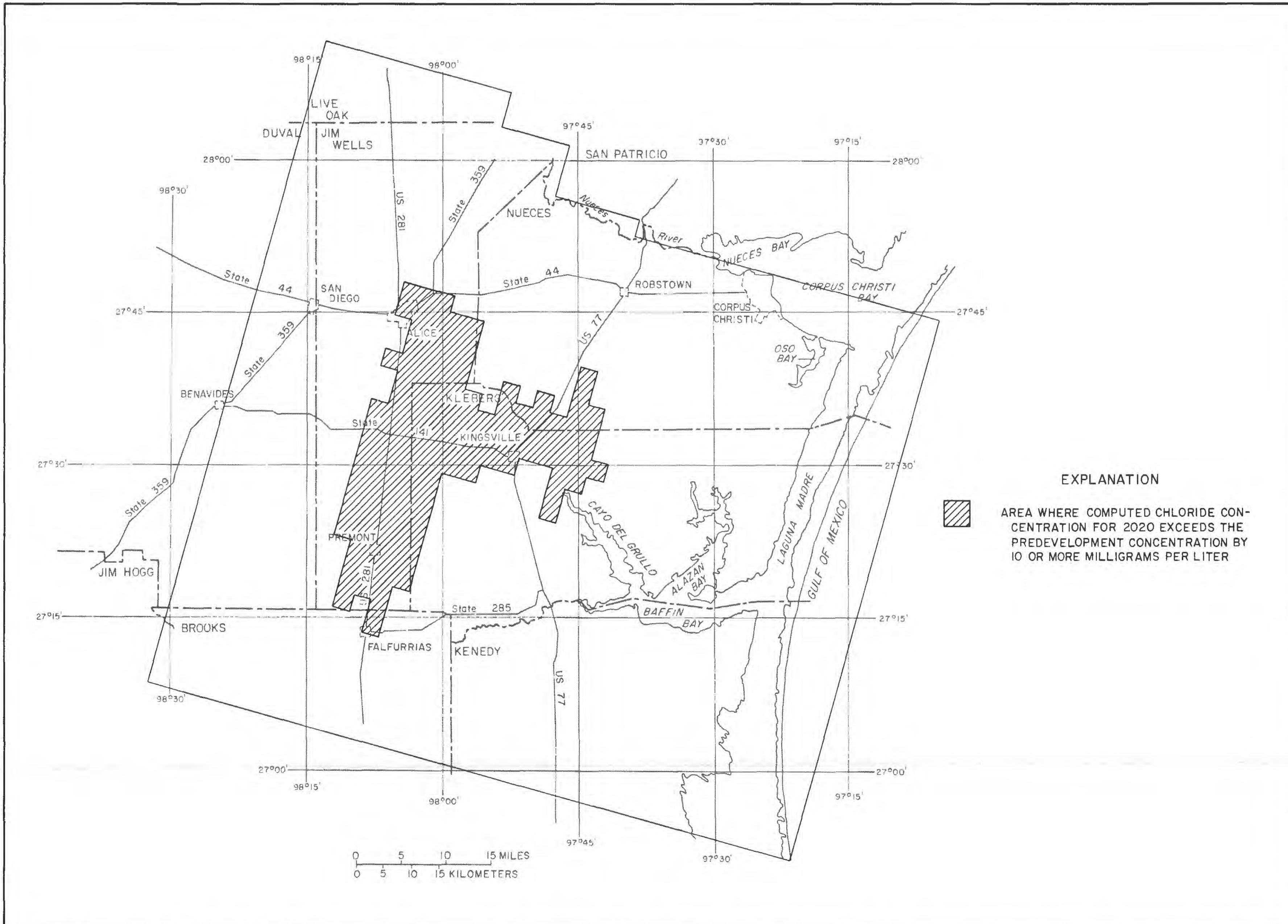

Figure 22.--Effect of the high estimate of pumpage on the computed chloride concentration in the Evangeline aquifer for 2020.

significant deterioration of the water quality will occur under these projected conditions. It is obvious, though, that degradation is much more likely to occur under these conditions than if Kingsville and the other municipalities go to surface-water supplies. Furthermore, if the actual properties and conditions in the aquifer are significantly different from those used in the model, deterioration of the water quality could be greater or less than presented here. The sensitivities discussed here are meant to show the possible range of best conditions and worst conditions. There is a large probability that the true properties and conditions of the aquifer system lie within the range of values tested here. Local contamination problems may occur which are on a scale too small for this model to discern. Regionally the area of the confined aquifer from the vicinity of Kingsville west to the edge of the Chicot aquifer and the area immediately south are the portions of the Evangeline aquifer that could experience water-quality problems under the pumping conditions.

SUMMARY

This assessment of the potential for water-quality degradation investigated the potential sources of slightly saline and saline water. Field data were compiled to use a mathematical model to simulate the aquifer and the effects of the historic pumpage on the present water quality.

Recharge to the Evangeline aquifer in south Texas is relatively small, about 0.06 in./yr over the outcrop area. In this part of this area, the aquifer is thin and the water quality is highly variable. The chloride concentrations range from 9 to 1,900 mg/L in this area. There is also cross-formational leakage of water from the underlying formations in this area. The water flows eastward and is confined under the Chicot aquifer.

The water in the Chicot aquifer is even more variable than the water in the outcrop area of the Evangeline aquifer. The estimated average water quality of the Chicot varies from slightly saline to saline and constitutes the greatest threat to the quality of the Evangeline water. Under predevelopment steady-state conditions, water from the Evangeline discharged upwards into the Chicot. Since intense pumping began, well discharge has exceeded the recharge and the flow between the two aquifers has reversed, and salinewater now flows into the Evangeline from the Chicot. The model constructed to simulate the potential for this type of contamination shows that the historical pumping stress has most likely not created water-quality degradation on a regional scale. This is confirmed by the field data.

The Evangeline aquifer in the confined zone contains water of marginal quality for drinking. Areas within the aquifer, such as under the Gulf of Mexico, contain salinewater. This is the second most important source of potential regional water-quality degradation. The results of the modeling show that degradation of the water quality has not occured from this source. The results also indicate that the potential for salinewater intrusion from underneath the Gulf is small, based on the estimated properties and conditions.

Transmissivity, vertical leakage, and storage were estimated and reevaluated to achieve a satisfactory model of the flow and solute transport in the aquifer. The resultant transmissivity and storage distributions are subject to relatively large errors of estimation. The resultant vertical leakage distribution has an unknown amount of uncertainty. The resultant head distribution shows a strong sensitivity to these properties; therefore, they must be more rigorously defined and measured to reduce the uncertainty of model computed head. The resultant chloride concentration distribution shows some sensitivity to the uncertainty of these properties. This is due, in part, to the lack of documented changes in the regional water quality and to the nature of the system. The head is relatively sensitive to the pumpage, but the estimated uncertainty of pumpage is relatively small. The sensitivity of the chloride transport to the pumpage estimation error is moderate.

CONCLUSIONS

The results of the modeling done as the major portion of this study indicate that although the field data are lacking in some important areas, the water quality has not been significantly affected by the large water-level declines. The water pumped by the wells is released from storage within the aquifer and from leakage from the Chicot aquifer. The storage coefficient is poorly defined and must be more rigorously measured in order to better assess the continued availability of good quality water from the Evangeline.

There are many sources and causes of potential water-quality degradation of the Evangeline aquifer. They are: Leaking well casings, discharge of underlying salinewater, irrigation return flow, oil-field brine disposal, in-situ uranium mining, and leakage from the Chicot aquifer. Of these, only leaking well casings and leakage from the Chicot are suspected of actually having caused deterioration. Leaking well casings are only a local problem.

The major source of potential contamination is the overlying Chicot aquifer. This aquifer contains slightly saline to saline water that is drawn into the Evangeline because of the downward gradient created by pumping. The storage coefficient of the Evangeline affects the difference in head between the Chicot and Evangeline aquifers and, thus, the influx of salinewater from the Chicot. The vertical head gradient and the vertical conductivity both need further refinement from the field to refine the accuracy of the model results. The computed concentrations for the Duval County area must be viewed with caution because of the observed vertical stratification of water quality.

A source of contamination that probably is not important is the possibility of salinewater encroachment from under the Gulf of Mexico. Various tests of this boundary and the resultant effects on the head and chloride concentration distributions indicate that for the conceptual system of this model, this boundary is insensitive and does not constitute a threat to the quality of the water in the Evangeline.

Projections of pumpage through 2020 include a low estimate in which several municipalities (most importantly Kingsville) no longer use the Evangeline as a major source of water. The results of simulations using this pumpage indicate that no significant regional water-quality changes are likely to occur between 1982 and 2020. The high estimate for pumpage includes greatly increased pumpage rates through 2020 for all the municipalities that were using Evangeline water in 1982. The results of this simulation also show that no significant regional water-quality degradation is likely to occur. However, all these results are based on estimates of aquifer properties and conditions, some of which have large errors of estimation. In spite of these errors and data deficiencies, the results are based on the best estimates currently available. The reliability of the conclusions should be judged on the adequacy of the data and the demonstrated sensitivity of the model results to these errors of estimation.

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APPENDIX: INPUT DATA LISTING WITH A BRIEF EXPLANATION

Calibrated Model of the Coastal Bend Study Area, Nov. 13, 1984

Time steps 11
Pumping periods 6
Nodes in X-direction 40
Nodes in Y-direction 40
Maximum number of particles 6500
Time-step interval for print-out 11
Number of iterations parameters (must be 10 for SIP) 10
Number of observation points 5
Maximum number of iterations 200
Number of wells in first pumoing period 0
Initial number of particles per node 4
Number of node indentification codes (aquifer boundaries) 9
Prints only at end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print concentration changes 1
Do not punch velocities 0
Years in first pumping period 50.00
Convergence criterion 0.001 feet.
Effective porosity 0.30 dimensionless.
Characteristic length 1.0 foot.
Storage coefficient 0.1E-3 dimensionless.
Time increment multiplier 1.30 dimensionless.
Sixe of initial time step 3.E+7 seconds.
Width of finite-difference cell in X-direction 10560 feet.
Width of finite-difference cell in Y-dorection 10560 feet.
Ratio of transverse to longitudinal dispersivity 0.30 dimensionless.
Maximum cell distance per particle move 0.50 dimensionless.
Ratio of Tyy to Txx 1.0 dimensionless.
Beta parameter for SIP 1.0 dimensionless.
X Y Coordinates of five observation wells
0621
0429
0431
1819
2421

Flag and transmissivity multiplication factor
1 0.30E-2 product of factor and array yields feet squared/second.

Transmissivity array

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.5	0.5	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.6	0.6	0.7	0.8	0.9	1.0	1.4	1.8	1.8	1.6	1.6	1.4	1.4	1.2	1.2	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

0	0.7	0.7	0.7	0.8	0.9	1.2	1.4	1.8	1.8	1.6	1.6	1.4	1.4	1.2	1.2	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.7	0.7	0.7	0.8	0.9	1.0	1.0	1.4	1.4	1.8	1.8	1.6	1.6	1.4	1.4	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.5	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.5	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.5	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.0	3.0	3.0	3.0	3.0	2.0	2.0	2.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	3.0	3.0	3.0	3.0	2.5	2.5	2.0	2.0	2.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.5	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0	3.0
2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.7	0.7	0.7	0.4	0.4	0.4	0.4	0.5	0.8	0.8	0.8	1.0	2.0	3.0	6.0	6.0	6.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.5	0.5	0.5	0.6	0.4	0.4	0.4	0.4	0.8	1.5	3.0	6.0	7.0	8.0	8.0	7.0	7.0	6.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.2	0.3	0.7	0.8	0.7	0.4	0.4	0.4	0.4	1.5	2.0	3.0	6.0	8.0	8.0	8.0	7.0	7.0	6.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.4	0.5	0.7	0.7	0.7	0.4	0.4	0.4	0.4	1.5	2.0	3.0	6.0	8.0	8.0	8.0	8.0	8.0	8.0
7.0	5.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.6	0.6	0.7	0.4	0.4	0.4	0.4	1.5	2.0	3.0	4.0	8.0	8.0	8.0	8.0	8.0	8.0
7.0	5.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	1.0	2.0	3.0	4.0	8.0	8.0	8.0	8.0	8.0	8.0
7.0	5.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	1.0	2.0	3.0	4.0	5.0	6.0	6.0	7.0	7.0	7.0
7.0	5.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	1.0	2.0	3.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.8	1.0	2.0	3.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	0.7	0.7	0.7	0.7	0.7	1.0	1.0	1.0	1.0	1.0	2.0	4.0	8.0	5.0	8.0	8.0	8.0	8.0	8.0
6.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0	4.0	4.0	5.0	6.0	7.0	7.0	7.0	6.0	6.0	6.0
5.0	4.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	8.0	8.0	8.0
5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0
0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	0
0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
5.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	3.0	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0	0
0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
7.0	7.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0	0
0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
7.0	7.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0	0
0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	6.0	6.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
7.0	7.0	6.0	5.0	5.0	4.0	3.0	3.0	2.0	2.0	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0	0

```
  0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 4.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 3.0 3.0 3.0 3.0 3.0 3.0 3.0 4.0 4.0 5.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 3.0 3.0 4.0 4.0 5.0 4.0 3.0 2.0 2.0 3.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 4.0 4.0 5.0 6.0 6.0 5.0 5.0 5.0 5.0 5.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 4.0 4.0 4.0 4.0 5.0 4.0 4.0 5.0 5.0 5.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 4.0 4.0 4.0 4.0 4.0 5.0 5.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 3.0 3.0 3.0 4.0 4.0 5.0 5.0 6.0 6.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0 2.0 2.0 2.0 2.0 2.0 2.0 3.0 3.0 5.0 6.0 8.0 8.0 8.0 7.0 7.0 7.0 7.0 7.0 7.0
7.0 7.0 6.0 5.0 5.0 4.0 3.0 3.0 2.0 2.0 1.5 1.5 1.5 1.5 1.5 1.5 1.0 1.0 1.0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
Flag and multiplication factor for aquifer thickness
1       1.0 product of factor and array yields feet.
```

Aquifer thickness array

```
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0  20  80 168 224 259 259 350 366 420 462 522   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
000 064 144 216 272 280 315 364 372 426 474 522   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
000 088 176 240 259 294 329 385 378 426 480 522 552 582 510 540   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
000 072 200 231 280 308 350 385 378 438 480 522 552 570 600 515   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
000 176 240 252 294 322 350 399 390 444 492 522 552 576 594 510   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
000 208 224 280 308 336 378 420 396 450 498 534 558 576 594 510 520 530 540 550
570 590 610 387 540 568 568 560 520 520 536 560 600 486 516 546 585 406 412 000
000 240 252 294 329 364 385 420 420 468 498 540 564 576 600 510 520 530 535 545
560 580 600 625 528 560 568 568 560 540 552 576 459 489 516 552 588 406 416 000
000 231 280 329 364 385 399 378 420 480 516 552 564 582 505 515 525 535 545 555
565 585 600 625 387 540 564 580 600 600 580 596 465 489 534 570 597 410 422 000
000 245 301 357 378 399 420 420 450 486 534 558 576 600 510 525 540 550 560 590
600 610 620 625 508 516 524 544 560 584 453 468 480 540 570 600 420 440 452 000
000 252 329 371 392 420 414 438 456 498 546 570 600 515 530 550 555 565 575 585
595 600 615 625 508 516 536 560 580 600 462 468 477 519 561 585 410 428 440 000
000 266 350 385 420 396 432 450 462 510 558 600 515 530 545 555 565 575 585 595
600 610 615 625 508 516 524 544 560 580 453 468 483 540 570 600 420 440 452 000
000 280 364 392 372 420 438 456 480 534 570 510 525 540 550 565 575 585 595 600
605 615 620 625 508 512 524 540 548 568 592 468 504 543 576 414 438 450 460 000
000 315 371 413 420 438 444 462 480 552 600 515 530 550 565 580 595 600 605 610
615 620 504 508 512 520 528 540 548 568 600 480 510 540 591 424 442 458 470 000
000 322 378 420 426 438 456 468 510 564 505 525 545 560 575 595 605 610 615 620
625 504 508 512 516 528 536 548 560 588 459 492 516 555 600 436 450 466 482 000
000 336 392 390 432 444 462 474 540 576 515 530 550 575 600 610 615 620 625 504
```

508	512	516	520	532	544	556	568	584	456	480	507	540	564	418	444	460	480	486	000
000	350	413	420	438	450	462	480	552	600	520	535	575	600	615	504	512	520	520	520
524	528	536	540	548	556	568	584	600	477	501	537	552	570	426	450	468	484	492	0
000	315	420	426	444	462	474	510	570	510	525	540	600	615	508	520	524	528	532	536
540	544	548	552	556	564	580	600	480	510	540	561	570	600	430	454	470	488	498	0
000	378	384	432	444	462	480	540	576	515	530	545	600	620	512	524	528	532	536	540
544	548	552	556	572	588	600	489	519	543	570	585	597	420	438	460	474	492	502	0
000	392	402	438	456	480	510	552	600	515	530	550	605	620	512	524	528	536	540	548
552	560	572	596	465	480	495	525	552	570	594	600	410	424	440	456	474	500	504	0
000	420	420	444	468	498	528	564	600	515	535	550	600	620	508	520	536	548	556	560
564	600	465	480	495	510	540	555	570	600	406	412	420	432	446	454	478	500	506	0
000	420	426	456	480	510	540	570	505	515	535	550	590	615	504	516	540	560	572	592
453	471	489	507	525	540	555	570	594	404	408	428	422	432	442	436	472	502	506	0
000	378	438	474	498	522	546	582	505	520	535	550	580	615	508	516	540	564	580	600
462	480	498	516	534	549	561	576	597	404	408	428	420	430	440	454	472	502	506	0
000	390	444	480	504	528	552	582	510	520	535	545	580	610	625	512	536	560	580	600
465	480	495	510	531	549	561	570	597	404	408	412	416	420	438	458	476	500	504	0
000	420	456	486	510	528	558	588	505	520	535	545	575	610	625	508	520	548	568	592
462	480	492	504	519	540	555	567	585	402	406	410	414	418	420	454	472	494	502	0
000	420	462	492	516	534	564	582	505	515	530	540	555	600	615	504	516	532	556	576
600	465	483	495	507	522	540	555	567	585	600	600	597	600	416	440	470	490	500	0
000	420	465	492	516	534	558	576	600	515	525	535	550	585	605	625	508	516	536	560
580	600	468	480	495	510	528	540	552	564	573	582	588	597	410	438	466	484	498	0
000	420	468	498	516	540	558	576	594	510	525	535	545	570	600	515	504	512	520	540
560	588	459	471	480	498	516	534	546	555	564	570	582	591	408	428	460	482	488	0
000	420	480	498	522	540	558	576	588	505	520	530	540	570	585	605	620	504	512	520
552	576	600	462	471	489	510	528	540	549	558	564	570	591	408	420	460	480	484	0
000	420	480	498	516	534	558	576	588	505	520	530	540	565	580	600	610	620	504	512
532	560	584	453	468	480	501	522	540	549	555	561	570	597	412	430	460	480	482	0
000	432	480	498	510	528	552	570	582	505	520	530	540	560	575	585	605	615	625	508
520	560	580	600	465	480	495	510	537	549	555	561	570	600	420	436	460	472	480	0
000	438	480	504	516	528	546	564	582	600	515	530	545	565	575	585	605	615	625	508
516	548	576	596	459	477	492	510	525	543	555	561	582	404	424	438	460	470	474	0
000	432	486	498	516	528	546	564	582	600	520	535	550	565	565	595	605	615	625	508
520	544	572	592	459	471	489	501	522	540	555	570	591	418	428	438	462	466	470	0
000	420	480	498	516	522	540	564	582	600	520	535	550	570	585	600	610	620	504	512
524	548	568	592	459	471	489	501	522	540	564	582	600	422	440	450	466	466	460	0
000	402	462	492	504	522	540	564	582	505	525	540	555	570	585	605	615	625	508	516
536	548	572	588	459	477	495	510	528	555	570	597	414	438	450	458	468	460	454	0
000	366	426	486	504	516	534	558	582	505	525	545	560	580	595	610	620	504	512	524
540	552	576	600	471	489	507	519	540	570	594	408	420	446	460	462	464	460	450	0
000	420	414	480	498	516	528	558	582	515	530	550	565	585	600	615	625	508	516	532
544	560	592	465	486	504	513	537	555	585	406	420	436	460	462	464	462	450	446	0
000	406	390	444	486	510	528	552	588	515	530	550	570	585	605	620	508	516	528	540
556	580	453	480	498	513	540	555	573	600	410	424	440	462	464	462	460	440	436	0
000	399	378	420	480	504	522	540	582	515	530	550	575	590	610	504	520	532	552	564
580	600	480	498	513	540	555	570	588	406	418	432	448	460	460	450	438	436	434	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Flag and multiplier for diffuse recharge or discharge
0 0 feet/second.

Flag and multiplier for node identification
1 1 product of factor and array yields dimensionless scalar.

Node identification array

```
0000000000000000000000000000000000000000
0900000000080000000000000000000000000000
0900000000080000000000000000000000000000
0900000000008888000000000000000000000000
0900000000000008000000000000000000000000
0900000000000008000000000000000000000000
0900000000000007666666555554444433333222 10
```

```
0000000000000000000000000000000000000000
0900000000080000000000000000000000000000
0900000000080000000000000000000000000000
0900000000008888000000000000000000000000
0900000000000008000000000000000000000000
0900000000000008000000000000000000000000
0900000000000766666655555444443333322210
0900000007777766666655555444443333322210
0900000007777766666655555444443333322210
0900000007777766666655555444443333322210
0900000007777766666655555444443333322110
0900000007777766666655555444443333322110
0900000007777766666655555444443333322110
0900000007777766666655555444443333322110
0900000007777766666655555444443333322110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000007777766666655555444443333321110
0900000077777766666655555444443333321110
0900000077777766666655555444443333321110
0900000077777766666655555444443333321110
0900000007777766666655555444443333321110
0900000077777766666655555444443333321110
0900000077777766666655555444443333322110
0900000077777766666655555444443333322110
0900007777777766666655555444443333322110
0900007777777766666655555444443333322110
0900007777777766666655555444443333322210
0900007777777766666655555444443333322210
0900007777777766666655555444443333322210
0900007777777766666655555444443333322210
0900007777777766666655555444443333322210
0900007777777766666655555444443333322210
0000000000000000000000000000000000000000
```

Array of node identification codes,leakance coefficients and concentrations for each code. Columns of zeros are override recharge and concentration values.

```
 1  0.12E-11 ft/sec.  10000.0 mg/L     0.0 0
 2  0.20E-11 ft/sec.  5000.00 mg/L     0.0 0
 3  0.26E-11 ft/sec.   5000.0 mg/L     0.0 0
 4  0.32E-11 ft/sec.   2000.0 mg/l     0.0 0
 5  0.30E-11 ft/sec.   2000.0 mg/L     0.0 0
 6  0.30E-11 ft/sec.  1500.00 mg/L     0.0 0
 7  0.60E-11 ft/sec.   1500.0 mg/L     0.0 0
 8   0.1E-10 ft/sec.    50.00 mg/L     0.0 0
 9   1.00000 ft/sec.    500.0 mg/L     0.0 0
```

Flag and multiplier for initial head and confining layer head

```
1      1.0 product of factor and array yields feet above sea level.
```

Initial head and confining layer head array

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	370	350	310	270	250	235	205	190	170	145	50	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	375	355	320	295	250	230	200	190	160	145	40	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	380	360	320	300	260	225	205	200	160	150	140	40	40	30	25	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	385	360	320	300	255	260	245	220	180	180	165	145	110	60	25	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	390	360	320	300	260	260	240	225	190	180	165	140	120	90	20	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	390	360	320	310	300	265	245	220	200	175	165	155	120	90	20	10	10	10	10
10	10	20	20	15	15	10	6	4	0	0	0	0	0	0	0	0	0	0	0
0	390	360	320	310	305	265	245	210	190	175	160	130	115	90	55	40	55	50	40
40	50	45	40	40	25	15	8	4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	410	380	340	315	305	260	250	230	190	170	140	115	110	90	80	60	65	65	65
63	55	50	45	40	20	17	13	10	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	430	400	350	320	300	270	250	220	190	165	140	120	110	80	77	74	70	66	62
60	55	45	35	30	25	18	15	13	10	5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	420	380	340	310	270	240	230	215	180	160	135	125	115	100	75	65	60	62	60
55	50	45	35	20	18	16	15	14	13	12	8	5	3	1.5	1.5	1.5	1.5	1.5	0
0	410	370	320	275	250	235	215	210	180	160	140	125	115	105	80	65	57	55	53
50	47	45	43	40	20	18	15	10	10	12	8	5	2	1.5	1.5	1.5	1.5	1.5	0
0	390	365	325	275	250	235	225	205	180	160	145	130	115	108	90	70	60	55	50
45	40	40	37	33	27	20	17	12	10	8	7	5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	370	350	320	290	260	235	225	200	180	160	145	130	120	105	100	70	60	55	42
40	37	35	30	28	25	23	20	15	10	10	7	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	380	340	315	290	255	235	220	200	180	160	145	130	120	110	105	75	65	55	40
38	35	33	30	27	25	22	20	15	9	7	5	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	380	340	310	285	255	235	220	195	185	170	145	130	120	110	90	70	60	50	40
35	30	20	20	20	18	16	14	12	10	7	5	31.50		1.5	1.5	1.5	1.5	1.5	0
0	360	345	310	285	260	235	210	180	180	165	145	130	115	100	80	70	55	50	45
35	30	20	19	17	15	14	13	12	10	10	6	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	360	345	320	285	260	230	205	190	180	160	145	125	115	100	70	58	55	48	43
35	25	20	18	17	16	14	13	12	10	7	5	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	380	350	320	290	270	220	200	185	175	145	135	120	115	100	75	60	50	40	35
25	20	18	16	14	12	10	10	9	7	8	9	10	1.5	1.5	1.5	1.5	1.5	1.5	0
0	400	360	320	290	270	215	195	185	170	140	130	115	110	100	75	65	50	38	32
27	21	18	15	12	10	8	7	6	7	8	10	10	1.5	1.5	1.5	1.5	1.5	1.5	0
0	375	350	310	285	260	220	195	185	170	140	130	110	105	95	75	65	55	30	18
20	22	20	18	16	13	12	10	8	7	8	10	10	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	315	300	270	240	230	200	185	170	150	130	110	105	90	75	60	45	25	20
15	18	20	18	16	14	12	10	6	3	1.5	10	10	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	320	295	255	245	230	200	185	170	150	135	110	100	90	70	55	45	25	20
10	9	10	11	10	12	11	9	5	1.5	1.5	10	6	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	320	280	255	245	230	195	185	170	155	135	110	95	85	75	60	50	40	30
20	10	9	8	9	10	10	7	4	1.5	1.5	5	5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	350	320	285	260	230	210	190	185	175	150	125	110	100	85	70	60	50	40	30
18	15	10	2	1.5	1.5	2	3	2	1.5	1.5	1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	315	285	260	230	210	190	185	170	150	130	110	100	95	75	65	55	45	30
18	15	13	10	5	1.5	1.5	2	1.5	1.5	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	315	285	260	230	215	190	180	165	155	135	115	105	95	80	60	50	40	30

20	18	15	11	7	3	1.5	1.5	1.5	1.5	1.5	1.5	2	1.5	1.5	1.5	1.5	1.5	1.5	0
0	350	310	290	250	225	210	190	175	165	150	140	115	105	90	75	60	50	40	33
25	15	10	5	1.5	1.5	1	1.5	1.5	1.5	1.5	2	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	310	300	245	235	215	195	175	160	150	140	115	100	85	70	65	53	40	30
22	10	10	10	10	10	6	3	4	5	4	3	2	1.5	1.5	1.5	1.5	1.5	1.5	0
0	345	320	300	270	240	220	190	170	150	145	130	115	100	80	70	65	55	40	25
10	10	18	15	12	10	8	7	6	5	4	3	2	1.5	1.5	1.5	1.5	1.5	1.5	0
0	345	325	320	270	245	220	190	170	155	145	120	110	90	80	65	45	40	20	15
15	20	20	18	12	10	9	8	7	6	5	4	3	1	1.5	1.5	1.5	1.5	1.5	0
0	350	330	325	300	250	220	195	170	160	140	115	105	85	80	70	60	35	30	30
27	25	23	18	14	12	10	9	7	6	5	3	2	1.5	1.5	1.5	1.5	1.5	1.5	0
0	350	330	305	280	250	220	200	175	160	135	115	100	75	75	65	62	50	45	37
33	28	23	18	16	14	13	12	11	10	7	5	3	1.5	1.5	1.5	1.5	1.5	1.5	0
0	340	315	300	280	260	230	200	170	160	135	110	95	80	80	67	63	55	45	37
33	28	23	20	20	20	17	15	13	10	8	5	2	1.5	1.5	1.5	1.5	1.5	1.5	0
0	330	315	300	270	250	215	190	165	150	130	110	95	90	85	80	70	60	45	40
37	32	28	22	20	18	16	14	12	10	8	6	4	2	1.5	1.5	1.5	1.5	1.5	0
0	320	310	290	265	240	210	170	150	135	125	110	95	90	85	80	70	60	50	40
37	32	27	23	20	18	16	14	12	11	7	4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	320	305	290	270	240	205	165	140	130	120	105	95	90	85	77	67	58	50	42
38	34	30	27	23	21	18	16	14	12	8	3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	320	300	285	270	240	210	165	140	130	120	100	90	87	80	70	60	55	45	40
38	34	30	27	23	20	18	16	14	12	7	4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	320	300	290	270	230	210	180	140	130	115	100	85	80	80	70	60	55	45	39
36	32	29	26	23	20	18	15	10	6	4	2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Flag and multiplication factor for initial potentiometric head in Evangeline.
1 1.0 product of factor and array yields feet above sea level.

Initial potentiometric head in the Evangeline

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	370	349	325	300	274	248	224	201	179	157	135	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	375	351	326	301	274	249	226	203	180	158	135	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	380	354	328	302	277	252	228	205	182	159	134	104	86	73	64	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	385	357	330	304	279	254	231	207	185	162	139	117	98	83	70	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	390	359	331	304	279	255	232	209	187	166	145	125	108	93	78	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	390	358	330	303	279	256	233	211	189	168	148	128	112	100	88	81	75	69	62
54	48	43	38	34	29	25	21	18	15	13	11	9	7	5	5	4	4	4	0
0	390	360	331	303	279	256	233	211	189	169	149	130	114	102	92	84	77	71	64
57	51	45	40	35	30	25	22	18	15	13	11	9	7	6	5	4	4	4	0
0	410	367	334	304	279	255	232	210	189	168	149	130	116	104	94	86	79	73	66
59	53	47	41	36	31	26	22	19	16	13	11	9	7	6	5	4	4	4	0
0	430	375	337	305	278	253	230	208	187	167	148	131	117	106	96	87	80	74	68
60	54	47	41	36	31	27	23	19	17	14	12	9	7	6	5	4	4	4	0
0	420	376	338	305	274	249	229	206	184	165	147	131	118	106	96	88	81	75	69
61	54	48	42	36	31	27	23	20	17	15	12	10	8	6	5	5	4	4	0

0	410	370	335	302	272	248	227	205	182	163	145	130	117	106	96	89	82	76	69
62	55	49	43	37	32	27	23	20	17	15	12	10	8	6	5	5	4	4	0
0	390	361	330	299	271	247	225	203	181	159	141	126	114	104	95	89	83	77	71
63	56	49	43	37	32	28	24	20	18	15	13	10	8	6	5	5	4	4	0
0	370	352	326	297	270	246	223	202	179	155	137	120	108	99	93	89	84	79	73
65	58	50	43	37	32	28	24	21	18	15	13	10	8	6	5	5	4	4	0
0	380	351	324	297	271	246	222	199	175	150	128	112	101	95	91	89	86	81	75
68	61	52	44	37	32	28	24	20	18	15	13	10	8	6	5	5	5	4	0
0	380	349	322	296	270	245	220	196	171	145	122	107	99	93	91	89	87	82	76
69	62	53	44	37	32	27	23	20	17	15	12	10	8	7	6	5	5	4	0
0	360	343	319	294	268	243	218	193	168	141	118	105	97	92	90	88	87	83	76
69	62	53	44	37	31	27	23	20	17	15	12	10	8	7	6	5	5	5	0
0	360	342	318	293	267	241	216	191	165	138	116	103	96	92	89	88	87	83	77
69	62	53	44	36	31	26	23	20	17	15	12	10	8	7	6	5	5	5	0
0	380	348	319	291	265	239	214	188	163	136	114	102	95	91	89	88	87	83	77
69	62	53	43	36	30	26	22	19	17	14	12	10	8	7	6	5	5	5	0
0	400	352	318	289	262	236	211	186	161	134	113	101	95	91	89	88	87	83	77
69	62	53	43	36	30	25	22	19	16	14	12	10	8	7	6	5	5	5	0
0	375	341	312	285	259	233	208	184	159	133	112	101	95	91	89	88	87	83	76
69	62	52	43	35	30	25	21	18	16	14	12	10	8	7	6	5	5	5	0
0	340	327	304	280	255	230	205	181	157	132	112	101	95	91	90	88	87	83	76
69	62	52	42	35	29	25	21	18	15	13	12	10	8	7	6	5	5	5	0
0	340	321	298	274	250	226	202	179	156	132	112	101	95	92	90	89	88	84	77
69	61	52	42	34	29	24	20	17	15	13	11	10	8	7	6	5	5	5	0
0	340	318	294	270	246	222	198	176	154	131	112	101	96	93	91	90	88	84	77
69	61	51	41	34	28	24	20	17	15	13	11	9	8	7	6	6	5	5	0
0	350	318	290	265	240	217	194	172	152	130	112	102	97	94	92	90	89	85	77
69	62	51	41	33	28	23	20	17	15	13	11	9	8	7	6	6	6	5	0
0	340	313	285	259	235	211	189	167	148	128	112	104	99	96	93	91	90	85	78
70	62	52	41	34	28	23	20	17	15	13	11	9	8	7	6	6	6	6	0
0	340	309	279	254	230	207	185	163	144	126	113	105	101	98	95	93	90	85	78
70	62	52	42	34	28	24	20	17	15	13	11	10	9	8	7	7	6	6	0
0	350	310	277	251	228	204	182	161	142	126	113	106	102	99	96	94	91	85	78
70	62	52	42	35	29	25	21	18	15	13	12	10	9	8	7	7	7	7	0
0	340	306	276	249	225	201	179	159	141	126	115	107	103	100	98	95	91	85	78
70	61	52	43	36	30	26	22	19	16	14	12	11	10	9	8	8	7	7	0
0	345	306	274	248	223	199	177	158	140	126	115	108	104	101	99	96	92	86	78
70	61	52	44	37	31	27	23	19	17	14	13	11	10	9	8	8	7	7	0
0	345	306	273	246	221	197	176	157	140	126	116	109	105	102	100	97	92	86	79
71	62	53	45	38	32	27	23	20	17	15	13	11	10	9	8	8	8	8	0
0	350	306	273	245	220	196	175	156	140	126	116	109	105	103	101	98	93	87	80
71	63	54	45	39	33	28	24	21	18	15	13	12	10	9	9	8	8	8	0
0	350	305	271	243	218	195	174	156	139	126	116	109	106	103	101	98	94	88	80
72	64	55	46	39	34	29	25	21	18	16	14	12	11	9	9	8	8	8	0
0	340	300	268	241	216	193	173	155	139	126	116	110	106	104	102	99	94	88	81
73	65	56	47	40	35	30	26	22	19	16	14	12	11	10	9	8	8	8	0
0	330	294	264	239	215	192	172	154	139	126	116	110	107	104	102	99	95	89	82
74	65	56	48	41	35	30	26	22	19	17	14	12	11	10	9	8	8	8	0
0	320	289	261	237	213	191	172	154	138	126	116	110	107	105	102	100	95	89	82
74	66	57	48	41	36	31	26	23	20	17	15	13	11	10	9	8	8	8	0
0	320	287	259	235	212	190	171	153	138	126	116	110	107	105	102	100	95	89	82
74	66	57	49	42	36	31	27	23	20	17	15	13	11	10	9	9	8	8	0
0	320	286	258	234	212	190	171	153	138	126	116	110	107	105	103	100	96	90	82
75	66	58	49	42	36	31	27	23	20	17	15	13	11	10	9	9	8	8	0

```
  0 320 286 258 234 211 190 170 153 138 126 116 110 107 105 103 100  96  90  83
 75  66  58  49  42  36  31  27  23  20  17  15  13  11  10   9   9   8   8   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
Flag and multiplication factor for storage coefficient
1     0.10 product of factor and array yields dimensionless scalar.
```

```
Storage coefficient array
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0.0.001.001.001.001.001.001.001.001.001.001.001 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001
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 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.002.002.002.002.002.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
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 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
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 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 .03 .03 .03 .03 .03 .03 .03 .03 .03.005.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.2.005.005.005.005.001.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
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.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
 0.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.1 0.1 0.1.010.010.010.010.010.001.001.001.001
.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001.001 0.0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

```
Flag and multiplication factor for initial concentration
1       10. product of factor and array yields mg/L chloride.
```

```
Initial concentration array
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
 0.0144.119. 99. 69. 11. 7.8 99. 99. 99. 99. 99. 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 99.100. 99. 90. 29. 17. 99. 99. 99. 99. 99. 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 99.105. 78. 70. 99. 31. 25. 99. 99. 99. 99. 13. 16. 18. 13. 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 99. 60. 60. 33. 75. 37. 26. 18. 47. 38. 45. 38. 33. 27. 19. 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 27. 25. 43. 57. 64. 61. 55. 44. 32. 63. 53. 51. 50. 38. 39. 0.0 0.0 0.0 0.0
 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
 0.0 16. 26. 62. 64. 55. 58. 53. 47. 46. 57. 54. 57. 56. 44. 46. 57. 60. 60. 89.
 91.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100. 0.0
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 0.0 43. 33. 80. 64. 37. 77. 40. 50. 52. 50. 50. 50. 46. 40. 47. 56. 66. 81.106.
111.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100.100. 0.0
 0.0 49. 25. 73. 68. 51. 60. 65. 57. 57. 49. 47. 46. 40. 44. 55. 65. 72. 75. 66.
 73. 90. 85.108.113.133.118.116.100.139.150.150.150.150.150.150.150.150.150. 0.0
 0.0 23. 33. 67. 74. 70. 83. 81. 61. 45. 58. 60. 55. 66. 56. 66. 72. 86. 65. 73.
 71. 62. 89. 70.102.122.112.111. 98.131.137.108.111.114.116.120.130.140.150. 0.0
 0.0 50. 51. 52. 44. 69.110. 81. 70. 58. 60. 63. 59. 66. 67. 71. 80. 81. 75. 71.
 70. 67. 78.109. 95.113.102.106.107.104.129.106. 87.108.111.120.130.140.150. 0.0
 0.0 54. 58. 58. 99. 78.124. 70. 71. 65. 67. 67. 60. 66. 67. 70. 80. 83. 77. 72.
 70. 68. 75. 83. 86.100.106.100. 88. 90.171.102.104. 97.100.120.130.140.150. 0.0
 0.0 28. 44. 47. 67. 69.117.109. 75. 67. 67. 71. 63. 68. 68. 69. 75. 83. 81. 83.
 40. 36. 73. 82.115.133.119.101.105. 95. 87. 91. 95. 99.103.120.130.140.150. 0.0
 0.0119. 98. 68. 54. 48. 20. 99. 63. 60. 62. 70. 66. 71. 77. 80. 78. 76. 78. 76.
 84. 66. 62. 94.101.150. 94. 82. 97. 90. 90. 97.128.136.142.120.130.140.150. 0.0
 0.0110. 48. 52. 99. 32. 35. 48. 55. 50. 62. 67. 66. 71. 80. 87. 81. 76. 66. 58.
 47. 55. 55. 59. 84. 88. 85. 92. 99. 87.103.103.121.129.137.120.130.140.150. 0.0
 0.0114. 80. 61. 47. 36. 43. 50. 53. 65. 62. 58. 61. 67. 70. 76. 88. 72. 57. 42.
 39. 42. 49. 55. 61. 69. 70. 92. 77. 75.101.108.115.123.131.120.130.140.150. 0.0
 0.0111. 80. 64. 36. 59. 67. 66. 58. 59. 57. 54. 53. 58. 61. 66. 67. 60. 46. 37.
 36. 38. 43. 46. 49. 51. 57. 60. 68. 79. 94.110.120.133.138.120.130.140.150. 0.0
 0.0 99. 65. 56. 24. 47. 67. 71. 53. 54. 47. 36. 42. 49. 53. 57. 28. 44. 39. 34.
 33. 29. 46. 43. 43. 46. 47. 48. 59. 73. 87. 99. 99. 99. 99.120.130.140.150. 0.0
 0.0 74. 66. 57. 24. 40. 56. 57. 46. 48. 40. 30. 36. 47. 47. 48. 39. 35. 92. 32.
 33. 38. 40. 40. 40. 42. 44. 47. 57. 68. 81. 91. 96.117. 99.120.130.140.150. 0.0
 0.0 96. 82. 14. 37. 25. 41. 46. 32. 37. 34. 29. 33. 42. 47. 41. 30. 23. 28. 30.
 32. 34. 34. 36. 37. 40. 42. 47. 55. 64. 76. 88. 99.115. 99.120.130.140.150. 0.0
 0.0 54. 99. 99. 81. 72. 34. 28. 27. 26. 26. 25. 28. 33. 37. 35. 28. 23. 25. 26.
 29. 27. 32. 33. 35. 37. 41. 45. 52. 60. 71. 85. 97. 99. 99.120.130.140.150. 0.0
 0.0138.124. 70. 58. 35. 32. 24. 21. 21. 22. 22. 23. 24. 25. 26. 27. 32. 36. 25.
 27. 30. 30. 31. 33. 36. 40. 45. 52. 57. 65. 79. 98.108.133.120.130.140.150. 0.0
 0.0151. 88. 76. 62. 42. 34. 23. 20. 20. 20. 19. 20. 20. 21. 23. 24. 25. 28. 25.
 24. 26. 27. 28. 31. 37. 42. 48. 51. 55. 60. 72. 87.104.121.120.130.140.150. 0.0
 0.0 99.118. 82. 63. 52. 99. 23. 20. 19. 19. 17. 17. 17. 20. 22. 22. 30. 22. 24.
 24. 23. 25. 27. 32. 40. 46. 51. 52. 53. 58. 66. 80. 96. 99.120.130.140.150. 0.0
 0.0 99. 95. 81. 66. 51. 30. 21. 19. 12. 17. 15. 16. 17. 19. 19. 21. 23. 23. 33.
 26. 26. 23. 26. 33. 40. 46. 51. 50. 50. 55. 63. 78. 92.107.120.130.140.150. 0.0
 0.0 99.111.119. 64. 49. 10. 21. 18. 16. 16. 17. 18. 19. 19. 18. 20. 21. 25. 32.
 26. 28. 24. 28. 29. 38. 44. 48. 50. 51. 52. 61. 73. 86. 87.120.130.140.150. 0.0
 0.0 99. 99. 99. 60. 34.  9. 18. 19. 19. 18. 19. 22. 22. 22. 19. 17. 19. 23. 25.
 29. 35. 28. 28. 30. 33. 47. 49. 48. 57. 60. 64. 71. 81. 99.120.130.140.150. 0.0
 0.0 23. 23. 15. 54. 36. 30. 16. 21. 20. 21. 22. 24. 24. 22. 18. 17. 18. 19. 21.
 26. 28. 22. 24. 32. 44. 50. 51. 52. 63. 69. 74. 71. 68. 33.120.130.140.150. 0.0
 0.0 99. 99. 0.9 55. 51. 44. 14. 21. 21. 22. 24. 22. 22. 21. 19. 18. 18. 19. 19.
 21. 25. 24. 27. 39. 60. 50. 50. 56. 62. 74. 87. 71. 46. 27.120.130.140.150. 0.0
 0.0 97. 99. 99. 81. 50. 40. 14. 22. 20. 22. 21. 22. 22. 21. 19. 17. 17. 17. 17.
 19. 21. 22. 24. 21. 29. 35. 43. 52. 60. 68. 73. 67. 45. 99.120.130.140.150. 0.0
 0.0120. 97.174. 81. 53. 41. 30. 19. 22. 22. 23. 23. 23. 21. 18. 16. 15. 15. 15.
 16. 19. 20. 22. 24. 29. 33. 39. 46. 52. 59. 62. 59. 39. 72.120.130.140.150. 0.0
 0.0 94. 99. 99. 45. 48. 29. 26. 24. 30. 24. 23. 21. 21. 20. 16. 14. 13. 13. 14.
 16. 19. 20. 22. 26. 30. 35. 37. 43. 48. 51. 55. 53. 59. 72.120.130.140.150. 0.0
 0.0107. 93. 78. 45. 45. 14. 22. 32. 25. 22. 33. 23. 18. 20. 17. 15. 12. 13. 14.
 17. 20. 20. 24. 29. 33. 35. 39. 44. 46. 54. 43. 63. 67. 75.120.130.140.150. 0.0
 0.0 76. 67. 49. 43. 40. 28. 35. 41. 32. 23. 22. 18. 19. 20. 12. 10. 12. 11. 13.
 17. 19. 21. 26. 32. 35. 38. 43. 46. 52. 64. 74. 73. 76. 75.120.130.140.150. 0.0
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 0.0 77. 65. 27. 42. 32. 30. 31. 26. 25. 30. 22. 16. 16. 18. 12. 16. 17. 13. 13.
 16. 20. 22. 29. 34. 33. 33. 39. 43. 48. 59. 65. 71. 76. 87.120.130.140.150. 0.0
 0.0 83. 99. 99. 58. 28. 20. 22. 18. 21. 45. 41. 21. 14. 16. 16. 13. 16. 14. 15.
 22. 30. 32. 37. 34. 31. 33. 36. 37. 42. 45. 47. 56. 78. 86.120.130.140.150. 0.0
 0.0 99. 40. 77. 56. 35. 21. 20. 21. 17. 23. 36. 24. 16. 17. 17. 14. 12. 17. 20.
 26. 38. 35. 31. 33. 33. 35. 37. 38. 40. 39. 38. 51. 63. 72.120.130.140.150. 0.0
 0.0127. 88. 99. 99. 56. 41. 21. 31. 22. 20. 18. 19. 19. 18. 18. 18. 11. 24. 25.
 28. 31. 38. 28. 28. 32. 35. 38. 40. 43. 40. 38. 50. 64. 79.120.130.140.150. 0.0
 0.0117.108.101. 95. 85. 60. 57. 31. 34. 33. 25. 99. 25. 23. 24. 24. 24. 25. 28.
 27. 27. 29. 28. 28. 31. 35. 40. 42. 44. 44. 42. 49. 63. 76.120.130.140.150. 0.0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
End of data for first pumping period.
Data for pumping period 1901-1935

Flag for revisions
1
Maximum number of time steps in this pumping period  10
Time-step interval for print-out  10
Number of iteration parameters  10
Maximum number of iterations 100
Number of pumping wells  41
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  35.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0929  .002
0930  .007
1014  .067
1027  .003
1029  .005
1032  .013
1111  .024
1115  .067
1132  .001
1133  .084
1206  .005
1225  .039
1228  .013
1230  .011
1231  .021
1234  .088
1236  .002
1328  .003
1333  .298
1334  .096
1335  .146
1431  .023
1432  .031
```

1532 .096
1633 .007
1732 .027
1733 .036
1821 .030
1920 .479
1923 .036
2228 .060
2328 .061
2426 .115
2427 .127
2526 .178
2528 .132
2529 .105
2627 .121
2631 .407
2632 .057
3014 .006

Flag for revisions
1
Maximum number of time steps in this pumping period 7
Time-step interval for print-out 7
Number of iteration parameters 10
Maximum number of iterations 100
Number of pumping wells 52
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 14.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0516 .202
0929 .011
0930 .046
1014 .584
1027 .058
1029 .041
1032 .085
1115 .600
1132 .008
1133 .064
1206 .080
1225 .122
1227 .088
1228 .062
1230 .248
1231 .791
1234 .013
1236 .001
1328 .111

1333 .591
1334 .067
1335 .017
1431 .211
1432 .093
1512 .017
1532 .150
1615 .221
1617 .149
1633 .031
1714 .075
1719 .031
1732 .046
1733 .077
1813 .002
1821 .389
1917 .423
1920 2.417
1922 .053
2019 .391
2022 .348
2228 .007
2329 .009
2426 .046
2427 .092
2516 .106
2526 .118
2528 .057
2529 .117
2627 .160
2631 .194
2632 .097
3014 .012

Flag for revisions
1
Maximum number of time steps in this pumping period 7
Time-step interval for print-out 7
Number of iteration parameters 10
Maximum number of iterations 100
Number of pumping wells 69
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 14.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0325 .044
0329 .005
0430 .039
0516 .370

0622	.033
0631	.003
0831	.103
0916	.530
0928	.149
0929	.020
0930	.109
1014	1.674
1027	.271
1028	.008
1029	.004
1032	.080
1115	1.673
1126	.165
1127	.247
1132	.037
1133	.077
1206	.150
1227	.634
1228	.133
1230	.084
1231	1.612
1323	.655
1328	.645
1333	1.186
1407	.017
1431	.056
1432	.084
1434	.027
1512	.122
1515	.221
1530	.022
1532	.068
1615	.133
1633	.040
1710	.009
1714	.518
1719	.248
1732	.066
1733	.028
1809	.039
1812	.008
1813	.153
1821	1.357
1917	1.309
1920	3.681
1922	.341
1923	.031
1930	.010
2014	.096
2019	.753
2022	.765
2208	.094
2227	.036

2427 .042
2430 .020
2516 .227
2526 .040
2529 .067
2627 .066
2631 .126
2632 .077
2720 .010
2730 .033
3014 .014

Flag for revisions
1
Maximum number of time steps in this pumping period 5
Time-step interval for print-out 5
Number of iteration parameters 10
Maximum number of iterations 200
Number of pumping wells 87
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 7.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0325 .155
0329 .019
0332 .106
0430 .051
0433 .062
0516 .406
0529 .013
0533 .013
0622 .093
0624 .066
0631 .060
0633 .210
0731 .079
0829 .044
0831 .195
0916 .062
0928 .241
0929 .028
0930 .563
1014 .337
1024 .058
1027 .481
1028 .052
1029 .032
1032 .328
1115 .298

1126	.294
1127	.323
1130	.054
1132	.012
1133	.077
1206	.174
1227	.613
1228	.519
1230	.169
1231	1.020
1323	3.891
1328	.895
1329	.046
1333	1.424
1404	.124
1407	.093
1431	.080
1432	.031
1434	.164
1505	.244
1506	.032
1508	.179
1512	.220
1515	.572
1530	.062
1532	.062
1617	.080
1633	.075
1710	.027
1714	.277
1719	.169
1730	.024
1732	.084
1809	.108
1812	.106
1813	.238
1821	1.951
1831	.011
1917	.624
1920	4.551
1922	.464
1923	.033
1930	.046
2014	.036
2019	.985
2022	.606
2208	.005
2227	.055
2427	.069
2430	.030
2516	.243
2526	.009
2528	.002
2529	.044
2627	.155

2631 .088
2632 .057
2720 .060
2730 .062
3014 .015
3430 .022

Flag for revisions
1
Maximum number of time steps in this pumping period 6
Time-step interval for print-out 6
Number of iteration parameters 10
Maximum number of iterations 100
Number of pumping wells 98
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 12.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0325 .077
0329 .019
0331 .286
0332 .093
0430 .034
0432 .040
0433 .418
0516 .974
0529 .048
0533 .085
0622 .070
0624 .077
0631 .064
0633 .171
0731 .165
0829 .072
0831 .083
0916 .046
0928 .209
0929 .019
0930 .727
1014 .058
1024 .069
1027 .066
1028 .378
1029 .046
1032 .568
1112 .008
1126 .390
1127 .193
1130 .187

1132	.129
1133	.077
1206	.244
1227	.077
1228	.033
1230	.335
1231	.695
1323	3.730
1328	1.476
1329	.110
1333	1.292
1404	.124
1407	.088
1408	.018
1431	.091
1432	.069
1434	.082
1505	.266
1506	.031
1508	.123
1512	.233
1515	.260
1523	.150
1530	.137
1532	.062
1617	.075
1621	.258
1630	.058
1633	.064
1710	.061
1714	.259
1719	.081
1730	.039
1732	.106
1809	.090
1812	.007
1813	.216
1820	3.476
1821	2.157
1831	.058
1917	.685
1920	1.826
1922	.801
1923	.053
1930	.095
2014	.097
2017	.028
2019	.586
2022	.519
2025	.067
2029	.098
2227	.084
2313	.004
2427	.095

2430 .027
2516 .154
2526 .015
2528 .015
2529 .027
2627 .113
2631 .062
2632 .031
2720 .055
2730 .031
2918 .301
3014 .013
3430 .031
End of calibration period

The following pumping periods are the low estimate for pumping

Flag for revisions
1
Maximum number of time steps in this pumping period 2
Time-step interval for print-out 2
Number of iteration parameters 10
Maximum number of iterations 200
Number of pumping wells 97
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 2.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0325 .077
0329 .019
0331 .286
0332 .093
0430 .034
0432 .040
0433 .418
0516 .974
0529 .048
0533 .085
0622 .070
0624 .077
0631 .064
0633 .171
0731 .165
0829 .072
0831 .083
0916 .046
0928 .209
0929 .019
0930 .727

1014	.058
1024	.069
1027	.066
1028	.378
1029	.046
1032	.568
1112	.008
1126	.390
1127	.193
1130	.187
1132	.129
1133	.077
1206	.244
1227	.077
1228	.033
1230	.335
1231	.695
1323	3.730
1328	1.476
1329	.110
1333	1.292
1404	.124
1407	.088
1408	.018
1431	.091
1432	.069
1434	.082
1505	.266
1506	.031
1508	.123
1512	.233
1515	.260
1523	.150
1530	.137
1532	.062
1617	.075
1621	.258
1630	.058
1633	.064
1710	.061
1714	.259
1719	.081
1730	.039
1732	.106
1809	.090
1812	.007
1813	.216
1821	2.157
1831	.058
1917	.685
1920	5.303
1922	.801
1923	.053
1930	.095

```
2014  .097
2017  .028
2019  .586
2022  .519
2025  .067
2029  .098
2227  .084
2313  .004
2427  .095
2430  .027
2516  .154
2526  .015
2528  .015
2529  .027
2627  .113
2631  .062
2632  .031
2720  .055
2730  .031
2918  .301
3014  .013
3430  .031

Flag for revisions
1
Maximum number of time steps in this pumping period  6
Time-step interval for print-out  6
Number of iteration parameters  10
Maximum number of iterations 200
Number of pumping wells  90
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  6.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325  0.0797
0329  0.0197
0331  0.2960
0332  0.0963
0430  0.0352
0432  0.0414
0433  0.4326
0516  1.0081
0529  0.0497
0533  0.0880
0622  0.0724
0624  0.0797
0631  0.0662
0633  0.1770
0731  0.1708
```

0829	0.0745
0831	0.0859
0916	0.0476
0928	0.2163
0929	0.0197
0930	0.7524
1014	0.0600
1024	0.0714
1027	0.0683
1028	0.3912
1029	0.0476
1032	0.5879
1112	0.0083
1126	0.4036
1127	0.1998
1130	0.1935
1132	0.1335
1133	0.0797
12 6	0.2525
1227	0.0797
1228	0.0342
1230	0.3467
1231	0.7193
1323	3.8605
1328	1.5277
1329	0.1138
1333	1.3372
14 4	0.1283
14 7	0.0911
14 8	0.0186
1431	0.0942
1432	0.0714
1434	0.0849
15 5	0.2753
15 6	0.0321
15 8	0.1273
1512	0.2412
1515	0.2691
1523	0.1552
1530	0.1418
1532	0.0642
1617	0.0776
1621	0.2670
1630	0.0600
1633	0.0662
1710	0.0631
1714	0.2681
1719	0.0838
1730	0.0404
1732	0.1097
18 9	0.0931
1813	0.2236
1831	0.0600
1917	0.7090

```
1922  0.8290
1923  0.0549
1930  0.0983
2017  0.0290
2029  0.1014
2227  0.0869
2313  0.0041
2427  0.0983
2430  0.0279
2516  0.1594
2526  0.0155
2528  0.0155
2529  0.0279
2627  0.1170
2631  0.0642
2632  0.0321
2720  0.0569
2730  0.0321
2918  0.3115
3014  0.0135
3430  0.0321

Flag for revisions
1
Maximum number of time steps in this pumping period  10
Time-step interval for print-out  10
Number of iteration parameters  10
Maximum number of iterations 200
Number of pumping wells  90
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  10.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325  0.0909
0329  0.0224
0331  0.3375
0332  0.1097
0430  0.0401
0432  0.0472
0433  0.4932
0516  1.1493
0529  0.0566
0533  0.1003
0622  0.0826
0624  0.0909
0631  0.0755
0633  0.2018
0731  0.1947
0829  0.0850
```

0831	0.0979
0916	0.0543
0928	0.2466
0929	0.0224
0930	0.8579
1014	0.0684
1024	0.0814
1027	0.0779
1028	0.4460
1029	0.0543
1032	0.6702
1112	0.0094
1126	0.4602
1127	0.2277
1130	0.2207
1132	0.1522
1133	0.0909
12 6	0.2879
1227	0.0909
1228	0.0389
1230	0.3953
1231	0.8201
1323	4.4014
1328	1.7417
1329	0.1298
1333	1.5246
14 4	0.1463
14 7	0.1038
14 8	0.0212
1431	0.1074
1432	0.0814
1434	0.0968
15 5	0.3139
15 6	0.0366
15 8	0.1451
1512	0.2749
1515	0.3068
1523	0.1770
1530	0.1617
1532	0.0732
1617	0.0885
1621	0.3044
1630	0.0684
1633	0.0755
1710	0.0720
1714	0.3056
1719	0.0956
1730	0.0460
1732	0.1251
18 9	0.1062
1813	0.2549
1831	0.0684
1917	0.8083
1922	0.9452

1923 0.0625
1930 0.1121
2017 0.0330
2029 0.1156
2227 0.0991
2313 0.0047
2427 0.1121
2430 0.0319
2516 0.1817
2526 0.0177
2528 0.0177
2529 0.0319
2627 0.1333
2631 0.0732
2632 0.0366
2720 0.0649
2730 0.0366
2918 0.3552
3014 0.0153
3430 0.0366

Flag for revisions
1
Maximum number of time steps in this pumping period 10
Time-step interval for print-out 10
Number of iteration parameters 10
Maximum number of iterations 200
Number of pumping wells 90
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years 10.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325 0.1001
0329 0.0247
0331 0.3718
0332 0.1209
0430 0.0442
0432 0.0520
0433 0.5434
0516 1.2662
0529 0.0624
0533 0.1105
0622 0.0910
0624 0.1001
0631 0.0832
0633 0.2223
0731 0.2145
0829 0.0936
0831 0.1079

0916	0.0598
0928	0.2717
0929	0.0247
0930	0.9451
1014	0.0754
1024	0.0897
1027	0.0858
1028	0.4914
1029	0.0598
1032	0.7384
1112	0.0104
1126	0.5070
1127	0.2509
1130	0.2431
1132	0.1677
1133	0.1001
12 6	0.3172
1227	0.1001
1228	0.0429
1230	0.4355
1231	0.9035
1323	4.8490
1328	1.9188
1329	0.1430
1333	1.6796
14 4	0.1612
14 7	0.1144
14 8	0.0234
1431	0.1183
1432	0.0897
1434	0.1066
15 5	0.3458
15 6	0.0403
15 8	0.1599
1512	0.3029
1515	0.3380
1523	0.1950
1530	0.1781
1532	0.0806
1617	0.0975
1621	0.3354
1630	0.0754
1633	0.0832
1710	0.0793
1714	0.3367
1719	0.1053
1730	0.0507
1732	0.1378
18 9	0.1170
1813	0.2808
1831	0.0754
1917	0.8905
1922	1.0413
1923	0.0689

```
1930  0.1235
2017  0.0364
2029  0.1274
2227  0.1092
2313  0.0052
2427  0.1235
2430  0.0351
2516  0.2002
2526  0.0195
2528  0.0195
2529  0.0351
2627  0.1469
2631  0.0806
2632  0.0403
2720  0.0715
2730  0.0403
2918  0.3913
3014  0.0169
3430  0.0403

Flag for revisions
1
Maximum number of time steps in this pumping period  10
Time-step interval for print-out  10
Number of iteration parameters  10
Maximum number of iterations 200
Number of pumping wells  90
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  10.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325  .115
0329  .028
0331  .426
0332  .138
0430  .051
0432  .060
0433  .623
0516 1.451
0529  .072
0533  .127
0622  .104
0624  .115
0631  .095
0633  .255
0731  .246
0829  .107
0831  .124
0916  .068
```

0928	.311
0929	.028
0930	1.083
1014	.086
1024	.103
1027	.098
1028	.563
1029	.068
1032	.846
1112	.012
1126	.581
1127	.288
1130	.279
1132	.192
1133	.115
1206	.364
1227	.115
1228	.049
1230	.499
1231	1.036
1323	5.558
1328	2.199
1329	.164
1333	1.925
1404	.185
1407	.131
1408	.027
1431	.136
1432	.103
1434	.122
1505	.396
1506	.046
1508	.183
1512	.347
1515	.387
1523	.224
1530	.204
1532	.092
1617	.112
1621	.384
1630	.086
1633	.095
1710	.091
1714	.386
1719	.121
1730	.058
1732	.158
1809	.134
1813	.322
1831	.086
1917	1.021
1922	1.193
1923	.079
1930	.142

2017 .042
2029 .146
2227 .125
2313 .006
2427 .142
2430 .040
2516 .229
2526 .022
2528 .022
2529 .040
2627 .168
2631 .092
2632 .046
2720 .082
2730 .046
2918 .448
3014 .019
3430 .046
End of projected pumping.

The following is the high estimate of projected pumpage.

Flag for revisions
1
Maximum number of time steps in this pumping period 2
Time-step interval for print-out 2
Number of iteration parameters 10
Maximum number of iterations 200
Number of pumping wells 97
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 2.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7
X Y Rate of pumping wells in cubic feet per second.
0325 0.0847
0329 0.0209
0331 0.3146
0332 0.1023
0430 0.0374
0432 0.0440
0433 0.4598
0516 1.0714
0529 0.0528
0533 0.0935
0622 0.0770
0624 0.0847
0631 0.0704
0633 0.1881
0731 0.1815
0829 0.0792

0831	0.0913
0916	0.0506
0928	0.2299
0929	0.0209
0930	0.7997
1014	0.0638
1024	0.0759
1027	0.0726
1028	0.4158
1029	0.0506
1032	0.6248
1112	0.0088
1126	0.4290
1127	0.2123
1130	0.2057
1132	0.1419
1133	0.0847
12 6	0.2684
1227	0.0847
1228	0.0363
1230	0.3685
1231	0.7645
1323	4.1030
1328	1.6236
1329	0.1210
1333	1.4212
14 4	0.1364
14 7	0.0968
14 8	0.0198
1431	0.1001
1432	0.0759
1434	0.0902
15 5	0.2926
15 6	0.0341
15 8	0.1353
1512	0.2563
1515	0.2860
1523	0.1650
1530	0.1507
1532	0.0682
1617	0.0825
1621	0.2838
1630	0.0638
1633	0.0704
1710	0.0671
1714	0.2849
1719	0.0891
1730	0.0429
1732	0.1166
18 9	0.0990
1812	0.0077
1813	0.2376
1821	2.3727
1831	0.0638

```
1917  0.7535
1920  5.8322
1922  0.8811
1923  0.0583
1930  0.1045
2014  0.1067
2017  0.0308
2019  0.6446
2022  0.5709
2025  0.0737
2029  0.1078
2227  0.0924
2313  0.0044
2427  0.1045
2430  0.0297
2516  0.1694
2526  0.0165
2528  0.0165
2529  0.0297
2627  0.1243
2631  0.0682
2632  0.0341
2720  0.0605
2730  0.0341
2918  0.3311
3014  0.0143
3430  0.0341

Flag for revisions
1
Maximum number of time steps in this pumping period  6
Time-step interval for print-out  6
Number of iteration parameters  10
Maximum number of iterations 200
Number of pumping wells  98
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  6.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325  0.0924
0329  0.0228
0331  0.3432
0332  0.1116
0430  0.0408
0432  0.0480
0433  0.5016
0516  1.1688
0529  0.0576
0533  0.1020
```

0622	0.0840
0624	0.0924
0631	0.0768
0633	0.2052
0731	0.1980
0829	0.0864
0831	0.0996
0916	0.0552
0928	0.2508
0929	0.0228
0930	0.8724
1014	0.0696
1024	0.0828
1027	0.0792
1028	0.4536
1029	0.0552
1032	0.6816
1112	0.0096
1126	0.4680
1127	0.2316
1130	0.2244
1132	0.1548
1133	0.0924
12 6	0.2928
1227	0.0924
1228	0.0396
1230	0.4020
1231	0.8340
1323	4.4760
1328	1.7712
1329	0.1320
1333	1.5504
14 4	0.1488
14 7	0.1056
14 8	0.0216
1431	0.1092
1432	0.0828
1434	0.0984
15 5	0.3192
15 6	0.0372
15 8	0.1476
1512	0.2796
1515	0.3120
1523	0.1800
1530	0.1644
1532	0.0744
1617	0.0900
1621	0.3096
1630	0.0696
1633	0.0768
1710	0.0732
1714	0.3108
1719	0.0972
1730	0.0468

```
1732  0.1272
18 9  0.1080
1812  0.0084
1813  0.2592
1820  4.1712
1821  2.5884
1831  0.0696
1917  0.8220
1920  2.1912
1922  0.9612
1923  0.0636
1930  0.1140
2014  0.1164
2017  0.0336
2019  0.7032
2022  0.6228
2025  0.0804
2029  0.1176
2227  0.1008
2313  0.0048
2427  0.1140
2430  0.0324
2516  0.1848
2526  0.0180
2528  0.0180
2529  0.0324
2627  0.1356
2631  0.0744
2632  0.0372
2720  0.0660
2730  0.0372
2918  0.3612
3014  0.0156
3430  0.0372

Flag for revisions
1
Maximum number of time steps in this pumping period  10
Time-step interval for print-out  10
Number of iteration parameters  10
Maximum number of iterations 200
Number of pumping wells  98
Print only at the end of time steps   0
Do not print velocities   0
Do not print dispersion coefficients   0
Print changes in concentration   1
Do not punch velocities   0
Pumping period in years  10.
Time increment multiplier  1.3
Size of initial time step in seconds 3.E+7
 X Y   Rate of pumping wells in cubic feet per second.
0325  0.1186
0329  0.0293
0331  0.4404
```

0332	0.1432
0430	0.0524
0432	0.0616
0433	0.6437
0516	1.5000
0529	0.0739
0533	0.1309
0622	0.1078
0624	0.1186
0631	0.0986
0633	0.2633
0731	0.2541
0829	0.1109
0831	0.1278
0916	0.0708
0928	0.3219
0929	0.0293
0930	1.1196
1014	0.0893
1024	0.1063
1027	0.1016
1028	0.5821
1029	0.0708
1032	0.8747
1112	0.0123
1126	0.6006
1127	0.2972
1130	0.2880
1132	0.1987
1133	0.1186
12 6	0.3758
1227	0.1186
1228	0.0508
1230	0.5159
1231	1.0703
1323	5.7442
1328	2.2730
1329	0.1694
1333	1.9897
14 4	0.1910
14 7	0.1355
14 8	0.0277
1431	0.1401
1432	0.1063
1434	0.1263
15 5	0.4096
15 6	0.0477
15 8	0.1894
1512	0.3588
1515	0.4004
1523	0.2310
1530	0.2110
1532	0.0955
1617	0.1155

1621	0.3973
1630	0.0893
1633	0.0986
1710	0.0939
1714	0.3989
1719	0.1247
1730	0.0601
1732	0.1632
18 9	0.1386
1812	0.0108
1813	0.3326
1820	5.3530
1821	3.3218
1831	0.0893
1917	1.0549
1920	2.8120
1922	1.2335
1923	0.0816
1930	0.1463
2014	0.1494
2017	0.0431
2019	0.9024
2022	0.7993
2025	0.1032
2029	0.1509
2227	0.1294
2313	0.0062
2427	0.1463
2430	0.0416
2516	0.2372
2526	0.0231
2528	0.0231
2529	0.0416
2627	0.1740
2631	0.0955
2632	0.0477
2720	0.0847
2730	0.0477
2918	0.4635
3014	0.0200
3430	0.0477

Flag for revisions
1
Maximum number of time steps in this pumping period 10
Time-step interval for print-out 10
Number of iteration parameters 10
Maximum number of iterations 200
Number of pumping wells 98
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0

Pumping period in years 10.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7

X Y	Rate of pumping wells in cubic feet per second.
0325	0.1363
0329	0.0336
0331	0.5062
0332	0.1646
0430	0.0602
0432	0.0708
0433	0.7399
0516	1.7240
0529	0.0850
0533	0.1504
0622	0.1239
0624	0.1363
0631	0.1133
0633	0.3027
0731	0.2920
0829	0.1274
0831	0.1469
0916	0.0814
0928	0.3699
0929	0.0336
0930	1.2868
1014	0.1027
1024	0.1221
1027	0.1168
1028	0.6691
1029	0.0814
1032	1.0054
1112	0.0142
1126	0.6903
1127	0.3416
1130	0.3310
1132	0.2283
1133	0.1363
12 6	0.4319
1227	0.1363
1228	0.0584
1230	0.5929
1231	1.2301
1323	6.6021
1328	2.6125
1329	0.1947
1333	2.2868
14 4	0.2195
14 7	0.1558
14 8	0.0319
1431	0.1611
1432	0.1221
1434	0.1451
15 5	0.4708
15 6	0.0549

15 8 0.2177
1512 0.4124
1515 0.4602
1523 0.2655
1530 0.2425
1532 0.1097
1617 0.1327
1621 0.4567
1630 0.1027
1633 0.1133
1710 0.1080
1714 0.4584
1719 0.1434
1730 0.0690
1732 0.1876
18 9 0.1593
1812 0.0124
1813 0.3823
1820 6.1525
1821 3.8179
1831 0.1027
1917 1.2124
1920 3.2320
1922 1.4178
1923 0.0938
1930 0.1681
2014 0.1717
2017 0.0496
2019 1.0372
2022 0.9186
2025 0.1186
2029 0.1735
2227 0.1487
2313 0.0071
2427 0.1681
2430 0.0478
2516 0.2726
2526 0.0265
2528 0.0265
2529 0.0478
2627 0.2000
2631 0.1097
2632 0.0549
2720 0.0973
2730 0.0549
2918 0.5328
3014 0.0230
3430 0.0549

Flag for revisions
1
Maximum number of time steps in this pumping period 10
Time-step interval for print-out 10
Number of iteration parameters 10

Maximum number of iterations 200
Number of pumping wells 98
Print only at the end of time steps 0
Do not print velocities 0
Do not print dispersion coefficients 0
Print changes in concentration 1
Do not punch velocities 0
Pumping period in years 10.
Time increment multiplier 1.3
Size of initial time step in seconds 3.E+7

X Y	Rate of pumping wells in cubic feet per second.
0325	.162
0329	.040
0331	.601
0332	.195
0430	.071
0432	.084
0433	.878
0516	2.045
0529	.108
0533	.178
0622	.147
0624	.162
0631	.134
0633	.359
0731	.346
0829	.151
0831	.174
0916	.097
0928	.439
0929	.040
0930	1.527
1014	.122
1024	.145
1027	.139
1028	.794
1029	.097
1032	1.193
1112	.017
1126	.819
1127	.405
1130	.393
1132	.271
1133	.162
1206	.512
1227	.162
1228	.069
1230	.704
1231	1.460
1323	7.833
1328	3.100
1329	.231
1333	2.713
1404	.260

1407	.185
1408	.038
1431	.191
1432	.145
1434	.172
1505	.559
1506	.065
1508	.258
1512	.489
1515	.546
1523	.315
1530	.288
1532	.130
1617	.158
1621	.542
1630	.122
1633	.134
1710	.128
1714	.544
1719	.170
1730	.082
1732	.223
1809	.189
1812	.015
1813	.454
1820	7.300
1821	4.530
1831	.122
1917	1.438
1920	3.835
1922	1.682
1923	.111
1930	.200
2014	.204
2017	.059
2019	1.231
2022	1.090
2025	.141
2029	.206
2227	.176
2313	.008
2427	.200
2430	.057
2516	.323
2526	.032
2528	.032
2529	.057
2627	.237
2631	.130
2632	.065
2720	.116
2730	.065
2918	.632
3014	.027
3430	.065

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