PROPOSED 10-YEAR PLAN FOR CONTINUATION OF HYDROLOGIC STUDIES OF THE EDWARDS AQUIFER, SAN ANTONIO AREA TEXAS

By Larry F. Land

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METRIC CONVERSIONS

For those readers interested in using the metric system, the inch-pound units of measurements used in this report may be converted to metric units by the following factors:

From	Multiply by	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer

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ABSTRACT

The importance of the Edwards aquifer as a freshwater resource and its susceptibility to being contaminated, being over utilized, or both resulted in the development of a proposed 10-year plan to monitor and study its hydrology. The plan proposes adjustments to the current monitoring activities of computing and measuring recharge, discharge, withdrawals, water levels, and water quality. To conduct the needed special studies, the plan recognizes the need for the construction and drilling of many new wells at specific locations and to selected depths. Many of the wells will be in clusters so that data can be obtained on a stratigraphic basis.

Some of the topics identified for special study include: (1) The potential of saline water entering the freshwater zone from the downdip boundary; (2) the possibility of water leaking into the aquifer from an overlying aquifer; (3) the effects of urbanization on ground-water quality in local areas; (4) the movement and dissipation of a recharge water plume; (5) the influx of water from the Glen Rose Formation; (6) the effects of the fault barriers, regional dense bed, and irregular geologic framework on ground-water flow patterns; (7) natural recharge-discharge relationships; (8) the aquifer stage-storage relationship; (9) natural water-quality evolution; and (10) a refinement of the hydrogeologic framework in a local area.

INTRODUCTION

For many years, the Edwards aquifer in the San Antonio area (fig. 1) has been the subject of many studies by geologists and hydrologists. They have collected substantial data and have written many reports. Some governmental agencies such as the U.S. Geological Survey, the Texas Department of Water Resources, the City of San Antonio, and the Edwards Underground Water District, have funded numerous data-collection activities and investigative projects in the past and continue to do so today (1984). These include networks of stations on streams to measure flow and water quality, networks of wells to measure water levels and water quality, and special studies of the hydrology and geology of the aquifer system. It was the interest of these National, State, and local agencies in the future development of this valuable freshwater resource that led to a meeting of representatives of those groups and to the decision to formulate a long-term plan for investigation of the Edwards aquifer system.

To date, most of the data for monitoring and studying the aquifer have been collected at existing wells. The only major investment in test wells and gaging sites has been the streamgaging stations and eight test holes drilled during the mid-1970's. This approach was appropriate at the time and has provided the information needed for a good general description of the hydrology and geology at a moderate cost. Because of the value of the aquifer as a freshwater resource and its potential for being contaminated, being over utilized to the point of causing adverse effects, or both, a long-range plan to monitor the system and to study various components is proposed. The purpose of the plan is to formulate a program of data collection and special studies that would aid water managers and policy makers in water-related decisions for many years to come. The program is intended to be flexible to allow for the modification of planned studies and for the scheduling and conducting of alternative or supplemental studies as the circumstances and priorities of the time indicate.

ACKNOWLEDGMENTS

The assistance of colleagues in developing the ideas for this 10-year plan is gratefully acknowledged. Special thanks are extended to the City of San Antonio Water Board and General Manager, Robert P. Van Dyke, and technical advisor, William L. Guyton; to the Edwards Underground Water District and General Manager, Thomas P. Fox, Jr., and his assistant, Robert Bader; to the City of San Antonio, represented by Robert B. Hahn, Frank Grant, and Barbara Smith-Townsend; to the Texas Department of Water Resources, represented by Tommy Knowles, Director, Data and Engineering Services, and Henry Alvarez, Chief, Data Collection and Evaluation Section; and to the San Antonio River Authority and General Manager, Fred W. Pfeiffer, and his assistant, Blair Warren. The support and assistance from those mentioned above and from others were extremely beneficial in developing this plan.

APPROACH

In developing this plan, numerous topics were identified as priority items for study in several informal meetings and private discussions. These topics were divided into two categories: monitoring and special studies. The monitor-

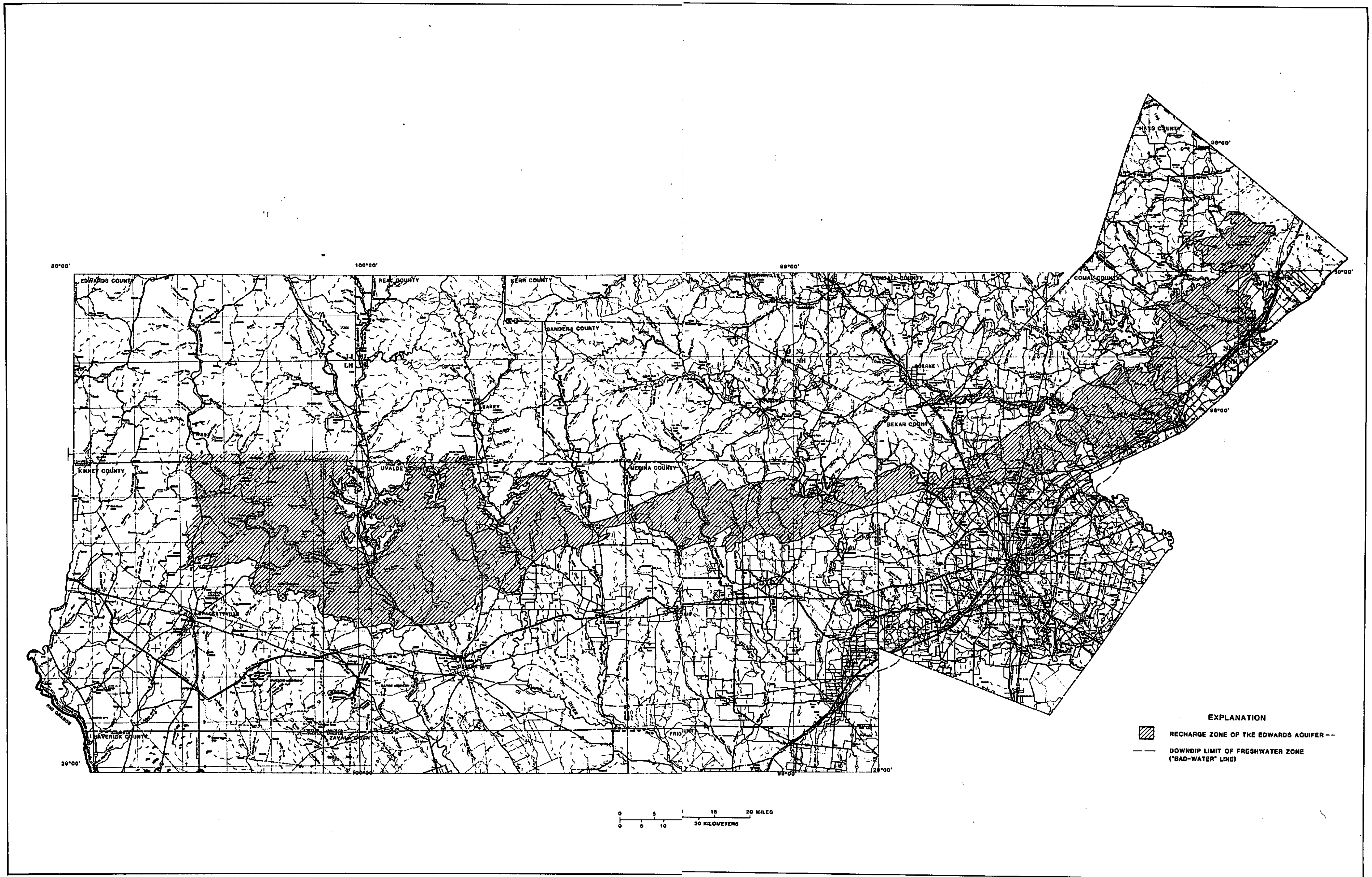

Figure I.--Location of Edwards aquifer in the San Antonio area ing activities would document the hydrologic conditions, determine trends and changes in hydrology, compute a water budget of the system, and provide information for managing the water resources. The special studies generally would involve collecting data in local areas, making analyses and interpretations of the data, and preparing and publishing reports. The major topics identified for special study include aquifer protection, ground-water movement, ground-water storage, water quality, and hydrogeologic framework.

The implementation of some aspects of the monitoring program and most of the proposed studies depends on having wells at specific locations open to selected zones of the aquifer. Some studies will use the traditional approach of using existing wells, some of which are believed to exist but need to be located by field inventories. However, many of the needed wells do not exist and need to be drilled.

The general approach in coordinating the well-drilling program into a single plan follows:

(1) Distribute the well drilling and installation throughout the study period because of the cost and time requirements.

(2) Have each well serve as many purposes as possible.

(3) Locate wells in clusters with each completed in different zones of the aquifer system.

(4) Place emphasis on the most pressing issues, which are believed to be aquifer protection, especially near the "bad-water" line and the effects of urbanization on the quantity and quality of water in the aquifer.

(5) Attempt to complete special studies or at least phases, as soon as possible after starting them, but also attempt to start as many of the studies as soon as possible. Thus, many of the studies will be conducted concurrently.

(6) Complete the drilling in a test area once started.

(7) Publish preliminary reports for studies taking several years.

(8) Add the new wells to the monitoring networks.

(9) Collect as much geologic, geophysical, geochemical, and hydrologic data as reasonable during the drilling process.

(10) Inventory existing wells in the areas of the special studies for the possibility of using them in the tests. However, few if any compromises on depths and locations will be permitted.

Monitoring Program

Under the existing monitoring program, several networks of streamgages, observation wells, and raingages are established on a more or less permanent basis to serve selected purposes. For example, a network of streamgages measures flow continuously and is used to compute the quantity of water recharging and discharging from the aquifer. Water samples can be collected from the streams at these stations to determine the quality of water entering and leaving the aquifer. Another network is a number of wells used to measure water levels and water-quality conditions. In addition to the networks, ground-water pumpage data are collected to compute an annual water budget.

In general, a good multipurpose monitoring program is in place. This program has been operated continuously since the 1930's and has been adjusted each year in consideration of current issues, data needs, and available funds. As a result, it is considered to be adequate, but some adjustments are needed.

Major components of the program are described below.

Recharge--A network of streamgages is in place to measure the flow in major streams upstream and downstream from the recharge zone (fig. 2). A network of raingages also are used in computing the recharge to the aquifer. No changes are needed.

Discharge--Gaging stations are established at the two major springs where most natural discharge occurs.

Water use--For major municipal and industrial suppliers, quantities will be obtained from their pumpage records as in the past. For irrigation, the current indirect determinations using power records and crop acreages also will continue, but statistical-sampling and remote-sensing techniques will be tested to assist in these determinations. Using statistical-sampling techniques, ground-water pumpage for about 5 percent of the farms for each major crop will be measured directly with flow meters, timing devices, or power consumption. With crop-type and acreage information, the total irrigation-water use can be determined. Research has been conducted using remote-sensing techniques and will be tested in the area. If this approach is successful, it will be developed and integrated into the current approach, which will supply the needed ground-truth information.

Water levels--A regional network of wells (fig. 3) is measured on a continuous or periodic basis. During 1984, 16 wells are measured periodically, and continuous recorders are in operation on 18 wells. Most of the wells measured periodically are active production wells. If the water level of the aquifer declines to the extent that the flow of Comal Springs decreases to 50 ft^3/s, the network will be expanded to about 150 wells for mass water-level measurements. The coverage is reasonably good for regional purposes; however, in critical areas, wells do not exist. This is especially true in the San Antonio area where the number of available observation wells are decreasing because major water-supply distribution lines are being laid in rural areas, thus causing supply wells to be abandoned and plugged. The process of urbanization destroys a substantial number of nonproduction observation wells. Wells drilled for other than hydrologic purposes generally provide less than optimum data because the wells are open to too much or too little of the formation, disturbed by pumping, or allow contaminants to reach the aquifer as a result of improper construction. Plans include expanding the regional network by field visits to locate new wells. Emphasis will be in the recharge area where the number of observation wells are most sparse. Selected wells from the proposed drilling program also will be added to the network. In addition to the regional network, local networks will be established in the Frio River area and in northern Bexar County for more detailed coverage and more frequent measurements.

Water-level mapping is planned on an annual basis for the local networks and on a 5-year basis for the regional network.

Water quality--A network of wells is in place for the collection of samples for water-quality analysis (fig. 4). A program for the collection and analysis of samples from a network of wells is rotated for complete coverage every third year. Samples will be collected from about 55 wells during 1984. Wells in critical areas will continue to be sampled each year. In local areas

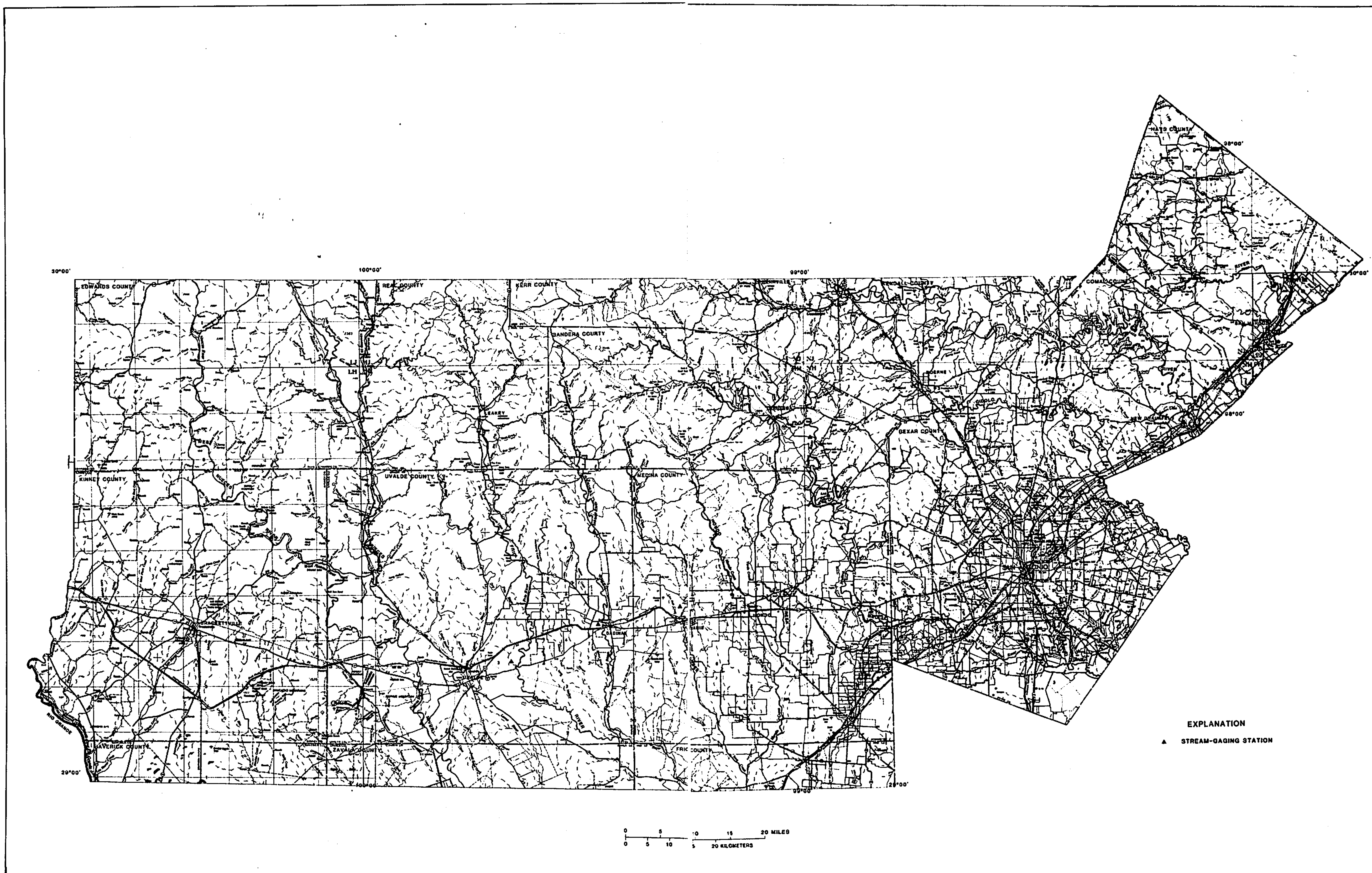

Figure 2.--Location of streamgaging stations

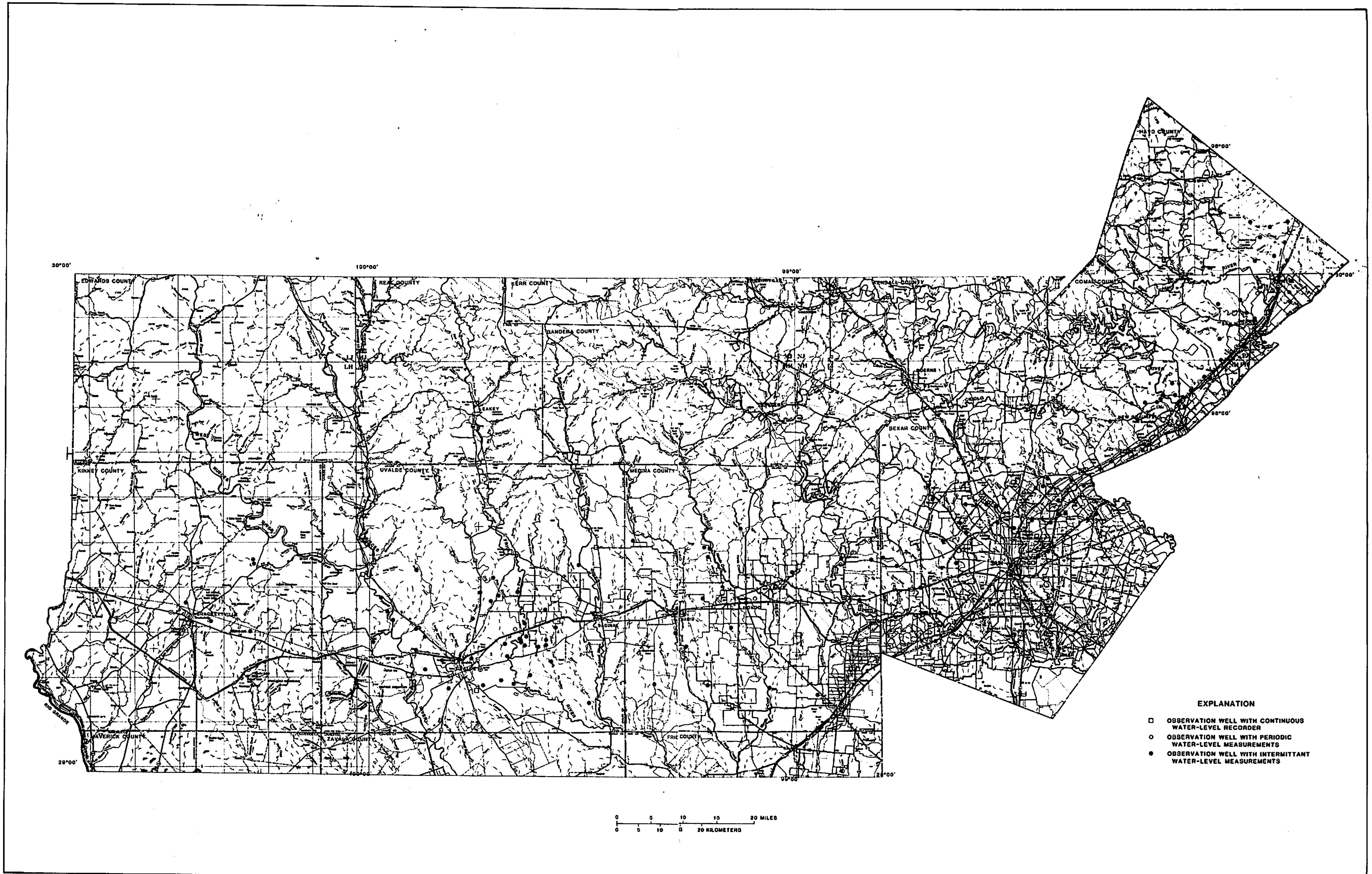

Figure 3.--Location of regional ground-water-level monitoring network

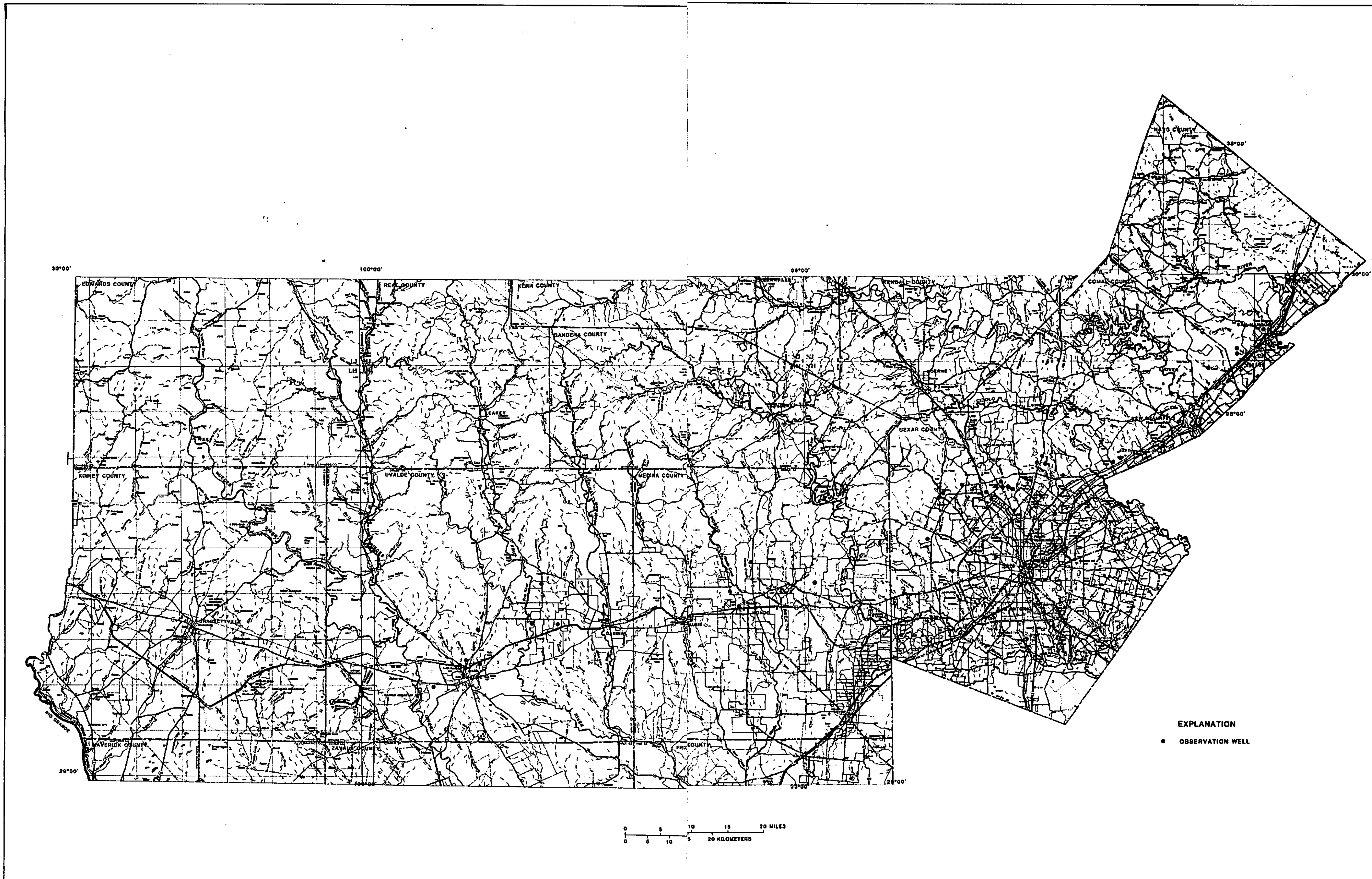

Figure 4.--Location of regional ground-water sampling network

having a significant potential for contamination, more detailed sampling networks are planned. The lack of a selection of depth intervals and wells in critical locations inhibits detailed analyses and dictates the development of an improved network.

"Bad-water" line--A network of observation wells are in place. If the flow of Comal Springs decreases to 50 ft^3/s, samples will be collected from about 35 wells along the "bad-water" line (fig. 5). Current monitoring programs will be continued.

Inventories--The program of continuing to inventory and document new major wells will continue. Also, geologic information that becomes available will be added to the files.

Special Studies

Reports in preparation for current studies include: (1) a map atlas containing areal and temporal variations of major, dissolved inorganic constituents in ground and surface waters of the Edwards aquifer system, 1968-83; (2) a lay-reader report describing in general terms the Edwards aquifer characteristics; (3) a data report describing the hydrogeology of the aquifer through the presentation of a number of cross sections, and (4) a preliminary report on the potential intrusion of saline water from downdip.

The topics identified for special study in this plan are aquifer protection, ground-water movement, storage and water-quality changes, and hydrogeologic-framework refinement.

For purposes of this plan, a well-numbering system has been devised to show the relationship between the study topics, test areas, well-cluster location, and well opening. Codes for these items follow:

Study-topic code

BWL	"Bad-water" line
URB	Urbanization
RR	Recharge reservoir
FB	Fault barrier
RDB	Regional dense bed
KNP	Knippa area
GR	Glen Rose Formation
AC	Austin Chalk
ND	Natural discharge

Test areas

a	San Antonio
b	Uvalde
c	San Marcos
d	Lawrence Creek
e	Vance Jackson Road
f	Farm to Market Road (FM) 1604 west
g	Hondo Creek
h	Elm Creek Reservoir
i	Farm to Market Road (FM) 1604 north
j	Interstate Highway 410 (I-410) and U.S. Highway (Hwy) 281 north
k	Medina River
l	Interstate Highway 410 (I-410) and U.S. Highway (Hwy) 90 west
m	Knippa
n	Hueco Springs
o	Sabinal
p	Nueces River

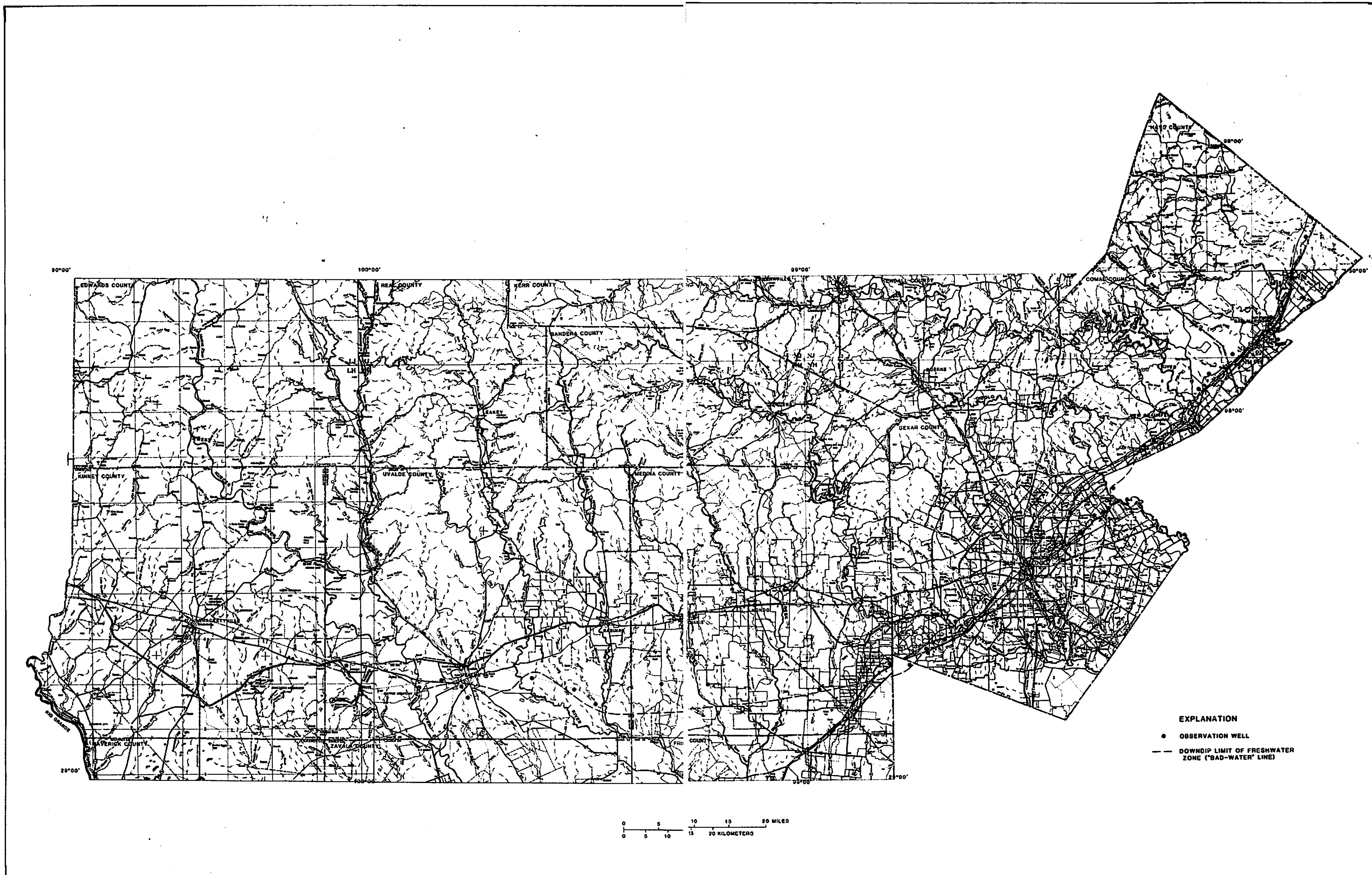

Figure 5.--Location of intensive ground-water-quality monitoring network along "bad-water" line

Cluster-location number		Well-opening code
Sequence number on map	0	Leona, Uvalde gravels
	1	Austin Chalk
	2	Top of Edwards Limestone
	3	Bottom of Edwards Limestone
	2-3	Edwards Limestone
	4	Glen Rose Formation

A typical well number is BWL a 1: 2. The uppercase alphabetical characters identify the study topic. The lowercase letter following the study-topic code identifies the test area that is shown in figure 6. The next character is a sequence number that identifies the cluster (well site) of wells on the associated map. The number after the colon identifies the formation in which the well is completed.

The work plan for well installation, data collection, analysis, and reports is given in figure 7. Details on the multipurpose use of the wells and for the studies are given in table 1. Each topic is discussed in the following sections.

Aquifer Protection

Special studies related to aquifer protection are needed to improve our understanding of how vulnerable the aquifer is to contamination. The avenues having a major potential for adversely affecting the water quality are believed to be the downdip boundary of the aquifer and the recharge zone. The special studies include: (1) Describing the potential for saline water moving into the aquifer from the downdip boundary, (2) showing the effect of direct recharge in an urban area using test sites in north and northwest San Antonio and a control site near Hondo, and (3) determining the fate of recharge water from a recharge reservoir (Elm Creek Reservoir).

"Bad-water" line

Because the possibility of saline water migrating into the aquifer from the downdip boundary is a major concern, this study will begin as soon as possible (FY 1985). There are three parts to the study; one part has the objective of compiling and publishing all data relevant to the "bad-water" line. The second part will identify water-level and water-quality changes and trends, if possible, and explain variations in the changes and trends, propose a hypothesis as to the relevance of the downdip formation on the aquifer, and propose studies and monitoring. The third part of the study has the objectives of establishing monitoring points for providing data on current and future water-level and water-quality conditions, defining the characteristics of the geology and hydrology of the transition zone between the saline and freshwater parts of the aquifer, and confirming, expanding, or discrediting the hypothesis proposed in the second part of the study.

The approach for the first part is to assemble, compile, and summarize site, water-level, and inorganic-chemistry data along the "bad-water" line. In the second part of the study, these data will be analyzed statistically with respect to time, depth, hydrologic conditions, position of saline water, and

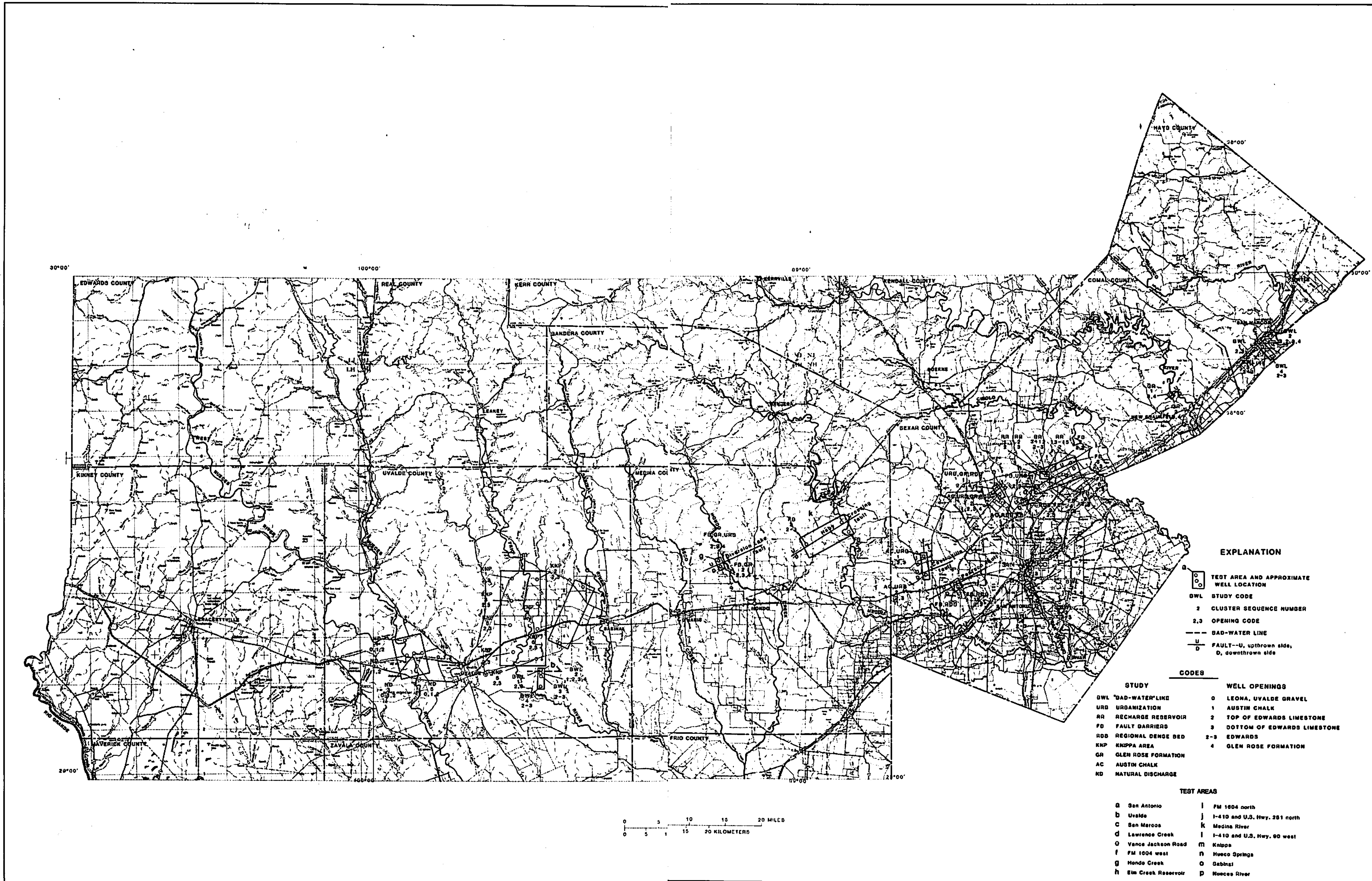

Figure 6.--Location of special study areas

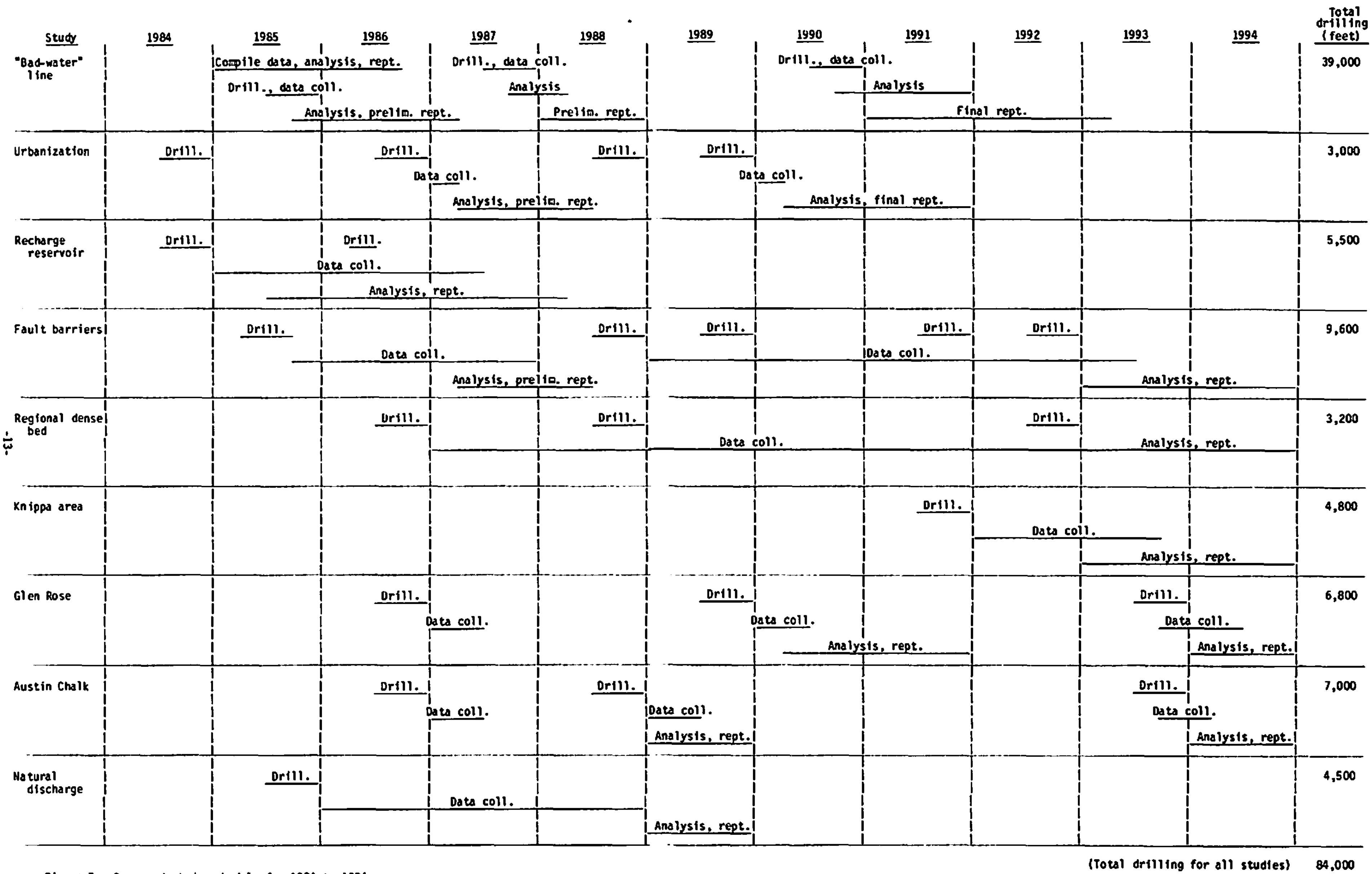

Figure 7.--Proposed study schedule for 1984 to 1994

Table 1.--Schedule of test-well installation 1/

1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
RR h 1: 2	BWL a 1: 2	URB e 1: 2	BWL b 1: 2	URB f 1: 2	URB g 1: 2	BWL c 1: 2	FB k 1: 2-3	FB l 1: 2	GR n 1: 3
2: 3	3	3	3	3	3	3	2: 2-3	3	4
3-12: 2-3	2: 1	2: 2	2: 1	2: 2		2: 1	3: 2-3	2: 2	2: 3
	2	3	2	3	FB g 1: 2	2		3	4
FB i 2: 2	3		3		3	3	KNP m 1: 2-3		
3	4	AC e 2: 1	4	AC f 1: 1	2: 2	4	2: 2-3	RDB l 1: 2	AC o 1: 1
	3: 2-3	2	3: 2-3	2	3	3: 2-3	3: 2-3	3	2
URB d 1: 2	4: 2-3		4: 2-3	2: 1		4: 2-3	4: 2-3	2: 2	2: 1
3		GR e 1: 3		2	GR g 1: 3		5: 2-3	3	2
	FB i 1: 2	4		j 1: 1	4		6: 2-3		
	3	2: 3		2	2: 3		7: 2-3		
	3: 2	4			4		8: 2-3		
	3			RDB j 1: 2					
	4: 2	RDB e 1: 2		3					
	3	3		2: 2					
	5: 2	2: 2		3					
	3	3							
	6: 2			FB j 1: 2					
	3	RR h 13-15: 2		3					
	ND p 1-5: 0			2: 2					
	1			3					
	2								
TOTAL DEPTH									
5,500 feet	23,000 feet	4,400 feet	16,000 feet	7,000 feet	4,300 feet	8,000 feet	6,200 feet	4,400 feet	5,200 feet

1/ Example well number: BWL a 1: 2 (BWL, study-topic code; a, test area; 1, cluster-location number; 2, well-opening code)

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Cluster-location number
Sequence number on map

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2-3	Edwards Limestone
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geochemistry. This information and principles of ground-water hydraulics, hydrology, and geochemistry, projected trends in water use, and probability of droughts will be used to state a hypothesis as to the movement of saline water into the freshwater part of the aquifer and to the changes occurring in the aquifer for various hydrologic or withdrawal conditions. Based on this study, a data-collection and investigation program will be designed to meet the objectives of the third part of the study. The approach for the third part of the study is to conduct tests in three test areas (fig. 6). For this general plan, a network of four well clusters is proposed for each test area. The clusters are to be in a line normal to the "bad-water" line. The number and general arrangement of the wells are illustrated in figure 8. Each well is to be designed and constructed so that hydraulic testing of the aquifer can be done. The most important data will be hydraulic heads, the horizontal and vertical gradients, aquifer permeabilities, and water quality. Modeling techniques will be used to analyze the data and to test the hypothesis stated earlier.

Wells for San Antonio (test area a), Uvalde (test area b), and San Marcos (test area c) will be drilled in FY 1985, 1987, and 1990, respectively. Preliminary reports will be prepared for each of the first two areas. A final report will describe all three areas and the results of the study.

Urbanization

One major possibility for contamination of the Edwards aquifer is urbanization on the outcrop. To date, there is limited development on the outcrop except in the San Antonio area where it is increasing rapidly. Even here the development is rather recent and is either residential or a combination of residential and light commercial.

The objectives of this study are to determine if contamination has occurred and, if so, to what extent, and to establish a monitoring network for future testing and analysis.

The approach is to select four test areas in or near the downdip limit of the recharge zone. Wells are to be constructed near the top and bottom of the Edwards aquifer and sampled and analyzed for inorganics, nutrients, heavy metals, and selected organic compounds. Comparison of the results from the two sets of samples is expected to show the effects of urbanization. Final analysis needs to consider geologic and hydrologic details in the area. Contamination, if it occurs, is expected to be detected in the well open to the top of the aquifer. Several sets of samples will be collected and analyzed during different hydrologic conditions to define the effects of varying climatic conditions.

One of the test areas is in the Lawrence Creek watershed (test area d) in north San Antonio. Streamflow and water-quality data have been collected at a station on the creek at Thousand Oaks Drive and is one of the reasons for selecting this area for tests.

The second area is on Vance Jackson Road (test area e) in northwest San Antonio, which is an area having probably the oldest urban development in the recharge zone. The third area is FM 1604 west (test area f), which is north-

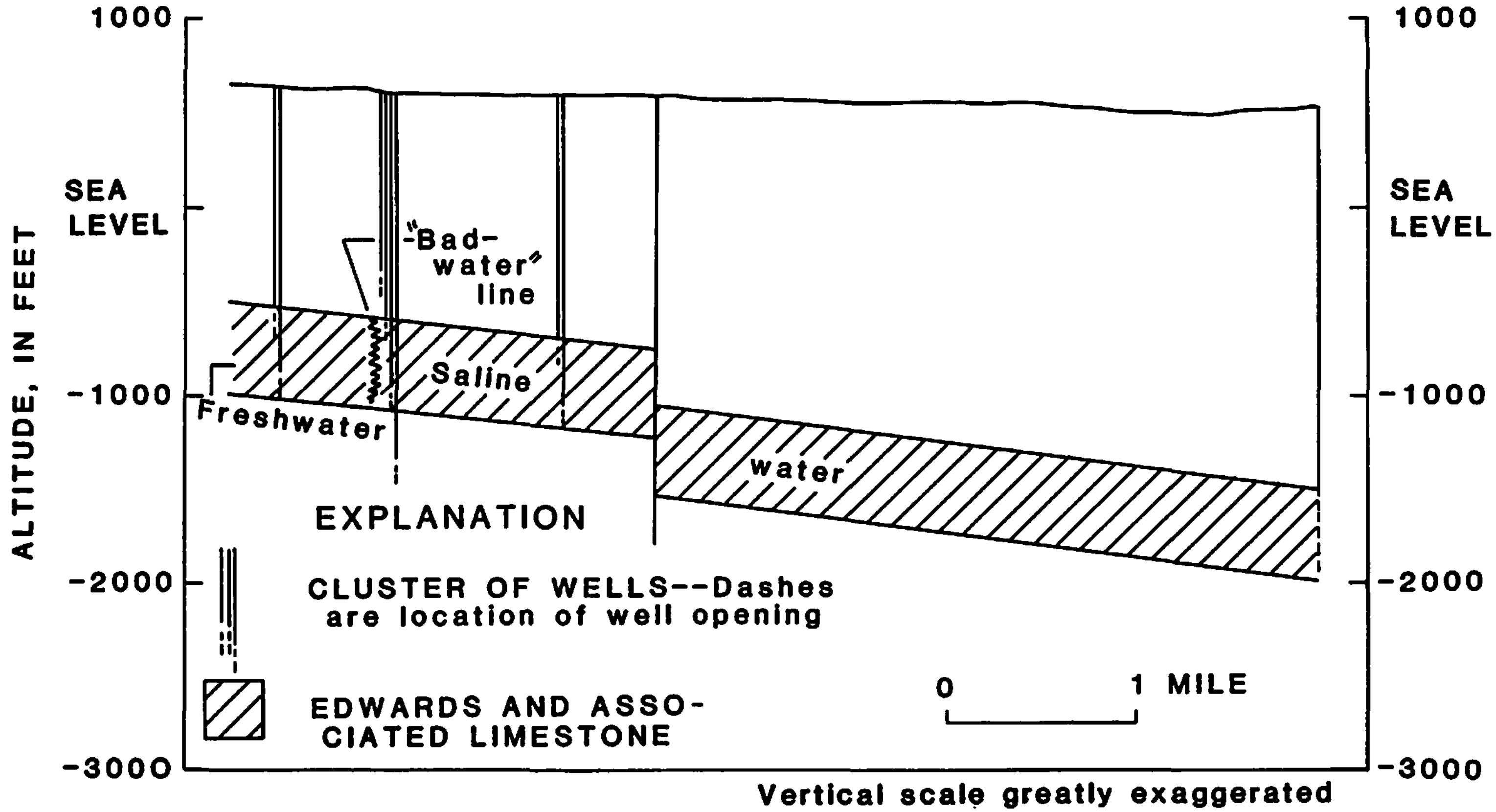

Figure 8.--Schematic showing location of wells in a typical cross section for proposed study of "bad-water" line

west of San Antonio and where development is expected in the near future. The fourth site (test area g) is near Hondo and will function as a control site.

Drilling for the Lawrence Creek site will be done during drilling for the Elm Creek Reservoir study. Drilling at the Vance Jackson Road, FM 1604 west, and Hondo Creek test areas will be done in FY 1986, 1988, and 1989, respectively. A report will be written summarizing results at the first two sites. A final report will be written summarzing results at all four sites to conclude the study.

Recharge reservoir

A recharge reservoir has been constructed in northern Bexar County at the confluence of East and West Elm Creeks to trap floodwaters and to allow this water to seep into the Edwards aquifer, thus recharging it. The watershed of the West Elm Creek is being developed into a residential area, and the watershed of East Elm Creek is expected to be developed with similar land use in several years. A data-collection program is currently in place to show the difference between the quality of water draining the developing and undeveloped watersheds. Water samples also are collected from the reservoir and are analyzed to determine the quality of water entering the Edwards aquifer. A nearby well is measured and sampled to determine the resulting water quality in the aquifer.

Using this hydrologic setting, objectives of the study are to quantify the relationship between the water levels in the area and the recharge rates, to determine the direction and rate of ground-water movement in the vicinity of the recharge reservoir, and to determine the change in ground-water quality in response to recharge, which is water from storms trapped in the reservoir.

The study will be conducted within the area of effective potential recharge to Elm Creek Reservoir (test area h). Detailed location of the wells are not shown in figure 7. Data-collection sites needed to accomplish the objectives will include two nearly perpendicular lines of wells with six wells in each line. Wells along one line will be parallel to the axis of Elm Creek Reservoir with four of the wells being located upstream from the dam and two being located downstream from the dam. Wells along the second line will be located upstream from and parallel to the dam. Three wells will be located on each side of the reservoir. All wells located upstream from the dam will be situated at an elevation above the overflow spillway of the dam. Each of the first 12 wells will penetrate the entire thickness of the aquifer.

Three additional wells to be used for collection of water-quality data will be drilled very near the reservoir. These wells will be completed to specified depths within the zone of water fluctuation and will be selected on the basis of geologic and water-level data obtained from the first 12 wells drilled at the Elm Creek site. These wells are anticipated to be drilled after about 1 year of data has been obtained from the first 12 wells. The study will begin with construction of the first 12 wells in FY 1984 and will be completed in FY 1988. A report is planned at completion of the study.

Ground-Water Movement

Although the movement of ground water in the Edwards aquifer is known in general terms, there is considerable uncertainty regarding flow in the vicinity of fault barriers, the regional dense bed, and the Knippa area. There also is an interest in knowing if water moves from the Austin Chalk and Glen Rose Formations into the Edwards aquifer. This aspect generally has been ignored or considered negligible by previous investigators. The natural discharge from the aquifer is principally from Comal and San Marcos Springs; however, the discharge to minor springs and alluvium along the Nueces and Frio Rivers is not well understood and needs to be investigated.

Fault barriers

Because the continuity of the Edwards aquifer is completely or substantially interrupted in several areas by faults, questions are raised as to how these faults affect ground-water flow. There is the possibility that the faults are effective in diverting regional ground-water flow in some areas.

The objective of the study is to demonstrate the effectiveness of the faults in several areas.

Five fault areas have been selected for tests. The first test area, which has the most detailed study, is FM 1604 north (test area i). In this area, wells will be aligned in the general direction of ground-water flow, which is believed to be parallel to the east-northeast trending faults. However, the direction of maximum hydraulic gradient is to the east-southeast. To demonstrate the effects of these faults, a line of three well clusters will be located updip of the two major faults and parallel to them. The center cluster of these three will be at the Elm Creek Reservoir. The fourth and fifth clusters will be downdip of the upper major fault; one near Elm Creek Reservoir and another at the Lawrence Creek test site. The sixth cluster will be downgradient from the two faults and in the southeast corner of the test area. At each of the six cluster sites, two wells are to be constructed; one open to the top of the saturated zone and the other open to near the bottom of the aquifer. This approach allows the tracking of freshly recharged water from Elm Creek Reservoir, which is expected to be at least temporarily stratified at the top of the saturated zone. Continuous water-level recorders are required at several wells. Sufficient water samples are to be collected and analyzed to determine the migration of plumes created by a selected number of recharge events to typify various hydrologic conditions. One well cluster of this study will utilize the wells to be drilled in the reservoir recharge study at the Elm Creek Reservoir in FY 1984. The remaining wells will be drilled in FY 1985. A preliminary report will be prepared for the first area. The information from this study will aid in the final design of the studies for the remaining four areas.

In each of the remaining four areas, a cluster of two wells, one open to the top of the Edwards and the other open to the bottom of the Edwards, is located on each side of the fault. Water-level measurements will be made to determine if abnormal gradients occur. In each area, other wells will be measured to develop regional flow patterns. Also, water samples will be collected and analyzed for inorganic constituents to determine if water-quality anomalies exist.

The second test area is located at I-410 and U.S. Hwy 281 in north San Antonio (test area j). Major pumpage occurs at a well field in the area and may cause water-level drawdowns to reflect off the fault barrier if it is effective. The drilling is planned for FY 1988.

The third test area is located near Hondo Creek (test area g). The same well configuration as the one designed for the I-410 and U.S. Hwy 281 north test area will be used here. Major recharge events along Hondo Creek are expected to cause a rapid rise of water levels on the updip side of the fault. The response on the downdip side will indicate the effectiveness of the fault barrier. The drilling is planned for FY 1989.

The fourth test is near Medina River (test area k) in northeast Medina County. The fault barrier is believed to divert water to the southwest instead of along the maximum hydraulic gradient, which is to the southeast. Three wells are planned and are open to the entire thickness of the Edwards. Two of the wells will be opposite each other and separated by the fault. Another well will be located on the updip side of the fault and to the southeast. The drilling is planned in FY 1991.

The fifth test area is at I-410 and U.S. Hwy 90 west (test area l), where a major fault partly separates a major producing zone. Major pumping occurs in the zone to the east. The test results are expected to be similar to the first test area. This drilling is planned in FY 1992.

A final report of the entire fault-barrier study is planned at completion of the study.

Regional dense bed

In the San Marcos platform depositional region, a regional dense bed vertically separates two very permeable zones. The dense bed underlies the eastern one-half of the Edwards aquifer. The effectiveness of the dense bed in limiting the vertical flow is unknown.

The objective of the study is to demonstrate, in selected test areas, the effectiveness of the regional dense bed in limiting vertical flow.

The approach to demonstrating the hydraulic connection is to construct pairs of wells, one open only to the upper zone and the other open only to the lower zone. The similarity of the responses to changes in water levels will indicate the hydraulic connection. Three tests are planned, all of which involve locating a pair of wells on each side of a fault. The first test area is located along Vance Jackson Road (test area e) and utilizes wells constructed for other studies. The second area is the I-410 and U.S. Hwy 281 north test area j. The third test is at I-410 and U.S. Hwy 90 west (test area l) in southwest Bexar County. Drilling is planned for FY 1986, 1988, and 1992, respectively, for the three test areas. A final report is planned at completion of the study.

Knippa area

The geologic framework in the Knippa area (test area m) is very complex because of the faulting and the transition between two depositional regions. Some hydrologists believe most of the water is diverted to a narrow pass north of Knippa. Using a network of new and existing wells, the water levels will be mapped in detail for several aquifer stages. Inventories in pumpage also will be made in an attempt to explain the water-level patterns. If any well construction is needed, it will be done in FY 1993. A report is planned at completion of the study.

Glen Rose Formation

Little is known about the flux of water between the Edwards aquifer and the underlying Glen Rose Formation. Because the water in the Glen Rose is more saline than that in the Edwards, it could have an adverse effect on the quality of water in the Edwards if the hydraulic connection is reasonably good and the water levels in the Edwards are lowered substantially. Attention needs to be given to the possibility of both vertical and horizontal inflow. Vertical flow can occur throughout the aquifer. Horizontal flow is possible at any fault, especially in the updip limit of the aquifer where the Glen Rose is butted up against the Edwards and the Glen Rose has a source of water in the Edwards Plateau.

The objective of the study is to determine if the Edwards aquifer receives inflow from the Glen Rose Formation.

The approach is to measure water levels and to collect samples from adjacent wells that are completed in the lower part of the Edwards and the upper Glen Rose and from another pair of wells completed in the same formations located across a fault. The first pair would be used for analysis of vertical ground-water flow and the latter for a horizontal ground-water flow analysis. A good correlation of water levels, especially during times of rapid water-level change, would indicate a relatively good hydraulic connection. Positive correlations of water chemistry also would indicate an interchange of water. Chemical balance techniques will be used to estimate mixing.

Three test areas have been selected. One is test area (e) on Vance Jackson Road. This test area is representative in the area of transition between confined and unconfined aquifer zones, especially in Bexar County. Three wells are to be drilled for this study in FY 1986, and a fourth well is to be constructed by another study. The second test area (g) is located at Hondo Creek and was selected for its western location and its location in the recharge zone. This test will require four wells to be drilled in FY 1989. The third test area is located near Hueco Springs (test area n), west of New Braunfels. The source of water for these springs is in doubt. Wells in the area will be inventoried and four wells drilled. Water-level measurements and water samples will be collected and analyzed in an attempt to determine the source or the mixing of the water for several water-level conditions. Chemical balancing techniques will be used to determine the mixing. The drilling is planned for FY 1993.

A preliminary report for the study is planned midway through the study. A final report is planned at completion of the study.

Austin Chalk

Little attention has been given to the water-bearing capability and water quality of the Austin Chalk. As a result, little is known about the hydraulic conection between this formation and the Edwards aquifer and the potential for contamination from the Austin Chalk. Geologically, the formations are separated by 150 to 200 ft of almost impermeable material; however, numerous faults in the area can cause the two formations to be butted against each other. At these locations, water can freely move horizontally between the two formations. Even if the faulting is not sufficient to butt the two formations against each other, fractures in the geologic units separating the two formations can allow vertical flow. If contaminated water occurs in the Austin Chalk, it can then enter the Edwards aquifer if the hydraulic gradient is in the direction of the Edwards aquifer.

The study has two objectives. One objective is to describe the hydrology and quality of water in the Austin Chalk aquifer. The second objective is to qualitatively describe the hydraulic connection between the Edwards and Austin aquifers where various degrees of faulting have occurred.

The approach to meet the first objective is to review files and reports for the identification of wells and availability of related information. Field inventories also will be conducted to locate wells that can aid in the description of the aquifer. Several wells will be constructed to address the second objective of this study and will be available for sampling.

The approach to meet the second objective is to conduct tests at four sites. At each site, wells will be open only to the Austin and to the Edwards so that water levels and water-quality determinations can be made in each formation. Preference was given to sites located near the downdip limit of the surface exposure of the Austin Chalk and on the updip side of a fault. Such a setting is expected to provide the greatest opportunity for the Austin Chalk to be contaminated and for the Austin Chalk water to enter the Edwards aquifer.

All wells are to be sampled and analyzed for inorganic constituents, trace metals, and organic compounds. Any other constituent that may be useful as a tracer also will be analyzed.

Three of the test areas are in or near San Antonio. They are the I-410 and U.S. Hwy 281 north test area (j); the Vance Jackson Road test area (e); and the FM 1604 west test area (f). All are developed or soon to be developed areas. The fourth test area is test area (o) near Sabinal, and its purpose is to determine if chemicals used in farming reached the Austin aquifer and finally the Edwards aquifer.

The Vance Jackson Road, I-410 and U.S. Hwy 281 north, FM 1604 west, and Sabinal test areas will be drilled in FY 1986, 1988, 1988, and 1993, respectively. A preliminary report will be written midway through the study and a final one at completion of the study.

Natural discharge

Most of the natural discharge from the Edwards aquifer is through two large springs, Comal and San Marcos Springs. It also is known that when water levels reach a specific stage, the intermittent springs such as San Pedro and San Antonio Springs begin to discharge water. The reason they begin to discharge water is that water levels in the Edwards aquifer have risen above the land-surface elevations of those particular outlets. Thus the springs begin to flow. There is a possibility that unknown, unmapped, or alluvium-covered intermittent discharge points or areas exist, particularly along the major rivers that cross the aquifer. The discharge from the aquifer could be a point source such as a spring orifice at the land surface, but more likely is discharge into overlying alluvial material. The water from these materials would then discharge into the stream when the alluvial ground-water levels are above the elevation of the water in the stream.

The objective of the study is to determine if water is discharged from the Edwards aquifer from currently unknown locations.

The Nueces River has been selected for this study (test area p). Five clusters of wells will be drilled along the Nueces River Valley. Each cluster will have three wells; one completed in the Edwards aquifer, another completed in the overlying consolidated material (probably the Austin Chalk), and the remaining one completed in unconsolidated gravel. A line of three well clusters will be established parallel to and about 1,500 ft east of the Nueces River. A second line of three clusters will be established across the valley. The center well cluster is common to both lines. One cluster on the cross valley line will be about 3,000 ft west of the river. The east cluster will be about 1 mi from the river. The study area will be located north of the "bad-water" line. The wells will be equipped with recorders to continually monitor water levels. Three temporary continuous-record gaging stations will be placed in operation on the Nueces River in addition to the three permanent stations. The new stations will include the bridge crossings on U.S. Hwy 90, U.S. Hwy 83, and State Hwy 76.

The wells should be drilled and gages installed by 1985. Monitoring of a minimum of 3 years is estimated to be required to determine if Edwards aquifer water is discharged or if recharge is rejected from the the Edwards into the local streams. Water-quality samples will be collected from the wells and streams to determine mixing during high water levels. A final report will be written after the necessary high water levels occur.

Storage

The change in water storage in the Edwards aquifer generally is known for the recorded range of aquifer stage; however, the availability of water is not known for stages below this range. Also, it is not known if water in the aquifer actually forms pools which may become substantially hydraulically disconnected at low water levels.

The objectives of this study are: (1) To extend the stage-storage relationship downward approximately 50 ft from the known range and (2) to validate or deny the pool concept and describe the hydraulic connection between them.

Because a very large percentage of the water stored in the aquifer is stored in a zone in the unconfined part of the aquifer for any reasonable range of water-level change, an effort will be focused on determining the storage characteristics in this zone. Using geophysical-log data and state-of-the-art techniques for determining storage (porosity) from these data, storage relationships will be established between the zone that periodically becomes saturated and unsaturated and the zone immediately below it. Using this relationship, the change in the physical geometry of the system and the expected configuration of the water table at selected stages from previous model studies will allow computations of the changes in storage for successive lowering of the water table and potentiometric surfaces. This relationship will be approximate and dependent upon selected withdrawal patterns.

The approach to evaluate the pool concept is to transfer the graphic cross-sectional information into a three-dimensional matrix for processing by computer. Using selected configurations of the water-table potentiometric surface and the appropriate specific yield/storage coefficients and hydraulic conductivity values, the hydraulic connection between various segments of the aquifer will be computed.

This study is not scheduled.

Evolution of Water Quality

The quality of the water in an aquifer is a function of the quality of the recharge water and the geology and mineralogy of the material the water passes through. Considerable interest is placed on the quality of the recharge water for the Edwards aquifer, as it should be, but there is little understanding of the effect the aquifer material has on water quality.

With an objective of developing a better understanding of the relationship between aquifer material and the chemistry of water in the aquifer, a study to determine the evolution of water chemistry as a water particle moves through the aquifer will be undertaken. Meeting this objective would provide information for predicting the movement of water and the evolution of the water chemistry in other areas of the aquifer.

The first phase of the study is to select a flow path in the vicinity of the "bad-water" line, compile inorganic water-chemistry data, make chemical and mineralogy analyses of the aquifer materials, and analyze the data using reaction path, water-chemistry modeling so that the origin, direction, and rate of movement of the ground water can determined in this zone.

The second phase is to apply the same approach using a lengthy flow path through the aquifer system.

This study is not scheduled.

Hydrogeologic Framework

Managing and protecting the Edwards require knowledge of the avenues water is likely to take entering the aquifer and moving through the system. The area of greatest potential of contamination is in northern Bexar County because of its large population and industrial and commercial development.

The objective of the study is to improve the description of the hydrogeologic framework of the Edwards Limestone and those formations overlying the aquifer in the northern Bexar County area. The scope of the study is limited to an area about 10 mi wide between the Bexar-Medina County line and Cibolo Creek with the northern boundary being the northern limit of the recharge zone. The refinement of the hydrogeologic framework will aid in understanding and testing water movement.

The general approach to the study is to map the surface in more detail and thereby refine the geologic cross sections. Existing geologic maps, reports, unpublished notes, geophysical logs, and areal photography and field inspection notes will be used to map the geology and locate faults and other significant geologic and hydrologic features such as sinkholes. Mapping is to be in sufficient detail for a 7-1/2-minute quadrangle map.

This study is not scheduled, but needs to be done within the next few years before urbanization covers up most of the surface exposure.

SUMMARY

A meeting of the officials and representatives of the City of San Antonio, Edwards Underground Water District, Texas Department of Water Resources, and Geological Survey was held at the end of 1983 to discuss topics for future study. The purpose was to identify the data and report needs for decision making by water managers and policy makers for many years to come. The ideas and concerns presented at this meeting provided the basis for developing this proposed 10-year plan.

The topics were divided into two categories; monitoring and special studies. The current monitoring plan was reviewed and minor revisions were suggested to focus on special data needs. The special-studies program includes the subcategories of aquifer protection, ground-water movement and storage, evolution of water quality, and geologic-framework refinement. Under the aquifer-protection subcategory, studies will be conducted to assess the potential of saline water moving into the freshwater section of the Edwards aquifer, the possiblity of contaminated water leaking into the Edwards from the Austin Chalk aquifer, the effects of urbanization on ground-water quality, and the movement and dissipation of a recharge-water plume. Under the ground-water movement subcategory, studies will be conducted to show the effects of fault barriers, the regional dense bed, natural recharge-discharge relationships, and the irregular geologic framework on ground-water flow patterns. Implementation of most all the special studies is dependent upon the construction of special-purpose observation wells. Many of the wells will be grouped in clusters with each well open only to one zone. In all, 16 test areas were identified. About 110 wells are needed and will total about 84,000 ft of depth.

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