EDWARDS UNDERGROUND
WATER DISTRICT

REPORT 95-03

EDWARDS/GLEN ROSE HYDROLOGIC COMMUNICATION, SAN ANTONIO REGION, TEXAS

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Prepared for

Edwards Underground Water District
San Antonio, Texas

March 1995

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March 21, 1995

Mr. Rick Illgner
General Manager
Edwards Underground Water District
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Dear Mr. Illnger:

Transmitted herewith is our report, "Edwards/Glen Rose Hydrologic Communication, San Antonio Region, Texas." This study was conducted and the report prepared by Messrs. William G. Stein and William B. Klemt, with some assistance from others of our firm. We have enjoyed working with the Edwards Underground Water District in making this study of the Edwards aquifer.

If you have any questions regarding the report or the results of the study, please let us know.

With best regards,

Sincerely yours,

LBG-GUYTON ASSOCIATES

Charles W. Kreitler
Senior Associate

Reviewed By: ____________________
Frank H. Crum
Principal

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EDWARDS/GLEN ROSE HYDROLOGIC COMMUNICATION, SAN ANTONIO REGION, TEXAS

SUMMARY

This report presents the results from a study conducted to evaluate and estimate the amount of water that might move directly from the Glen Rose aquifer into the Edwards aquifer in the San Antonio region. Three main approaches were used for identifying hydrologic communication and the potential amount of flow between the Glen Rose and the Edwards aquifers: (1) geologic evidence, (2) hydrologic evidence and (3) hydrochemical evidence. The geologic and hydrologic evidence was used both on a site-specific area (Haby Crossing fault area) and regionally to determine quantities of inflow from the Glen Rose.

Hydrologic communication between the Glen Rose and Edwards aquifers in the Cibolo Creek basin has previously been considered different from water transfers between the two aquifers elsewhere. Historically, recharge to the Edwards aquifer in Cibolo Creek basin has been calculated using stream losses from Boerne to Bracken, even though lower Glen Rose is exposed in the creek between Boerne and Bulverde. Based principally on stream-loss records, available water-level records and the absence of a previously known discharge area, recharge has been assumed to enter the Edwards aquifer as underflow from the Glen Rose Formation in the subsurface through a shallow karst system under Cibolo Creek. However, mapping of the extent of Honey Creek Cave, northeast of Cibolo Creek in this area, and hydrogeologic observations indicate that some water is diverted through cave conduits to the Guadalupe River. As a result, the large stream losses in Cibolo Creek over the lower Glen Rose member previously used to calculate Edwards aquifer recharge may not find its way to the Edwards aquifer unless the water is recharged in the Guadalupe River basin.

The Haby Crossing fault area, because of the relatively large fault displacement, is one of the best locations for the Edwards and Glen Rose Limestones to be juxtaposed to one another, which gives the best potential for hydrologic

communication between the two aquifers. Based on calculations from water-level and pumping-test data, it is estimated that about 360 acre-feet per year (ac-ft/yr) of inflow could be transmitted to the Edwards aquifer along a 14-mile length of the Haby Crossing fault under 1994 water-level conditions. This amount is relatively small compared to the average calculated direct recharge in the Medina River basin (about 61,000 ac-ft/yr, as calculated by the U. S. Geological Survey) and the average total aquifer recharge (about 682,800 ac-ft/yr) for the Edwards aquifer in the San Antonio region. Geochemical modeling confirms that only small amounts of Glen Rose water are entering the Edwards aquifer as compared to other recharge sources, possibly on the order of 5 percent of the total water immediately downgradient of the Haby Crossing fault. This initial mix of Edwards and Glen Rose water continues to be diluted as the water travels downgradient toward the main artesian part of the Edwards aquifer near San Antonio. Based on geochemical models using NETPATH and median chemical values, the chemical content of water representative of the Edwards aquifer in the San Antonio region is diluted to less than 1 percent Glen Rose water as compared to the total water content.

Regionally, underflow from the Glen Rose Formation to the Edwards aquifer along the Balcones fault zone can occur by ground water moving laterally in a downgradient direction within the Glen Rose and entering the Edwards aquifer through fault planes. The amount of ground water in transit is dependent on the length of the line of entry (fault plane) through which water enters the Edwards aquifer, the water-level gradient across the fault plane from the Glen Rose to the Edwards aquifer, and the effective transmissivity for the Glen Rose aquifer upgradient and along this line. Using this method, which excludes recharge in Cibolo Creek through the lower Glen Rose to the Edwards and contributions from the Edwards-Trinity Plateau aquifer at the western end of the aquifer, an approximate range of total Glen Rose underflow to the Edwards aquifer would be about 2,700 to about 11,400 ac-ft/yr in the San Antonio region. These estimates are based on high and low median transmissivities and a positive water-level gradient from the Glen Rose to the Edwards aquifer. As compared to the total Edwards aquifer water budget, these estimates indicate that the Glen Rose contribution is probably less than 2 percent of the total water budget during average recharge conditions.

INTRODUCTION

This report presents the results from a study made to evaluate and estimate the amount of water that might move directly from the Glen Rose aquifer into the Edwards aquifer in the San Antonio region. The Edwards aquifer supplies drinking water to more than 1.3 million people in the San Antonio region (Figure 1) and is administered by the Edwards Underground Water District (EUWD). Length of the aquifer in the San Antonio region extends approximately 180 miles from the ground-water divide near Brackettville on the west to the ground-water divide north of Kyle on the northeast (Figure 1). Width of the aquifer varies from 5 to 40 miles from the northern limit of the recharge zone to the southern limit of fresh water, which is a gradational area of increasing salinity from 350 milligrams per liter (mg/l) (or parts per million) to over 300,000 mg/l total dissolved solids (TDS). Locally, the point where TDS reaches 1,000 mg/l is contoured and referred to as the "bad-water line." This line represents the approximate southern extent of potable water in the Edwards aquifer. The most probable area where quantities of fresh water might move from the Glen Rose aquifer to the Edwards aquifer is located along the northern limit of the aquifer.

Most of the recharge to the Edwards aquifer results from stream loss as rivers and streams cross the Edwards outcrop within the Balcones fault zone. The source of this water is precipitation both over the Hill Country to the north-northwest and over the Edwards aquifer recharge zone. Runoff from precipitation either flows directly to the rivers or percolates through rocks of the Edwards aquifer, Edwards-Trinity aquifer or Trinity Group aquifer (Table 1). The Edwards-Trinity aquifer, located on the Edwards Plateau, and the Trinity Group aquifer are updip of the Edwards aquifer recharge zone. The water recharged to the Edwards-Trinity and Trinity Group aquifers may later reappear as springs and seeps along the numerous creeks and rivers in this region, which provide the source of much of the perennial river flow in the Edwards Plateau and the Hill Country (Figure 1).

The lower Glen Rose is a productive part of the Edwards-Trinity and Trinity Group aquifers in the Hill Country. Because of faulting, the Edwards aquifer in many areas over the 180-mile length between the two ground-water divides is juxtaposed to the Glen Rose aquifer both at the surface and at depth, and therefore, the Glen Rose may discharge directly into the Edwards aquifer.

Three main approaches were used for identifying hydrologic communication and the potential amount of flow between the Glen Rose and the Edwards aquifer: (1) geologic evidence, (2) hydrologic evidence and (3) hydrochemical evidence. Geologic data were collected primarily to map distribution of faults in both the recharge zone (Edwards outcrop) and in the artesian section. The amount of fault displacement was determined from available reports, surface geologic maps and subsurface geologic data to demonstrate that the Glen Rose Limestone is faulted against the Edwards and associated limestones. Hydrologic data were used primarily to map regional potentiometric surfaces, determine gradients and estimate quantities of water. Water chemistries were used to document the occurrence of leakage and to estimate amounts of leakage based on models of chemical mass balance equations. Besides standard analyses for major ions, strontium (Sr) was analyzed to help identify differences between waters of the Edwards and Glen Rose aquifers.

The geologic and hydrologic evidence was used both on a site-specific area (Haby Crossing fault area) and regionally to determine quantities of inflow from the Glen Rose. However, since water-chemistry data are relatively sparse regionally and the chemistries become diluted so quickly once entering the Edwards aquifer, only water-chemistry data from the Haby Crossing fault area had enough detail to be used for Edwards-Glen Rose communication evaluations. The regional water-quality data, generally from a few wells per county, were used to estimate average water-quality conditions in the Edwards aquifer. The numbering systems used to identify wells inventoried for this study and other wells used in this report are discussed in Appendix 2.

Previous Investigations

Several studies have developed a reasonable Edwards aquifer water balance of recharge through stream loss and infiltration of precipitation over the outcrop and discharge from springs and wells. Guyton (1955a) and Lowry (1955) in two reports to the San Antonio City Water Board and a U. S. Geological Survey report covering similar topics by Petitt and George (1956) provided much initial detailed knowledge of the Edwards aquifer including regional hydrogeologic concepts and a water balance of recharge and discharge. Although the recharge and discharge estimates for the water budget calculations may be off by as much as 25 percent, the original calculations by Lowry (1955) were within 5 percent of balancing between long-term recharge and discharge in the Edwards aquifer. Lowry suggested that the required additional recharge needed for balancing the water budget may be attributed, at least in part, to leakage from the Glen Rose aquifer in addition to the amount included in the Cibolo Creek basin recharge estimates.

Maclay and Small (1984), using available geologic, hydrologic and hydrochemical data, better defined the locations of external and internal boundaries, and the flow pattern within the Edwards aquifer. They suggested that displacement greater than 50 percent of the total thickness of the aquifer could result in fault barriers within the Edwards aquifer. Senger and Kreitler (1984), in a study in the Austin region, felt that the greater the fault displacement, the greater the possibility that the Glen Rose might be faulted against the Edwards and therefore provide a pathway for leakage. Small (1986) constructed 27 hydrogeologic sections that illustrate the structural and stratigraphic Edwards/Glen Rose relationships along the 180-mile-long extent of the aquifer. Stein (1993) suggested that the barrier faults with major displacements would juxtapose the Glen Rose Limestone and Edwards and associated limestones, and therefore, create potential communication points between the two aquifers. Stein also pointed out how cave development in the recharge zone can create conduits between the Edwards and Glen Rose.

Computer model studies have been conducted to better understand the groundwater storage, flow and water-budget concepts regarding the Edwards aquifer in the

San Antonio region. Klemt and others (1979) simulated historical water levels and springflows using historical recharge and discharge rates for the aquifer. The above workers concurred with the Guyton (1955a) and Lowry (1955) investigations in that the Glen Rose Formation may contribute underflow to the Edwards aquifer. Maclay and Land (1988), based on their computer simulations of the aquifer, identified several areas where possible ground-water inflow from the Glen Rose along the updip limit of the aquifer may occur. Kuniansky and Barker (1994), as part of the U. S. Geological Survey's continuing studies of the Edwards-Trinity aquifer, have collected historical Trinity aquifer pumping-test data and conducted regional ground-water computer simulation studies to estimate total recharge to the Edwards aquifer, including water entering laterally along the updip limit of the study region.

Several other recent hydrologic reports on the Edwards-Trinity aquifer have been published by the U. S. Geological Survey as part of the continuing Regional Aquifer Systems Analysis program. The area for this study covers much of west-central Texas and includes the Edwards aquifer in the San Antonio region. Barker and Ardis (1992) evaluated the geology of the Edwards-Trinity aquifer and the units forming the aquifer's base. Bush and others (1993) mapped the historical potentiometric surface of the Edwards-Trinity aquifer system and adjoining hydraulically connected units in the study area. The saturated thickness of the aquifers was evaluated by Ardis and Barker (1993), and the aquifer geochemistry of the region was evaluated by Bush and others (1994).

Geochemically, Senger and Kreitler (1984) observed Glen Rose leakage in the Austin region by mapping the chemical distribution of sulfate (SO_4) and Sr in the confined section of the Edwards from the ground-water divide at Kyle to the Colorado River. They recognized that ground waters in the Glen Rose often had SO_4 and Sr concentrations higher than the fresh-water section of the Edwards, and therefore, elevated SO_4 and Sr in the fresh-water section of the Edwards suggested hydrologic communication between formations. They could separate Glen Rose leakage water from Edwards aquifer "bad-water line" waters by comparing Sr to sodium (Na) and SO_4 to chloride (Cl). The increased SO_4 and Sr may be from dissolution of gypsum and celestite, respectively, in the Glen Rose. Glen Rose leakage waters were high in SO_4 and Sr but low in Na and Cl, whereas "bad-water line" Edwards waters had high Na and Cl. William F. Guyton Associates (1993) in their recent investigation of ground-water resources in north Bexar County, however, recognized a wide range of SO_4 concentrations in the Glen Rose, with the higher SO_4 values in the upper Glen Rose and lower concentrations in the lower Glen Rose.

Several local studies furthered the understanding of the interaction between the Glen Rose and Edwards aquifers. Waddell (1977) reported higher concentrations of SO_4, Na and potassium (K) in a well located near the Haby Crossing fault in northwest Bexar County that may indicate flow from the Glen Rose Formation across the fault into the Edwards aquifer. Waterreus (1992) observed variations for SO_4, magnesium (Mg) and Sr in Glen Rose ground water in the Camp Bullis area in northern Bexar County, with the upper Glen Rose exhibiting higher concentrations than the lower Glen Rose and most Edwards ground water. Waugh and Walthour (1993) performed a hydrogeologic assessment of the Government Canyon area in northwestern Bexar County, Texas, which concluded that ground-water flow from the Glen Rose may cross the Haby Crossing fault into the Edwards aquifer in the vicinity of their study area. William F. Guyton Associates (1993) in a joint water-resources investigation with W. E. Simpson Company, Inc. estimated the occurrence and availability of ground water from the Trinity Group aquifer, which includes the Glen Rose Formation, in northern Bexar County. The investigation concluded that discharge from the Trinity Group aquifer, beyond wells and springs, also occurs as interformational leakage to adjacent hydrologic units.

REGIONAL HYDROGEOLOGY OF THE GLEN ROSE AND EDWARDS AQUIFER SYSTEMS

The study area includes all or parts of the Hill Country, Edwards Plateau and Balcones fault zone, with the Balcones fault zone comprising the Edwards aquifer in the San Antonio region. The following three aquifers form the hydrologic system in the study area: (1) the Trinity, (2) the Edwards and (3) the Edwards-Trinity.

Stratigraphy

Stratigraphic units and their water-bearing properties for the study area are summarized in Table 1. The Trinity Group and the Edwards and associated limestones are the more important water-bearing units in the study region. The Trinity overlies rocks of Paleozoic age and is overlain in some of the study region by younger rocks.

The Trinity Group is divided into the following formations from the oldest to youngest: Travis Peak (also known as Pearsall Formation from Stricklin and others, 1971) and Glen Rose. The Travis Peak Formation is subdivided into the following members in order from oldest to youngest: Hosston Sand, Sligo Limestone, Hammett Shale, Cow Creek Limestone, Bexar Shale and Hensell Sand (Ashworth, 1983). The Glen Rose Formation is a shallow-water limestone that forms the uppermost unit of the Trinity Group in south-central Texas. The Glen Rose Formation is divided informally into two members, lower and upper. At the top of the lower member of the Glen Rose Formation is a distinctive and persistent marker bed, which has been named the "Corbula Bed" for the abundant rice-shaped clam fossils that it contains. The upper member of the Glen Rose Formation, when weathered, creates the distinctive Hill Country "stairstep" topography (Stricklin and others, 1971).

Contact between the Glen Rose Formation and the overlying Edwards Group is generally disconformable (Rose, 1972). The limestone of the Edwards Group was deposited in a shoaling, lagoonal environment during the Fredericksburg and Washita Ages of the Lower Cretaceous more than 100 million years ago. The Edwards aquifer covers three depositional provinces, (1) San Marcos platform, (2) Devils River trend and (3) Maverick basin, as shown in the inset of Table 2. The formations (Table 2) that stratigraphically compose the Edwards aquifer for the respective provinces are: (1) the Kainer, Person and Georgetown Formations in the San Marcos platform; (2) the Devils River Limestone along the Devils River trend; and (3) the Salmon Peak, McKnight and West Nueces Formations in the Maverick basin. The formations in the San Marcos platform are further subdivided into members that correspond to eight aquifer subdivisions (Rose, 1972; Maclay and Small, 1984).

Structure

Cretaceous sedimentary rocks in the study area generally strike northeast and dip to the southeast toward the Gulf of Mexico. The dominant structure over the study area is the Balcones fault zone, which forms the Balcones Escarpment at the edge of the Edwards Plateau that is generally depicted on Figure 1. The last major episode of movement in the Balcones fault zone occurred during the late Early Miocene, approximately 15 million years ago (Young, 1972).

Although most of the faults in the area trend northeast, a smaller set of cross-faults trend northwest. Most of the faults are nearly vertical, normal faults. Generally, the faults are en echelon, with the down-dropped blocks toward the southeast. The structural and stratigraphic Edwards/Glen Rose relations along the 180-mile-long extent of the aquifer are shown by 27 hydrogeologic cross sections in Small (1986). Many faults are not one sharp break as suggested by a line drawn on a geologic map, but are usually a narrow zone of shattered rocks. Because rocks on both sides of a fault are sometimes equally resistant to weathering, some faults in the study area do not result in sharp topographic relief.

Aquifer Systems

The major aquifer systems that are pertinent to this underflow investigation are the Trinity Group aquifer and the Edwards aquifer. The aquifers are hydraulically connected along the Balcones fault zone where the Trinity Group aquifer, because of the faulting, is juxtaposed to the Edwards aquifer in many areas over the 180-mile length between Brackettville in Kinney County eastward to Kyle in Hays County (Figure 1).

Water-bearing rocks of the Trinity Group are organized into the three following aquifer units (Ashworth, 1983): (1) the lower Trinity aquifer consisting of the Hosston Sand and Sligo Limestone members of the Travis Peak Formation; (2) the middle Trinity aquifer consisting of the lower member of the Glen Rose Limestone, and the Hensell Sand (Bexar Shale) and Cow Creek Limestone (and Hammett Shale) members of the Travis Peak Formation; and (3) the upper Trinity aquifer consisting of the upper Glen Rose Limestone. Collectively these are called the Trinity Group aquifer. The Hammett Shale is relatively impermeable and acts as a confining bed that divides the producing units of the lower and middle Trinity aquifer. The Glen Rose water-bearing units, the upper and middle Trinity aquifer, have been differentiated because they have very different water-quality characteristics.

The upper member of the Glen Rose Limestone, which forms the upper Trinity aquifer, has significant beds of evaporite minerals such as anhydrite and gypsum, which can cause the water to be unusually high in sulfate content and slightly saline. Ground-water flow and circulation in the upper member of the Glen Rose Limestone is poor, and as a result, the aquifer usually yields only small amounts of mineralized water to wells.

The lower member of the Glen Rose Formation has much better water quality than the upper member. The lower member has very little evaporite minerals and gypsum, and consequently, much better water quality. The lower Glen Rose member contains massive reefal limestones with good permeability near its base. In some localities, the lower member can provide large quantities of water to wells.

Because of the Glen Rose thickness and the fault displacements in the Balcones fault zone, the Glen Rose Limestone is the unit within the Trinity Group that will be in contact with the Edwards and associated limestones providing opportunity to transfer water between the aquifers. Sometimes the Glen Rose Limestone collectively is itself called the Glen Rose aquifer and, in this report, is sometimes referred to that way.

In the subsurface, the top of the Edwards aquifer is confined by the Del Rio Clay. The base of the aquifer is confined by the upper member of the Glen Rose Formation. The relatively small permeability of these confining units greatly restricts vertical leakage from or to other water-bearing units, although some water probably moves vertically along inclined fractures and faults (Maclay and Land, 1988). Porosity within the Edwards aquifer is primarily the result of post-depositional diagenesis within certain less-resistive stratigraphic units, along bedding planes, joints and fractures.

In the San Marcos Platform, the Edwards aquifer has been divided into eight hydrostratigraphic units (Maclay and Small, 1984). Aquifer subdivisions 3, 5 and 6 of the eight Edwards aquifer subdivisions (Table 2) are the most permeable. Aquifer subdivisions 1, 4 and 8 are relatively impermeable, and the remaining aquifer subdivisions are somewhat variable in permeability and porosity based on core observations, geophysical logs and packer tests of test holes (Maclay and Small, 1984). The Kirschberg evaporite member (aquifer subdivision 6) generally is the most productive, and excluding fracturing or faulting, the regional dense bed (aquifer subdivision 4) is the most impermeable unit. However, in the outcrop of the recharge zone, aquifer subdivision 8 (basal nodular member) has gone through extensive karstification, generating secondary porosity as large lateral caves (Stein, 1993). As a result, in some locations, the basal nodular member can receive and transmit substantial amounts of ground water.

The Devils River trend is hydrostratigraphically undivided and is believed to be a barrier reef deposit around the exterior of the Maverick basin. The best porosity and permeability in the Devils River Limestone is generally toward the middle and upper parts (Maclay and Small, 1984). In the Maverick basin, the best porosity and permeability generally occur at the top of the Salmon Peak Formation. Some porosity also occurs near the top of the West Nueces Formation (Maclay and Small, 1984). Porosity and permeability often are modified by local fracturing or karstification, which usually is more common and intense near creeks or streams.

Recharge to the Edwards aquifer and discharge from wells and springs, etc. probably has averaged about 675,000 ac-ft/yr since the mid-1930's (Kuniansky and Barker, 1994). This estimate includes the subsurface contribution from the Glen Rose Formation in the vicinity of Cibolo Creek where it crosses the Balcones fault zone. However, the 675,000 ac-ft/yr recharge estimate does not include other water entering laterally in the subsurface from the Glen Rose Limestone along the Balcones fault zone or in Kinney County where the Edwards (Balcones fault zone) aquifer is continuous with the Edwards Plateau aquifer (Kuniansky and Barker, 1994; Maclay and Land, 1988). Maclay and Land (1988) also indicate that unaccounted for outflow probably occurs in the western part of the aquifer in southern Kinney and Uvalde Counties, where ground water is believed to be diverted into the saline-water parts of the aquifer.

Lowry (1955), based on 20 years of historical Edwards recharge and discharge data, estimated that about 24,400 ac-ft/yr of water was unaccounted for and should be added to the estimates of recharge. He thought the additional recharge could be attributed, at least in part, to contributions from the Glen Rose Formation. This is in addition to the Cibolo Creek estimates and contributions to the Edwards aquifer in the Guadalupe River basin that do not return to the river through Hueco and other springs above the New Braunfels gaging station. Klemt and others (1979), based on their computer model simulations of the Edwards aquifer for the period 1947 through 1971, found they agreed with Lowry and that an additional 32,000 ac-ft/yr of recharge was required to properly simulate the above historical record.

Kuniansky and Barker (1994) estimate the total quantity of water entering the Edwards aquifer laterally from the Glen Rose Formation, for the most part, along the Balcones fault zone could be as high as 100,000 ac-ft/yr, and in addition, these workers indicate the diffuse upward leakage of ground water to the aquifer from the Glen Rose may be on the order of 10,000 ac-ft/yr. To offset this amount of underflow, Kuniansky and Barker assume there are losses from the Edwards upward through the Del Rio Clay into overlying formations (Buda, Austin, etc.).

CIBOLO CREEK

Hydrologic communication between the Glen Rose and Edwards aquifers in the Cibolo Creek basin has previously been considered different from water transfers between the two aquifers elsewhere. Historically, Cibolo Creek stream loss to the lower Glen Rose between Boerne and Bulverde has been assumed to recharge the Edwards aquifer as underflow from the Glen Rose Formation in the subsurface. This was based principally on stream-loss records, available water-level records and the absence of a previously known discharge area (Lowry, 1955; Petitt and George, 1956;

Puente, 1976). Livingston (1940) and Guyton (1958, 1970) provide interesting details regarding the geologic distribution of streamflow losses along Cibolo Creek near Boerne, Texas and along the Cibolo from Boerne to Selma, Texas, respectively. However, some relatively recent mapping in the mid- to late 1980's of Honey Creek Cave and hydrogeologic observations made by Veni (1994a) show that the Guadalupe River may pirate some flow through cave conduits during higher flow conditions in Cibolo Creek.

Recharge to the Edwards aquifer in Cibolo Creek basin has been calculated using stream losses from Boerne to Bracken (Lowry, 1955; Petitt and George, 1956; Puente, 1976). The average rate of natural recharge to the Edwards aquifer for the Cibolo Creek basin averaged 53,800 ac-ft/yr for the period 1934 through 1953 (Lowry, 1955). William F. Guyton & Associates (1970) reports, for the period 1942 through 1961, the rate of natural recharge to the Edwards from the Cibolo Creek basin averaged about 60,000 ac-ft/yr, according to calculations by Lowry and Erickson. For the period of record, 1934 to 1992, the U. S. Geological Survey has estimated average annual recharge in the Cibolo and Dry Comal Creek basins combined at almost 107,000 ac-ft/yr (Bader and others, 1993).

Stream-discharge measurements made on January 28-30, 1958 indicated that for the reach of Cibolo Creek underlain by the lower Glen Rose, extending from approximately Boerne to Bulverde, about 100 cubic feet per second (cfs) of water was lost to the lower Glen Rose (Guyton, 1970). These measurements also showed that about 20 cfs flowed past the lower Glen Rose outcrop in Cibolo Creek.

When recharge is large to the lower Glen Rose, the water-level gradient becomes even steeper. Water levels in lower Glen Rose wells near Cibolo Creek, during wet periods when extensive recharge to the aquifer occurs, have risen 200 feet or more (Guyton, 1970). The City of Fair Oaks has maintained an observation well in the middle Trinity aquifer located 0.6 mile south of Cibolo Creek along Ralph Fair Road. From the middle of December 1991 to the third week in January 1992, this monitor well showed a rise of over 100 feet (Figure 2). This generally indicates the regional transmissivity of the Glen Rose is low, and its ability to transmit water in the direction of the regional water-level gradient away from the Cibolo Creek area is somewhat limited.

Guyton (1958) in a report to the San Antonio City Water Board suggested that the Cibolo Creek's wide terraced valley and meanders within the valley indicate the Cibolo is a very old stream with conditions favorable for the solution of Glen Rose rocks underlying the meander plain of the Cibolo. Guyton's analysis indicates that, quite possibly, in the shallow subsurface below Cibolo Creek, there are high permeability pathways that parallel the meander plain of the Cibolo and can transmit large quantities of ground water.

Espey, Huston & Associates (1982) provided the following insights with regard to ground-water flow in the general area downstream of Bulverde on Cibolo Creek near Natural Bridge Caverns and Bracken Bat Cave: (a) two flow investigations in 1981 indicated an increase in flow in the reach of Cibolo Creek underlain by the upper Glen Rose, in contrast to stream losses over the lower Glen Rose; (b) typical yields of upper Glen Rose water wells are 5 to 10 times higher than the regional average for such wells; (c) of four wells drilled in the vicinity of Natural Bridge Caverns, three of the wells initially had yields of less than 1-1/2 gallons per minute; however, the fourth well that was drilled into the River Styx of the caverns produced 30 gallons per minute; and (d) water-level elevations in the above wells generally ranged from 675 feet to 820 feet, the higher water-level elevation being in the River Styx well. The River Styx provides a pathway for large volumes of ground water to enter the caverns.

Many recharge solution features found associated with the upper member of the Glen Rose Formation near Cibolo Creek above the outcrop of the Edwards aquifer are associated with secondary porosity, such as joints, fractures, faults and karstification. In this general area, Bracken Bat Cave, Natural Bridge Caverns and numerous caves, sinkholes etc. are examples of solutioning that can occur in the upper Glen Rose (Espey, Huston & Associates, 1982; Veni, 1988). The presence of these solution features over a broad area in the upper Glen Rose is an excellent example that, although the upper Glen Rose is routinely characterized as a low permeability unit, there are localized areas of high permeability. This may allow some transfer of water from the lower Glen Rose member upstream along the Cibolo Creek to the Edwards aquifer downstream.

Relatively recent mapping by a number of local spelunkers of Honey Creek Cave along the Comal-Kendall County border has shown a direct link between Cibolo Creek and the Guadalupe River. Honey Creek Cave is now known as the longest mapped cave in Texas and extends from Cibolo Creek to the Guadalupe River basin (Figure 3). The cave is formed in the base of the lower Glen Rose member and is thought to have been created by a series of ground-water piracies. Observations by Veni (1994a) indicate that during storm events, Cibolo Creek water is discharged through Honey Creek Cave to the Guadalupe River basin at Honey Creek Cave spring entrance. Additional flow from the Cibolo to the Guadalupe River may occur through other unmapped karst features paralleling the Honey Creek Cave system.

In summary, significant quantities of water are recharged to the lower member of the Glen Rose Formation where the unit underlies Cibolo Creek. Because the regional transmissivity of the lower Glen Rose is relatively limited, the recharged ground water probably moves through shallow subsurface karst conduits. Previously, the direction of flow has been assumed parallel to Cibolo Creek where permeability has been enhanced due to solutioning until it reaches the Bracken Bat Cave and Natural Bridge Caverns area. There, it was believed that the majority of water lost to the lower Glen Rose would eventually find its way to the Edwards aquifer. However, mapping of the extent of Honey Creek Cave, northeast of Cibolo Creek in this area, and hydrogeologic observations indicate that some water is diverted through cave conduits to the Guadalupe River. The large stream losses in Cibolo Creek over the lower Glen Rose member may not find their way to the Edwards aquifer unless the water is recharged to the Edwards aquifer in the Guadalupe River basin. As a result, previous estimates of recharge to the Edwards aquifer in the Cibolo Creek basin may be overestimated.

HABY CROSSING FAULT AREA

Haby Crossing fault is a relatively large displacement fault located generally from central Medina County to north-central Bexar County (Figure 4). The displacement is somewhat variable but exceeds 400 feet in many areas and, as a result, juxtaposes the Glen Rose Limestone and the Edwards and associated limestones. The surface geology of the area has Edwards or Glen Rose on the north side of the fault and generally Austin or Pecan Gap Chalk on the south side of the fault (Figure 4). A hydrogeologic cross section K-K' (Figure 5) modified from Small (1986) shows the juxtaposition of the two aquifers in the Haby Crossing fault area. The study area for examining site-specific hydrologic communication between the Glen Rose and Edwards aquifers is updip and downdip from the Haby Crossing fault generally from the City of Helotes to Diversion Lake downstream from Medina Lake, about a 14-mile length along the fault.

Twenty-three wells were inventoried in the Haby Crossing fault area (Table 3 and Figure 6). Water levels were measured in 17 wells (Table 3 and Figure 7), and water samples were collected from 20 wells to be analyzed for basic inorganic chemistry, with the addition of Sr to help identify Glen Rose aquifer water (Table 4 and Appendix 3). Pumping tests were performed on two wells completed in the Glen Rose aquifer (transmissivities of 100 gallons per day per foot (gpd/ft) and 181 gpd/ft) and on one well completed in the Edwards aquifer in the Haby Crossing fault area. These pumping-test data are given in Appendix 4.

Analysis of Water Levels

The elevation of and depth to water levels in wells measured in the Haby Crossing fault area are shown in Figure 7. The measured wells were separated into two groups (Table 3), those wells that produce from the Edwards aquifer and those wells that produce from the Glen Rose aquifer. The water-level gradient determined from these measured water levels is much steeper in the Glen Rose aquifer located upgradient from the Haby Crossing fault than in the Edwards aquifer located downgradient of the fault. The gradient is about 75 to 100 feet per mile (ft/mi) in the tighter Glen Rose aquifer and 25 to 30 ft/mi in the more transmissive Edwards aquifer. The water-level contours for the Glen Rose aquifer are approximately parallel to the Haby Crossing fault, which indicates that ground-water flow generally is toward the fault at about S20°E and that the major discharge point of the Glen Rose aquifer is located along the length of the fault. The Edwards aquifer water-level contours are at an oblique angle away from the fault, with the general direction of ground-water flow at about S40° to 50°E.

Two areas along the Haby Crossing fault have water-level elevations in wells that are very similar for both aquifers on either side of the fault. One area is in the vicinity of Helotes Ranch Acres subdivision (Figure 6), located to the west of the City of Helotes, and the second area is near Diversion Lake. In the Helotes Ranch Acres area, 2-1/2-minute section AY-68-27-4, water-level elevations on both sides of the fault are similar, ranging from 767 to 790 feet above mean sea level. Water-level contours indicate that similar water-level conditions exist for an area from west of the City of Helotes to about the Government Canyon area along the Haby Crossing fault. Moving to the southwest along the fault, the water levels seem to diverge between the Glen Rose to the northwest of the fault and the Edwards to the southeast of the fault. This difference in water levels between aquifers across the fault seems to persist until the Diversion Lake area, where similar water levels are again seen for the two aquifers.

The relative water-level differences on either side of the Haby Crossing fault may be a function of efficiency of hydrologic pathways across the fault between the two aquifers. On the geologic map (Figure 4), some cross faults have been mapped just southeast of the Diversion Lake area and southeast of the Helotes Ranch Acres area that trend at about N70°W. This trend differs from a majority of the faults in the Balcones fault zone, which trend in a northeast direction. The faults probably have associated zones of increased fracturing that may create preferred easier pathways for water to move from the Glen Rose aquifer to the Edwards aquifer, and therefore a flatter potentiometric surface was observed in those areas.

Analysis of Water-Chemistry Data

In addition to the 20 wells sampled for this project, approximately 50 fresh-water Edwards aquifer wells, which have been previously sampled either annually or semiannually, were sampled this year by representatives of the EUWD. Analyses of water samples from those wells, generally a few per county in the San Antonio region, that were not fresh-water/saline-water interface monitor wells were used to determine an average water chemistry (Table 5) for the Edwards aquifer for comparison to the wells sampled in the Haby Crossing fault area (Table 4). Selected chemical constituents, such as TDS, SO_4, Mg and Sr, from analyses of the 20 samples of well water in the Haby Crossing fault area are shown in mg/l on Figure 8 and indicate the distribution of water chemistries for the Glen Rose and the Edwards aquifers in this area. Statistical summaries of the analyzed chemical constituents are given in Table 4. For the selected constituents shown in Figure 8, the median values in mg/l for the sampled wells in the Haby Crossing fault area are as follows:

	Glen Rose Aquifer	Edwards Aquifer
TDS	2,224	368
SO_4	1,055	31
Mg	117	16
Sr	10.6	0.6

This shows the distinct differences in water chemistry between the Glen Rose and Edwards aquifers. The logarithmic molar ion plots in Figure 9 of Sr versus SO_4 and Sr versus the ratio of calcium (Ca) to Mg also graphically show the distinct differences in water chemistry between the two aquifers in this area except one Edwards well, 33-3ba4, and one Glen Rose well, 25-9ha7. These wells are elaborated on later in this section. Also, the straight line relation of the Edwards aquifer water chemistries (Figure 9) may indicate the mixing of Edwards and Glen Rose waters to differing degrees.

The trilinear Piper diagram shown on Figure 10 was generated from results of the inorganic water analyses to visually demonstrate major groupings or trends in water chemistry between the Edwards and Glen Rose aquifers. The composition of most natural waters can be approximated in terms of three sets of cations (Ca, Mg and Na plus K) and three sets of anions (bicarbonate plus carbonate, SO_4 and Cl) expressed in percentage of total milliequivalents. The proportions are plotted as points in separate triangles of cation and anion constituents. These points are then projected into a central diamond-shaped field to identify general composition in terms of water-chemistry types (Hem, 1985; Freeze and Cherry, 1979).

Data on Figures 8, 9 and 10 illustrate that the water-chemistry differences between the Glen Rose and Edwards aquifers, which are located generally upgradient and downgradient, respectively, of the Haby Crossing fault in northwestern Bexar County and northeastern Medina County. The samples from wells completed in the Edwards aquifer are a calcium-bicarbonate-type water, whereas, the samples from wells completed in the Glen Rose aquifer are generally calcium and magnesium-sulfate-type water.

Well 26-5he1 was initially thought to be a Glen Rose aquifer well because the well was identified as D-8-7 by Holt (1956) to be a Glen Rose well with a reported depth of 671 feet. The reported depth of this well may be incorrect or has been changed over the past 40 years since Holt's study. A water-level measurement was not obtainable in this well during this study. However, a water sample was taken from the well. Because the water chemistries of this well (Table 4) are similar to most Edwards aquifer water and dissimilar from Glen Rose aquifer water, the well now is assumed to be Edwards. This is probable given that the well is located on top of a hill with Kirschberg to grainstone member in the upper part of the Kainer Formation exposed at the surface near this well. This gives an effective available Edwards thickness of about 220 feet, which is probably ample thickness for the well to produce from the Edwards at this location. At Wells 26-5ea6 and 26-8bb5 located to the north and south, respectively, from Well 26-5he1, the land surface is topographically and stratigraphically lower, and therefore, these wells only produce from the Glen Rose aquifer.

The chemistry analyzed for the water sample from Well 25-9ha7 is different from the other Glen Rose aquifer samples analyzed for this study, as mentioned previously. Because the well is located next to Diversion Lake, it is surmised that the water from this well is diluted, as compared to most Glen Rose aquifer water, by recharged water from Diversion or Medina Lake to the Glen Rose aquifer near the well.

Additionally, two other wells sampled, Wells 33-3ba4 and 26-9fe5 identified in Figure 10 as 12 and 6, respectively, plot in different areas of the trilinear Piper diagram than other Edwards aquifer water samples analyzed for this study. These water samples show elevated NaCl as compared to other samples from both Edwards and Glen Rose aquifer wells. Austin Chalk is at the surface near both of these Edwards aquifer wells. Both wells are old and the depth and condition of the well casing is not known. Well 26-8cd2 is an Austin Chalk well inventoried within the study area. The well was not working at the time of the study and, as a result, was not sampled. Limited information on water produced from Austin Chalk wells in Medina County indicate that the Austin Chalk water is comparatively high in Na and Cl (Holt, 1956). The water sampled from Wells 33-3ba4 and 26-9fe5 may have been mixed with Austin Chalk water either in the well bore or near the well.

<u>Geochemical Modeling</u>

A U. S. Geological Survey geochemical model known as NETPATH (Prestemon and others, 1990) was used to analyze ground-water chemistries in the Haby Crossing fault area. NETPATH is a computer program that calculates thermodynamic solutions to net geochemical mass balance problems such as mixing waters, evaporation, dilution, precipitation or dissolution of rock phases. The program uses water chemistries and expected mineral phases to calculate geochemical models that give mixing proportions and final expected products between mixed waters. The following mineral phases were used in the model runs: aragonite, calcite, dolomite, gypsum, fluorite, halite, strontianite, SiO_2, Na-Mg/Ca ion exchange, carbon dioxide gas, and hydrogen sulfide gas.

Three different runs were made with NETPATH. Two were made with specific transects of wells. The third was made with median values for the 20 samples retrieved in the Haby Crossing fault area and for the 15 other wells sampled by representatives of the EUWD this year in Bexar and Medina Counties. These wells were not fresh-water/saline-water interface monitor wells.

The first computer run was made using water chemistries for samples from Well 27-4ff1 (Glen Rose aquifer) as the initial water chemistry and from Well 27-4ff9 (Edwards aquifer) as the final water chemistry. NETPATH came up with 24 different mixing models to potentially explain these water chemistries. All of the models indicated that dilution with pure water (i.e., rainwater) was needed at a 1:16.9 ratio, which means that Edwards Well 27-4ff9 could have about 5.9 percent Glen Rose water mixed with pure water (i.e., recharged rainwater) to produce the end chemistry found in the sample from Well 27-4ff1.

The second NETPATH run was made using the water chemistry of Well 27-4ff1 (Glen Rose aquifer) designated as "initial1" mixed with the water chemistry from Well 27-4fi4 (Edwards aquifer) designated as "initial2" to produce the final water chemistry from Well 27-4ff9 (Edwards aquifer). All matching models found required pure water dilution. The models indicate a mixing of 31 percent water from Well 27-4ff1 with 69 percent water from Well 27-4fi4 and then dilution at a 1:5.2 ratio. This means that Well 27-4ff9 (final Edwards) could have about 6 percent of the original Glen Rose water similar to the water chemistry found in Well 27-4ff1.

The third NETPATH run was made using median chemical values for the Haby Crossing fault area. The Glen Rose aquifer wells were designated as "initial1," median values for Haby Crossing fault area Edwards aquifer wells were designated as "initial2," and the median values for the other Edwards aquifer wells sampled by EUWD representatives in Medina and Bexar Counties were designated as the final water chemistry. Because of the skewing effects of statistical outliers on arithmetic means, median chemical values were used in the model instead of arithmetic means to represent "average" water chemistries. Outliers are present in the Haby Crossing fault area data as discussed previously. No models were found without dilution with pure water. All matched models indicate mixing 0.6 percent median Glen Rose water with 99.4 percent Haby Crossing fault area Edwards water and then dilution at a 1:1.04 ratio to get Medina and Bexar County median Edwards water chemistry. This means that the final median Edwards water chemistry could have about 0.5 percent of the original Haby Crossing fault area median Glen Rose water.

Haby Crossing Fault Area Conclusions

The Haby Crossing fault area, because of the relatively large fault displacement, is one of the best locations for the Edwards and associated limestones to be juxtaposed to the Glen Rose Limestone. This gives the best potential for hydrologic communication between the two aquifers. The Glen Rose aquifer, which is much less transmissive than the Edwards aquifer, is the limiting factor in transmission between the two aquifers. Based on water-level data and pumping-test data, the amount of water (Q) that the Glen Rose aquifer could possibly transmit to the Edwards aquifer in the Haby Crossing fault area can be estimated with Darcy's equation. The following numbers seem reasonable based on data collected for this study: Glen Rose transmissivity (T) in the study area is low at about 200 gpd/ft, the gradient (I) in the Glen Rose aquifer upgradient of the fault is about 100 ft/mi, and the fault length (L) in the study area is about 14 miles. (It should be noted that this is **not** the full length of the fault but just the length within the study area.) Multiplying these together results in:

$$Q = T \times I \times L = (200\ \text{gpd/ft}) \times (100\ \text{ft/mi}) \times (14\ \text{mi}) = 280{,}000\ \text{gpd} = 314\ \text{ac-ft/yr}$$

This is relatively small, especially when considering other sources of recharge to the Edwards aquifer. For comparison, the direct recharge to the Edwards aquifer in the Medina River basin on the western end of the site-specific study area has averaged about 61,000 ac-ft/yr and the total recharge for the Edwards aquifer in the San

Antonio region has averaged about 682,800 ac-ft/yr from 1934 to 1992 (Bader and others, 1993).

The chemistry for water sampled from the Glen Rose aquifer is very different from that of the Edwards aquifer. Geochemical modeling confirms that only small amounts of Glen Rose water are entering the Edwards aquifer; water from the Glen Rose represents approximately 5 percent of the total water immediately downgradient of the Haby Crossing fault. This mixed water continues to be diluted as the water travels downgradient toward the main artesian part of the aquifer near San Antonio. Based on geochemical models, the mixed water is diluted to less than 1 percent of the total water content of median water found downgradient in the main artesian part of the Edwards aquifer in Medina and Bexar Counties.

REGIONAL COMMUNICATION BETWEEN THE GLEN ROSE AND EDWARDS AQUIFERS

The connection between the Edwards and Trinity aquifers is common throughout the study area. Above the Edwards recharge zone, Edwards rocks overlie the upper and lower members of the Glen Rose Formation. Under these conditions, the Edwards and Trinity aquifers act as a leaky system. Within the Edwards recharge zone, the Glen Rose has been faulted against the Edwards aquifer, and in this situation, these units are considered hydrologically connected.

The flow of ground water from the rocks of the Glen Rose Formation across the Balcones fault zone to the Edwards aquifer depends on a number of factors including the following: (1) the ability of the Glen Rose to transmit water (transmissivity) to the fault area where the two aquifers are across from each other; (2) suitable water-level gradient between aquifers; and (3) amount of fault displacement that juxtaposes the aquifers and creates a "window" across the fault between the Glen Rose and Edwards aquifers. Ground water flows from the Glen Rose aquifer to the Edwards aquifer under suitable water-level gradients, where water levels in the Glen Rose aquifer are higher than or near equal to the juxtaposed Edwards aquifer on the downthrown side of the faults.

Total thickness of the Glen Rose Formation is from about 800 feet to over 1,000 feet and the most permeable sections of the Glen Rose aquifer are in the lower part. As a result, the closer the displacement of the fault is to the total thickness of the Glen Rose, the larger the "window" between the two aquifers. As fault displacement and the size of the "window" increase, interformational flow through the "window" will increase if other parameters (water-level gradient, transmissivity, etc.) remain the same. In those situations where the "window" is limited, ground water may move along the fault until flow can take place to the Edwards at a suitable location in the subsurface.

The ground-water flow properties in the vicinity of and along faults within the Balcones fault zone are assumed not to be a limiting factor for communication of water between the Glen Rose and Edwards aquifers. Numerous springs issuing along faults, such as San Pedro, Comal and San Marcos Springs, indicate that fault planes and gouge zones in the San Antonio region are permeable. Also, the transmissivity of the Edwards aquifer probably is not a limiting factor since the transmissivity of the Glen Rose is generally much less than the Edwards. The ability of the Glen Rose to transmit water in the direction of the regional water-level gradient is somewhat limited.

Analysis of Cross Sections

Small (1986) constructed 27 hydrogeologic sections (Figure 11) to document the geologic framework of the Edwards aquifer. The sections were constructed along lines that are oriented approximately south-southeast and generally parallel to the regional dip of the Edwards. The section lines are at about 5- to 10-mile intervals across the aquifer. These sections show the following: (a) stratigraphic and structural relationships of rocks forming the Edwards aquifer and those younger and older rocks which are hydraulically associated with the aquifer; (b) regional dip of the rocks; (c) locations and vertical displacements of the faults they cross; (d) water levels, and on certain sections, (e) the approximate contact between fresh water and saline water. The hydrogeologic cross section (Figure 5) illustrates the above and, in addition, potential lateral and vertical flow paths of ground water associated with the Glen Rose Formation and Edwards aquifer.

The hydrogeologic sections prepared by Small (1986) and water levels provided by Bush and others (1993) were used to determine the extent the Glen Rose Formation is juxtaposed against the Edwards aquifer and favorable locations for underflow from the Glen Rose along the Balcones fault zone in the study area. The fault displacement and the length of the section through which ground water enters the Edwards from the Glen Rose were estimated from the above sections. The historical water-level surface of the Edwards-Trinity aquifer system (which includes the Glen Rose Formation) is shown on Figure 12. The major faults which facilitate underflow from the Glen Rose, section locations and fault displacements, etc. are shown on Figure 11.

Analysis of Water Levels

Most rivers and streams in the study area traverse the Glen Rose Formation above the Edwards recharge zone. A review of the historical streamflow gain and loss studies indicates that most of the streams generally show increases in base flow in the downstream direction indicating that some of the ground water is moving from the Glen Rose to the streams. This reemerged surface water often ultimately recharges the Edwards aquifer as those streams then cross the Edwards outcrop.

Above the Balcones fault zone, the water-level gradient is steep and ground-water flow is generally in the southeast direction toward the Edwards aquifer (Figure 12). The Glen Rose generally has a steep hydraulic gradient, which demonstrates that movement of ground water through the Glen Rose is restricted and slow. In the vicinity of the Edwards recharge zone, the water probably enters the Edwards aquifer where faults have brought the Edwards and associated limestones down against the Glen Rose Formation. The regional direction of ground-water flow for the Trinity Group aquifer is toward the Gulf Coast to the southeast. Within the Edwards aquifer, direction of flow extends from recharge areas in the unconfined zone generally southeast to the confined zone, and then generally from west to east toward the major spring discharge points.

In the Balcones fault zone, the potentiometric surface of the Edwards-Trinity aquifer system is a much less effective indicator of the specific direction of ground-water flow than in other areas due to the anisotropy of the series of southwest-to-northeast trending faults and secondarily developed karst conduits. In addition, static water levels in the Glen Rose Formation generally reflect the combined influences of the different water-bearing units open to wells (Guyton, 1955b).

The water-level map, modified from Bush and others (1993), portrays the regional predevelopment potentiometric surface over broad areas of the study region for the Edwards-Trinity aquifer system (Figure 12). The contours on the map are very generalized, but appropriate for determining the approximate direction of ground-water flow, hydraulic gradients and relationship of topography and streams to water levels for the Glen Rose Formation and Edwards aquifer.

The estimated water-level gradients just upgradient from the Edwards aquifer recharge zone in the Trinity Group aquifer near the area of each cross section generally range up to about 60 ft/mi. Because these gradients are inclusive of those for the entire Trinity Group aquifer, the gradients are less steep as compared to the determined gradient measured in the Haby Crossing fault area for just the Glen Rose aquifer, which was about 75 to 100 ft/mi.

Analysis of Aquifer Tests

An aquifer's hydraulic characteristics are generally described in terms of its coefficients of transmissivity and storage. The coefficient of transmissivity is an index to an aquifer's ability to transmit water, and is the amount of water, in gallons per day, that will pass through a vertical strip of the aquifer 1 foot wide extending through the full saturated vertical thickness of the aquifer at a hydraulic gradient of 1 foot per foot and at the prevailing temperature of the water. The coefficient of storage is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer, per unit change in the component of hydrostatic pressure normal to that surface.

The inadequacy of the coefficients of transmissivity and storage to describe ground-water flow in carbonate rocks has been a topic of discussion for a long time. The basic assumption of most equations is that flow takes place in a homogeneous medium, which karst limestones generally are not. Carbonate rocks have little primary porosity, and the voids in the rock are in the form of joints, fractures and solution features. Some flow in a carbonate aquifer is similar to flow through a rough pipe rather than a homogeneous medium.

One of the difficulties in working with limestone aquifers, such as the Glen Rose and Edwards aquifers, is the seeming inconsistency in the hydraulic characteristics of wells within a small area (William F. Guyton Associates, 1993). However, the larger the area considered, the more nearly the limestone aquifers effectively assume the hydraulic characteristics of a homogeneous medium.

Transmissivities from Pumping Tests

Transmissivities of the Glen Rose aquifer are generally several orders of magnitude less than transmissivities for the Edwards aquifer. As a result, the limiting factor for water to be transmitted from the Glen Rose aquifer to the Edwards aquifer is the Glen Rose transmissivities. Therefore, only the estimate of transmissivity for the Glen Rose Formation is required to estimate interformational flow. Kuniansky and Barker (1994) provided transmissivity estimates for the Trinity Group aquifer from a number of historical pumping tests which were conducted by the U. S. Geological Survey and the various Texas water agencies. LBG-Guyton Associates selected the results from 42 locations in the following counties located north and west of the Edwards recharge zone: southeast Real, Bandera, northern Medina and Bexar, and northwestern Comal and Hays. In addition to the above pumping tests, the results of 11 additional tests in northern Bexar County were selected. Two tests were conducted during this study (Appendix 4) and nine were conducted during the northern Bexar County water-resource study (William F. Guyton Associates, 1993). The selected test sites are believed representative and used to estimate transmissivity for the Glen Rose Formation immediately updip of the Edwards recharge zone. The locations and results of the above tests are shown on Figure 13. The statistics for these pumping tests in gpd/ft are as follows:

County	Number of Tests	Transmissivity (gpd/ft) Average	Median	Maximum	Minimum
Hays	9	5,839	957	43,795	90
Comal	7	2,497	3,104	4,967	22
Bexar	22	5,663	1,799	35,200	32
Bandera, Medina, Real, Uvalde	15	3,496	1,668	17,301	105
Area Total	53	4,661	1,668	43,795	22

Median values instead of arithmetic means (average) are probably more appropriate for representing "average" conditions because of the skewing effects of very high or very low statistical outliers on the arithmetic means. As a result, median values were used for the underflow calculations.

Transmissivities Estimated from Specific-Capacity Tests

Ogden (1965) developed a method for estimating the transmissivity from specific-capacity tests made from one drawdown measurement. By using the non-equilibrium method (Theis, 1935), Ogden derived the following expression:

$$uW(u) = (1.87 \times r^2 \times s \times S) \div (114.6 \times Q \times t)$$

The left side of the equation, uW(u), can be computed from existing tables; for each value of uW(u) there is only one value of u. All terms on the right side of the equation can be measured at the pumping well except the coefficient of storage (S). Assuming a value for S and using the radius of the casing or screen (r), drawdown (s), the pumping time in days (t), and the discharge (Q), the value uW(u) can be computed. The single value of u corresponding to the value computed for uW(u) can be determined from tables or a curve, and the calculation of transmissivity (T) using the equation below is the final step.

$$T = (1.87 \times \times r^2 \times S) \div (u \times t)$$

This method has been tested by using actual drawdown data by Ogden (1965), and he concludes that values of transmissivity obtained are approximate but reasonably reliable.

The pumping-test results from William F. Guyton Associates (1993) were used to verify the relation of an assumed value of the coefficient of storage (S = 0.0005) and the transmissivity (T) calculated on the basis of one drawdown measurement from actual pumping tests. Computed transmissivities for the 10 pumping tests ranged from 74 percent to 350 percent (the median was 169 percent) of the value determined by the full test. Therefore, the method provides an estimate that is typically higher than an exact determination of transmissivity. However, it should be noted that the range in results is not much larger than the range in answers reached by some aquifer tests.

Transmissivity estimates were made using Ogden's method from 102 selected water well drillers' reports, which provided drawdown information for the well performance tests. These wells were selected for the following reasons: (a) the wells are located within or slightly updip of the Edwards recharge zone where underflow to the Edwards aquifer may occur; (b) the well performance test data reported by the driller appear reliable and accurate; and (c) wells appeared to be completed in both the upper and lower Glen Rose and perhaps lower into the Hensell and Cow Creek members of the Travis Peak Formation. The transmissivity estimates are listed by county in Table 6 and the locations of wells in that area completed in a relatively larger section (not shallow upper Glen Rose) are shown on Figure 13. The statistics of the transmissivity in gpd/ft of the above wells by county are as follows:

County	Number of Tests	Transmissivity (gpd/ft)		
		Median	Maximum	Minimum
Hays	7	37	95	6
Comal	27	93	1,085	3
Bexar	32	480	8,976	1
Medina	27	424	17,952	13
Uvalde	14	499	5,212	24
Area Total	102	219	17,952	1

The differences that can be seen in the actual pumping-test data shown in the previous section and the data derived from drillers' reports may be related to the wells being public water supply versus domestic water supply wells. Most of the wells used in this analysis are domestic wells reported to the state by individual drillers. Public water supply wells tend to be larger in diameter with more extensive well development, such as overpumping, surging and acidizing, and, most important, are generally completed to a greater depth and therefore penetrate a greater thickness of the aquifer, as compared to most smaller domestic wells. All of these differences in completion and construction of the well can affect the producing ability of the well and affect pumping tests performed on these wells that are used to calculate the transmissivities of the aquifer.

Looking at the composite transmissivities on Figure 13 for both data sets, pumping tests and one-drawdown tests, indicates a general decrease in transmissivity in the downdip or southeast direction. In the immediate vicinity of the Edwards aquifer recharge zone where the Edwards and Glen Rose aquifers are juxtaposed by faulting, transmissivities appear to be relatively lower than Glen Rose transmissivities found upgradient from the recharge zone.

Estimates of Glen Rose Regional Underflow to the Edwards Aquifer

Underflow from the Glen Rose Formation to the Edwards aquifer along the Balcones fault zone can occur by ground water moving laterally in a downgradient direction within the Glen Rose and entering the Edwards through the "window" across the fault plane. Also, in the case where the "window" is small because of fault displacement, underflow to the Edwards can occur through the fault. In either case, the amount of ground water which enters the Edwards aquifer is dependent on the length of the line of entry (fault-plane length), the water-level gradient across the fault plane, and the effective transmissivity for the respective total thickness of section of Glen Rose along this line. The estimates made for Glen Rose underflow are exclusive of inflow of water from the Edwards-Trinity Plateau aquifer that occurs in parts of

Uvalde and Kinney Counties and recharge to the lower Glen Rose in the Cibolo Creek basin that has historically been counted as Edwards aquifer recharge.

In some areas within the Edwards aquifer recharge zone, the gradient is actually reversed and ground-water flow is from the Edwards to the Glen Rose. In the northern Bexar County water-resource study (William F. Guyton Associates, 1993), the 1992 water-level elevations were actually higher in the Edwards than the Glen Rose through the central part of the study area. This indicates that, under the water-level conditions during this study, ground-water flow was from the Edwards to the Glen Rose. For the purpose of estimating maximum possible inflow, the gradient between the two aquifers will be assumed to be from the Glen Rose to the Edwards. The following inflow estimates should be considered a maximum potential quantity of inflow from the Glen Rose. In actuality, the inflow may be less because of the reversed water-level gradients in some areas during certain hydrologic conditions.

As previously discussed, the approximate median transmissivity for the Glen Rose aquifer above the Edwards aquifer recharge zone by county is used in calculating total underflow. The pumping-test data are probably representative of relatively higher transmissivities, possibly because of differences in well completions, which are used for the higher end of the range for underflow calculations. The data compiled and estimated from drillers' reports, however, are thought to be representative of the lower end of the range for underflow calculations.

The following two examples illustrate the methodology used to estimate underflow from the Glen Rose to the Edwards along the Balcones fault zone which is in addition to the contribution in the vicinity of Cibolo Creek.

1. Where hydrogeologic section E intersects the fault as shown on Figure 11, the length of the line of entry is estimated to be 6 miles. This is measured along the fault in a southwest direction from about midway between cross sections D and E to a point approximately midway between cross sections E and F. The average water-level gradient across the line of entry is about 29

ft/mi based on water-level contours (Figure 12), and the average transmissivity of the Glen Rose Formation for both the low and high ranges is estimated to be about 500 and 1,800 gpd/ft, respectively. Using these factors, the amount of underflow entering the Edwards is estimated to be 97 ac-ft/yr for the low case and 351 ac-ft/yr for the high case.

2. Segmentation of the Edwards aquifer into separate fault-bounded blocks provides multiple opportunities for underflow to occur to the Edwards through or along fault planes from the Glen Rose Formation. The locations where hydrogeologic section K intersects two faults with large displacements are shown on Figure 5 and located on Figure 11 and are indicated by items K(1) and K(2) on Table 7. The K(1) and K(2) locations are with respect to the westernmost and easternmost faults, respectively. The Glen Rose underflow calculations for hydrogeologic section K are as described above for the two lines of entry; the results are shown on Table 7.

An approximate range of Glen Rose underflow to the Edwards aquifer, excluding the Cibolo Creek contribution, appears to be from about 2,700 ac-ft/yr to about 11,400 ac-ft/yr in the study area. The total inflow estimates are also exclusive of inflow of water from the Edwards-Trinity Plateau aquifer that occurs in parts of Uvalde and Kinney Counties. These estimates are based on transmissivities for the high and low cases as described above and a positive water-level gradient from the Glen Rose to the Edwards. Table 7 provides a summary of the line-of-entry lengths as measured along the fault-line traces, water-level gradients, average transmissivities for both the high and low cases, and estimated underflow from the Glen Rose.

The Glen Rose inflow values generally compare with the minimum discharge estimates determined in the regional analyses. Cross sections I, J(1) and K(1) are approximately equivalent to the area evaluated in the Haby Crossing fault site-specific analysis. Adding these cross-section discharges gives 393 ac-ft/yr to 1,417 ac-ft/yr, which compares to the Haby Crossing fault estimate of 314 ac-ft/yr.

Compared to the total Edwards aquifer water budget, the cumulative estimate of inflow from the Glen Rose is slightly lower than Lowry's original determination of 5 percent of the total. Estimates made in this study indicate that the total Glen Rose contribution is probably less than 2 percent of the total water budget during average recharge conditions for the Edwards aquifer. This percentage would be higher during times of less precipitation or drought, because the discharge from the Glen Rose to the Edwards would not fluctuate as rapidly or greatly as the precipitation over the Edwards recharge zone might from year to year. This estimate compares well with the regional geochemical model using NETPATH discussed in the Haby Crossing fault section, which indicated that the mixing of less than 1 percent of Glen Rose water could produce median Edwards water chemistry found downgradient in the artesian portion of the Edwards aquifer. Even if the above maximum estimates of transmissivity were off by almost an order of magnitude, for example 10,000 gpd/ft, the total underflow from the Glen Rose to the Edwards aquifer would still be only about 9 percent of total average recharge to the Edwards aquifer.

SELECTED REFERENCES

Ardis, A. F., and Barker, R. A., 1993, Historical saturated thickness of the Edwards-Trinity aquifer system and selected contiguous hydraulically connected units, west-central Texas: U. S. Geological Survey Water-Resources Investigations Report 92-4125, 2 sheets.

Ashworth, J. B., 1983, Ground-water availability of the Lower Cretaceous formations in the Hill Country of south-central Texas: Texas Department of Water Resources Report 273, 173 p.

Bader, R. W., Walthour, S. D., and Waugh, J. R., 1993, Edwards aquifer hydrogeologic status report for 1992: Edwards Underground Water District Report 93-05, 71 p.

Barker, R. A., and Ardis, A. F., 1992, Configuration of the base of the Edwards-Trinity aquifer system and hydrogeology of the underlying pre-Cretaceous rocks, west-central Texas: U. S. Geological Survey Water-Resources Investigations Report 91-4071, 25 p.

Bush, P. W., Ardis, A. F., and Wynn, K. H., 1993, Historical potentiometric surface of the Edwards-Trinity aquifer system and contiguous hydraulically connected units, west-central Texas: U. S. Geological Survey Water-Supply Paper 92-4055, 3 sheets.

Bush, P. W., Ulery, R. L., and Rittmaster, R., 1994, Dissolved solids concentrations and hydrochemical facies in water of the Edwards-Trinity aquifer system, west-central Texas: U. S. Geological Survey Water-Resources Investigations 93-4126 (in press).

Buszka, P. M., 1987, Relation of water chemistry of the Edwards aquifer to hydrogeology and land use, San Antonio region, Texas: U. S. Geological Survey Water-Supply Paper 87-4116, 100 p.

Dougherty, J. P., 1980, Streamflow and reservoir-content records in Texas, compilation report, January 1889 through December 1975: Texas Department of Water Resources Report 244, 321 p.

Espey, Huston & Associates, 1982, Feasibility study of recharge facilities on Cibolo Creek: Draft consulting report to the Edwards Underground Water District, 56 p.

Freeze, R. A., and Cherry, J. W., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

Guyton, W. F., and Associates, 1955a, The Edwards limestone reservoir: Consulting report to the San Antonio City Water Board, 38 p.

Guyton, W. F., and Associates, 1955b, Proposed Canyon Reservoir, Guadalupe River: Consulting report to the San Antonio City Water Board, 108 p.

Guyton, W. F., and Associates, 1958, Memorandum on ground-water gains in upper Cibolo Creek area: Consulting report to the San Antonio City Water Board, 8 p.

Guyton, W. F., and Associates, 1970, Memorandum on Cibolo Creek studies: Consulting report to the San Antonio City Water Board, 17 p.

Guyton, W. F., Associates, 1993, Ground-water resources of the Trinity Group aquifer, north Bexar County, Texas: Consulting report to the Edwards Underground Water District, v. 1, 64 p.

Hem, J. D., 1985, Study and interpretation of the chemical characteristics of natural water: U. S. Geological Survey Water-Supply Paper 2254, 263 p.

Holt, C. L. R., Jr., 1956, Geology and ground-water resources of Medina County, Texas: Texas Board of Water Engineers Bulletin 5601, 278 p.

Klemt, W. B., Knowles, T. R., Elder, G. R., and Sieh, T. W., 1979, Ground-water resources and model applications for the Edwards (Balcones fault zone) aquifer in the San Antonio region, Texas: Texas Department of Water Resources Report 239, 88 p.

Kuniansky, E. L., and Barker, R. A., 1994, Written communications: U. S. Geological Survey, Water Resources Division, Texas District.

Livingston, Penn, 1940, Ground-water conditions in vicinity of reservoir site on Cibolo Creek at Boerne, Texas: U. S. Geological Survey, memorandum report (unpub.), 7 p.

Lowry, R. L., 1955, Recharge to Edwards ground-water reservoir: Consulting report to the San Antonio City Water Board, 66 p.

Maclay, R. W., and Land, L. F., 1988, Simulation of flow in the Edwards aquifer, San Antonio region, Texas, and refinement of storage and flow concepts: U. S. Geological Survey Water-Supply Paper 2336, 48 p.

Maclay, R. W., and Small, T. A., 1984, Carbonate geology and hydrology of the Edwards aquifer in the San Antonio area, Texas: U. S. Geological Survey Open-File Report 83-537, 72 p.

Ogden, A. E., Quick, R. A., Rothermel, S. R., and Lunsford, D. L., 1986, Hydrogeological and hydrochemical investigation of the Edwards aquifer in the San Marcos area, Hays County, Texas: Edwards Aquifer Research and Data Center Report R1-86.

Ogden, L., 1965, Estimating transmissibility with one drawdown: Ground Water, v. 3, no. 3, p. 51-55.

Petitt, B. M., Jr., and George, W. O., 1956, Ground-water resources of the San Antonio area, Texas: Texas Board of Water Engineers Bulletin 5608, v. I, 80 p., and v. II, pt. III, 231 p.

Prestemon, E. C., Plummer, L. N., and Parkhurst, D. L., 1990, NETPATH - an interactive code for net geochemical mass balance modeling along flow paths: U. S. Geological Survey draft report, 32 p.

Puente, Celso, 1978, Method of estimating natural recharge to the Edwards aquifer in the San Antonio area, Texas: U. S. Geological Survey Water-Resources Investigations 78-10, 34 p.

Rose, P. R., 1972, Edwards Group, surface and subsurface, central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 74., 198 p.

Senger, R. K., and Kreitler, C. W., 1984, Hydrogeology of the Edwards aquifer, Austin area, central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 141, 35 p.

Small, T. A., 1986, Hydrogeologic sections of the Edwards aquifer and its confining units in the San Antonio area, Texas: U. S. Geological Survey Water-Resources Investigations 85-4259, 52 p.

Stein, W. G., 1993, Hydrogeologic map and characteristics of the recharge zone of the Edwards aquifer, Bexar County, Texas: The University of Texas at San Antonio, M.S. thesis (unpub.), 83 p.

Stricklin, F. L., Jr., Smith, C. I., and Lozo, F. E., 1971, Stratigraphy of Lower Cretaceous Trinity deposits of central Texas: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 71, 63 p.

Theis, C. V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using ground-water storage: Am. Geophysical Union Trans., 16th Annual Meeting, pt. 2, p. 519-524.

Veni, George, 1988, The caves of Bexar County: The University of Texas at Austin, Texas Memorial Museum, 300 p.

Veni, George, 1994a, Honey Creek Cave *in* Elliott, W. R., and Veni, George, eds., The caves and karst of Texas: National Speleological Society 1994 Convention guidebook, p. 175-178.

Veni, George, 1994b, Geomorphology, hydrogeology, geochemistry and evolution of the karstic Lower Glen Rose aquifer, south-central Texas: Pennsylvania State University, Ph.D. dissertation (unpub.), 721 p.

Waddell, R. K., 1977, Environmental geology of the Helotes quadrangle, Bexar County, Texas: The University of Texas at Austin, M.S. thesis (unpub.), 160 p.

Waterreus, P. A., 1992, Hydrogeology of the Camp Bullis area, northern Bexar County: The University of Texas at San Antonio, M.S. thesis (unpub.), 186 p.

Waugh, J. R., and Walthour, S. D., 1993, Government Canyon geologic and hydrologic assessment: Edwards Underground Water District, Field Operations Division Report 93-10, 14 p.

Welder, F. A., and Reeves, R. D., 1964, Geology and ground-water resources of Uvalde County, Texas: U. S. Geological Survey Water-Supply Paper 1584, 49 p.

Young, K., 1972, Mesozoic history, Llano region, *in* Barnes, V. E., Bell, W. C., Clabaugh, S. E., Cloud, P. E., Jr., McGehee, R. V., Rodda, P. U., and Young, K., eds., Geology of the Llano region and Austin area, field excursion: The University of Texas at Austin, Bureau of Economic Geology Guidebook 13, 77 p.

TABLES

TABLE 1
STRATIGRAPHIC UNITS AND THEIR WATER-BEARING PROPERTIES

System	Series	Stage/Group	Stratigraphic Unit		Hydrologic Unit		Approximate Thickness (feet)	Character of Rocks	Water-Bearing Properties
Cretaceous	Comanche	Washita	Buda Limestone and Del Rio Clay				100-200	Dense, hard, nodular limestone in the upper part and clay in lower part. Thickens to the west.	Upper confining unit.
		Fredericksburg	Edwards and associated limestones		Edwards aquifer (See Table 2 for additional detail.)		500-700	Hard, massive, cherty limestone; marly shale at bottom. Cavernous in places. Thickens to the west.	Yields moderate to large quantities of fresh water.
		Trinity	Glen Rose Formation	Upper member	Upper Trinity aquifer unit	Trinity Group aquifer	500-1,500	Alternating resistant and nonresistant beds of shale, nodular marl and fossiliferous limestone. Also contains distinct evaporite beds.	Lower confining unit. Yields small quantities of fresh to mineralized water.
				Lower member	Middle Trinity aquifer unit			Massive, fossiliferous limestone grading upward into thin beds of limestone, dolomite, marl and shale with numerous caves and reefs.	Yields small to large quantities of fresh to slightly saline water.
			Travis Peak Formation (Pearsall in subsurface)	Hensell Sand member			300-400	Red to gray clay, silt, sand, conglomerate and thin limestone beds grading downdip into finer grained material.	
				Bexar Shale member				Marl and shaley limestone, to silty dolomite.	
				Cow Creek Limestone member				Massive, fossiliferous, white to gray, argillaceous to dolomitic limestone with local thin beds of sand, shale and lignite. Moldic porosity near top.	
				Hammett Shale member				Dark blue to gray, fossiliferous, dolomitic shale with thin interbedded layers of limestone and sand.	Not known to yield water.
				Sligo Limestone member	Lower Trinity aquifer unit		100-1,500	Sandy dolomitic limestone.	Yields small to moderate quantities of slightly saline to saline water.
				Hosston Sand member				Red and white conglomerate, sandstone, claystone, shale, dolomite and limestone.	
Pre-Cretaceous rocks								Black, red and green, folded shale, hard massive dolomite, limestone, sandstone and slate.	Not known to yield water.

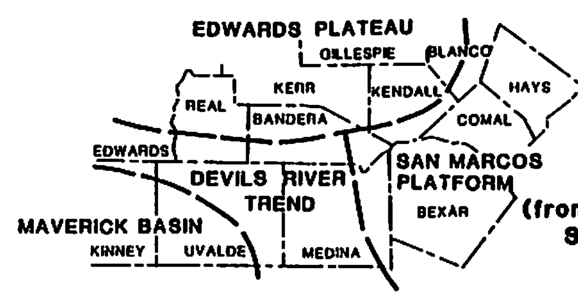
TABLE 2
CORRELATION OF LOWER CRETACEOUS STRATIGRAPHY IN THE SAN ANTONIO REGION

SERIES	AGE	MAVERICK BASIN	DEVILS RIVER TREND	SAN MARCOS PLATFORM			HYDROGEOLOGY	
							AQUIFER SUBDIVISIONS[3]	
UPPER CRETACEOUS	GULF AGE	AUSTIN GROUP	AUSTIN GROUP	AUSTIN GROUP			AQUIFER	
		EAGLE FORD GROUP	EAGLE FORD GROUP	EAGLE FORD GROUP			CONFINING UNIT	
	LATE WASHITA AGE	BUDA LIMESTONE	BUDA LIMESTONE	BUDA LIMESTONE				
		DEL RIO CLAY	DEL RIO CLAY	DEL RIO CLAY				
LOWER CRETACEOUS		SALMON PEAK[1] FORMATION	DEVILS RIVER LIMESTONE	GEORGETOWN FORMATION			I	EDWARDS AQUIFER
	EARLY WASHITA AGE			EDWARDS GROUP[2]	PERSON[2] FORMATION	Cyclic and Marine Members	II	
						Leached and Collapsed Members	III	
						Regional Dense Member	IV	
	FREDERICKSBURG AGE	McKNIGHT[1] FORMATION / WEST NUECES[1] FORMATION			KAINER[2] FORMATION	Grainstone Member	V	
						Kirschberg Evaporite	VI	
						Dolomitic Member	VII	
						Basal Nodular Member	VIII	
	TRINITY AGE	GLEN ROSE FORMATION	GLEN ROSE FORMATION	GLEN ROSE FORMATION	UPPER		CONFINING UNIT	
					LOWER		AQUIFER	

[1] Of Lozo and Smith, 1964

[2] From Rose, 1972

[3] Aquifer Subdivisions from Maclay and Small, 1984



(from Maclay and Small, 1986)

TABLE 3
RECORDS OF INVENTORIED WELLS IN THE HABY CROSSING FAULT AREA

Well Number	Well Owner	Latitude	Longitude	Year Completed	Well Depth (feet)	Producing Unit [1/]	Land-Surface Elevation (feet above MSL)	Water-Level Data: MP above Land Surface (feet)	Water-Level Data: Date of Measurement	Water-Level Data: Depth to Water (feet)	Water-Level Data: Elevation (feet above MSL)
TD-68-25-9gi3	BMA	293014	985412	1989	217	Ked	890	2.7	7/15/94	22.04	870.66
TD-68-25-9ha7	BMA (Patteson)	293034	985407	1989	430	Kgr	980	0.7	7/13/94	104.52	876.18
AY-68-26-3ih3	EUWD (Little windmill)	293513	984519	--	--	Kgr	1,190	0.9	3/31/94	59.95	1,130
TD-68-26-5ea6	Doug McNeel	293401	984853	--	--	Kgr	1,128	0.3	7/8/94	55.34	1,072.96
TD-68-26-5he1	Quarry Material Corp.	293301	984847	1939	--	Kgr?	1,245	--	--	--	--
AY-68-26-6fg1	EUWD (Wildcat well)	293333	984548	--	286	Kgr	1,044	0	6/2/94	134.78	909.22
TD-68-26-7bd4	Redland Worth	293207	985133	1980	863	Kgr	1,178	--	--	--	--
TD-68-26-7hc4	G. Schultze	293042	985101	~1982	--	Ked	1,056	--	--	--	--
TD-68-26-8ai7	Medina Crushed Stone	293143	984923	--	--	Ked?	1,041	--	--	--	--
TD-68-26-8ai9	Medina Crushed Stone	293140	984914	1990	950	Ked	1,019	1.9	6/16/94	178.8	842.1
TD-68-26-8bb5	Quarry Material Corp.	293221	984843	1950	671	Kgr	1,045	0.75	6/29/94	125.69	920.06
AY-68-26-8cd2	R. E. McDonald	293209	984812	~1943	218	Kau	1,070	--	--	--	--
AY-68-26-9fe5	Larry Perkins	293115	984522	--	~400	Ked	965	0.5	7/22/94	224.58	740.92
AY-68-27-4fe8	C. Beeche/J. Bocquet	293338	984256	--	--	Kgr	1,083	--	--	--	--
AY-68-27-4fe9	Earl Herring	293341	984250	1974	650	Kgr	1,094	1.7	6/27/94	305.26	790.44
AY-68-27-4ff1	Mudd	293343	984244	--	--	Kgr	1,088	2.3	6/28/94	303.81	786.49
AY-68-27-4ff9	Clayton Nolte	293341	984231	--	--	Ked	1,044	1.5	7/21/94	278.79	766.71
AY-68-27-4fh5	Wooten	293326	984251	--	--	Ked	1,058	3.2	6/28/94	270.84	790.36
AY-68-27-4fi4	Page	293330	984241	1992	420	Ked	1,088	3.25	6/30/94	309.65	781.6
AY-68-27-4gb4	EUWD (-401 well)	293310	984438	--	--	Ked	1,032	1.05	7/20/94	260.23	772.82
AY-68-27-5bg9	Our Lady of Guadalupe Church	293413	984125	--	--	Kgr	1,010	0.15	7/8/94	134.04	876.11
AY-68-27-5ee1	J. D. Smith	293352	984119	--	~410	Ked	1,001	1.1	7/14/94	248.07	754.03
TD-68-33-3ba4	H. Haby	292952	985406	--	400	Ked	926	1.1	7/15/94	57.37	869.73

FOOTNOTE: [1/] Producing unit: Ked - Edwards aquifer
Kgr - Glen Rose aquifer
Kau - Austin Chalk

TABLE 4
RESULTS OF CHEMICAL ANALYSES FROM THE HABY CROSSING FAULT AREA

Well ID Number	Trilinear Diagram Number in Figure 10	Producing Unit [1/]	Sample Date	Sample Time	Well Depth (feet)	Pumping or Flow Period Prior to Sampling (minutes)	Flow Rate (gpm)	Water Temper-ature (° C)	Field Specific Conduct-ance (mS/cm)	Lab Specific Conduct-ance (mS/cm)	Field pH (units)	Lab pH (units)	Alka-linity (mg/l as $CaCO_3$)
TD-68-25-9gi3	1	Ked	7/15/94	1140	217	90	11	21.0	451	450	7.5	7.2	184
TD-68-26-5he1	2	Ked?	6/29/94	1730	671?	60	~10	24.0	484	488	6.4	7.3	211
TD-68-26-7hc4	3	Ked	7/20/94	2010	795	30	~85	22.5	522	500	7.3	7.5	204
TD-68-26-8ai7	4	Ked?	--	--	--	Windmill	~5-10	22.0	674	--	--	--	--
TD-68-26-8ai9	5	Ked	6/16/94	1515	950	65	149	23.5	504	500	6.3	7.0	208
AY-68-26-9fe5	6	Ked	7/22/94	1505	~400	75	~5-10	21.5	660	680	7.4	7.5	214
AY-68-27-4fl9	7	Ked	7/21/94	1735	300+	31	~5-10	23.0	572	530	7.3	7.2	242
AY-68-27-4fh5	8	Ked	6/28/94	1605	300+	60	--	24.0	486	486	7.3	7.1	216
AY-68-27-4fi4	9	Ked	6/30/94	1500	420	60	~100	22.5	479	469	6.7	7.3	218
AY-68-27-4gb4	10	Ked	7/20/94	1645	300+	200	~10-20	23.0	560	510	7.3	7.4	210
AY-68-27-5eel	11	Ked	7/14/94	1120	~410	45	~15	22.5	500	487	7.1	7.2	222
TD-68-33-3ba4	12	Ked	7/15/94	1500	260	16+	--	22.0	1,071	1,000	7.3	7.1	248
Average								**22.6**	**580**	**555**	**7.1**	**7.3**	**216**
Median								**22.5**	**513**	**500**	**7.3**	**7.2**	**214**
Maximum								**24.0**	**1,071**	**1,000**	**7.5**	**7.5**	**248**
Minimum								**21.0**	**451**	**450**	**6.3**	**7.0**	**184**
TD-68-25-9ha7	13	Kgr	7/13/94	1600	430	38	>10	21.5	688	650	7.2	7.4	204
TD-68-26-5ca6	14	Kgr	7/08/94	1025	--	Windmill	~2-5	25.0	3,040	2,620	6.3	7.4	192
AY-68-26-6fg1	15	Kgr	6/01/94	1510	671?	230	6	22.5	2,230	2,130	7.1	7.0	192
TD-68-26-7bd4	16	Kgr	7/21/94	1350	863	360+	~120	24.0	2,870	2,530	6.9	6.9	162
TD-68-26-8bb5	17	Kgr	6/29/94	1630	671	310	11	23.0	2,520	2,190	6.5	7.0	204
AY-68-27-4fc8	18	Kgr	6/24/94	1150	--	20	5	24.0	1,560	1,550	7.3	7.1	224
AY-68-27-4fe9	19	Kgr	6/27/94	1940	650	30	8	23.5	2,400	2,400	7.1	7.0	208
AY-68-27-4ff1	20	Kgr	6/28/94	1215	~300	60	~10	24.0	1,150	1,170	7.3	7.1	232
AY-68-27-5bg9	21	Kgr	7/08/94	1445	--	40	~5-10	23.5	1,730	1,730	7.0	7.2	234
Average								**23.4**	**2,021**	**1,886**	**7.0**	**7.1**	**206**
Median								**23.5**	**2,230**	**2,130**	**7.1**	**7.1**	**204**
Maximum								**25.0**	**3,040**	**2,620**	**7.3**	**7.4**	**234**
Minimum								**21.5**	**688**	**650**	**6.3**	**6.9**	**162**

FOOTNOTE: [1/] Producing unit: Ked - Edwards aquifer; Kgr - Glen Rose aquifer

Well ID Number	Hardness Total (mg/l as $CaCO_3$)	Calcium, Dissolved (mg/l as $CaCO_3$)	Magnesium, Dissolved (mg/l as Mg)	Sodium, Dissolved (mg/l as Na)	Potassium, Dissolved (mg/l as K)	Chloride, Dissolved (mg/l as Cl)	Sulfate, Dissolved (mg/l as SO_4)	Fluoride, Dissolved (mg/l as F)	Silica, Dissolved (mg/l as SiO_2)	Solids, Sum of Constituents, Dissolved (mg/l)	Strontium, Dissolved (mg/l (as Sr)
TD-68-25-9gi3	216	70	13	7.0	1.0	18	31	0.14	5.60	296	0.64
TD-68-26-5he1	240	66	18	5.0	0.5	20	22	0.26	3.52	368	0.50
TD-68-26-7hc4	250	75.4	18	7.5	<1	18	55	0.34	7.80	372	0.90
TD-68-26-8ai7	--	--	--	--	--	--	--	--	--	--	--
TD-68-26-8ai9	248	82.2	15	8.0	2.0	16	31	0.23	6.30	340	0.56
AY-68-26-9fe5	288	84.5	22	35.0	<1	60	60	0.47	8.00	488	1.28
AY-68-27-4ff9	268	97.2	13	11.0	<1	23	31	0.22	7.50	368	0.62
AY-68-27-4fh5	236	88.8	11	5.0	1.0	16	17	0.13	4.32	308	0.40
AY-68-27-4fi4	220	79.8	9	4.0	0.0	17	14	0.12	4.06	292	0.24
AY-68-27-4gb4	260	85.2	18	9.0	<1	18	49	0.34	8.50	388	0.94
AY-68-27-5cc1	244	71.8	16	6.0	<1	17	14	0.20	5.20	328	0.76
TD-68-33-3ba4	440	87.2	57	64.0	3.0	49	242	0.50	6.00	756	19.04
Average	**265**	**80.7**	**19.1**	**14.7**	**1.3**	**25**	**51**	**0.27**	**6.07**	**391**	**2.35**
Median	**248**	**82.2**	**16.0**	**7.5**	**1.0**	**18**	**31**	**0.23**	**6.00**	**368**	**0.64**
Maximum	**440**	**97.2**	**57.0**	**64.0**	**3.0**	**60**	**242**	**0.50**	**8.50**	**756**	**19.04**
Minimum	**216**	**66.0**	**9.0**	**4.0**	**0.0**	**16**	**14**	**0.12**	**3.52**	**292**	**0.24**
TD-68-25-9ha7	344	66.6	44	10.0	1.0	17	128	0.79	5.30	488	3.10
TD-68-26-5ea6	2,200	538	185	10.0	4.5	40	1,631	3.85	4.14	3,172	10.62
AY-68-26-6fg1	1,460	417	120	20.0	9.0	45	1,055	3.15	5.90	2,224	12.96
TD-68-26-7bd4	1,980	567	127	14.0	6.0	18	1,710	3.00	8.00	3,002	10.30
TD-68-26-8bb5	1,656	520	95	11.5	4.5	19	1,203	2.65	3.21	2,528	15.06
AY-68-27-4fe8	936	178.4	117	0.0	10.0	45	543	4.20	3.78	1,260	10.10
AY-68-27-4fe9	1,636	438	144	13.0	8.8	20	1,428	4.17	4.56	2,436	9.22
AY-68-27-4ff1	656	121	92	11.0	7.0	50	349	4.17	4.20	940	12.30
AY-68-27-5bg9	1,200	367	67	16.0	2.5	50	861	2.35	3.96	1,664	14.96
Average	**1,341**	**357.0**	**110.1**	**13.1**	**5.9**	**34**	**990**	**3.15**	**4.78**	**1,968**	**10.96**
Median	**1,460**	**417.0**	**117.0**	**12.0**	**6.0**	**40**	**1,055**	**3.15**	**4.20**	**2,224**	**10.62**
Maximum	**2,200**	**567.0**	**185.0**	**20.0**	**10.0**	**50**	**1,710**	**4.20**	**8.00**	**3,172**	**15.06**
Minimum	**344**	**66.6**	**44.0**	**10.0**	**1.0**	**17**	**128**	**0.79**	**3.21**	**488**	**3.10**

TABLE 5
STATISTICS OF CHEMICAL CONSTITUENTS DETECTED IN SAMPLES FROM OTHER EDWARDS AQUIFER WELLS IN THE SAN ANTONIO REGION

Wells by County Sampled in 1994 by EUWD Representatives

Bexar	Comal	Hays	Medina	Uvalde	Surface Water Sampled
AY-68-28-203	DX-68-15-901	LR-67-01-302	TD-68-25-071	YP-69-36-702	Medina River
AY-68-28-501	DX-68-16-502	LR-67-01-801	TD-68-26-701	YP-69-50-203	Frio River
AY-68-28-904	DX-68-22-901	LR-67-01-806	TD-68-33-202	YP-69-50-506	Dry Frio River
AY-68-29-109	DX-68-22-902	LR-67-09-105	TD-68-41-303		Nueces River
AY-68-29-405	DX-68-23-156	LR-67-09-111	TD-69-29-901		Sabinal River
AY-68-29-410	DX-68-23-301		TD-69-40-403		Seco Creek
AY-68-36-803	DX-68-23-302		TD-69-47-301		Hondo Creek
AY-68-36-908	DX-68-23-303				
	DX-68-23-305				

	pH (units)	Alkalinity, mg/l as $CaCO_3$	Calcium, Dissolved mg/l as $CaCO_3$	Magnesium, Dissolved mg/l as Mg	Sodium, Dissolved mg/l as Na	Potassium, Dissolved mg/l as K	Chloride, Dissolved mg/l as Cl	Sulfate, Dissolved mg/l as SO_4	Fluoride, Dissolved mg/l as F	Silica, Dissolved mg/l as SiO_2	Solids, Sum of Constituents, Dissolved (mg/l)
Bexar County (8 total)											
Average	7.2	256	98	11	12	1.4	25	15	0.11	7.1	246
Median	7.1	259	101	11	11	1.3	23	14	0.10	7.1	246
Maximum	7.6	297	126	17	21	2.0	44	27	0.19	8.3	272
Minimum	6.9	200	71	4	8	1.0	17	7	0.02	5.4	224
Comal County (9 total)											
Average	7.1	244	90	15	9	1.3	18	19	0.19	7.0	269
Median	7.2	245	89	15	9	1.0	18	17	0.18	6.7	272
Maximum	7.3	262	103	17	12	2.0	21	37	0.33	8.7	308
Minimum	6.7	222	82	11	6	1.0	14	8	0.06	6	240
Hays County (5 total)											
Average	7.3	238	93	22	12	1.3	27	48	0.78	6.5	315
Median	7.3	256	101	19	13	1.3	25	28	0.22	6.6	266
Maximum	7.4	258	113	40	15	2.0	34	134	2.98	7.8	506
Minimum	7.1	196	65	17	10	0.5	22	23	0.13	4.7	240
Medina County (7 total)											
Average	7.4	227	76	11	7	0.4	17	17	0.19	5.2	281
Median	7.4	226	75	9	8	0.2	16	13	0.18	5.2	280
Maximum	7.7	258	84	19	9	1.0	27	44	0.32	6.2	338
Minimum	7.2	212	67	6	5	0.2	13	6	0.08	3.4	244

	pH (units)	Alkalinity, mg/l as $CaCO_3$	Calcium, Dissolved mg/l as $CaCO_3$	Magnesium, Dissolved mg/l as Mg	Sodium, Dissolved mg/l as Na	Potassium, Dissolved mg/l as K	Chloride, Dissolved mg/l as Cl	Sulfate, Dissolved mg/l as SO_4	Fluoride, Dissolved mg/l as F	Silica, Dissolved mg/l as SiO_2	Solids, Sum of Constituents, Dissolved (mg/l)
Uvalde County (3 total)											
Average	7.5	200	82	11	16	1.3	37	15	0.12	5.1	319
Median	7.5	208	88	9	20	1.0	35	16	0.11	5.6	332
Maximum	7.6	212	90	15	20	2.0	42	18	0.19	6.3	336
Minimum	7.4	180	69	8	9	1.0	34	12	0.07	3.5	288
Medina and Bexar Counties (15 total)											
Average	7.3	232	87	11	9	0.9	21	16	0.15	6.2	263
Median	7.3	216	81	11	8	1.0	20	13	0.15	6.2	256
Maximum	7.7	297	126	19	21	2.0	44	44	0.32	8.3	338
Minimum	6.9	194	67	4	5	0.2	13	6	0.02	3.4	224
TOTAL WELLS, San Antonio Region (32 total)											
Average	7.3	233	89	14	10	1.1	23	22	0.27	6.4	278
Median	7.3	235	88	14	9	1.0	21	17	0.17	6.5	269
Maximum	7.7	297	126	40	21	2.0	44	134	2.98	8.7	506
Minimum	6.7	180	65	4	5	0.2	13	6	0.02	3.4	224
Surface Water Sampled in San Antonio Region (7 total)											
Average	8.3	155	61	13	7	1.0	17	31	0.16	6.8	250
Median	8.3	161	60	12	7	1.0	17	23	0.16	6.5	244
Maximum	8.3	172	76	18	7	1.0	17	68	0.31	7.7	324
Minimum	8.1	124	54	10	6	1.0	15	10	0.07	5.9	220

TABLE 6
TRANSMISSIVITIES ESTIMATED FROM SPECIFIC-CAPACITY TESTS OF WELLS IN THE SAN ANTONIO REGION

County	2-1/2-Minute Quadrangle Location	Owner	Dis-charge (gpm)	Duration of Test (hours)	Well Radius (inches)	Draw-down (feet)	Total Depth (feet)	Producing Unit 1/	Estimated Transmis-sivity (gpd/ft)	COUNTY TOTALS Transmissivity (gpd/ft) Average	Median	Maximum	Minimum
BEXAR										1,161	480	8,976	1
	68-21-7	Dorothy Bonner	14	48.00	6	60	675	Kgr	385				
	68-21-8	Manuel Cantu	15	2.00	6	40	640	Kgr	488				
	68-21-8	Richard Landry	3	0.50	6	150	510	Kgru	14				
	68-21-9	Clyd Cox	60	0.25	6	20	475	Kgru	3,907				
	68-21-9	Mike Evetts	10	1.00	6	60	455	Kgru	180				
	68-21-9	Tom Lancaster	15	2.00	6	40	480	Kgru	488				
	68-26-3	Charles Hatzenbuehler	1	1.00	-	365	765	Kgr	2				
	68-26-3	Graham	12	1.00	-	15	450	Kgru	1,048				
	68-26-3	Robert Dickerson	11	0.75	-	112	850	Kgr	97				
	68-27-1	Arch C. Holden	10	1.00	6	60	320	Kgru	180				
	68-27-1	Bruce Hartman	14	1.00	-	15	280	Kgru(?)	1,239				
	68-27-1	Glen Bowman	18	1.00	-	12	380	Kgru	2,075				
	68-27-1	Joe Swinger	12	1.00	-	10	325	Kgru	1,628				
	68-27-1	John H. White	4	2.50	6	275	650	Kgr	13				
	68-27-2	Billy Floerke	5	1.00	-	30	515	Kgr	180				
	68-27-2	Bob Hewley	10	1.00	-	40	507	Kgr	281				
	68-27-2	Bill Liles	13	1.00	6	20	360	Kgru	836				
	68-27-2	Felix Madla	10	1.00	-	15	380	Kgru	859				
	68-27-2	Jim Burling	25	1.00	-	20	540	Kgru	1,702				
	68-27-2	John Hecker	10	1.00	-	25	500	Kgr	471				
	68-27-2	Phil Galm	15	1.00	-	30	350	Kgru	629				
	68-27-2	Rudy Zepeda	0.42	2.50	-	205	515	Kgru	1				
	68-27-3	Dr. Koli	30	0.25	-	30	795	Kgr	1,123				
	68-27-3	Tracy Smith	25	1.00	-	23	865	Kgr	1,462				
	68-27-4	Mike Lumman	15	1.00	-	16	500	Kgru	1,245				
	68-27-5	Raymond Costello	26	1.00	-	478	750	Kgr	52				
	68-28-1	S.W. Municipal Serv.	75	6.00	6	20	650	Kgr	6,566				
	68-28-1	S.W. Municipal Serv.	100	6.00	6	20	312	Kgr	8,976				

County	2-1/2-Minute Quadrangle Location	Owner	Discharge (gpm)	Duration of Test (hours)	Well Radius (inches)	Drawdown (feet)	Total Depth (feet)	Producing Unit 1/	Estimated Transmissivity (gpd/ft)	COUNTY TOTALS Transmissivity (gpd/ft) Average	Median	Maximum	Minimum
BEXAR (Continued)	68-28-2	Redland Worth Corp.	128	72.00	-	540	1,574	Kgr,Hensell Kcc, Hosston	405				
	68-29-1	Handy-Andy Inc.	15	2.00	6	180	682	Kgr	90				
	68-29-1	James D. Dement	20	0.50	6	75	500	Kgr	281				
	68-29-1	Sam Dunlap	10	2.00	6	50	635	Kgru	236				
COMAL										257	93	1,085	3
	68-14-7	Alan D. Moore	15	1.00	6	60	800	Kgr	281				
	68-14-7	Bill Byerly	15	2.00	6	60	800	Kgr	314				
	68-14-7	Ira West	18	2.00	6	40	700	Kgr	595				
	68-14-8	G.P. Construction	10	2.00	6	50	540	Kgr	236				
	68-15-4	Kasarak Ranch	8	2.00	6	140	400	Kgru	59				
	68-15-5	Henry Semler	3	0.75	6	492	589	Kgr	4				
	68-15-7	Henry McCloud	3	1.00	6	435	696	Kgr	5				
	68-15-8	Hanno F. Welschar	10	1.00	6	335	535	Kgru	26				
	68-16-1	David Doss	15	1.00	6	200	345	Kgru	75				
	68-16-1	Felix Gongola	5	2.50	6	110	520	Kgru	47				
	68-16-1	Rick Thompson	1.5	2.00	6	50	530	Kgru	29				
	68-16-2	Scott Vanghel	6	0.50	6	120	550	Kgru	3				
	68-16-2	Tom Reel	12	1.00	6	60	515	Kgru	219				
	68-16-4	Bob Ed Cockran	5	0.50	6	12.5	920	Kgr	439				
	68-16-4	Bob Fergurson	2	0.50	6	300	1,010	Kgr	4				
	68-22-1	Bobby McGee	15	1.00	6	100	594	Kgr	160				
	68-22-1	Joe L. Pleasant	12	1.50	6	15	600	Kgr	1,085				
	68-22-2	Robert Ohlrich	10	1.00	6	165	440	Kgru					
	68-22-2	Terrance Powell	10	2.00	6	100	455	Kgru	110				
	68-22-3	David Padalecki	1	1.50	6	35	512	Kgru	27				
	68-22-3	Donald L. Tousley	20	1.00	6	30	325	Kgru	859				
	68-22-3	Pat Simon	2	0.75	6	132	375	Kgru	12				
	68-22-3	Tandy Schubert	10	0.50	6	12	240	Kgru	986				

County	2-1/2-Minute Quadrangle Location	Owner	Dis-charge (gpm)	Duration of Test (hours)	Well Radius (inches)	Draw-down (feet)	Total Depth (feet)	Producing Unit 1/	Estimated Transmis-sivity (gpd/ft)	COUNTY TOTALS Transmissivity (gpd/ft) Average	Median	Maximum	Minimum
COMAL (Continued)	68-22-4	Natural Bridge Wildlife Ranch	8	0.50	6	265	655	Kgr	24				
	68-22-4	Raymond & Trudy Soechting	10	0.50	6	70	1,060	Kgr	141				
	68-22-5	Natural Bridge Wildlife Ranch	5	0.50	-	190	535	Kgru	21				
	68-23-4	Herberth H. Neuse	12	2.00	-	18	560	Kgru	913				
HAYS										40	37	95	6
	68-08-4	Sam Cutts Construction	10	0.50	6	100	434	Kgru	95				
	68-08-5	Jack Hoch	8	0.50	-	184	410	Kgru	37				
	68-08-5	Kenn Brown	5	0.50	-	415	660	Kgr	8				
	68-08-7	Andrew Tickle	8	0.50	-	220	470	Kgru	30				
	68-08-8	Bruce Ingram	8	0.50	-	135	500	Kgru	52				
	68-08-9	Carter Longhorn Ranch	2	1.50	-	250	665	Kgr	6				
	68-08-9	Gabril Doria	10	2.50	-	205	520	Kgru	51				
MEDINA										1,521	424	17,952	13
	68-25-6	Art Hinshaw	15	0.25	-	101	440	Kgru	136				
	68-25-6	Dan Rittimann	11	1.00	-	20	800	Kgr	697				
	68-25-6	John Suhr	5	1.00	-	80	530	Kgru	61				
	68-25-6	Tom Gibson	25	0.33	-	50	750	Kgr	538				
	68-25-7	Kermit Alsom	7	1.00	-	40	500	Kgru	190				
	68-25-7	Mike Tuck	5	1.50	-	30	740	Kgr	187				
	68-25-8	Medina Ranch, Inc.	30	3.00	-	40	320	Kgru	1,075				
	68-25-8	Phillip Becker	20	0.75	-	10	630	Kgr	2,768				
	68-25-9	W.L. Cunningham	40	3.00	-	140	400	Kgru	377				
	68-26-1	Bill McNeel	4	1.25	-	80	875	Kgr	49				
	68-26-1	John E. & M. Braziel	27.5	3.00	-	10	650	Kgr	4,412				
	68-26-2	Bill McNeel	6	0.50	-	215	818	Kgr	22				
	68-26-4	William P. Teich	100	3.00	-	10	700	Kgr	17,952				
	69-29-6	Ashley Rugh	10	1.00	-	90	580	Kgr	115				
	69-30-5	John Sturam	15	1.00	-	35	365	Kgru	509				
	69-31-4	H.H. Moeller	4	2.00	-	200	680	Kgru	19				

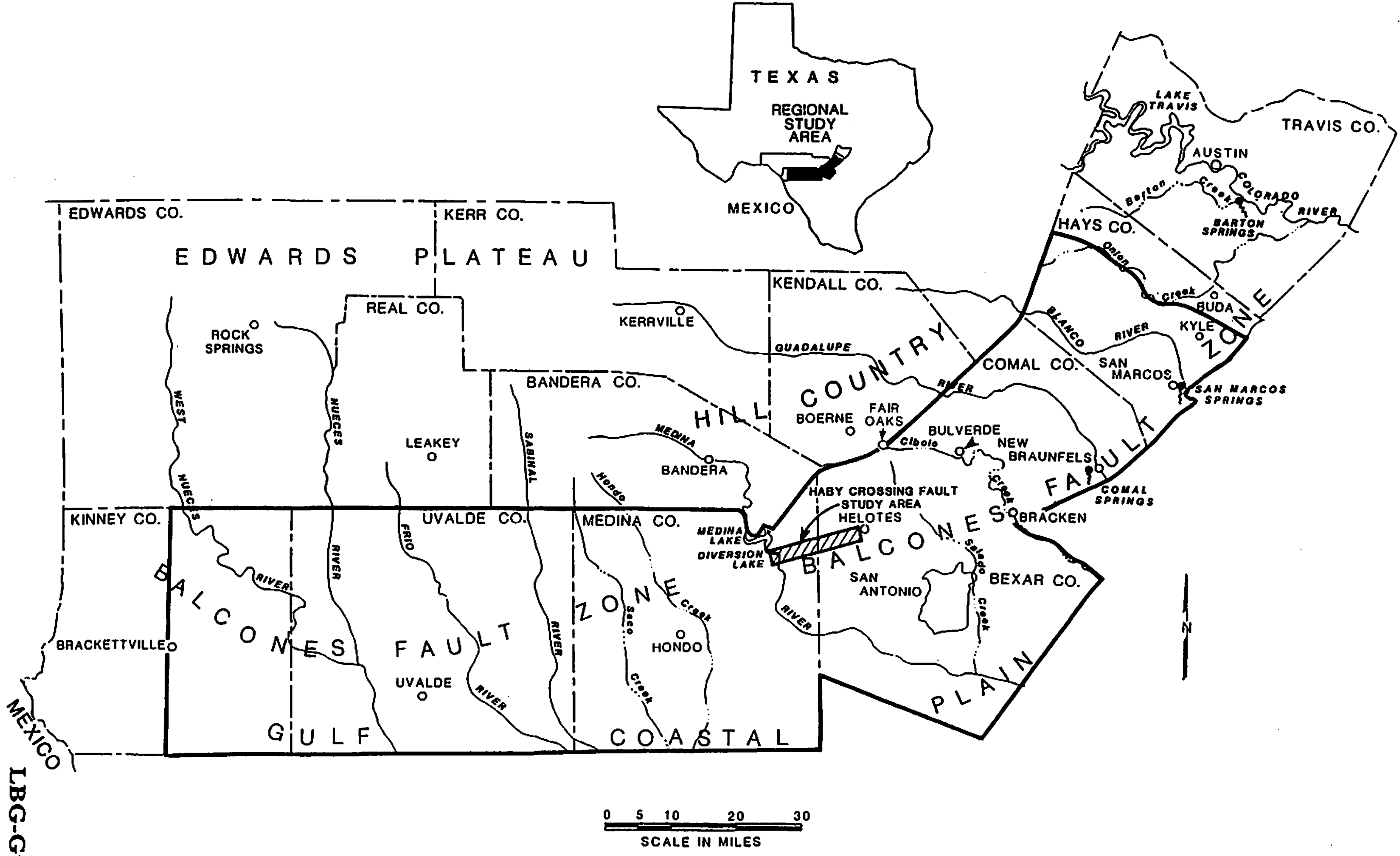
County	2-1/2-Minute Quadrangle Location	Owner	Discharge (gpm)	Duration of Test (hours)	Well Radius (inches)	Drawdown (feet)	Total Depth (feet)	Producing Unit 1/	Estimated Transmissivity (gpd/ft)	COUNTY TOTALS Transmissivity (gpd/ft) Average	Median	Maximum	Minimum
MEDINA (Continued)	69-31-6	Albert Gutierrez	20	1.00	-	50	485	Kgru	471				
	69-31-6	Barry Cox	10	2.00	-	70	415	Kgru	163				
	69-31-6	Mike Duerler	15	1.00	-	10	600	Kgru	2,075				
	69-32-5	Albert Haas	16	2.00	-	20	600	Kgru	1,113				
	69-32-6	Evelyn Franks	8	2.00	-	20	540	Kgru	524				
	69-32-9	W.L. Smith	3.5	0.50	-	200	440	Kgru	13				
UVALDE										1,259	499	5,212	24
	69-25-5	V.E. Cook, Jr.	60	1.00	6	86	110	Kgru	903				
	69-27-4	Herman Van Pelt	16	1.00	-	21	110	Kgru	994				
	69-27-4	Herman Van Pelt	20	1.00	-	6	110	Kgru	4,943				
	69-27-6	Buckie Murray	12	0.50	-	365	450	Kgru	27				
	69-27-7	Avant Camp	6.5	1.00	-	130	200	Kgru	48				
	69-27-7	Norment Foley	10	1.00	-	10	82	Kgru(?)	1,335				
	69-28-4	Bill Allen	35	1.00	-	10	250	Kgru	5,212				
	69-28-4	Marshall S. McCrea, Jr.	30	1.00	-	21	70	Kgru	1,968				
	69-28-4	Marshall S. McCrea, Jr.	1.5	2.50	-	57	100	Kgru	26				
	69-28-5	Bobby Harton	4.5	1.00	-	100	100	Kgru	42				
	69-28-6	H.H. Phillips	2	0.50	-	30	205	Kgru	60				
	69-28-6	H.H. Phillips	2	2.00	-	20	324	Kgru	95				
	69-28-9	Luois Germer	8	2.50	-	330	450	Kgru	24				
	69-29-7	Mary K. Kindred	25	1.25	-	18	152	Kgru	1,946				
ALL FIVE COUNTIES								TOTAL		942	219	17,952	1

FOOTNOTE: 1/ Producing unit: Kgr - Glen Rose Limestone
Kgru - Upper Glen Rose
Kcc - Cow Creek Limestone

TABLE 7
LENGTHS OF FAULTS, GLEN ROSE WATER-LEVEL GRADIENTS, ESTIMATED TRANSMISSIVITIES AND ESTIMATES OF GLEN ROSE UNDERFLOW TO THE EDWARDS AQUIFER IN THE SAN ANTONIO REGION

Cross Section	County	Length of Fault (miles)	Gradient (feet/mile)	Low Transmissivity (gpd/ft)	Low Volume of Discharge (ac-ft/yr)	High Transmissivity (gpd/ft)	High Volume of Discharge (ac-ft/yr)
A	Hays	17	16	50	15	1,000	305
B	Comal	8	25	100	22	3,100	694
C	Comal	4	27	100	12	3,100	375
D	Comal	5	25	100	14	3,100	434
E	Bexar	6	29	500	97	1,800	351
F	Bexar	0	--	500	0	1,800	0
G	Bexar	5	27	500	76	1,800	272
H	Bexar	4	28	500	63	1,800	226
I	Bexar	5	53	500	148	1,800	534
J(1)	Bexar	5	54	500	151	1,800	544
J(2)	Bexar	6	54	500	181	1,800	653
K(1)	Bexar	3	56	500	94	1,800	339
K(2)	Bexar	2	56	500	63	1,800	226
L(1)	Medina	2	56	450	56	1,700	213
L(2)	Medina	1	56	450	28	1,700	107
L(3)	Medina	2	56	450	56	1,700	213
M(1)	Medina	2	50	450	50	1,700	190
M(2)	Medina	2	50	450	50	1,700	190
M(3)	Medina	2	50	450	50	1,700	190
N(1)	Medina	3	50	450	76	1,700	286
N(2)	Medina	1	50	450	25	1,700	95
N(3)	Medina	1	50	450	25	1,700	95
O(1)	Medina	5	39	450	98	1,700	371
O(2)	Medina	5	39	450	98	1,700	371
P(1)	Medina	7	33	450	116	1,700	440
P(2)	Medina	5	33	450	83	1,700	314
Q(1)	Medina	5	29	450	73	1,700	276
Q(2)	Medina	5	29	450	73	1,700	276
R(1)	Medina	2	29	450	29	1,700	110
R(2)	Medina	2	29	450	29	1,700	110
S	Medina	2	29	450	29	1,700	110
T	Medina	3	29	450	44	1,700	166
U(1)	Medina	6	29	450	88	1,700	331
U(2)	Medina	6	30	450	91	1,700	343
V(1)	Uvalde	8	30	500	134	1,700	457
V(2)	Uvalde	10	30	500	168	1,700	571
W	Uvalde	0	--	500	0	1,700	0
X	Uvalde	0	--	500	0	1,700	0
Y	Uvalde	0	--	500	0	1,700	0
Z	Uvalde	5	33	500	92	1,700	314
ZZ	Uvalde	4	33	500	74	1,700	251
TOTALS		166			2,677		11,348

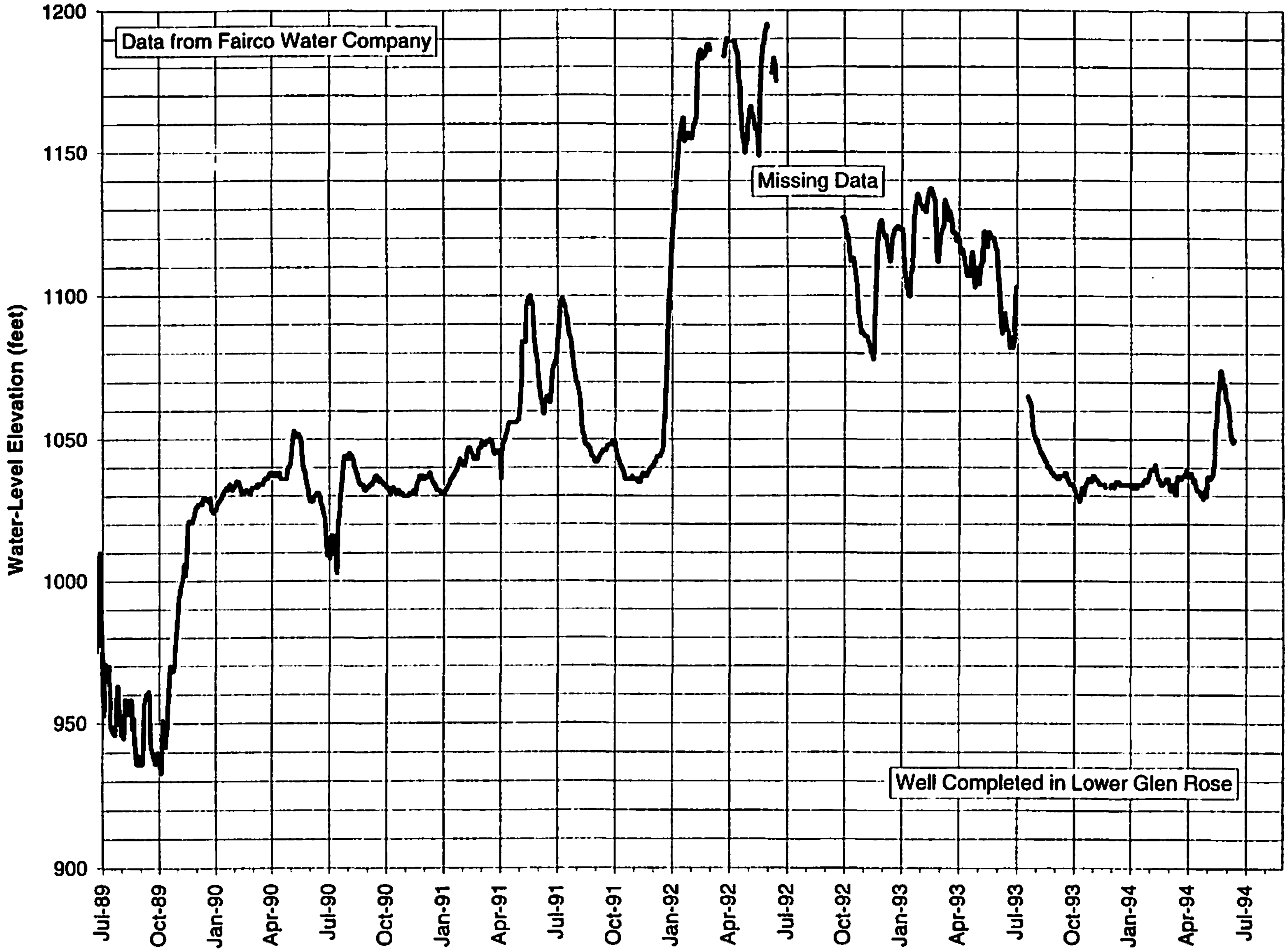
FIGURES



LOCATION OF STUDY AREA

FIGURE 1

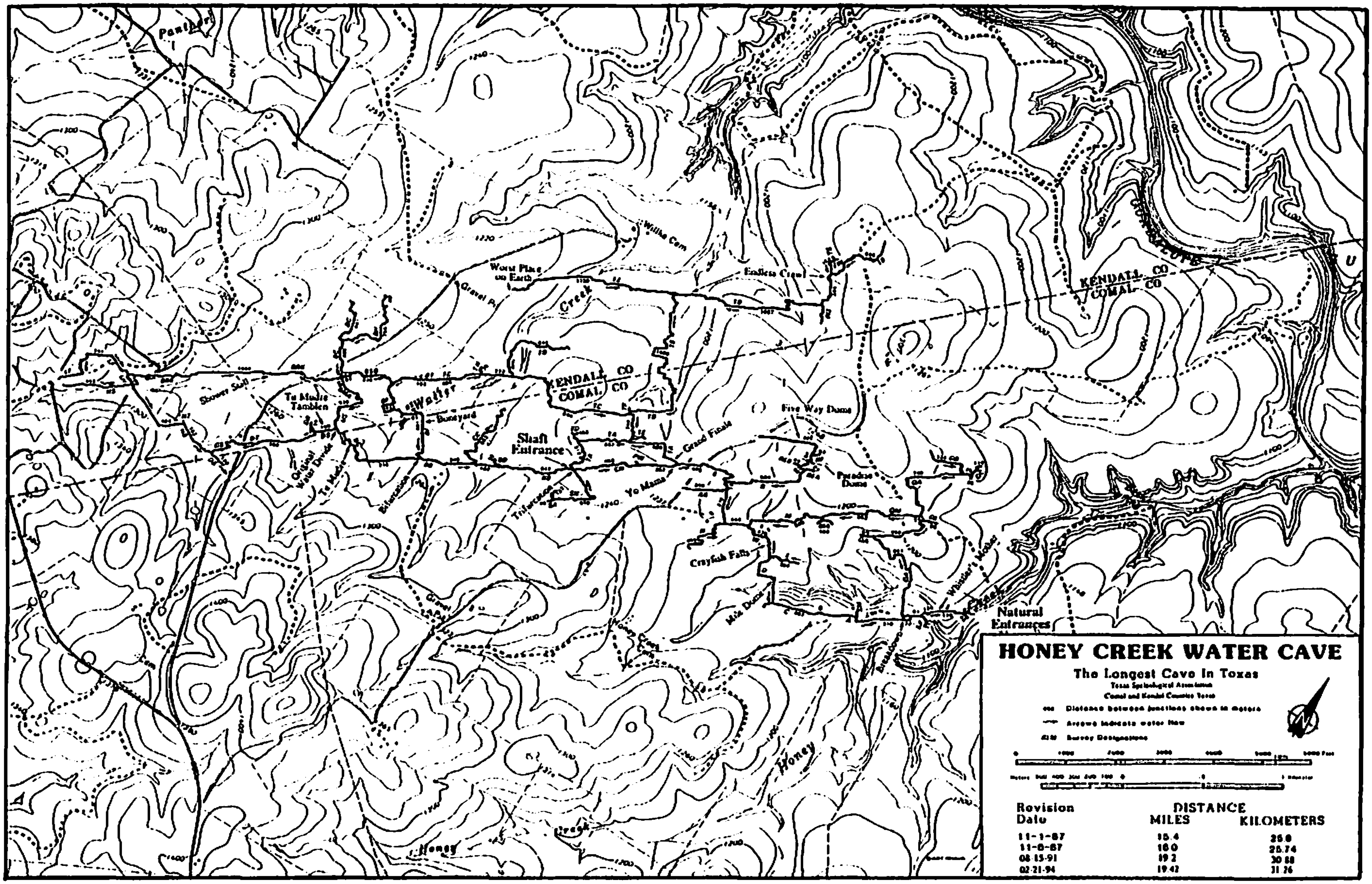
LBG-GUYTON ASSOCIATES



DAILY NOON WATER LEVELS IN MONITOR WELL AT FAIR OAKS, TEXAS

FIGURE 2

LBG-GUYTON ASSOCIATES

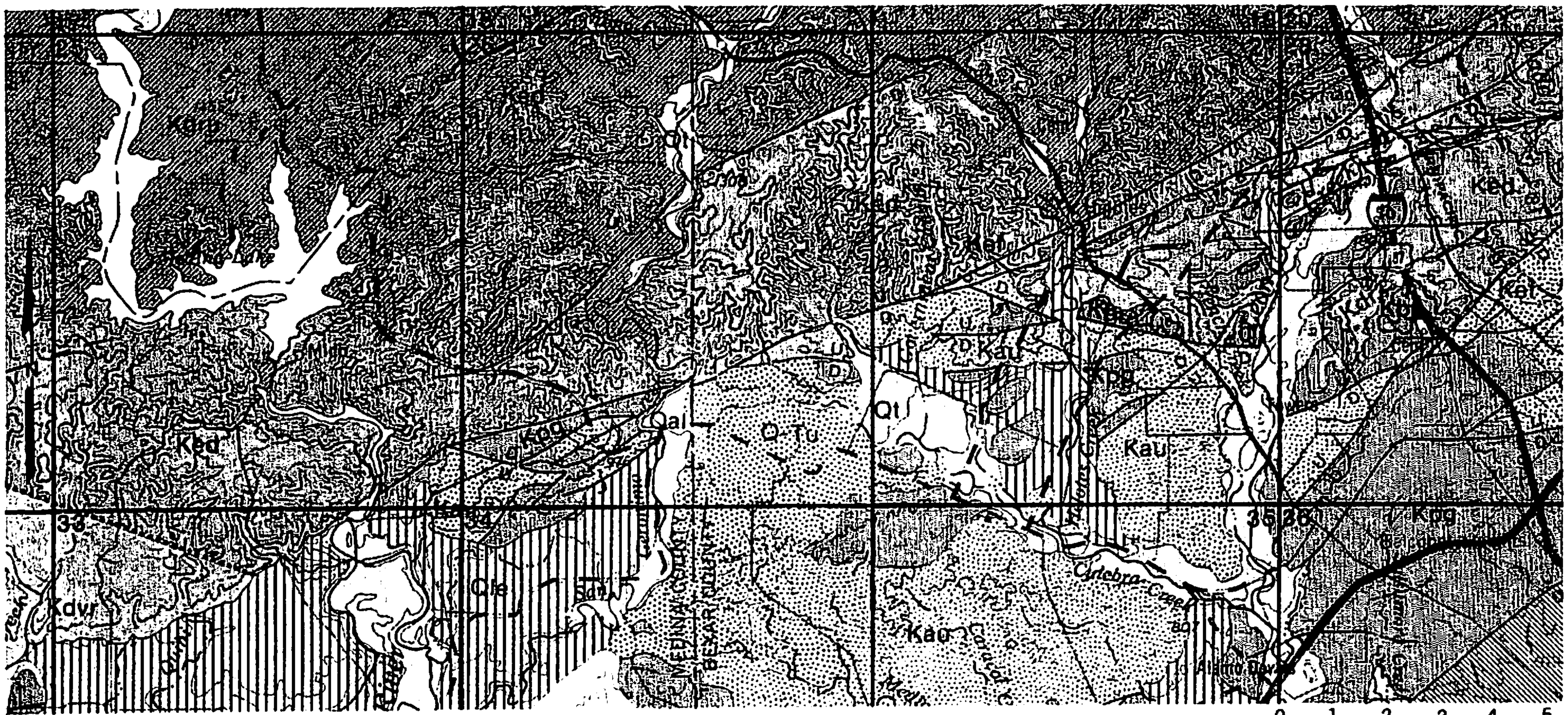


(from Veni, 1994a)

HONEY CREEK CAVE

FIGURE 3

LBG-GUYTON ASSOCIATES



EXPLANATION

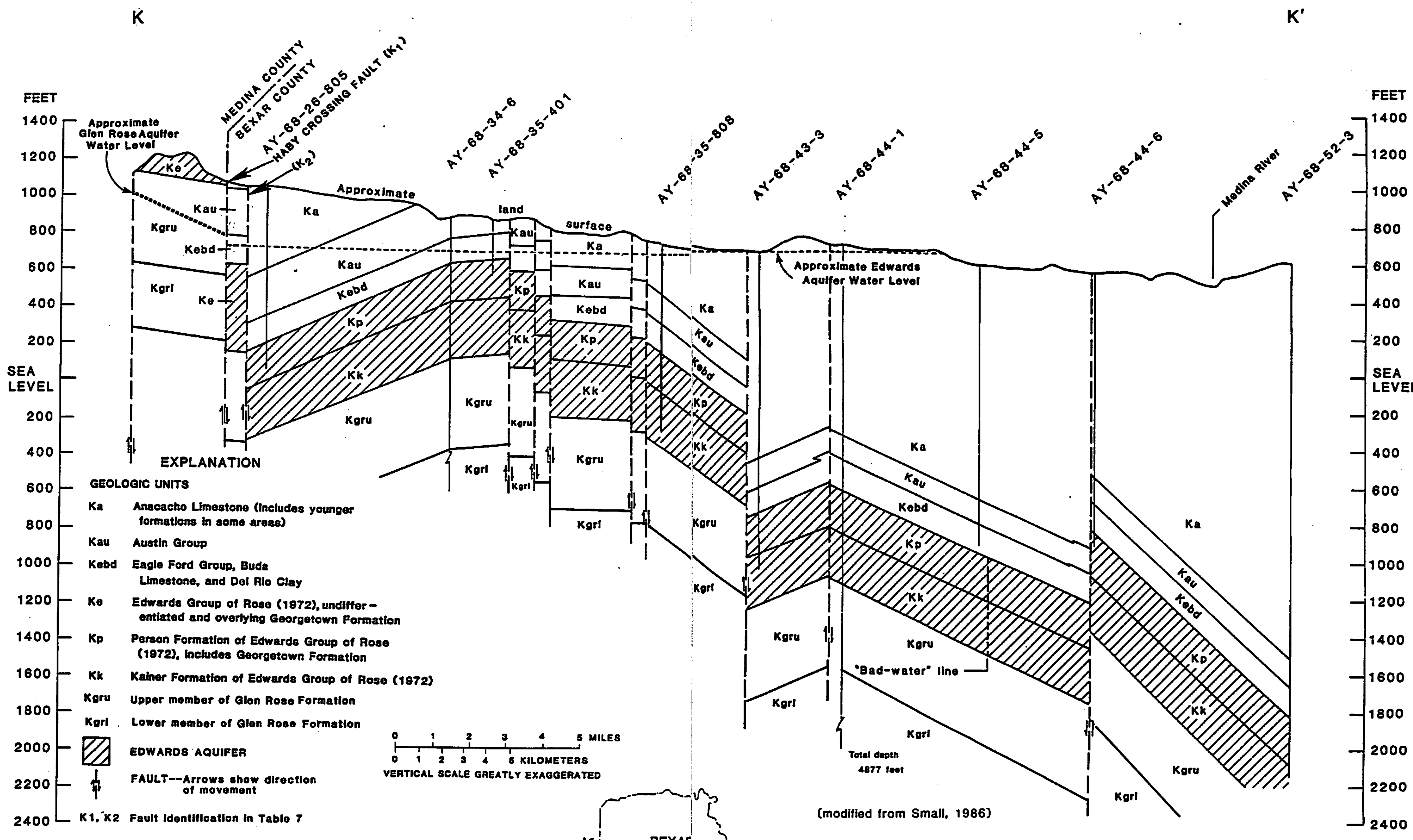
- Qal — Alluvium
- Qle — Leona Formation
- Kknm — Navarro Group
- Kau — Austin Chalk
- Kbu — Buda Limestone
- Ked — Edwards Limestone undivided
- Kgru / Kgrl — Glen Rose Formation
- Qt — Fluviatile terrace deposits
- Q-Tu — Uvalde Gravel
- Kpg — Pecan Gap Chalk
- Kef — Eagle Ford Group
- Kdr — Del Rio Clay

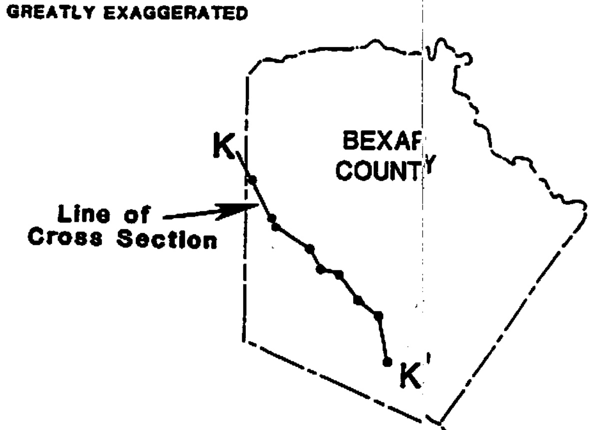
(modified from B.E.G. Geologic Atlas of Texas, San Antonio sheet, 1983)

SURFACE GEOLOGY IN THE HABY CROSSING FAULT AREA

FIGURE 4

LBG-GUYTON ASSOCIATES

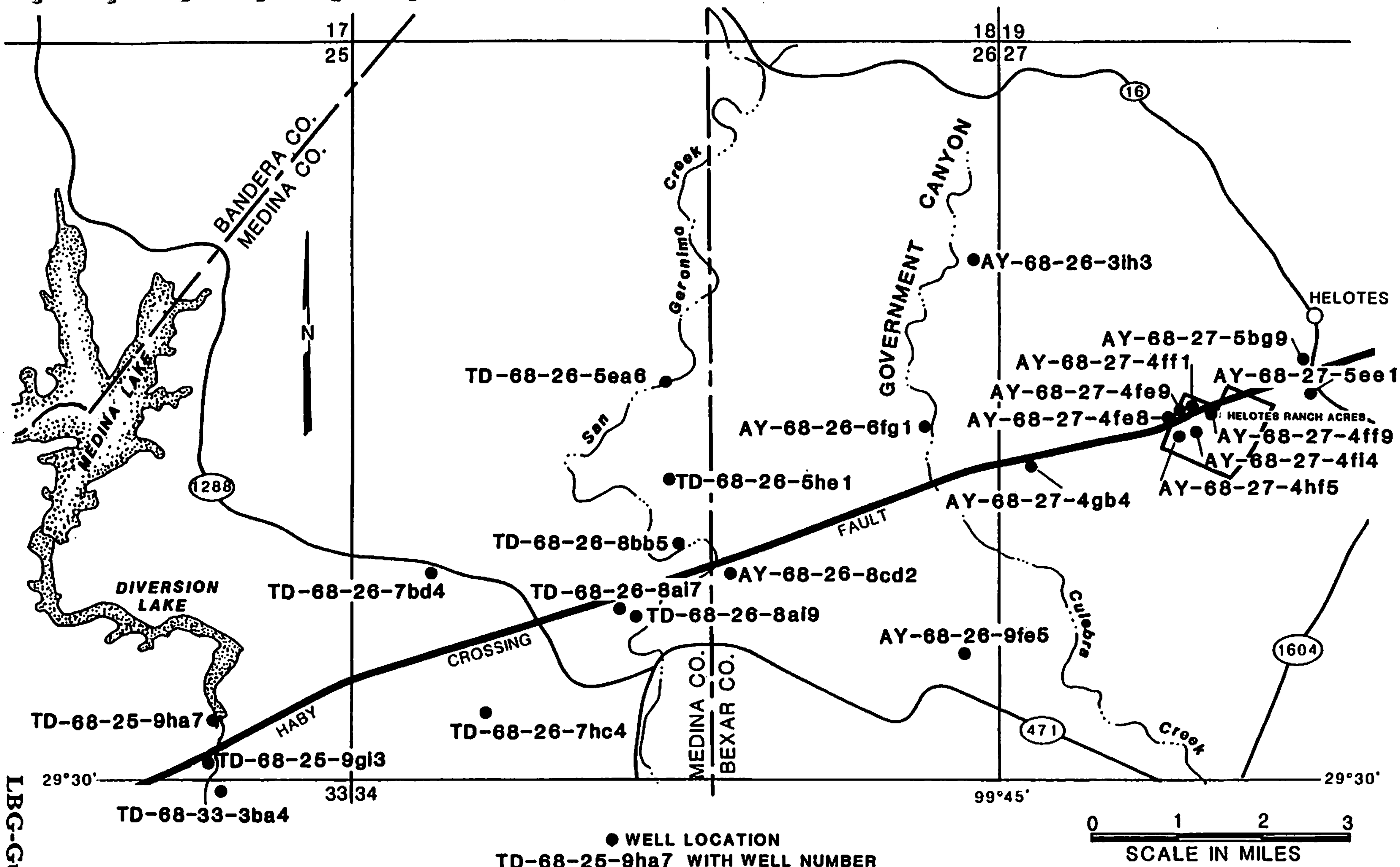




HYDROGEOLOGIC CROSS SECTION K TO K'

FIGURE 5

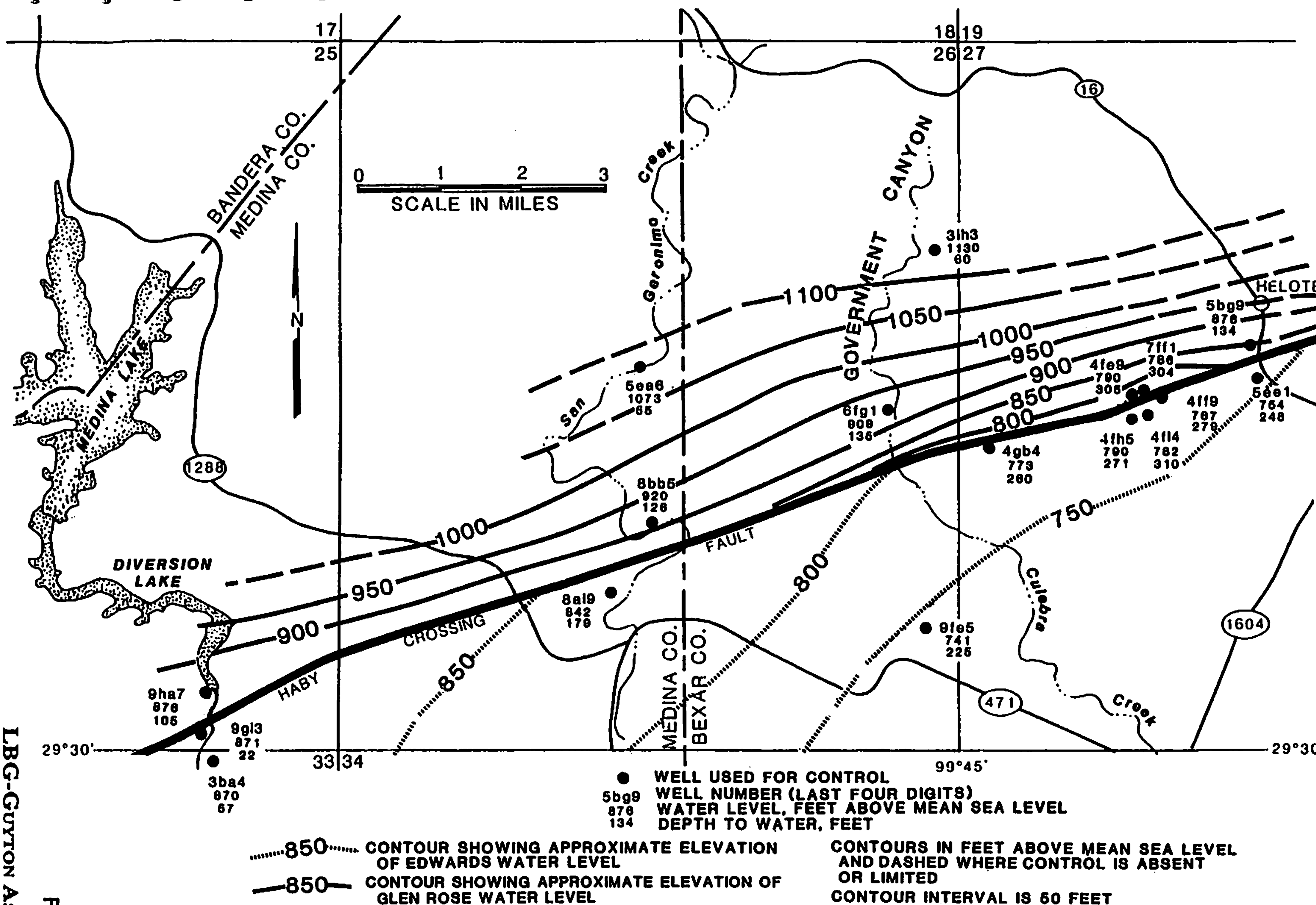
LBG-GUYTON ASSOCIATES



LOCATION OF INVENTORIED WELLS IN VICINITY OF HABY CROSSING FAULT

FIGURE 6

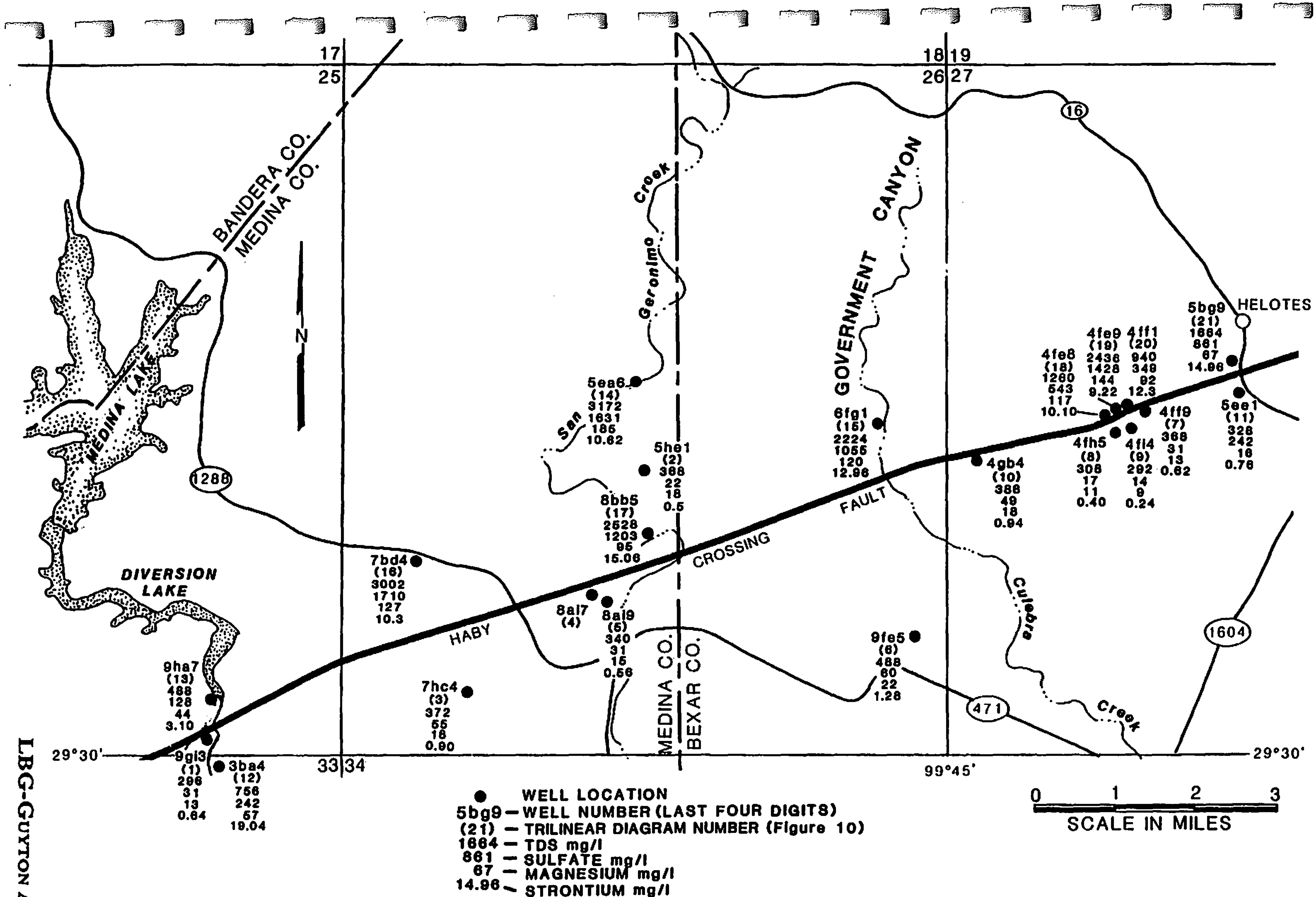
LBG-GUYTON ASSOCIATES



ELEVATION OF AND DEPTH TO WATER LEVELS IN THE GLEN ROSE AND EDWARDS AQUIFER IN THE VICINITY OF HABY CROSSING FAULT

FIGURE 7

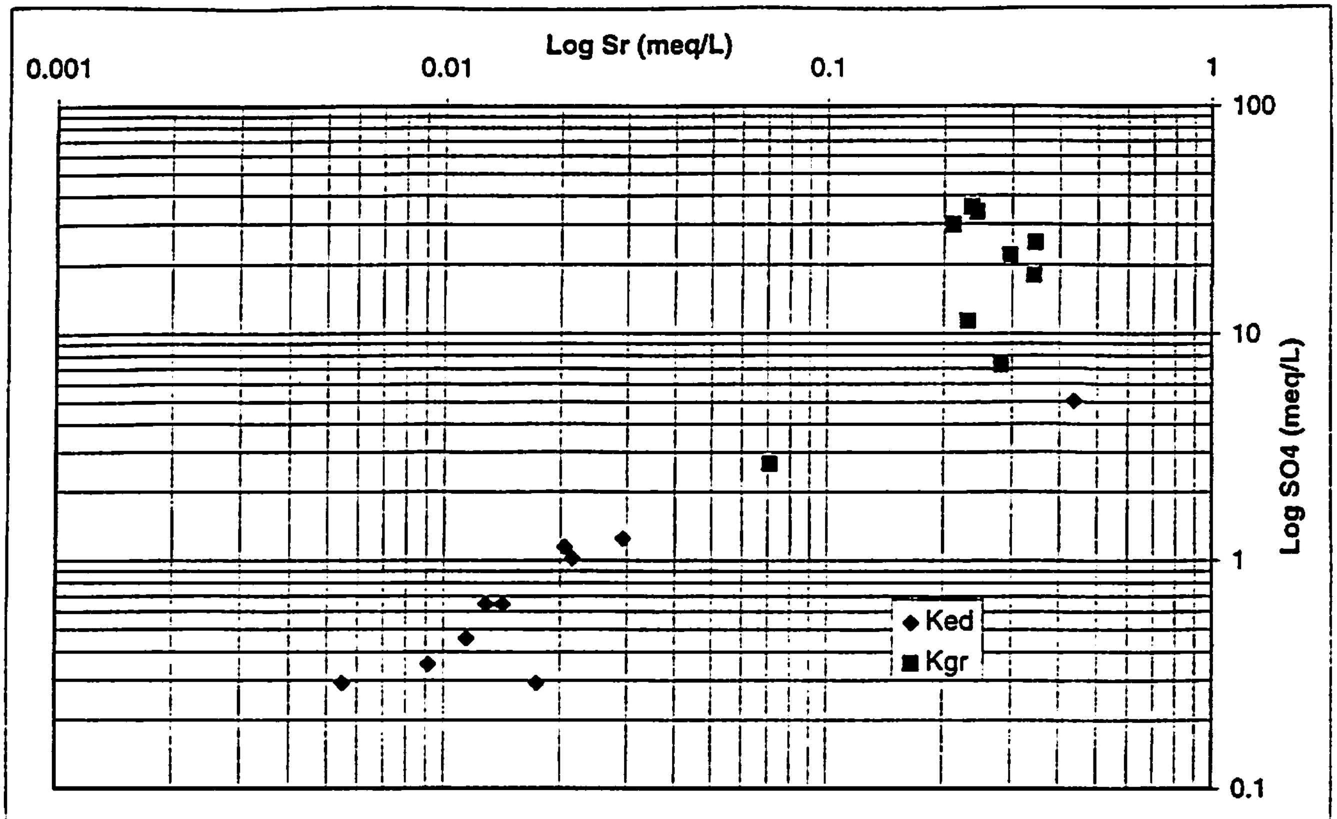
LBG-GUYTON ASSOCIATES

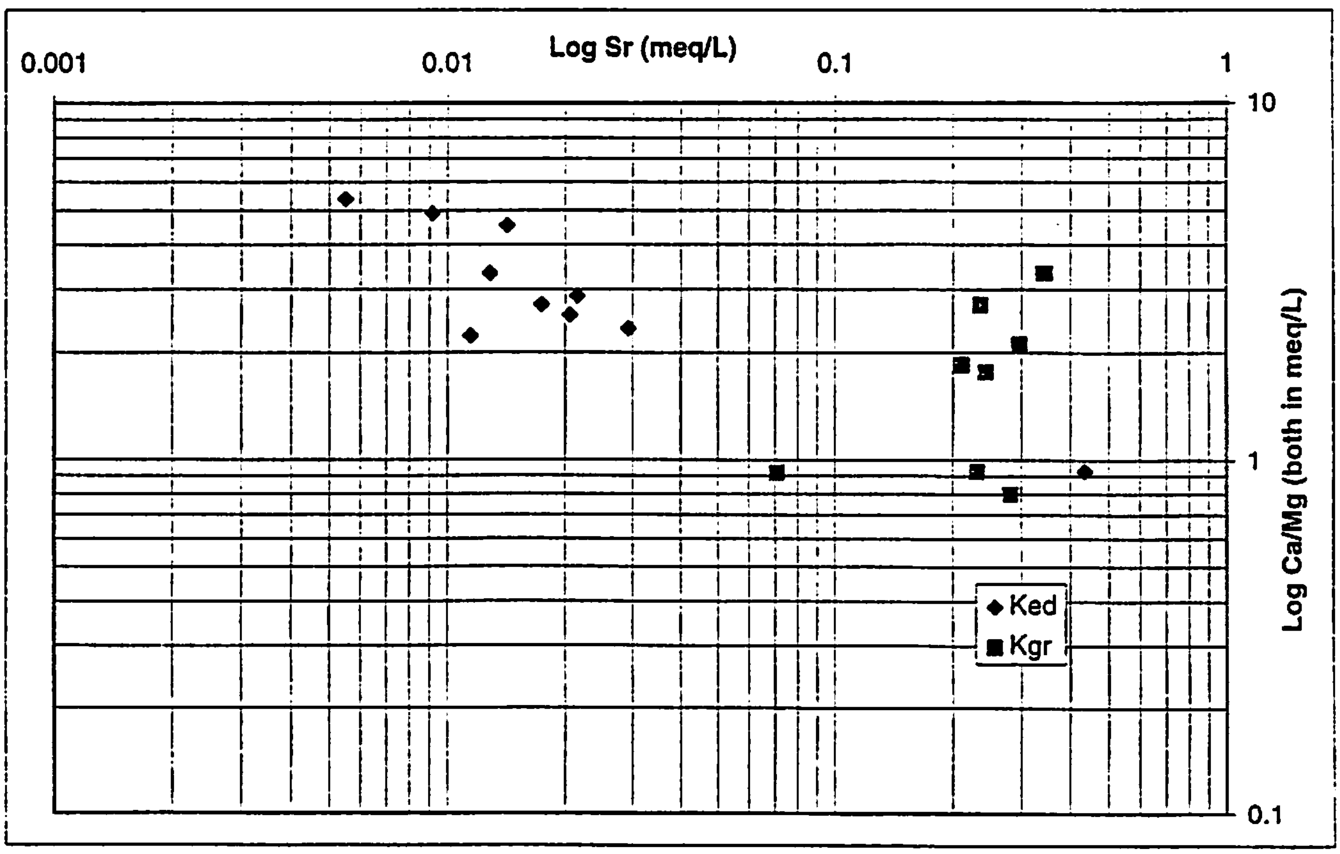


LBG-GUYTON ASSOCIATES

FIGURE 8

TOTAL DISSOLVED SOLIDS, SULFATE, MAGNESIUM, AND STRONTIUM CONTENT IN WATER SAMPLES RETRIEVED FROM WELLS IN THE HABY CROSSING FAULT AREA

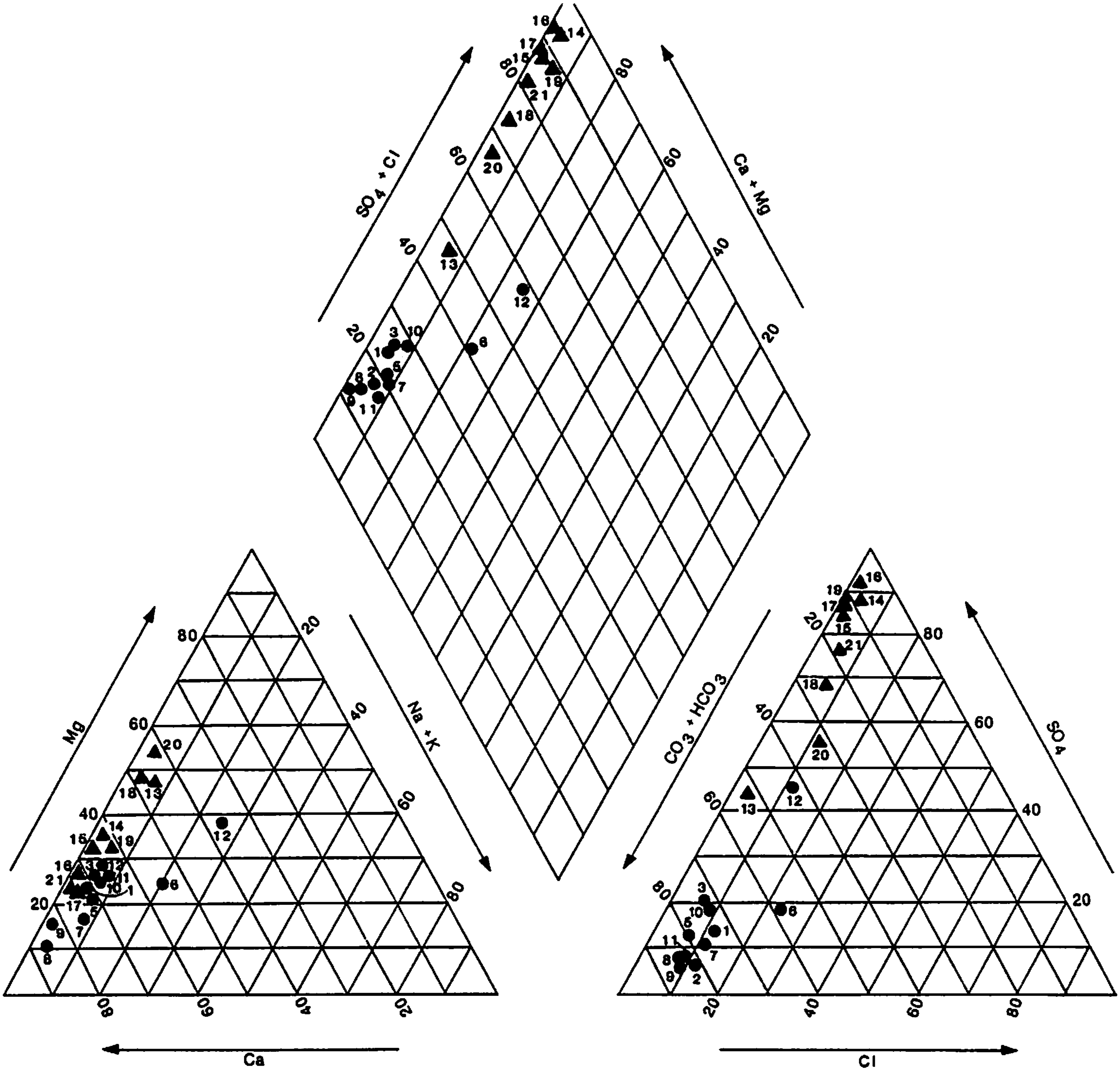




LOG OF MOLAR CONCENTRATIONS OF Sr VERSUS SO_4, AND Sr VERSUS Ca/Mg RATIO FOR WATER SAMPLES RETRIEVED FROM THE HABY CROSSING FAULT AREA

FIGURE 9

LBG-GUYTON ASSOCIATES



MILLIEQUIVALENCE PER LITER

Explanation

● EDWARDS AQUIFER SAMPLES

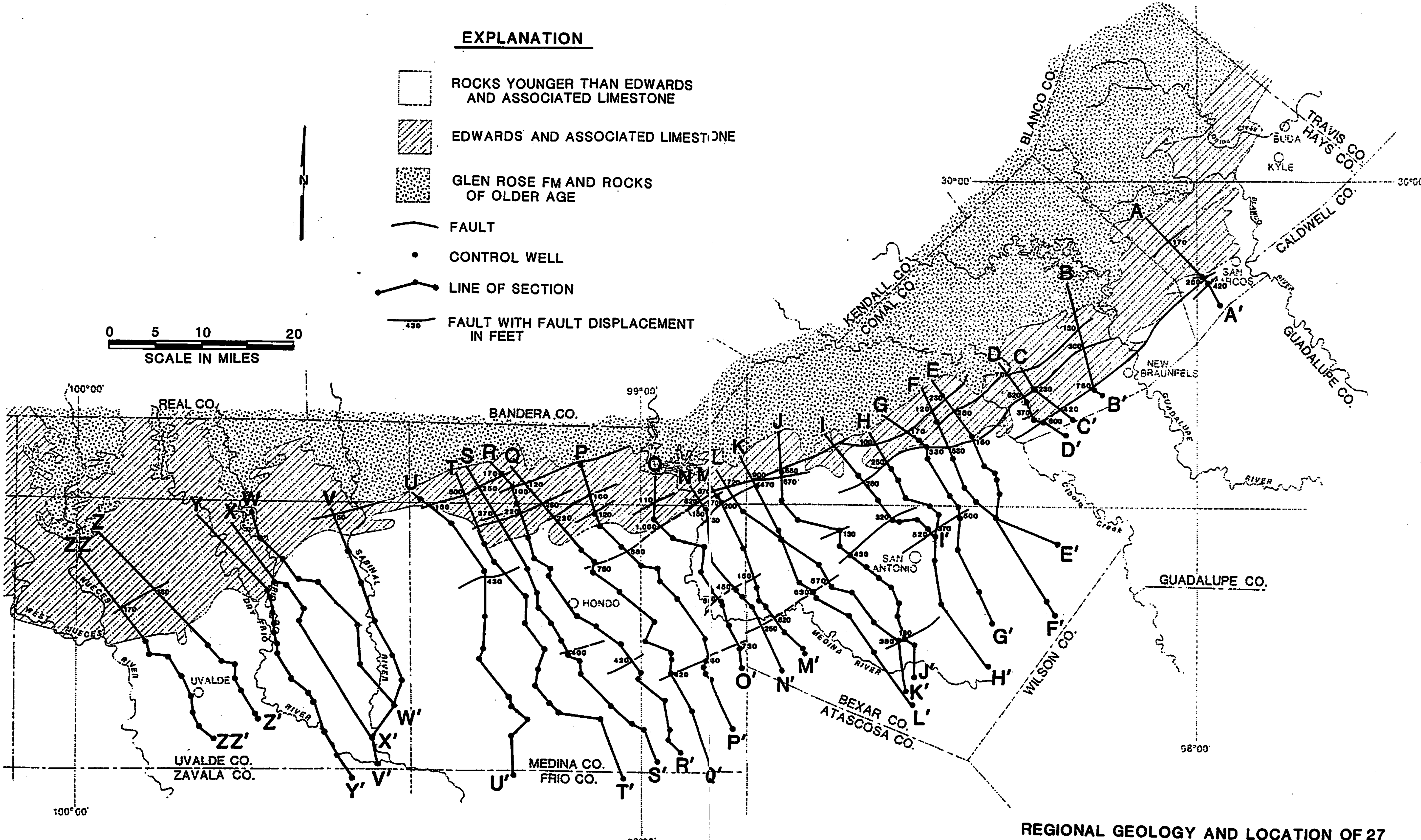
▲ GLEN ROSE AQUIFER SAMPLES

10 NUMBERS CORRESPONDING TO PLOTTED POINTS ARE CROSS REFERENCED TO SPECIFIC ANALYSES IN TABLE 4.

TRILINEAR DIAGRAM SHOWING INORGANIC ANALYSES FOR WATER SAMPLES RETRIEVED FROM WELLS IN THE HABY CROSSING FAULT AREA

FIGURE 10

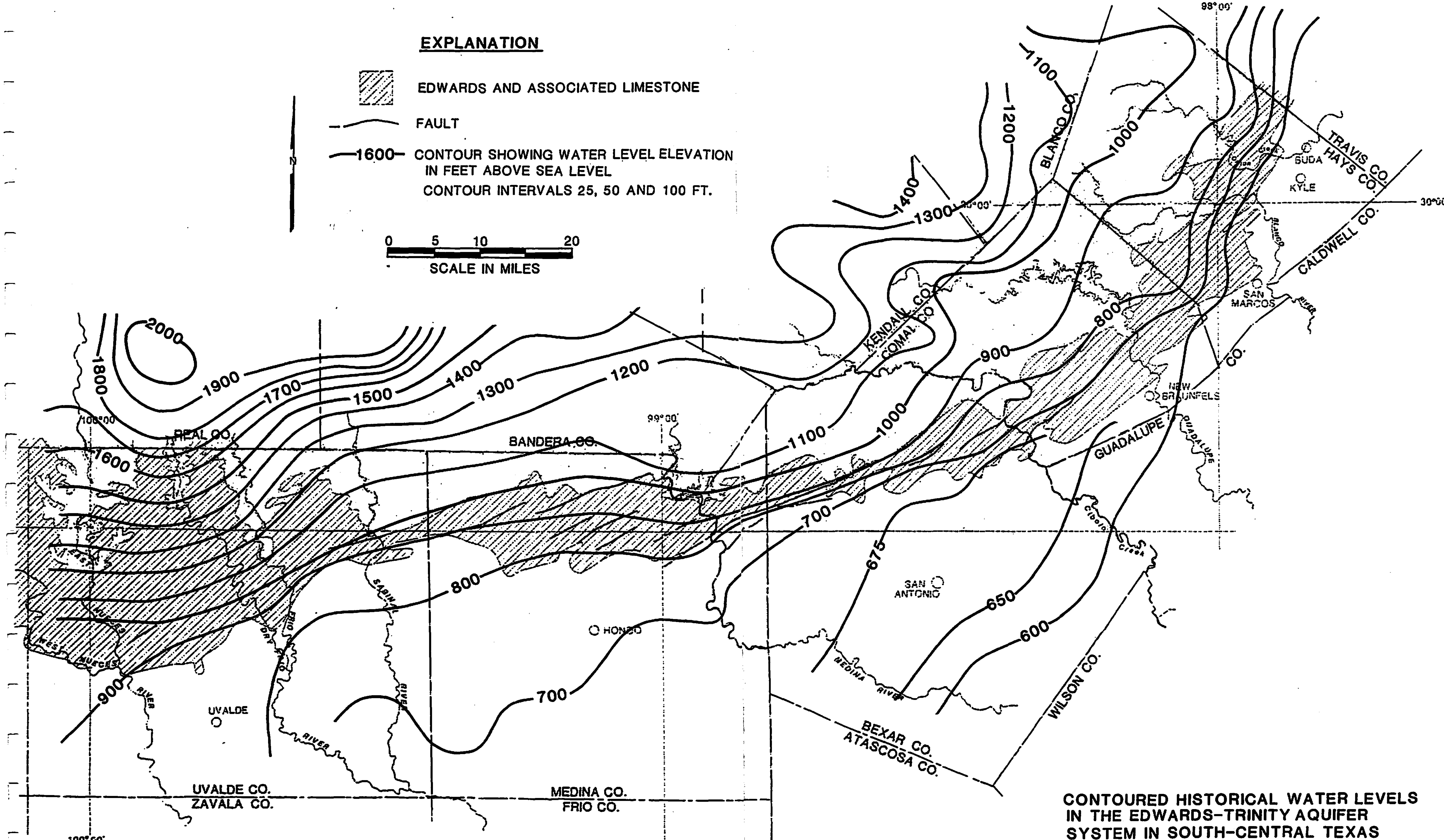
LBG-GUYTON ASSOCIATES



BASE MAP ADAPTED FROM B.E.G. GEOLOGIC ATLAS OF TEXAS MAPS, DEL RIO, SAN ANTONIO, SEGUIN, LLANO, AND AUSTIN SHEETS

REGIONAL GEOLOGY AND LOCATION OF 27 CROSS SECTIONS FROM SMALL (1986)

FIGURE 11

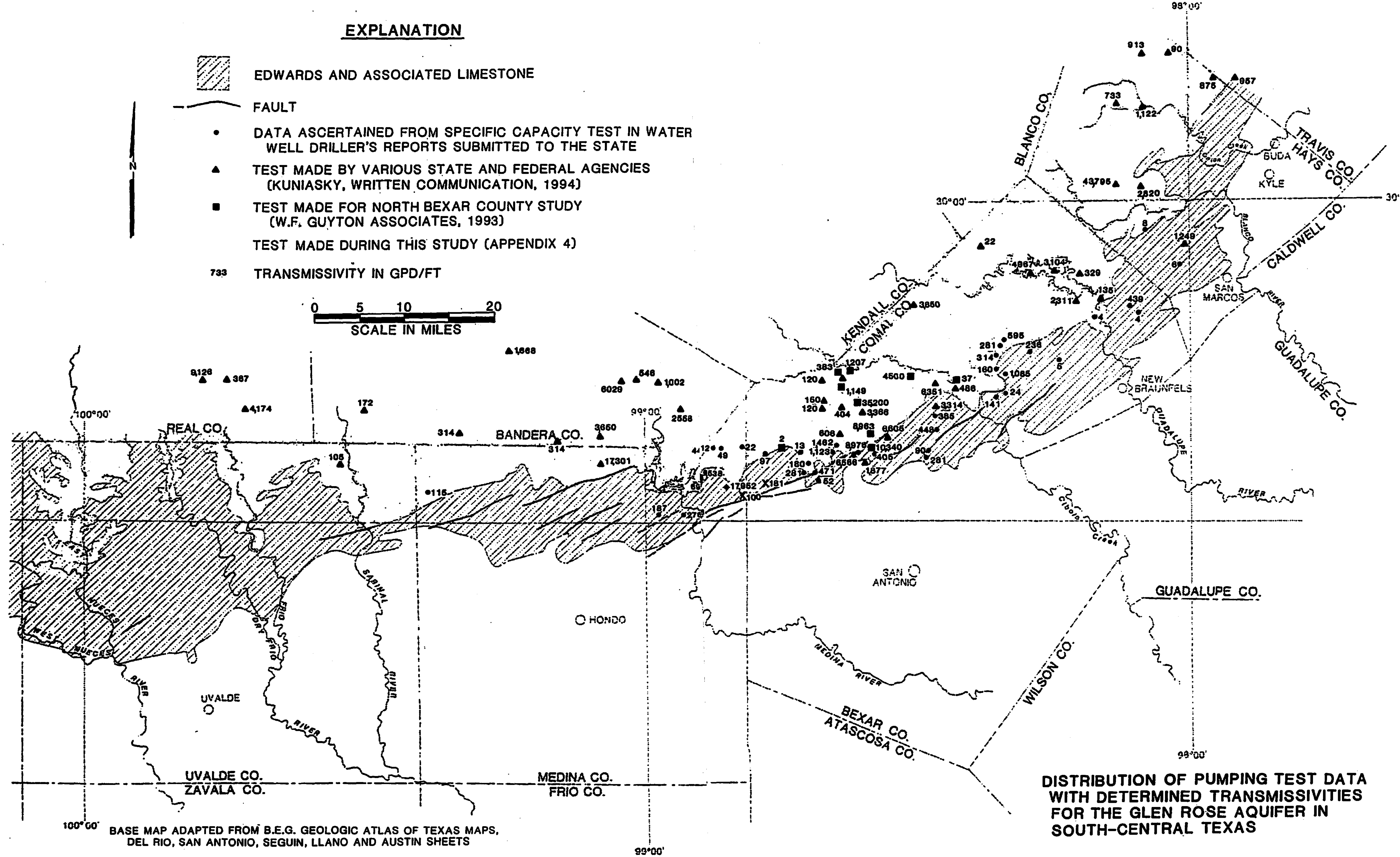


BASE MAP ADAPTED FROM B.E.G. GEOLOGIC ATLAS OF TEXAS MAPS, DEL RIO, SAN ANTONIO, SEGUIN, LLANO, AND AUSTIN SHEETS
CONTOURS FROM BUSH, ARDIS AND WYNN, 1993

CONTOURED HISTORICAL WATER LEVELS IN THE EDWARDS–TRINITY AQUIFER SYSTEM IN SOUTH-CENTRAL TEXAS

FIGURE 12

LBG-GUYTON ASSOCIATES



DISTRIBUTION OF PUMPING TEST DATA WITH DETERMINED TRANSMISSIVITIES FOR THE GLEN ROSE AQUIFER IN SOUTH-CENTRAL TEXAS

FIGURE 13

LBG-GUYTON ASSOCIATES

APPENDIX 1

METRIC CONVERSIONS

APPENDIX 1
METRIC CONVERSIONS

The inch-pound units of measurement used in this report may be converted to metric units (International System) by the following factors:

Multiply inch-pound unit	by	To obtain metric units
acre-foot (ac-ft)	1,233	cubic meter (m^3)
foot (ft)	0.3048	meter (m)
inch	25.4	millimeters (mm)
mile (mi)	1.609	kilometer (Km)
gallons per minute (gpm)	0.06300	liters per second (l/s)
gallons per minute per foot (gpm/ft)	0.207	liters per second per meter (l/s/m)
degree Fahrenheit (°F)	5/9 x (°F-32)	degree Celsius (°C)

APPENDIX 2

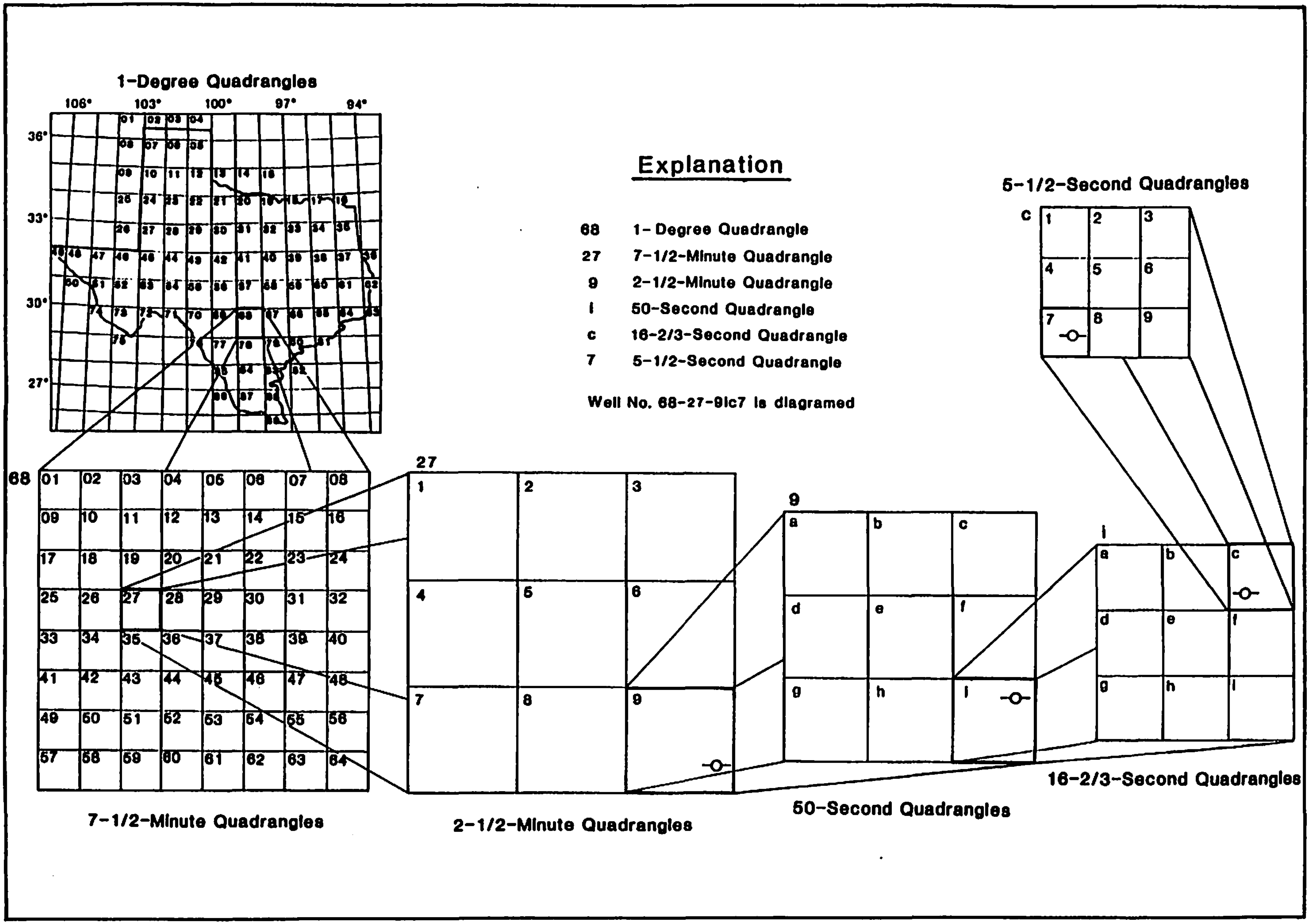
WELL-NUMBERING SYSTEM

APPENDIX 2
WELL-NUMBERING SYSTEM

The numbering system that is used in this report is based on subdivisions of latitude and longitude as shown by the diagram at the end of Appendix 2. The TWDB, TNRCC and the USGS use a similar well identification system in Texas with the exception of the last few digits of the well identification which are unique to this study. The first two letters identify the county in Texas, which for this report are AY for Bexar County, DX for Comal County, LR for Hays County, TD for Medina County, YP for Uvalde County and RP for Kinney County.

Next, each one-degree by one-degree section of the state has been assigned a two-digit number from 01 to 89 and this becomes the first set of numbers in the well identification. Each one-degree section is divided further into sixty-four 7-1/2-minute topographic quadrangles, numbered from 01-64, and this two-digit number becomes the second set of numbers in the well identification. Each 7-1/2-minute quadrangle is divided into 2-1/2-minute blocks, which are numbered from 1 to 9. This is the first digit in the third set of numbers (the fifth number) in the well identification.

At this point the state system and the system used for this study differ. Within the 2-1/2-minute sections, the state system then assigns numbers sequentially as needed regardless of location within the section. However, the numbering system used for this study subdivides each 2-1/2-minute section into the following series of progressively smaller sections of nine quadrangles each, as shown by the diagram on Figure 2. The first two series of subdivisions, 50-second and 16-2/3-second quadrangles, use letters "a" through "i" to avoid possible confusion with the state identification system. The third and last subdivision, which is a 5-1/2-second quadrangle, is given a number from 1 to 9 to locate the well within an area approximately 500 feet by 500 feet. As an example, Well AY-68-27-9ic7 would be located in Bexar County within the one-degree section 68 and in the sequentially subdivided quadrangles as illustrated in the following figure.



WELL- NUMBERING SYSTEM

APPENDIX 3

LABORATORY REPORTS OF CHEMICAL ANALYSES IN THE HABY CROSSING FAULT AREA

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37369
Sample ID: 25-9gi3	**Date Rec'd:** 07/15/94
Date Taken: 07/15/94	**Time Rec'd:** 1645
Time Taken: 1140	**Report Date:** 07/28/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.2	S.U.	07/15/94	1745	4500-H+ B
Conductivity,Specific	450	umhos/cm	07/25/94	1650	120.1
Hardness as CaCO3	216	mg/L	07/26/94	1240	330.2
Alkalinity, Total	184	mg/L	07/26/94	1355	2320 B
TDS	296	mg/L	07/26/94	1340	160.1
Calcium (Dissolved)	70.00	mg/L	07/19/94	1516	200.7
Magnesium (Dissolved)	13.00	mg/L	07/19/94	1544	200.7
Sodium (Dissolved)	7	mg/L	07/25/94	1730	200.7
Sulfate (Dissolved)	31	mg/L	07/28/94	1325	4500-SO4 E
Chloride (Dissolved)	18	mg/L	07/26/94	1315	4500-Cl B
Fluoride (Dissolved)	0.14	mg/L	07/28/94	0945	340.1
Potassium (Dissolved)	1	mg/L	07/27/94	1245	258.1
Silica (Dissolved)	5.6	mg/L	07/28/94	1500	4500-Si D.
Strontium/ICP	0.64	mg/L	07/19/94	1428	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37369

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	70.00	CALCIUM	me/l Ca :	3.4930
mg/l Mg :	13.00	MAGNESIUM	me/l Mg :	1.0686
mg/l Na :	7.00	SODIUM	me/l Na :	0.3045
mg/l K :	1.00	POTASSIUM	me/l K :	0.0256
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	4.8917

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	224.48	ALKAL,BICARB	me/l HCO3:	3.6815
mg/l SO4 :	31.00	SULFATE	me/l SO4 :	0.6448
mg/l Cl- :	18.00	CHLORIDE	me/l Cl- :	0.5076
mg/l Fl- :	0.14	FLUORIDE	me/l Fl- :	0.0074
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	4.8413

%ERROR = : 0.5178

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37113
Sample ID: 26-5he1	**Date Rec'd:** 6/30/94
Date Taken: 6/29/94	**Time Rec'd:** 1710
Time Taken: 1730	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.3	S.U.	6/30/94	4500-H+ B
Conductivity,Specific	488	umhos/cm	7/13/94	120.1
Hardness as CaCO3	240	mg/L	7/13/94	330.2
Alkalinity, Total	211	mg/L	7/13/94	2320 B
TDS	368	mg/L	7/13/94	160.1
Calcium (Dissolved)	66.0	mg/L	7/12/94	200.7
Magnesium (Dissolved)	18.0	mg/L	7/12/94	200.7
Sodium (Dissolved)	5	mg/L	7/13/94	200.7
Sulfate (Dissolved)	22	mg/L	7/14/94	4500-SO4 E
Chloride (Dissolved)	20	mg/L	7/13/94	4500-Cl B
Fluoride (Dissolved)	0.26	mg/L	7/14/94	340.1
Potassium (Dissolved)	0.5	mg/L	7/18/94	258.1
Silica (Dissolved)	3.52	mg/L	7/20/94	4500-Si D.
Strontium/ICP	0.50	mg/L	7/12/94	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37113

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	66.00	CALCIUM	me/l Ca :	3.2934
mg/l Mg :	18.00	MAGNESIUM	me/l Mg :	1.4796
mg/l Na :	5.00	SODIUM	me/l Na :	0.2175
mg/l K :	0.50	POTASSIUM	me/l K :	0.0128
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	5.0033

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	257.42	ALKAL,BICARB	me/l HCO3:	4.2217
mg/l SO4 :	22.00	SULFATE	me/l SO4 :	0.4576
mg/l Cl- :	20.00	CHLORIDE	me/l Cl- :	0.5640
mg/l Fl- :	0.26	FLUORIDE	me/l Fl- :	0.0137
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.2570

%ERROR = : -2.4726

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37507
Sample ID: 26-7hc4	**Date Rec'd:** 07/22/94
Date Taken: 07/20/94	**Time Rec'd:** 1640
Time Taken: 2010	**Report Date:** 08/08/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.5	S.U.	07/22/94	1655	4500-H+ B
Conductivity,Specific	500	umhos/cm	08/02/94	1135	120.1
Hardness as CaCO3	250	mg/L	08/02/94	1820	330.2
Alkalinity, Total	204	mg/L	08/03/94	1030	2320 B
TDS	372	mg/L	08/06/94	1220	160.1
Calcium (Dissolved)	75.4	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	18.0	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	7.5	mg/L	08/06/94	1340	200.7
Sulfate (Dissolved)	55	mg/L	08/03/94	1640	4500-SO4 E
Chloride (Dissolved)	18	mg/L	08/05/94	1140	4500-Cl B
Fluoride (Dissolved)	0.34	mg/L	08/06/94	1250	340.1
Potassium (Dissolved)	<1	mg/L	08/05/94	1230	258.1
Silica (Dissolved)	7.8	mg/L	08/06/94	1425	4500-Si D.
Strontium/ICP	0.90	mg/L	07/26/94	1629	200.7

Approved by: [signature]

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37507

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	75.40	CALCIUM	me/l Ca :	3.7625
mg/l Mg :	18.00	MAGNESIUM	me/l Mg :	1.4796
mg/l Na :	7.50	SODIUM	me/l Na :	0.3263
mg/l K :	0.90	POTASSIUM	me/l K :	0.0230
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	5.5914

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	248.88	ALKAL,BICARB	me/l HCO3:	4.0816
mg/l SO4 :	55.00	SULFATE	me/l SO4 :	1.1440
mg/l Cl- :	18.00	CHLORIDE	me/l Cl- :	0.5076
mg/l Fl- :	0.34	FLUORIDE	me/l Fl- :	0.0179
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.7511

%ERROR = : -1.4080

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name: 9	**PCS Sample #:** 36821
Sample ID: 26-8ai8	**Date Rec'd:** 6/16/94
Date Taken: 6/16/94	**Time Rec'd:** 1740
Time Taken: 1515	**Report Date:** 7/26/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.0	S.U.	6/9/94	4500-H+ B
Conductivity,Specific	500	umhos/cm	6/20/94	120.1
Hardness as CaCO3	248	mg/L	6/22/94	330.2
Alkalinity, Total	208	mg/L	6/21/94	2320 B
TDS	340	mg/L	6/24/94	160.1
Calcium (Dissolved)	82.2	mg/L	6/17/94	200.7
Magnesium (Dissolved)	15.0	mg/L	6/17/94	200.7
Sodium (Dissolved)	8	mg/L	6/28/94	200.7
Sulfate (Dissolved)	31	mg/L	6/27/94	4500-SO4 E
Chloride (Dissolved)	16	mg/L	6/22/94	4500-Cl B
Fluoride (Dissolved)	0.23	mg/L	6/28/94	340.1
Potassium (Dissolved)	2	mg/L	6/27/94	258.1
Silica (Dissolved)	6.3	mg/L	6/27/94	4500-Si D.
Strontium/ICP	0.56	mg/L	6/17/94	200.7

Approved by: Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 36821

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	82.20	CALCIUM	me/l Ca :	4.1018
mg/l Mg :	15.00	MAGNESIUM	me/l Mg :	1.2330
mg/l Na :	8.00	SODIUM	me/l Na :	0.3480
mg/l K :	2.00	POTASSIUM	me/l K :	0.0512
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	5.7340

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	253.76	ALKAL,BICARB	me/l HCO3:	4.1617
mg/l SO4 :	31.00	SULFATE	me/l SO4 :	0.6448
mg/l Cl- :	16.00	CHLORIDE	me/l Cl- :	0.4512
mg/l Fl- :	0.23	FLUORIDE	me/l Fl- :	0.0121
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.2698

%ERROR = : 4.2185

Parameters not requested left blank.

POLLUTION CONTROL SERVICES

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37510
Sample ID: 26-9fe5	**Date Rec'd:** 07/22/94
Date Taken: 07/22/94	**Time Rec'd:** 1640
Time Taken: 1505	**Report Date:** 08/08/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.5	S.U.	07/22/94	1655	4500-H+ B
Conductivity,Specific	680	umhos/cm	08/02/94	1135	120.1
Hardness as CaCO3	288	mg/L	08/02/94	1820	330.2
Alkalinity, Total	214	mg/L	08/03/94	1030	2320 B
TDS	488	mg/L	08/06/94	1220	160.1
Calcium (Dissolved)	84.5	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	22.0	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	35	mg/L	08/06/94	1340	200.7
Sulfate (Dissolved)	60	mg/L	08/03/94	1640	4500-SO4 E
Chloride (Dissolved)	60	mg/L	08/05/94	1140	4500-Cl B
Fluoride (Dissolved)	0.47	mg/L	08/06/94	1250	340.1
Potassium (Dissolved)	<1	mg/L	08/05/94	1230	258.1
Silica (Dissolved)	8.0	mg/L	08/06/94	1425	4500-Si D.
Strontium/ICP	1.28	mg/L	07/26/94	1629	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37510

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	84.50	CALCIUM	me/l Ca :	4.2166
mg/l Mg :	22.00	MAGNESIUM	me/l Mg :	1.8084
mg/l Na :	35.00	SODIUM	me/l Na :	1.5225
mg/l K :	0.90	POTASSIUM	me/l K :	0.0230
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	7.5705

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	261.08	ALKAL,BICARB	me/l HCO3:	4.2817
mg/l SO4 :	60.00	SULFATE	me/l SO4 :	1.2480
mg/l Cl- :	60.00	CHLORIDE	me/l Cl- :	1.6920
mg/l Fl- :	0.47	FLUORIDE	me/l Fl- :	0.0247
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	7.2464

%ERROR = : 2.1874

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37509
Sample ID: 27-4ff9	**Date Rec'd:** 07/22/94
Date Taken: 07/21/94	**Time Rec'd:** 1640
Time Taken: 1735	**Report Date:** 08/08/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.2	S.U.	07/22/94	1655	4500-H+ B
Conductivity,Specific	530	umhos/cm	08/02/94	1135	120.1
Hardness as CaCO3	268	mg/L	08/02/94	1820	330.2
Alkalinity, Total	242	mg/L	08/03/94	1030	2320 B
TDS	368	mg/L	08/06/94	1220	160.1
Calcium (Dissolved)	97.2	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	13.0	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	11	mg/L	08/06/94	1340	200.7
Sulfate (Dissolved)	31	mg/L	08/03/94	1640	4500-SO4 E
Chloride (Dissolved)	23	mg/L	08/05/94	1140	4500-Cl B
Fluoride (Dissolved)	0.22	mg/L	08/06/94	1250	340.1
Potassium (Dissolved)	<1	mg/L	08/05/94	1230	258.1
Silica (Dissolved)	7.5	mg/L	08/06/94	1425	4500-Si D.
Strontium/ICP	0.62	mg/L	07/26/94	1629	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37509

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	97.20	CALCIUM	me/l Ca :	4.8503
mg/l Mg :	13.00	MAGNESIUM	me/l Mg :	1.0686
mg/l Na :	11.00	SODIUM	me/l Na :	0.4785
mg/l K :	0.90	POTASSIUM	me/l K :	0.0230
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	6.4204

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	295.24	ALKAL,BICARB	me/l HCO3:	4.8419
mg/l SO4 :	31.00	SULFATE	me/l SO4 :	0.6448
mg/l Cl- :	23.00	CHLORIDE	me/l Cl- :	0.6486
mg/l Fl- :	0.22	FLUORIDE	me/l Fl- :	0.0116
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	6.1469

%ERROR = : 2.1763

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37042
Sample ID: 27-4fh5	**Date Rec'd:** 6/28/94
Date Taken: 6/28/94	**Time Rec'd:** 1740
Time Taken: 1605	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.1	S.U.	6/28/94	4500-H+ B
Conductivity,Specific	486	umhos/cm	6/29/94	120.1
Hardness as CaCO3	236	mg/L	7/9/94	330.2
Alkalinity, Total	216	mg/L	7/9/94	2320 B
TDS	308	mg/L	7/12/94	160.1
Calcium (Dissolved)	88.8	mg/L	6/29/94	200.7
Magnesium (Dissolved)	11.0	mg/L	6/30/94	200.7
Sodium (Dissolved)	5	mg/L	7/11/94	200.7
Sulfate (Dissolved)	17	mg/L	7/11/94	4500-SO4 E
Chloride (Dissolved)	16	mg/L	7/11/94	4500-Cl B
Fluoride (Dissolved)	0.13	mg/L	7/12/94	340.1
Potassium (Dissolved)	1	mg/L	7/12/94	258.1
Silica (Dissolved)	4.32	mg/L	7/12/94	4500-Si D.
Strontium/ICP	0.40	mg/L	6/29/94	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37042

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	88.80	CALCIUM	me/l Ca :	4.4311
mg/l Mg :	11.00	MAGNESIUM	me/l Mg :	0.9042
mg/l Na :	5.00	SODIUM	me/l Na :	0.2175
mg/l K :	1.00	POTASSIUM	me/l K :	0.0256
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	5.5784

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	263.52	ALKAL,BICARB	me/l HCO3:	4.3217
mg/l SO4 :	17.00	SULFATE	me/l SO4 :	0.3536
mg/l Cl- :	16.00	CHLORIDE	me/l Cl- :	0.4512
mg/l Fl- :	0.13	FLUORIDE	me/l Fl- :	0.0068
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.1333

%ERROR = : 4.1553

Parameters not requested left blank.

POLLUTION CONTROL SERVICES

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37114
Sample ID: 27-4fi4	**Date Rec'd:** 6/30/94
Date Taken: 6/30/94	**Time Rec'd:** 1710
Time Taken: 1500	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.3	S.U.	6/30/94	4500-H+ B
Conductivity,Specific	469	umhos/cm	7/13/94	120.1
Hardness as CaCO3	220	mg/L	7/13/94	330.2
Alkalinity, Total	218	mg/L	7/13/94	2320 B
TDS	292	mg/L	7/13/94	160.1
Calcium (Dissolved)	79.8	mg/L	7/12/94	200.7
Magnesium (Dissolved)	9.00	mg/L	7/12/94	200.7
Sodium (Dissolved)	4	mg/L	7/13/94	200.7
Sulfate (Dissolved)	14	mg/L	7/14/94	4500-SO4 E
Chloride (Dissolved)	17	mg/L	7/13/94	4500-Cl B
Fluoride (Dissolved)	0.12	mg/L	7/14/94	340.1
Potassium (Dissolved)	0	mg/L	7/18/94	258.1
Silica (Dissolved)	4.06	mg/L	7/20/94	4500-Si D.
Strontium/ICP	0.24	mg/L	7/12/94	200.7

Approved by:

Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37114

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	79.80	CALCIUM	me/l Ca :	3.9820
mg/l Mg :	9.00	MAGNESIUM	me/l Mg :	0.7398
mg/l Na :	4.00	SODIUM	me/l Na :	0.1740
mg/l K :	0.00	POTASSIUM	me/l K :	0.0000
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	4.8958

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	265.96	ALKAL,BICARB	me/l HCO3:	4.3617
mg/l SO4 :	14.00	SULFATE	me/l SO4 :	0.2912
mg/l Cl- :	17.00	CHLORIDE	me/l Cl- :	0.4794
mg/l Fl- :	0.12	FLUORIDE	me/l Fl- :	0.0063
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.1386

%ERROR = : -2.4197

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37506
Sample ID: 27-4gb4	**Date Rec'd:** 07/22/94
Date Taken: 07/20/94	**Time Rec'd:** 1640
Time Taken: 1645	**Report Date:** 08/08/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.4	S.U.	07/22/94	1655	4500-H+ B
Conductivity,Specific	510	umhos/cm	08/02/94	1135	120.1
Hardness as CaCO3	260	mg/L	08/02/94	1820	330.2
Alkalinity, Total	210	mg/L	08/03/94	1030	2320 B
TDS	388	mg/L	08/06/94	1220	160.1
Calcium (Dissolved)	85.2	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	18.0	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	9	mg/L	08/06/94	1340	200.7
Sulfate (Dissolved)	49	mg/L	08/03/94	1640	4500-SO4 E
Chloride (Dissolved)	18	mg/L	08/05/94	1140	4500-Cl B
Fluoride (Dissolved)	0.34	mg/L	08/06/94	1250	340.1
Potassium (Dissolved)	<1	mg/L	08/05/94	1230	258.1
Silica (Dissolved)	8.5	mg/L	08/06/94	1425	4500-Si D.
Strontium/ICP	0.94	mg/L	07/26/94	1629	200.7

Approved by: Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37506

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	85.20	CALCIUM	me/l Ca :	4.2515
mg/l Mg :	18.00	MAGNESIUM	me/l Mg :	1.4796
mg/l Na :	9.00	SODIUM	me/l Na :	0.3915
mg/l K :	0.90	POTASSIUM	me/l K :	0.0230
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	6.1456

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	256.20	ALKAL,BICARB	me/l HCO3:	4.2017
mg/l SO4 :	49.00	SULFATE	me/l SO4 :	1.0192
mg/l Cl- :	18.00	CHLORIDE	me/l Cl- :	0.5076
mg/l Fl- :	0.34	FLUORIDE	me/l Fl- :	0.0179
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.7464

%ERROR = : 3.3569

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37348
Sample ID: 27-5eel	**Date Rec'd:** 07/14/94
Date Taken: 07/14/94	**Time Rec'd:** 1610
Time Taken: 1120	**Report Date:** 07/28/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.20	S.U.	07/14/94	1525	4500-H+ B
Conductivity,Specific	487	umhos/cm	07/25/94	1650	120.1
Hardness as CaCO3	244	mg/L	07/26/94	1240	330.2
Alkalinity, Total	222	mg/L	07/26/94	1355	2320 B
TDS	328	mg/L	07/26/94	1340	160.1
Calcium (Dissolved)	71.80	mg/L	07/14/94	1836	200.7
Magnesium (Dissolved)	16.00	mg/L	07/14/94	1908	200.7
Sodium (Dissolved)	6	mg/L	07/25/94	1730	200.7
Sulfate (Dissolved)	14	mg/L	07/28/94	1325	4500-SO4 E
Chloride (Dissolved)	17	mg/L	07/26/94	1315	4500-Cl B
Fluoride (Dissolved)	0.2	mg/L	07/28/94	0945	340.1
Potassium (Dissolved)	<1	mg/L	07/27/94	1245	258.1
Silica (Dissolved)	5.2	mg/L	07/28/94	1500	4500-Si D.
Strontium/ICP	0.76	mg/L	07/14/94	1746	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37348

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	71.80	CALCIUM	me/l Ca :	3.5828
mg/l Mg :	16.00	MAGNESIUM	me/l Mg :	1.3152
mg/l Na :	6.00	SODIUM	me/l Na :	0.2610
mg/l K :	<1	POTASSIUM	me/l K :	0.0000
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	5.1590

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	270.84	ALKAL,BICARB	me/l HCO3:	4.4418
mg/l SO4 :	14.00	SULFATE	me/l SO4 :	0.2912
mg/l Cl- :	17.00	CHLORIDE	me/l Cl- :	0.4794
mg/l Fl- :	0.20	FLUORIDE	me/l Fl- :	0.0105
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	5.2229

%ERROR = : -0.6155

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37370
Sample ID: H-Haby 33-3ba4	**Date Rec'd:** 07/15/94
Date Taken: 07/15/94	**Time Rec'd:** 1645
Time Taken: 1500	**Report Date:** 08/01/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.1	S.U.	07/15/94	1745	4500-H+ B
Conductivity,Specific	1000	umhos/cm	07/25/94	1650	120.1
Hardness as CaCO3	440	mg/L	07/26/94	1240	330.2
Alkalinity, Total	248	mg/L	07/30/94	1615	2320 B
TDS	756	mg/L	07/26/94	1340	160.1
Calcium (Dissolved)	87.20	mg/L	07/19/94	1516	200.7
Magnesium (Dissolved)	57.00	mg/L	07/19/94	1544	200.7
Sodium (Dissolved)	64	mg/L	07/30/94	1250	200.7
Sulfate (Dissolved)	242	mg/L	07/28/94	1325	4500-SO4 E
Chloride (Dissolved)	49	mg/L	07/26/94	1315	4500-Cl B
Fluoride (Dissolved)	0.50	mg/L	07/28/94	0945	340.1
Potassium (Dissolved)	3	mg/L	07/27/94	1245	258.1
Silica (Dissolved)	6.0	mg/L	07/28/94	1500	4500-Si D.
Strontium/ICP	19.04	mg/L	07/19/94	1428	200.7

Approved by:
Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37370

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	87.20	CALCIUM	me/l Ca :	4.3513
mg/l Mg :	57.00	MAGNESIUM	me/l Mg :	4.6854
mg/l Na :	64.00	SODIUM	me/l Na :	2.7840
mg/l K :	3.00	POTASSIUM	me/l K :	0.0768
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	11.8975

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	303.00	ALKAL,BICARB	me/l HCO3:	4.9692
mg/l SO4 :	242.00	SULFATE	me/l SO4 :	5.0336
mg/l Cl- :	49.00	CHLORIDE	me/l Cl- :	1.3818
mg/l Fl- :	0.50	FLUORIDE	me/l Fl- :	0.0263
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	11.4109

%ERROR = : 2.0877

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37317
Sample ID: 25-9ha7	**Date Rec'd:** 07/13/94
Date Taken: 07/13/94	**Time Rec'd:** 1845
Time Taken: 1600	**Report Date:** 07/28/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.4	S.U.	07/13/94	1535	4500-H+ B
Conductivity,Specific	650	umhos/cm	07/19/94	2000	120.1
Hardness as CaCO3	344	mg/L	07/20/94	1540	330.2
Alkalinity, Total	204	mg/L	07/20/94	1605	2320 B
TDS	488	mg/L	07/21/94	0845	160.1
Calcium (Dissolved)	66.6	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	44.0	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	10	mg/L	07/25/94	1730	200.7
Sulfate (Dissolved)	128	mg/L	07/25/94	1130	4500-SO4 E
Chloride (Dissolved)	17	mg/L	07/25/94	1040	4500-Cl B
Fluoride (Dissolved)	0.79	mg/L	07/25/94	1340	340.1
Potassium (Dissolved)	1	mg/L	07/25/94	1030	258.1
Silica (Dissolved)	5.3	mg/L	07/25/94	1430	4500-Si D.
Strontium/ICP	3.10	mg/L	07/26/94	1813	200.7

Approved by:

Chuck Wallgren
Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37317

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	66.60	CALCIUM	me/l Ca :	3.3233
mg/l Mg :	44.00	MAGNESIUM	me/l Mg :	3.6168
mg/l Na :	10.00	SODIUM	me/l Na :	0.4350
mg/l K :	1.00	POTASSIUM	me/l K :	0.0256
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	7.4007

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	248.88	ALKAL,BICARB	me/l HCO3:	4.0816
mg/l SO4 :	128.00	SULFATE	me/l SO4 :	2.6624
mg/l Cl- :	17.00	CHLORIDE	me/l Cl- :	0.4794
mg/l Fl- :	0.79	FLUORIDE	me/l Fl- :	0.0416
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	7.2650

%ERROR = : 0.9253

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37247
Sample ID: 26-5ea6	**Date Rec'd:** 07/08/94
Date Taken: 07/08/94	**Time Rec'd:** 1620
Time Taken: 1025	**Report Date:** 07/26/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.4	S.U.	07/08/94	1650	4500-H+ B
Conductivity,Specific	2620	umhos/cm	07/18/94	1415	120.1
Hardness as CaCO3	2200	mg/L	07/20/94	1540	330.2
Alkalinity, Total	192	mg/L	07/20/94	1605	2320 B
TDS	3172	mg/L	07/21/94	0845	160.1
Calcium (Dissolved)	538	mg/L	07/12/94	1712	200.7
Magnesium (Dissolved)	185	mg/L	07/12/94	1814	200.7
Sodium (Dissolved)	10	mg/L	07/18/94	1415	200.7
Sulfate (Dissolved)	1631	mg/L	07/25/94	1130	4500-SO4 E
Chloride (Dissolved)	40	mg/L	07/19/94	1107	4500-Cl B
Fluoride (Dissolved)	3.85	mg/L	07/25/94	1340	340.1
Potassium (Dissolved)	4.5	mg/L	07/18/94	1615	258.1
Silica (Dissolved)	4.14	mg/L	07/20/94	1200	4500-Si D.
Strontium/ICP	10.62	mg/L	07/12/94	1525	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37247

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	538.00	CALCIUM	me/l Ca :	26.8462
mg/l Mg :	185.00	MAGNESIUM	me/l Mg :	15.2070
mg/l Na :	10.00	SODIUM	me/l Na :	0.4350
mg/l K :	4.50	POTASSIUM	me/l K :	0.1152
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	42.6034

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	234.24	ALKAL,BICARB	me/l HCO3:	3.8415
mg/l SO4 :	1631.00	SULFATE	me/l SO4 :	33.9248
mg/l Cl- :	40.00	CHLORIDE	me/l Cl- :	1.1280
mg/l Fl- :	3.85	FLUORIDE	me/l Fl- :	0.2025
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	39.0968

%ERROR = : 4.2920

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 36459
Sample ID: WILDCAT 26-6fg1	**Date Rec'd:** 6/3/94
Date Taken: 6/1/94	**Time Rec'd:** 1915
Time Taken: 1510	**Report Date:** 6/18/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.0	S.U.	6/3/94	4500-H+ B
Conductivity,Specific	2130	umhos/cm	6/7/94	120.1
Hardness as CaCO3	1460	mg/L	6/10/94	330.2
Alkalinity, Total	192	mg/L	6/10/94	2320 B
TDS	2224	mg/L	6/13/94	160.1
Calcium (Dissolved)	417	mg/L	6/17/94	200.7
Magnesium (Dissolved)	120	mg/L	6/7/94	200.7
Sodium (Dissolved)	20	mg/L	6/7/94	200.7
Sulfate (Dissolved)	1055	mg/L	6/8/94	4500-SO4 E
Chloride (Dissolved)	45	mg/L	6/13/94	4500-Cl B
Fluoride (Dissolved)	3.15	mg/L	6/16/94	340.1
Potassium (Dissolved)	9	mg/L	6/13/94	258.1
Silica (Dissolved)	5.9	mg/L	6/8/94	4500-Si D.
Strontium/ICP	12.96	mg/L	6/8/94	200.7
Bromide	0.50	mg/L	6/4/94	4500-Br. B.

Approved by:
Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 36459

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	417.00	CALCIUM	me/l Ca :	20.8083
mg/l Mg :	120.00	MAGNESIUM	me/l Mg :	9.8640
mg/l Na :	20.00	SODIUM	me/l Na :	0.8700
mg/l K :	9.00	POTASSIUM	me/l K :	0.2304
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	31.7727

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	234.24	ALKAL,BICARB	me/l HCO3:	3.8415
mg/l SO4 :	1055.00	SULFATE	me/l SO4 :	21.9440
mg/l Cl- :	45.00	CHLORIDE	me/l Cl- :	1.2690
mg/l Fl- :	3.15	FLUORIDE	me/l Fl- :	0.1657
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	27.2202

%ERROR = : 7.7170

Parameters not requested left blank.

POLLUTION CONTROL SERVICES

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37508
Sample ID: 26-7bd4	**Date Rec'd:** 07/22/94
Date Taken: 07/21/94	**Time Rec'd:** 1640
Time Taken: 1350	**Report Date:** 08/08/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	6.9	S.U.	07/22/94	1655	4500-H+ B
Conductivity,Specific	2530	umhos/cm	08/02/94	1135	120.1
Hardness as CaCO3	1980	mg/L	08/02/94	1820	330.2
Alkalinity, Total	162	mg/L	08/03/94	1030	2320 B
TDS	3002	mg/L	08/06/94	1220	160.1
Calcium (Dissolved)	567	mg/L	07/26/94	1813	200.7
Magnesium (Dissolved)	127	mg/L	07/27/94	1545	200.7
Sodium (Dissolved)	14	mg/L	08/06/94	1340	200.7
Sulfate (Dissolved)	1710	mg/L	08/03/94	1640	4500-SO4 E
Chloride (Dissolved)	18	mg/L	08/05/94	1140	4500-Cl B
Fluoride (Dissolved)	3.0	mg/L	08/06/94	1250	340.1
Potassium (Dissolved)	6	mg/L	08/05/94	1230	258.1
Silica (Dissolved)	8.0	mg/L	08/06/94	1425	4500-Si D.
Strontium/ICP	10.3	mg/L	07/26/94	1629	200.7

Approved by:
[signature]
Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37508

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	567.00	CALCIUM	me/l Ca :	28.2933
mg/l Mg :	127.00	MAGNESIUM	me/l Mg :	10.4394
mg/l Na :	14.00	SODIUM	me/l Na :	0.6090
mg/l K :	6.00	POTASSIUM	me/l K :	0.1536
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	39.4953

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	197.64	ALKAL,BICARB	me/l HCO3:	3.2413
mg/l SO4 :	1710.00	SULFATE	me/l SO4 :	35.5680
mg/l Cl- :	18.00	CHLORIDE	me/l Cl- :	0.5076
mg/l Fl- :	3.00	FLUORIDE	me/l Fl- :	0.1578
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	39.4747

%ERROR = : 0.0261

Parameters not requested left blank.

POLLUTION CONTROL SERVICES

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #: 37112**
Sample ID: 26-8bb5	**Date Rec'd:** 6/30/94
Date Taken: 6/29/94	**Time Rec'd:** 1710
Time Taken: 1630	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.0	S.U.	6/30/94	4500-H+ B
Conductivity,Specific	2190	umhos/cm	7/13/94	120.1
Hardness as CaCO3	1656	mg/L	7/13/94	330.2
Alkalinity, Total	204	mg/L	7/13/94	2320 B
TDS	2528	mg/L	7/13/94	160.1
Calcium (Dissolved)	520	mg/L	7/12/94	200.7
Magnesium (Dissolved)	95.0	mg/L	7/12/94	200.7
Sodium (Dissolved)	11.5	mg/L	7/13/94	200.7
Sulfate (Dissolved)	1203	mg/L	7/14/94	4500-SO4 E
Chloride (Dissolved)	19	mg/L	7/13/94	4500-Cl B
Fluoride (Dissolved)	2.65	mg/L	7/14/94	340.1
Potassium (Dissolved)	4.5	mg/L	7/18/94	258.1
Silica (Dissolved)	3.21	mg/L	7/20/94	4500-Si D.
Strontium/ICP	15.06	mg/L	7/12/94	200.7

Approved by:

Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37112

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	520.00	CALCIUM	me/l Ca :	25.9480
mg/l Mg :	95.00	MAGNESIUM	me/l Mg :	7.8090
mg/l Na :	11.50	SODIUM	me/l Na :	0.5003
mg/l K :	4.50	POTASSIUM	me/l K :	0.1152
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	34.3725

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	248.88	ALKAL,BICARB	me/l HCO3:	4.0816
mg/l SO4 :	1203.00	SULFATE	me/l SO4 :	25.0224
mg/l Cl- :	19.00	CHLORIDE	me/l Cl- :	0.5358
mg/l Fl- :	2.65	FLUORIDE	me/l Fl- :	0.1394
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	29.7792

%ERROR = : 7.1601

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 36975
Sample ID: 27-4fe8	**Date Rec'd:** 6/24/94
Date Taken: 6/24/94	**Time Rec'd:** 1330
Time Taken: 1150	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.1	S.U.	6/24/94	4500-H+ B
Conductivity,Specific	1550	umhos/cm	6/24/94	120.1
Hardness as CaCO3	936	mg/L	6/29/94	330.2
Alkalinity, Total	224	mg/L	6/29/94	2320 B
TDS	1260	mg/L	6/30/94	160.1
Calcium (Dissolved)	178.40	mg/L	6/27/94	200.7
Magnesium (Dissolved)	117.0	mg/L	6/27/94	200.7
Sodium (Dissolved)	12	mg/L	7/11/94	200.7
Sulfate (Dissolved)	543	mg/L	7/11/94	4500-SO4 E
Chloride (Dissolved)	45	mg/L	6/30/94	4500-Cl B
Fluoride (Dissolved)	4.2	mg/L	7/12/94	340.1
Potassium (Dissolved)	10	mg/L	7/12/94	258.1
Silica (Dissolved)	3.78	mg/L	7/12/94	4500-Si D.
Strontium/ICP	10.10	mg/L	6/27/94	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 36975

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	178.40	CALCIUM	me/l Ca :	8.9022
mg/l Mg :	117.00	MAGNESIUM	me/l Mg :	9.6174
mg/l Na :	12.00	SODIUM	me/l Na :	0.5220
mg/l K :	10.00	POTASSIUM	me/l K :	0.2560
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	19.2976

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	273.28	ALKAL,BICARB	me/l HCO3:	4.4818
mg/l SO4 :	543.00	SULFATE	me/l SO4 :	11.2944
mg/l Cl- :	45.00	CHLORIDE	me/l Cl- :	1.2690
mg/l Fl- :	4.20	FLUORIDE	me/l Fl- :	0.2209
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	17.2661

%ERROR = : 5.5561

Parameters not requested left blank.

POLLUTION CONTROL SERVICES

435 Isom Road, Suite 228 San Antonio, TX 78216 (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37041
Sample ID: 27-4fe9	**Date Rec'd:** 6/28/94
Date Taken: 6/27/94	**Time Rec'd:** 1740
Time Taken: 1940	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.0	S.U.	6/28/94	4500-H+ B
Conductivity,Specific	2400	umhos/cm	6/29/94	120.1
Hardness as CaCO3	1636	mg/L	7/9/94	330.2
Alkalinity, Total	208	mg/L	7/9/94	2320 B
TDS	2436	mg/L	7/12/94	160.1
Calcium (Dissolved)	438	mg/L	6/29/94	200.7
Magnesium (Dissolved)	144	mg/L	6/30/94	200.7
Sodium (Dissolved)	13	mg/L	7/13/94	200.7
Sulfate (Dissolved)	1428	mg/L	7/14/94	4500-SO4 E
Chloride (Dissolved)	20	mg/L	7/13/94	4500-Cl B
Fluoride (Dissolved)	4.17	mg/L	7/12/94	340.1
Potassium (Dissolved)	8.8	mg/L	7/12/94	258.1
Silica (Dissolved)	4.56	mg/L	7/12/94	4500-Si D.
Strontium/ICP	9.22	mg/L	6/29/94	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37041

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	438.00	CALCIUM	me/l Ca :	21.8562
mg/l Mg :	144.00	MAGNESIUM	me/l Mg :	11.8368
mg/l Na :	13.00	SODIUM	me/l Na :	0.5655
mg/l K :	8.80	POTASSIUM	me/l K :	0.2253
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	34.4838

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	253.76	ALKAL,BICARB	me/l HCO3:	4.1617
mg/l SO4 :	1428.00	SULFATE	me/l SO4 :	29.7024
mg/l Cl- :	20.00	CHLORIDE	me/l Cl- :	0.5640
mg/l Fl- :	4.17	FLUORIDE	me/l Fl- :	0.2193
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	34.6474

%ERROR = : -0.2367

Parameters not requested left blank.

P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37040
Sample ID: 27-4ff1	**Date Rec'd:** 6/28/94
Date Taken: 6/28/94	**Time Rec'd:** 1740
Time Taken: 1215	**Report Date:** 7/27/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	DATE ANALYZED	METHOD USED
pH	7.1	S.U.	6/28/94	4500-H+ B
Conductivity,Specific	1170	umhos/cm	6/29/94	120.1
Hardness as CaCO3	656	mg/L	7/9/94	330.2
Alkalinity, Total	232	mg/L	7/9/94	2320 B
TDS	940	mg/L	7/12/94	160.1
Calcium (Dissolved)	121	mg/L	6/29/94	200.7
Magnesium (Dissolved)	92.0	mg/L	6/30/94	200.7
Sodium (Dissolved)	11	mg/L	7/11/94	200.7
Sulfate (Dissolved)	349	mg/L	7/11/94	4500-SO4 E
Chloride (Dissolved)	50	mg/L	7/11/94	4500-Cl B
Fluoride (Dissolved)	4.17	mg/L	7/12/94	340.1
Potassium (Dissolved)	7	mg/L	7/12/94	258.1
Silica (Dissolved)	4.2	mg/L	7/12/94	4500-Si D.
Strontium/ICP	12.3	mg/L	6/29/94	200.7

Approved by:

Chuck Wallgren

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37040

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	121.00	CALCIUM	me/l Ca :	6.0379
mg/l Mg :	92.00	MAGNESIUM	me/l Mg :	7.5624
mg/l Na :	11.00	SODIUM	me/l Na :	0.4785
mg/l K :	7.00	POTASSIUM	me/l K :	0.1792
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	14.2580

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	283.04	ALKAL,BICARB	me/l HCO3:	4.6419
mg/l SO4 :	349.00	SULFATE	me/l SO4 :	7.2592
mg/l Cl- :	50.00	CHLORIDE	me/l Cl- :	1.4100
mg/l Fl- :	4.17	FLUORIDE	me/l Fl- :	0.2193
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	13.5304

%ERROR = : 2.6184

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P O L L U T I O N   C O N T R O L   S E R V I C E S

435 Isom Road, Suite 228   San Antonio, TX 78216   (210) 340-0343

REPORT OF SAMPLE ANALYSIS

To: John Waugh
Edwards Underground Water District
P.O. Box 15830
San Antonio, TX 78212

CLIENT INFORMATION	*LABORATORY INFORMATION*
Project Name:	**PCS Sample #:** 37248
Sample ID: 27-5bg9	**Date Rec'd:** 07/08/94
Date Taken: 07/08/94	**Time Rec'd:** 1620
Time Taken: 1445	**Report Date:** 07/26/94

TEST DESCRIPTION	SAMPLE RESULT	UNITS	ANALYZED DATE	ANALYZED TIME	METHOD USED
pH	7.2	S.U.	07/08/94	1650	4500-H+ B
Conductivity,Specific	1730	umhos/cm	07/18/94	1415	120.1
Hardness as CaCO3	1200	mg/L	07/20/94	1540	330.2
Alkalinity, Total	234	mg/L	07/20/94	1605	2320 B
TDS	1664	mg/L	07/21/94	0845	160.1
Calcium (Dissolved)	367	mg/L	07/12/94	1712	200.7
Magnesium (Dissolved)	67.0	mg/L	07/12/94	1814	200.7
Sodium (Dissolved)	16	mg/L	07/18/94	1415	200.7
Sulfate (Dissolved)	861	mg/L	07/25/94	1130	4500-SO4 E
Chloride (Dissolved)	50	mg/L	07/19/94	1107	4500-Cl B
Fluoride (Dissolved)	2.35	mg/L	07/25/94	1340	340.1
Potassium (Dissolved)	2.5	mg/L	07/18/94	1615	258.1
Silica (Dissolved)	3.96	mg/L	07/20/94	1200	4500-Si D.
Strontium/ICP	14.96	mg/L	07/12/94	1525	200.7

Approved by:

Chuck Wallgren
Owner

Pollution Control Services
Mineral Analysis QA Check - Stabler Formula

PCS Sample#: 37248

Enter cation results in mg/l

mg/l Iron:		IRON	me/l Iron:	0.0000
mg/l Ca :	367.00	CALCIUM	me/l Ca :	18.3133
mg/l Mg :	67.00	MAGNESIUM	me/l Mg :	5.5074
mg/l Na :	16.00	SODIUM	me/l Na :	0.6960
mg/l K :	2.50	POTASSIUM	me/l K :	0.0640
mg/l Mn :		MANGANESE	me/l Mn :	0.0000
			Sum Cations(me/l):	24.5807

Enter anion results in mg/l

mg/l CO3 :			me/l CO3 :	0.0000
mg/l HCO3:	285.48	ALKAL,BICARB	me/l HCO3:	4.6819
mg/l SO4 :	861.00	SULFATE	me/l SO4 :	17.9088
mg/l Cl- :	50.00	CHLORIDE	me/l Cl- :	1.4100
mg/l Fl- :	2.35	FLUORIDE	me/l Fl- :	0.1236
mg/l NO3 :		NITRATE-N	me/l NO3N:	0.0000
			Sum Anions (me/l):	24.1243

%ERROR = : 0.9371

Parameters not requested left blank.

APPENDIX 4

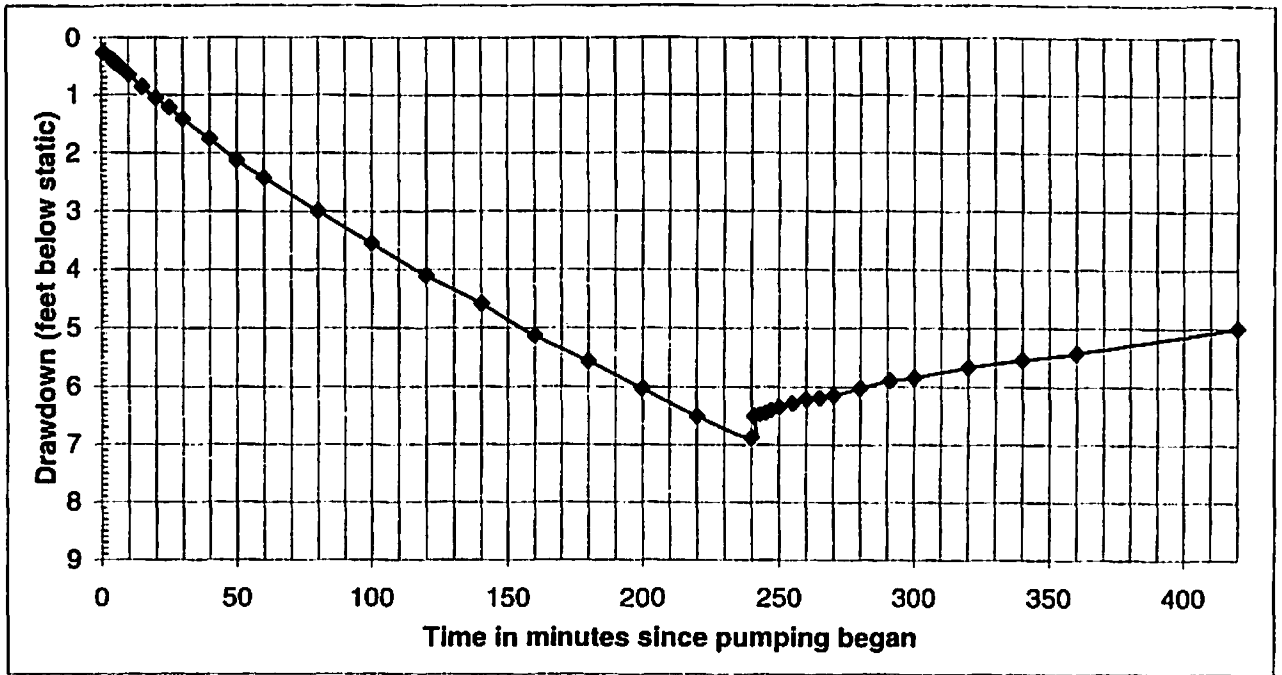
PUMPING-TEST DATA FOR THREE WELLS IN THE HABY CROSSING FAULT AREA

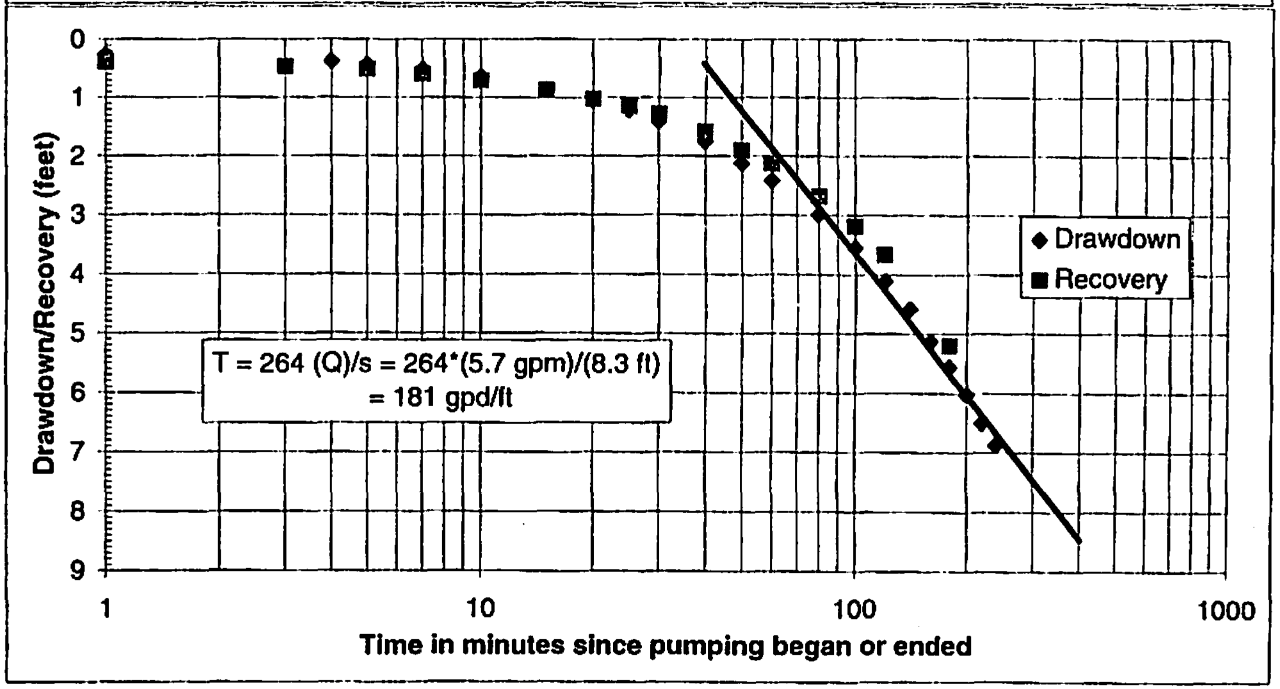
Pumping Test of AY-68-26-6fg1 (Wild Cat Well)

Conducted on 6/2/94

DATA

Time since pumping began/ended (min)	Depth to water (ft)	Drawdown/ recovery (change in ft)
0	134.99	-
1	135.26	0.27
4	135.37	0.38
5	135.43	0.44
7	135.51	0.52
10	135.64	0.65
15	135.85	0.86
20	136.05	1.06
25	136.21	1.22
30	136.41	1.42
40	136.75	1.76
50	137.12	2.13
60	137.42	2.43
80	137.99	3.00
100	138.54	3.55
120	139.10	4.11
140	139.58	4.59
160	140.13	5.14
180	140.56	5.57
200	141.02	6.03
220	141.50	6.51
240	141.87	6.88
241(1)	141.49	0.40
243(3)	141.47	0.47
245(5)	141.44	0.52
247(7)	141.39	0.61
250(10)	141.34	0.72
255(15)	141.28	0.87
260(20)	141.21	1.03
265(25)	141.18	1.15
270(30)	141.14	1.29
280(40)	141.02	1.59
291(51)	140.89	1.91
300(60)	140.84	2.14
320(80)	140.66	2.69
340(100)	140.53	3.19
360(120)	140.42	3.67
420(180)	139.99	5.21



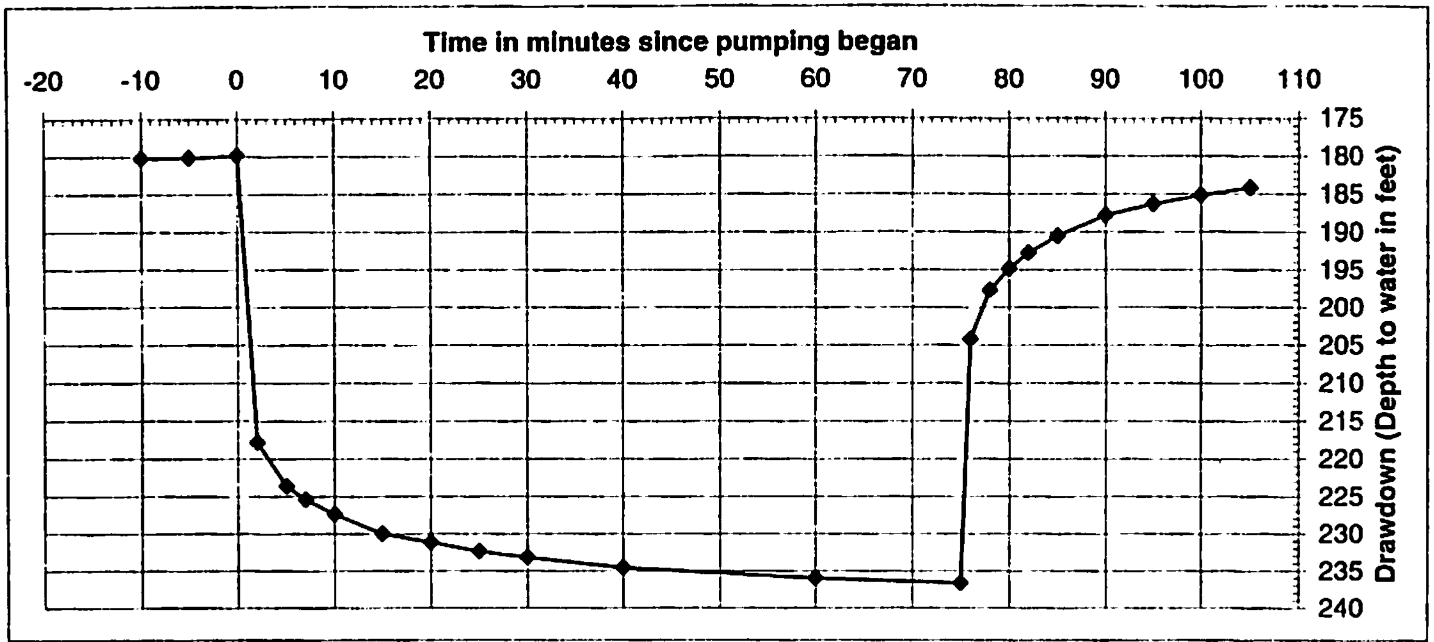


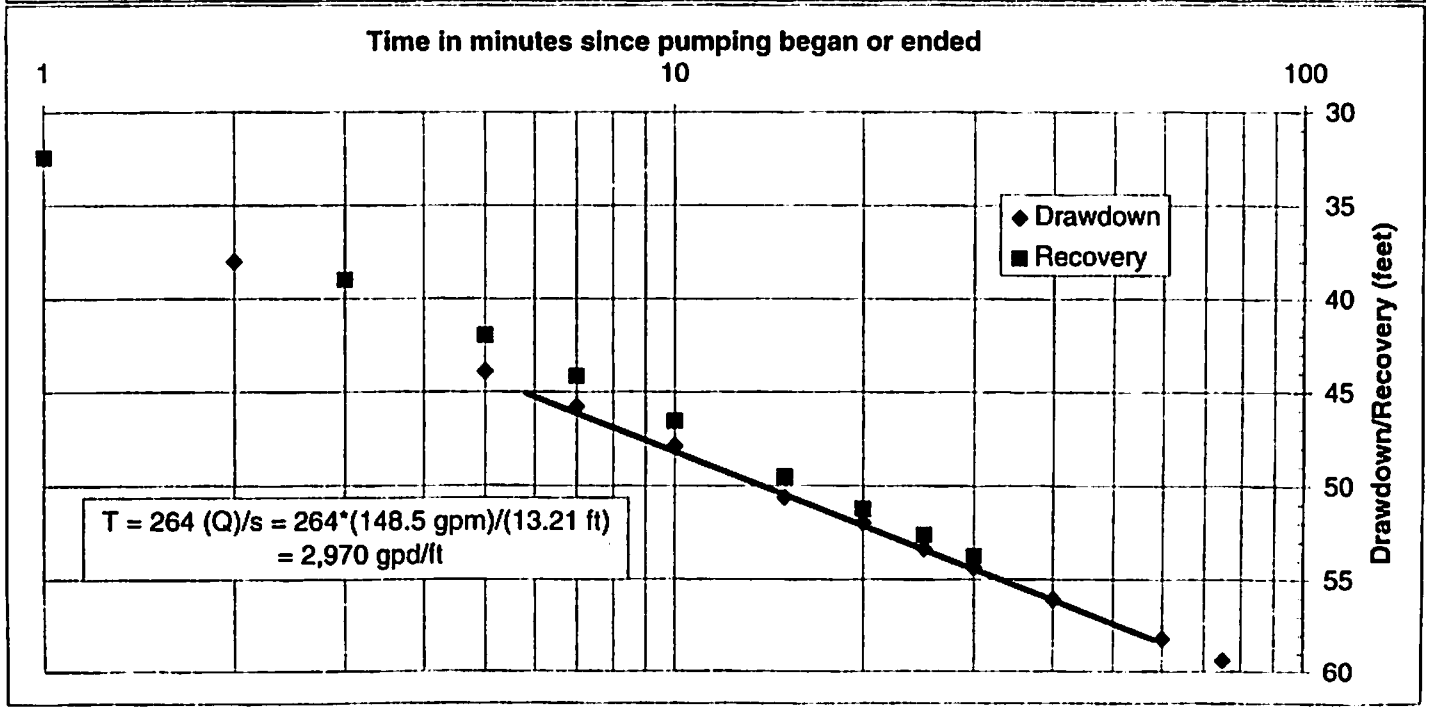
Pumping Test of TD-68-26-8ai9 (Edwards Well)

Conducted on 6/16/94

DATA

Time since pumping began/ended (min)	Depth to water (ft)	Adjusted drawdown/ recovery (change in ft)
-10	180.23	-
-5	180.12	-
0	179.88	-
2	217.84	38.03
5	223.63	43.93
7	225.44	45.81
10	227.41	47.88
15	230.01	50.66
20	231.17	51.99
25	232.38	53.38
30	233.21	54.38
40	234.56	56.08
60	235.99	58.21
75	236.66	59.41
76(1)	204.24	32.46
78(3)	197.79	39.00
80(5)	194.88	42.00
82(7)	192.77	44.20
85(10)	190.52	46.59
90(15)	187.81	49.52
95(20)	186.30	51.25
100(25)	185.14	52.64
105(30)	184.23	53.77





Pumping Test of TD-68-26-8bb5

Conducted on 6/29/94

DATA

Time since pumping began/ended (min)	Depth to water (ft)	Drawdown/ recovery (change in ft)
0	125.69	-
1	126.56	0.87
3	126.88	1.19
5	127.09	1.40
8	127.42	1.73
10	127.66	1.97
15	128.14	2.45
20	128.52	2.83
25	128.95	3.26
32	129.53	3.84
40	130.14	4.45
50	130.80	5.11
60	131.46	5.77
80	132.69	7.00
100	133.89	8.20
120	134.95	9.26
140	136.01	10.32
160	137.03	11.34
185	138.32	12.63
270	142.21	16.52
315	144.08	18.39
420	148.19	22.50
430	148.48	22.79
431(1)	147.56	0.95
433(3)	147.36	1.21
437(7)	147.10	1.58
440(10)	146.89	1.88
445(15)	146.58	2.33
450(20)	146.35	2.71
455(25)	146.14	3.07
460(30)	145.94	3.41
470(40)	145.57	4.07
480(50)	145.28	4.65
490(60)	144.91	5.31
510(80)	144.48	6.32