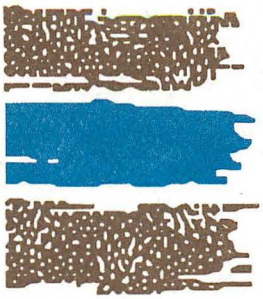

EDWARDS UNDERGROUND
WATER DISTRICT

Report 94-05

1994 Review and Update of the Position of the Edwards Aquifer Freshwater/Saline-Water Interface from Uvalde to Kyle, Texas

1994 REVIEW AND UPDATE

of the

POSITION OF THE EDWARDS AQUIFER FRESHWATER/SALINE-WATER INTERFACE

from Uvalde to Kyle, Texas

Prepared for the
EDWARDS UNDERGROUND WATER DISTRICT
SAN ANTONIO, TEXAS

by

Alvin L. Schultz

November, 1994

CONTENTS

ILLUSTRATIONS

(Figures 1, 7, 8, and 9 also included as plates at back of report)

TABLES

FORWARD

The currently mapped location of the Edwards aquifer freshwater/saline-water interface recognized by regulatory and governing bodies needs to be updated in light of new test well data and recent studies. Edwards Underground Water District (EUWD) South Medina County Observation Well #1 yielded freshwater from the entire Edwards aquifer interval during tests conducted during July and August of 1993. This well is approximately three miles south of the currently mapped interface (Brown, et al, 1992). The ability to rely upon geophysical log derived values of specific conductance and/or total dissolved solids has been shown in EUWD reports 92-02 (Poteet, et al, 1992), 92-03 (Schultz, 1992), and 93-06 (Schultz, 1993). These reports are specific investigations describing various aspects of the interface from Kyle to Uvalde, Texas. Reports 92-03 and 93-06 both reveal that TDS values obtained from geophysical logs are usable for defining the interface position in areas where measured data is lacking or sparse. The combining of TDS maps presented in the previously cited studies produces a trace of the freshwater/saline-water interface that appears authentic.

This report more precisely defines the freshwater/saline-water interface between Uvalde and Lytle, Texas, by incorporating the new test well results with additional geophysical log recordings obtained since the completion of EUWD Report 92-03. All sources of data have been merged so that measured and calculated data complement each other.

A DILIGENT AND CONCENTRATED EFFORT HAS GONE INTO THE PREPARATION OF THIS REPORT. HOWEVER, ALL INTERPRETATIONS ARE BASED UPON INFERENCES FROM ELECTRICAL AND OTHER MEASUREMENTS AND OTHER DATA. THE AUTHOR, AND OFFICERS, AGENTS, DIRECTORS, AND/OR EMPLOYEES OF THE EDWARDS UNDERGROUND WATER DISTRICT CANNOT, AND DO NOT GUARANTEE THE ACCURACY OR CORRECTNESS OF ANY INTERPRETATIONS OR THE RELIABILITY OF THE DATA SUPPLIED FROM OTHER SOURCES, AND SHALL NOT BE LIABLE OR RESPONSIBLE FOR ANY LOSS, COSTS, DAMAGES OR EXPENSES INCURRED OR SUSTAINED BY ANYONE RESULTING FROM ANY RELIANCE UPON ANY INTERPRETATION MADE IN THIS REPORT.

PURPOSE

The purpose of this study is to update and present a more accurate location of the Edwards aquifer freshwater/saline-water interface between Uvalde and Kyle, Texas. Two detailed interface studies, new test well data, recently acquired geophysical logs, and additional measured data are employed to produce a current trace of the interface as revealed by available data. First priority was placed upon fine tuning the portion of the interface west of San Antonio, Texas, since EUWD Report 93-06 "*Defining the Edwards Aquifer Freshwater/Saline-Water Interface with Geophysical Logs and Measured Data (San Antonio to Kyle, Texas),*" written by A. Schultz in 1993, presents a current revised trace of the interface in Bexar, Comal, Guadalupe, and Hays Counties. Comparison of crossplot porosity results and sonic transit time measurements are made in order that sonic log data can be used to obtain reliable porosity values. Preparation of plots to determine relationships between measured specific conductance, calculated specific conductance and total dissolved solids (TDS) was performed so that a "tailor-made" solution of estimated total dissolved solids resulted from geophysical log interpretations. Data from all wells previously shown in the first study of the interface using geophysical logs (EUWD Report 92-03 "*Using Geophysical Logs in the Edwards aquifer to Estimate Water Quality Along the Freshwater/Saline-Water Interface(Uvalde to San Antonio, Texas),*" prepared by A. Schultz in 1992, was reviewed. Recalculation of specific conductance was executed when required. All TDS estimates presented in EUWD Report 92-03 were recalculated using new relationships made specifically for the area west of Lytle, Texas.

Revised specific conductance and TDS maps of the revised portion of the interface from Uvalde to Kyle were merged with the maps shown in EUWD Report 93-06 to form the most recent interpretation of the position of the freshwater/saline-water interface from Lytle to Uvalde, Texas.

New and additional control consisting of new actual measured data and calculated values, which practical experience has shown to be satisfactory, are combined to portray an updated version of the interface that can be adjusted as more accurate data are acquired in the future.

INTRODUCTION

Over 150 geophysical logs and 128 measured samples were used to update the mapped location of the Edwards aquifer freshwater/saline-water interface from Uvalde to Kyle, Texas. The preponderance of well data was obtained from EUWD Reports 92-03 and 93-06. These two studies present a usable map of the interface over the study area. The area covered by EUWD Report 93-06 possesses abundant well control composed of both measured data and calculated values to yield a usable location of the interface. Report 93-06 confirmed close agreement with a recent published interface trace (Brown, et al, 1992) and only minor changes were required for a more precise definition, some of which can be attributed to contour options on the part of the different investigators. However, the area west of Lytle, Texas , as shown in EUWD Report 92-03 has large areas where measured water quality data is lacking and reliance upon estimated (TDS) values from geophysical logs was necessary. The most significant source of data to verify the position of the freshwater/saline-water interface shown on the maps in Report 92-03 is EUWD South Medina County Observation Well #1, drilled and tested during July and August of 1993. This well produced freshwater from the entire Edwards aquifer interval. Additionally, the TDS measured was less than that currently mapped (Brown, et al, 1992) or shown on the TDS map in Report 92-03. After evaluating the new well's tests, it was apparent that previous estimates of the freshwater/saline-water interface position needed to be re-evaluated. Consequently, the test results of the new well have been combined with 24 recently acquired geophysical logs and additional specific conductance and TDS measurements to "fine tune" the interface location from Lytle to Uvalde, Texas.

The methodology, interpretations, and maps presented in EUWD Report 93-06 are current and do not need to be changed until added measured data or additonal geophysical logs are obtained on old or new wells. The addition of the new test well data and subsequent acquisition of additional geophysical logs, not available during preparation of EUWD Report 92-03, shows that the interface location from Uvalde to Lytle, Texas needs to be more specifically defined. Therefore, the methodology employed in the first two studies has again been used to formulate a more nearly correct interface trace from Lytle to Uvalde, Texas.

EUWD Report 92-03 presents a comprehensive review of the techniques and methods used in this report to determine TDS estimates from geophysical log interpretation.

ACQUISITION OF ADDITIONAL DATA (LYTLE TO UVALDE)

All data concerning EUWD South Medina County Observation Well #1 was taken from EUWD Report 93-11 "*South Medina County Observation Well Project*", authored by John Waugh in 1993.

Geophysical logs on 24 wells, previously unavailable to the author, were obtained from private companies or the United States Geological Survey (USGS). Additional porosity logs were procured on six wells not available for release during the preparation of EUWD 92-03. Four control points with only measured specific conductance and TDS data were added to a geologically complicated area northeast of Uvalde.

All wells used to map the interface position west of Lytle, Texas, are shown on **Figure 1** and **Plate 1** and are listed in **Table 1**.

LOCATION OF ADDITIONAL WELLS (LYTLE TO UVALDE)

Latitude and longitude coordinates were determined for the additional wells in the study area. Commercial maps, USGS topographic maps, and data in EUWD files were all used as sources of information. Locations were checked and discrepancies were resolved with EUWD staff.

Locations may differ among various sources; therefore, any new well drilled requiring an accurate location with respect to surrounding control should be positioned **using new surveyed data of all wells related to the new well's proposed location.**

POROSITY DETERMINATION USING SONIC LOGS (LYTLE TO UVALDE)

Three different relationships were used to determine porosity from sonic log recordings in the study area west of Lytle, Texas. Previous experience gained during the study presented in EUWD Report 92-03 and data presented as part of an EUWD Logging Short Course (August 26, 1993) shows that a matrix velocity of 23,000 feet/second is a

satisfactory sonic log relationship to use in Uvalde and Zavala counties. However, crossplots of density and neutron log porosity compared to sonic log interval transit time recordings indicate that two relationships are appropriate in Medina and Frio counties. The study area was divided in half with a relationship determined for the **Eastern Area** of Medina County and another for the **Western Area** of Frio County. The relationships are identical for the same portions of each county and are shown for simplicity as only Medina County **(Figures 2 and 3).** The wells (1Al, 20KB, 29TD, 37TD, 9KB, and 8TD) used to determine the sonic - porosity relationships are in an area near the freshwater/saline-water interface **(Figure 1).**

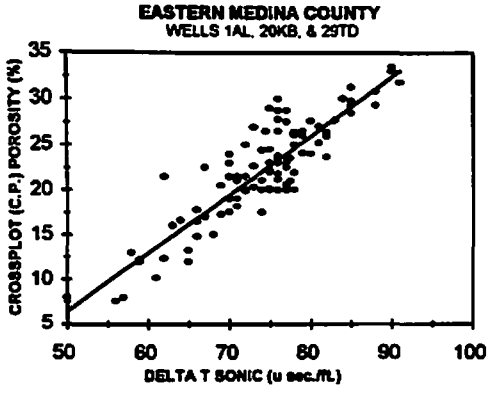

Figure 2. Plot of density-neutron log-derived porosity versus interval transit time, used to derive empirical relationship for determining porosity from 3 sonic logs in eastern Medina County. Relationship is: Porosity (sonic) = .65(Delta T sonic log) - 25.9

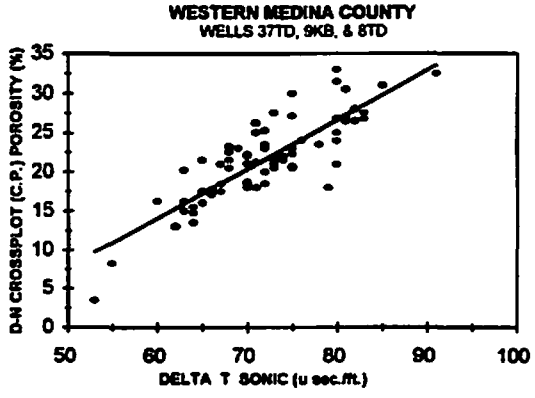

Figure 3. Plot of density-neutron log-derived porosity versus interval transit time, used to derive empirical relationship for determining porosity from 3 sonic logs in western Medina County. Relationship is: Porosity (sonic) = .63 (Delta T sonic log) - 23.6

TOTAL DISSOLVED SOLIDS AND MEASURED SPECIFIC CONDUCTANCE CORRELATION (LYTLE TO UVALDE)

Total dissolved solids (TDS) and specific conductance measurements (Ct) on 44 Edwards aquifer water samples were obtained from 21 wells near the interface between Lytle and Uvalde. These values of TDS and Ct were crossplotted to secure a relationship between the two different types of measurement. Tabulated data **(Table 2)** displays TDS values ranging from less than 300 mg/L to over 3000 mg/L. The correlation coefficient squared (r^2)

is high (.97). All recent interface studies (Schultz, 1992 &1993), have shown excellent correlation between TDS and Ct measurements. Observation of a plot of TDS versus Ct **(Figure 4)** exhibits a generally uniform close distribution of points when specific conductance values are equal to or greater than 1200 microsiems per centimeter. Points in the low conductivity range less than 500 uS/cm tend to be off the linear regression line to the northwest. A similar phenomenon was seen in the study conducted between San Antonio and Kyle (Schultz, 1993), and is believed to be caused by a change in water types existing between water with specific conductance less than 500 uS/cm and water measuring over 1000 uS/cm. Changes in hydrochemical facies are documented in the Edwards aquifer (Maclay, et al, 1980) and different water types with equal TDS can have variable specific conductance values (Alger, 1966).

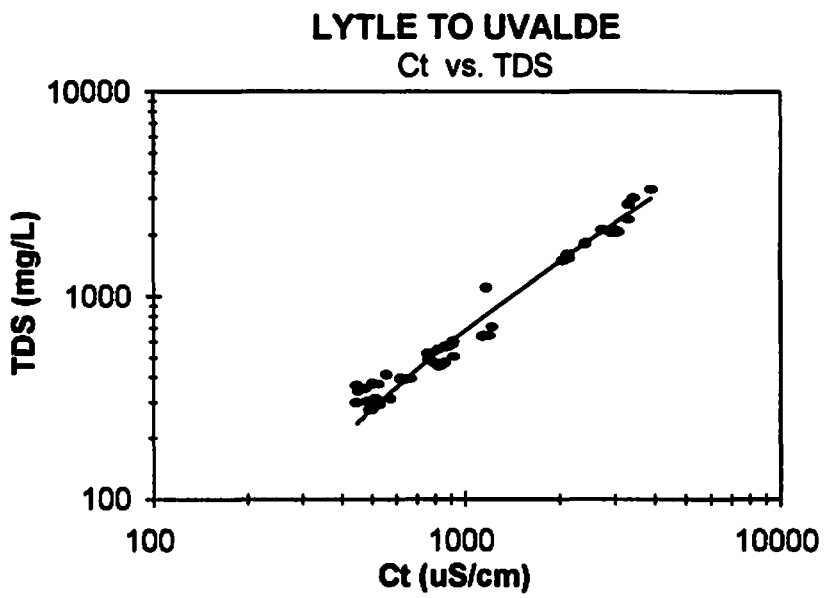

Figure 4. Relationship of measured total dissolved solids (TDS) to measured specific conductance (Ct) for control wells (Table 2). Total dissolved solids in mg/L. Specific conductance in microsiemens per centimeter (uS/cm). $r^2 = .977$. Concentration of points having TDS <600 mg/L, which are positioned above the simple fit line, is interpreted to be the result of a change in the hydrochemical facies between the freshwater zone and saline zones. Relationship is: Estimated total dissolved solids (TDSest.) = .8Ct - 122.

MEASURED AND GEOPHYSICAL LOG DERIVED VALUES OF SPECIFIC CONDUCTANCE (LYTLE TO UVALDE)

A comparison of specific conductance measured versus that calculated from geophysical logs is necessary to establish confidence in utilizing log- derived values of TDS. Examination of a plot **(Figure 5)** of measured specific conductance (Ct) versus specific conductance determined from geophysical logs (Ca) exhibits a very high quality correlation. The correlation coefficient squared (r^2) is .99. This indicates that geophysical logs can be used with confidence to yield usable values of TDS in areas where measured TDS data is not available and test well drilling is very expensive.

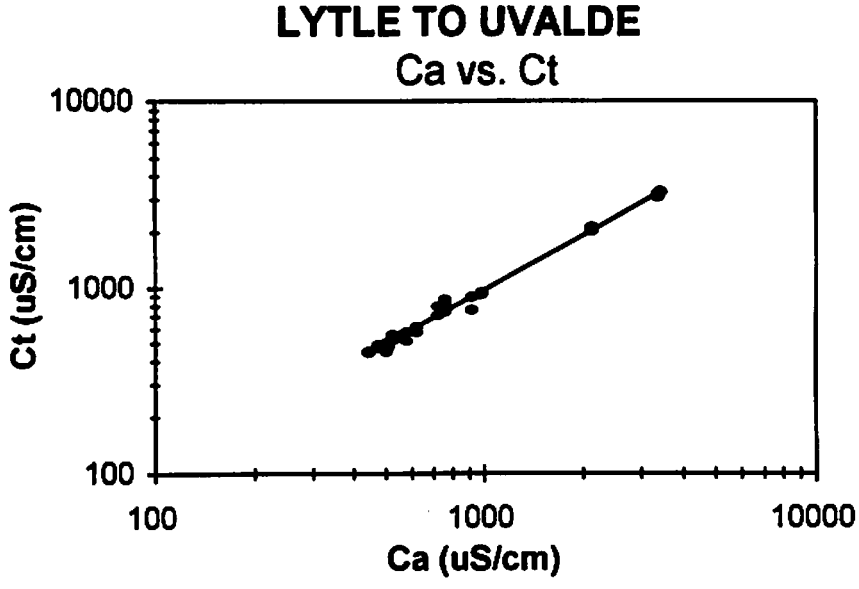

Figure 5. Correlation between measured specific conductance (Ct) and geophysical log-derived specific conductance (Ca) for control wells (Table 3). Specific conductance in microsiemens/cm. r^2 (correlation coefficient squared) =.994. Relationship is: Ct (from Ca) = .94Ca + 26.

RELATIONSHIP BETWEEN TOTAL DISSOLVED SOLIDS AND LOG DERIVED SPECIFIC CONDUCTANCE (LYTLE TO UVALDE)

Comparison of these two sets of data is often difficult because a low percentage of Edwards aquifer wells have both measured water sample information and adequate geophysical log recordings. Testing and logging of EUWD South Medina County

Observation Well #1 has appreciably aided in establishing a relationship between TDS and Ca in an area previously lacking controlled measurements of the entire Edwards interval. Data from the new test well was combined with measured TDS values and specific conductance calculations from nine other wells in the area between Lytle and Uvalde to construct a plot **(Figure 6)** which yields a good correlation. The correlation coefficient squared (r^2) is .979, which is comparable to that observed for Ct versus TDS (measured), which is .977 **(Figure 5).** Most of the points shown on the Ca vs. TDS plot **(Figure 6)** represent TDS values less than 1000 mg/L. However, the plot of Ct vs. TDS **(Figure 4)** has 18 points which are greater than 1000 mg/L. This observation indicated that two relationships needed to be employed in order to most effectively utilize the various combinations of Ct, Ca, and TDS.

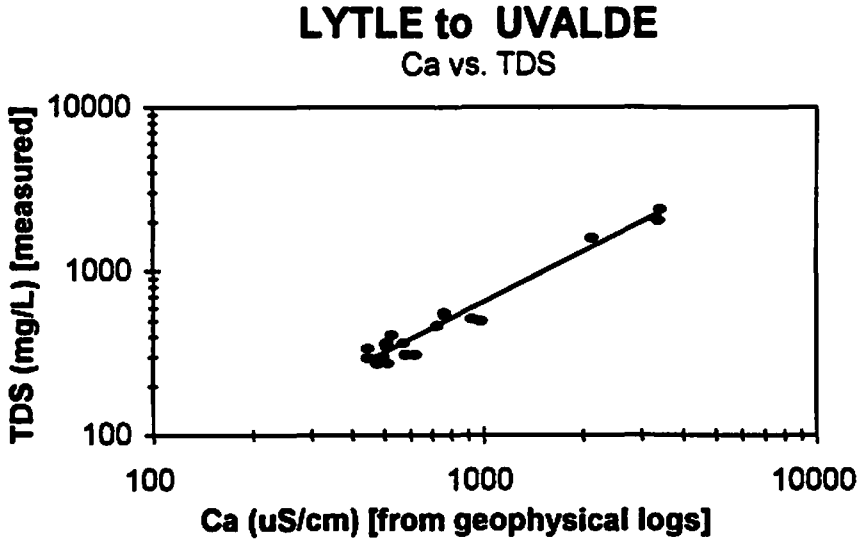

Figure 6. Correlation between measured total dissolved solids (TDS) and specific conductance (Ca) calculated from geophysical logs of control wells (Table 3). Crossplot reveals a well defined trend and a high correlation coefficient squared (r^2) = .979. Total dissolved solids in mg/L. Specific conductance in microsiemens /cm. Relationship is: TDS estimated (TDSest.) = .67Ca - 12.

ALGORITHM FOR ESTIMATING TOTAL DISSOLVED SOLIDS USING SPECIFIC CONDUCTANCE VALUES CALCULATED FROM LOGS

A critical review of all plots relating measured to calculated water quality parameters indicates that the estimated TDS values can best be determined by using two equations which

represent concentrations of data in two ranges. For estimating TDS values where log derived specific conductance is less than 1200 uS/cm, data shown on **Figure 6** appears to have the best fit in the lower range. Additionally this crossplot has a high percentage of specific conductance values less than 1000 uS/cm which were acquired from EUWD South Medina Observation Well #1 **(Table 3)**. This is desirable because the water type in this well may be representative of a majority of the freshwater/saline-water in Medina County. However, whenever specific conductance values are greater than 1200 uS/cm, the data shown on **Figure 4** more accurately describes the comparison. Employing these two preferred plots to determine estimated TDS from logs within the ranges where they have the best fit is enhanced by the comparison of **Ca vs. Ct (Figure 5)** which demonstrates a close fit of measured and log derived specific conductance data. As a result, a review of the data (Gary Stewart, personal communication, 1994) bares out the conclusion that the most usable TDS estimates calculated from geophysical log interpretations are as follows:

WHEN Ca > 1200 uS/cm: TDSest. = .75Ca - 101

WHEN Ca < 1200 uS/cm: TDSest. = .67Ca -12

The intent of this approach is to add a new dimension of exactness to the methodology.

SPECIFIC CONDUCTANCE MAP (LYTLE TO UVALDE)

Minimum calculated and/or measured specific conductance values from 135 wells **(Table 1)** were posted on a base map of the area from Lytle to Uvalde, Texas **(Figure 7, Plate 2)** and contours were constructed. The same contour intervals shown in EUWD Reports 92-03 and 93-06 have been repeated in order that comparisons can easily be made between the two studies. Also, the same symbols and other well identification nomenclature presented in EUWD Report 92-03 have been adopted. Only small changes have resulted in the update of the specific conductance map shown in EUWD Report 92-03. One of these differences is located between EUWD South Medina Observation Well #1 (37TD) and wells designated as 36TD and 38TD (approximately 6 miles west of Devine, Texas) **(Figure 7, Plate 2)** Calculated specific conductance values from well 38TD is 903 uS/cm which is an indication from past experience, that the 1000 mg/L TDS trace is relatively near. This information, plus the data from wells 36TD, 20KB, and 37TD is the reason for the

noticeable change in the specific conductance contours over this portion of the interface. Additional measured data in conjunction with calculated specific conductance values has also altered the position of contours between Uvalde and Sabinal. The revised edition displays an area with the 1000 uS/cm contour further south than that presented in EUWD Report 92-03. The change has been generated by added control. The two isolated areas north of the main 1000 uS/cm contour are also justified by the new well control.

TOTAL DISSOLVED SOLIDS MAP (LYTLE TO UVALDE)

The different vintages and interpretations of the freshwater/saline-water interface are best compared with maps using units expressed in total dissolved solids (TDS), since by definition the interface is the 1000 mg/L contour. The high degree of correlation between measured and calculated data **(Figures 4, 5, & 6)** provides some assurance that maps constructed utilizing a mix of actual measured data and points obtained from geophysical logs are valid and usable. The revision of the TDS map in EUWD Report 92-03 was undertaken because of the excellent data obtained from EUWD South Medina Observation Well #1 and subsequent acquisition of geophysical logs gathered after publication of EUWD Report 92-03. Additional data, both measured and calculated, has provided the means by which more accurate basic mapping values have been posted on the TDS map representing the area between Lytle and Uvalde, Texas. Examination of this map **(Figure 8, Plate 3)** depicts a very similar interface trace as previously shown in EUWD Report 92-03. Since there is a high degree of correlation between specific conductance and TDS **(Figure 4)**, changes in one will impact the other when empirical relationships are employed in generating map values. It follows that the area in the middle of the TDS map **(Figure 8, Plate 3)** representing the area between the recent test well (37TD) and wells 36TD and 38TD to the east has the same small change of contour geometry as that shown on the specific conductance map **(Figure 7, Plate 2)**. The moving of the 1000 mg/L TDS contour generally north between well 37TD and well 38TD is interpretative since few control points are present. However, the higher average specific conductance value obtained from geophysical log interpretations in well 38TD indicate that the revised position is justified.

The most southern extension of the interface in Frio County is south of the estimate

shown on the TDS map in EUWD Report 92-03. This minor difference between the two maps is caused by an updated sonic-porosity relationship, revised estimated TDS vs. specific conductance comparisons, and additional porosity log control. Estimating the position of the freshwater/saline-water interface position in this area using geophysical logs is very interpretative because the ratio of TDS to specific conductance may be much higher than that obtained from any of the plots. A hint of this problem is shown by well 8ZX where the ratio of TDS to specific conductance is .84 **(Table 2)**. More actual measured data needs to be acquired before a firm judgement can be made.

Improved resolution of the interface location northeast of Uvalde has been produced with the aid of additional measured data and newly acquired well logs. Positioning of the interface trace is based upon the lowest estimated or measured TDS value in each well. Several wells reveal multiple zones with variable water quality **(Table 1).** Faulting and igneous activity (Maclay, etal, 1984) possibly play a role in the location of the two isolated areas with TDS greater than 1000 mg/L northeast of Uvalde, that are north of the main interface contour.

TOTAL DISSOLVED SOLIDS (TDS) MAP (KYLE TO UVALDE)

A composite TDS map **(Figure 9, Plate 4)** constructed using results of this study, EUWD Reports 92-03 and 93-06 is shown for the entire area from Kyle to Uvalde, Texas. The interface position is well defined from Kyle to the Medina County line. Sufficient measured and log derived TDS control provide a means to construct a 1000 mg/L contour that can be used with confidence. The level of accuracy is controlled by the distribution and density of points measured and those obtained from quantitative geophysical log interpretation. The revised 1000 mg/L contour between Kyle and Lytle **(Figure 9, Plate 4 & Figure 22 &Plate 3[EUWD Report 93-06])** closely parallels recent published interface data (Schultz, 1993). For most practical aquifer management applications, the revised freshwater/saline-water interface position east of Lytle should be satisfactory.

The freshwater/saline-water interface from Lytle to Uvalde has been extensively revised and updated. Major differences are evident **(Figure 9, Plate 4)** when comparing the updated version to one of the common recent published (Brown, et al, 1992) interface

locations. The primary source of data demonstrating a need for revision is EUWD South Medina Observation Well #1, which tested freshwater from the entire Edwards aquifer interval. This well is nearly three miles south of the previous interface trace (Waugh, 1993). "Fine tuning" of the entire interface west of Lytle to Uvalde was accomplished by merging the new test well data with all other measured and geophysical log derived estimates as described in this report. All of the major changes **(Figure 9, Plate 4)** are the result of additional control, both measured and calculated. These changes are not to be construed to be the result of a major shift in the position of the freshwater/saline-water interface. Data and results of this study are intended to supply a usable interface location. Considerable additional observation wells equipped with measuring devices capable of recording water quality and hydrologic data over several cycles of high and low regional water levels will be required to confidently determine changes in the freshwater/saline-water interface position.

Improvements in the location of the freshwater/saline-water interface are inevitable, as shown by the past history (Schultz, 1992) of changes. This report is an attempt to place the interface position accurately by using data and technology currently readily accessible. A cooperative effort by all interested parties will aid in further refinements in this important aspect of aquifer management.

SUMMARY AND CONCLUSIONS

This report is the latest attempt to accurately describe the location of the freshwater/saline-water interface from Kyle to Uvalde, Texas. Multiple sources were used to obtain high quality measured specific conductance and total dissolved solids values. All comparisons relating specific conductance to total dissolved solids have shown a high degree of correlation in every area near the interface. Total dissolved solids estimates derived from quantitative geophysical log recordings agree well with actual measurements taken in the same boreholes. The practical use of merged, measured, and calculate data is demonstrated along the interface from Kyle to Lytle, where abundant measured data is observed to be sufficiently distributed among map values generated from geophysical logs. As a result, the revised interface closely parallels former estimates. The changes are dictated by added control and, to a minor degree, by the contour options on the part of the various investigators.

The area from Lytle to Uvalde is lacking an abundant supply of TDS measurements. Therefore, reliance upon TDS estimates obtained from quantitative geophysical log interpretations is necessary. This is especially true in southern Medina County. To verify the major difference between the interface location presented in EUWD Report 92-03, EUWD South Medina Observation Well #1 was drilled. This well proved that freshwater was at least three miles south of the commonly accepted freshwater/saline-water interface. This test well data and other additional geophysical logs were used to enhance the TDS and specific conductance maps furnished in EUWD Report 92-03. The TDS map shown in EUWD Report 93-06 has been merged with the TDS map shown in this report (Lytle to Uvalde) to provide the most current interpretation of the freshwater/saline-water interface position from Kyle to Uvalde, Texas. Accuracy of the interface position west of Lytle is not as sound as that shown for the area east extending to Kyle, Texas. To more precisely determine the freshwater/saline-water interface location between Lytle and Uvalde, acquisition of measured well data, which may have been overlooked in the past, and drilling of additional observation wells will be required. The position of these new wells will be dependent upon the area where the most critical information is required.

REFERENCES CITED

Alger, R. P., 1966, Interpretation of electric logs in fresh water wells in unconsolidated formations, paper CC, *in* 7th annual symposium transactions: Society of Professional Well Log Anallysts, 25p.

Brown, D. S., B. L. Petri, and G. M. Alley, 1992, Compilation of hydrologic data for the Edwards aquifer, San Antonio area, Texas, 1991, with 1934-91 summary: Edwards Underground Water District Bulletin 51, 169 p.

Maclay, R. W., P. L. Rettman, and T. A. Small, 1980, Hydrochemical data for the Edwards aquifer, in the San Antonio area, Texas: Texas Department of Water Resources, LP-131, 38p.

_____ and T. A. Small, 1984, Carbonate geology and hydrology of the Edwards aquifer in the San Antonio area, Texas: U. S. Geological Survey Open-File Report 83-537, 70p.

Poteet, D., H. A. Collier, and R. W. Maclay, 1992, Investigation of the fresh/saline-water interface in the Edwards aquifer in New Braunfels and San Marcos, Texas: Edwards Underground Water District Report 92-02, 172 p.

Schultz, A. L., 1992, Using geophysical logs in the Edwards aquifer to estimate water quality along the freshwater/saline-water interface (Uvalde to San Antonio, Texas) : Edwards Underground Water District Report 92-03, 47 p.

_____ 1993, Defining the Edwards aquifer freshwater/saline-water interface with geophysical logs and measured data (San Antonio to Kyle, Texas) : Edwards Underground Water District Report 93-06, 81 p.

Waugh, J. R., 1993, South Medina County observation well project: Edwards Underground Water District Report 93-11, 10 p.

Table 1 . Calculated and/or measured data from geophysical logs and other sources (Lytle to Uvalde)

Frio County

Map I. D. Number	Other well Identification	Depth from:	interval to:	Ca	Ct	TDSm	TDSest.	Mo/yr log recorded	Mo/yr measured	*Remarks
1KB	Tenneco #1 Mechen	3504	3878	2376			1681	6/69		EUWD 92-03, recalculated
2KB	Kirkwood #1-A Brown	4440	4782	5507			4029	8/61		sonic added
3KB	Gen. Crude #1 Browne	4490	4632	3978			2883	5/62		EUWD 92-03
5KB	Moncrief #2 Rheiner	4596	4780	2243			1581	11/68		EUWD 92-03, recalculated
		4850	4968	1577			1082			"
		4982	4990	2761			1970			"
		5120	5130	40613			30359			"
6KB	Arrow #1 Thompson	4910	4930	245360			183919	12/89		EUWD 92-03
7KB	Energy Exp. #1 Boysville	4980	4990	116145			87008	8/76		"
9KB	Tenneco #1 Goad	3736	4440	1792			1243	6/69		"
10KB	Amerada #1 Hiler	3300	3900	1098			724	4/55		"
11KB	Tobin #1 McMahan	3240	3305	685			447	10/68		"
12KB	Tobin #2 McMahan	3300	3340	785			514	1/69		"
13KB	Graham #1 Ireland	3130	3160	463			298	7/59		"
14KB	Tenneco #1 Mack	5045	5580	34404			25702	3/68		"
15KB	Moncrief #1 Rheiner	4888	5620	34913			26084	8/68		"recalculated
16KB	Tenneco #1 Stoker	4685	5410	49821			37265	10/67		EUWD 92-03
17KB	Jergins #1 Goad	3900	3930	2471			1752	1/53		"
18KB	Strake #1 Henry	3610	3670	1063			700	8/46		"
19KB	Tenneco #1 Wilbeck	4160	4552	5303			3876	1/69		"
		4740	4800	10976			8131			"
20KB	Allied #1 Williams	3374	3766	2473			1754	2/83		"
		3782	3983	3952			2863			"
21KB	Border #1 Mann	3382	3790	2721			1940	11/80		"
		3836	3998	4388			3190			"
23KB	Tenneco #1 Sirianni	3976	4552	4628			3370	2/68		"

***Remarks: An explanation of units, symbols used, and other notations under Remarks is shown for Tables 1, 2, and 3 at the end of Table 3, page 31.**

Estimated TDS values shown in Table 1 have been calculated using the following:
When Ca> 1200uS/cm: TDSest. = .75Ca - 101
When Ca< 1200uS/cm: TDSest. = .67Ca - 12

Table 1 . Continued

Map I. D. Number	Other well Identification	Depth interval from:	to:	Ca	Ct	TDSm	TDSest.	Mo/yr log recorded	Mo/yr measured	Remarks
24KB	Tenneco #1 Edgar	3710	3862	4152			3013	1/69		"
		3938	4180	5812			4258			"
		4250	4283	11922			8841			"
25KB	Pagenkopf #1 Blackaller	3200	3605	926			608	6/37		"
26KB	Strake #1 Henry	3590	3605	1602			1101	6/46		"
27KB	GO #1 Patterson	3340	3750	2469			1751	8/92		additional well
		3792	3950	4082			2961			"
Medina County										
4TD	Humble #1 Wilson	2815	3240	493			318	11/48		" recalculated
5TD	Tenneco #1 Ney	1450	1827	661			431	10/66		"
6TD	Ford #1 Nunley	1750	2126	560			363	12/59		"
7TD	Ford #1 Raybourn	1365	1780	341			216	11/59		" sonic added
8TD	Galaxy #1 Leoncita	2540	3218	1042			686	10/77		"
9TD	Tenneco #1 Hardie	2644	3300	546			354	5/69		" sonic added
10TD	Tenroc #1 Hardie	2570	2650	312			197	4/81		"
11TD	SA Oil #1 Adams	1990	2025	402			257	10/56		"
12TD	Tenneco #1 Wilson	2275	2700	698			456	6/67		"recalculated
13TD	Mowinkle #1 Mofield	1920	1950	610			397	7/49		"
14TD	Johnson #1 Howard	2340	2750	558			362	2/65		" sonic added
16TD	Parker #1 McCune	2180	2240	246			153	9/51		"
17TD	Tenneco #1 Carroll	2314	2698	917			602	10/69		" recalculated
18TD	Wood #2 Collins	2557	2685	3153			2264	12/69		"
		2720	3050	3987			2889			"
19TD	Wood #1 Collins	2708	2856	2612			1858	5/69		"
		2885	3056	4043			2931			"
20TD	Venus #1 Collins	2715	2890	2570			1827	10/79		"
		2890	3136	3401			2450			"
21TD	Moncrief #1 Collins	2828	2978	3831			2772	7/68		"recalculated
		3043	3290	4602			3351			" "
22TD	Tenneco #1 Powell	2730	3112	2076			1456	7/67		"
23TD	Hughes #1 Plachy	2604	2832	1856			1291	11/68		"
		2877	3102	4133			2999			"
24TD	Cities S. #1 Briscoe	2518	2866	430			276	1/72		"recalculated
25TD	Hughes #1 Keller	2404	2618	1888			1315	6/69		" "
		2662	2898	828			543			" "
26TD	Hughes #1 Cadenhead	2498	2740	1116			736	11/68		" "
		2766	2912	934			614			" "

Table 1 . Continued

Map I. D. Number	Other well Identification	Depth from:	interval to:	Ca	Ct	TDSm	TDSest.	Mo/yr log recorded	Mo/yr measured	Remarks
27TD	Progress #1 Haass	2685	2910	881			578	1/56		EUWD 92-03
		3000	3160	723			472			"
28TD	Progress #1 Bendele	2715	2935	520			336	11/54		"
		2990	3210	470			303			"
29TD	TD-68-49-813	2605	3098	760	865	562	497	3/73	3/73	sonic log added, LP-131
		2838	3098	762	821	544	499			"
30TD	Pan Am #1 Knipp	2995	3258	1902			1326	11/65		"recalculated
		3289	3398	3013			2159			"
		3452	3558	3696			2671			"
31TD	Pan Am #1 Lilly	3010	3154	1242			831	1/67		"recalculated
		3226	3362	2621			1865			"
		3387	3564	4471			3252			"
32TD	Douglas #1 Watson	2988	3216	2634			1875	2/72		"recalculated
		3257	3408	2003			1401			"
		3450	3500	4583			3336			"
33TD	Hart-Bar Deer Farm	1990	2227	527			341	12/89		"recalculated
35TD	Fair #1 McAnelly	2080	2580	398			255	11/45		"
36TD	Atkinson #1 Crain	2519	3011	849			557	8/85		additional well
37TD	EUWD S. Med. Obv. #1	2690	3327	510	477	349	330	8/93	8/93	additional well, see Tbl 2
38TD	Atkinson #1 McDonough	2700	3192	903			593	11/85		additional well
39TD	Atkinson #1 Lilly	2895	3126	1888			1315	1/86		additional well
		3170	3395	1218			813			"
40TD	Med-Tex #1 Robertson	2745	2972	555			360	12/56		additional well
41TD	Glasscock #1 Mercantile	1990	2290	563			365	6/46		additional well
42TD	Ginther #1 Carle	1940	2350	486			314	6/66		additional well
43TD	TD-69-56-507	2160	2648	512	503	276	331	12/75	7/89	additional well, EUWD #49
44TD	TD-69-55-701	2190	2800	475	491	274	306	9/75	9/90	additional well, EUWD #50
		2190	2800		532	293			1/76	LP-131
45TD	TD-68-49-501	2250	2708	494	484	302	319	5/78	2/78	additional well, USGS -SA
46TD	City of Devine #2 (4/91)	2224	2661	537			348	4/91		additional well

Table 1 . Continued

Uvalde County

Map I. D. Number	Other well Identification	Depth from:	interval to:	Ca	Ct	TDSm	TDSest.	Mo/yr log recorded	Mo/yr measured	Remarks
1YP	Branham #1 Downie	720	850	2857			2042	7/64		EUWD 92-03
3YP	YP-69-53-701	2200	2200	619	620	393	403	6/60	7/74	"
		2470	2480	1532			1048			"
4YP	YP-69-53-703	2150	2380	884	763	484	580	7/60	4/72	"
5YP	Howeth #1 Kincaid	2735	3116	1303			876	7/63		"recalculated
		3144	3151	4998			3648			"
		3222	3233	7989			5891			"
6YP	Int. Nuclear #1 Kincaid	2230	2280	5284			3862	11/68		"
7YP	Int. Nuclear #2 Kincaid	1790	1884	7370			5427	12/68		"recalculated
8YP	Phillips #2 Kincaid	2520	2620	1909			1331	5/50		"
9YP	Steeger #1 Kincaid	2420	2480	25329			18896	7/61		"
10YP	Steeger #2 Kincaid	1885	2040	21983			16386	12/61		"
11YP	Tenneco #1 Kincaid	1940	1975	3504			2527	8/69		"
12YP	Gorman #B-11Woodley	2350	2500	799			523	3/64		"
		2590	2610	3287			2364			"
13YP	Gorman #B-1 Woodley	2470	2500	2445			1733	8/60		"
		2660	2700	811			531			"
		2915	2970	1045			688			"
14YP	YP-69-51-702		1000		2430	1800			7/85	EUWD 92-03
15YP	YP-69-51-703		1580		2740	2100			7/85	"
16YP	YP-69-51-704		1640		3330	2800			7/85	"
17YP	YP-69-51-705		1660		3450	3000			8/85	"
18YP	YP-69-51-501		1050		3320	2380			10/72	LP-131
19YP	YP-69-52-403	967	1175	3376	3090	2050	2431	3/74	7/89	logs added, EUWD #49
20YP	YP-69-51-104	130	240	981	920	503	645	2/75	5/89	" "
21YP	YP-69-51-112		250		1170	1100			3/85	EUWD #45
22YP	YP-69-51-115		570		885	560			3/85	"
23YP	YP-69-51-102		391		639	390			3/85	"
24YP	Gorman #B-5 Woodley	2410	2420	1225			818	10/60		EUWD 92-03
25YP	Gorman #B-9 Woodley	2400	2415	1226			819	2/61		"
26YP	Gorman #B-10 Woodley	2260	2280	705			460	3/61		"
28YP	Freisenhahn	1010	1050	1182			780	4/90		"recalculated
29YP	YP-69-50-803	696	770	2635			1875	11/90		EUWD 92-03
30YP	General Tire Co.	1830	1890	9152			6763	7/88		"
31YP	Mosing/4-M Ranch	932	1394	1003			651	8/89		"recalculated

Table 1. Continued

Map I. D. Number	Other well Idintification	Depth from:	interval to:	Ca	Ct	TDSm	TDSest.	Mo/yr log recorded	Mo/yr measured	Remarks
32YP	YP-69-50-100	680	750	529			342	3/88		EUWD 92-03
35YP	Bennett & Sorrells #1 Rehn	1165	1410	512			331	12/44		additional well
36YP	YP-69-45-401	1004	1336	497			321	4/73		"
37YP	YP-69-44-401	744	850	728			476	11/72		"
38YP	Nelson #1 Water Well	1430	1660	499			322	1/57		"
39YP	YP-69-51-602	978	1180	3432			2473	10/72		"
40YP	YP-69-52-201	950	1075	5470			4002	5/71		additional well
		1090	1370	2076			1456			"
41YP	YP-69-43-603		1373		591	396			7/74	LP-131
42YP	YP-69-43-906		850		1830	1100			2/74	"
43YP	YP-69-44-703	980	1230	2062			1446	5/71		additional well
		1250	1505	883			580			"
44YP	Charles K. Wooten	935	1460	999			657	3/74		"
45YP	Jess Ward	844	880	425			273	6/73		"
46YP	Woodley (YP-69-44-4..)	645	1048	1572			1078	1/72		"
47YP	YP-69-43-908		1010		2560	1460			4/72	LP-131
48YP	YP-69-43-909		1305		1110	664			10/73	"
ZAVALA COUNTY										
1ZX	Andreen #1 Batesville Fmg.	3654	3708	36654			27390	3/75		EUWD 92-03
2ZX	Bluebonnet #1 Kincaid	3570	4268	3326			2394	5/54		"
3ZX	Rowe #1 Kincaid	3643	4248	3193			2294	12/68		"
4ZX	Exxon #1 Kincaid	2900	2990	2154			1515	5/61		"
5ZX	Exxon #3 Kincaid	3320	3460	2544			1807	6/63		sonic added
7ZX	Magnolia #1 Capps	3654	3670	11044			8182	10/48		EUWD 92-03
8ZX	ZX-69-61-526				3920	3300			3/75	LP-131

Table 2. Calculated and/or measured specific conductance and measured total dissolved solids from selected area wells (used as control data for construction of Ct, Ca, and TDS relationships). Calculated values are derived from geophysical logs.

Map I. D. Number	Other well identification	Depth interval from:	to:	Ca	Ct	TDSm	TDSest	Mo/Yr log recorded	Mo/Yr measured	Remarks
1AL	Tenneco #1 Smith	2306	2858	2124	2130	1600	1577	1/68	7/85	CONTROL IS 5AL
5AL	AL-68-51-101		2656		2130	1600	1577		7/85	EUWD #45
			2650		2060	1500	1521		7/85	EUWD #45
					2150	1530	1593		7/89	EUWD #49
6AL	AL-68-50-201				759	518	483		7/70	Lytle City Well, LP-131
N/A	AL-68-50-301		2650		912	580	605		4/85	EUWD #45
					915	597	608		7/89	EUWD #49
17TD	Tenneco #1 Carroll	2314	2698	917	759	518	483	10/69	7/70	CONTROL IS 6AL, 131-LP
29TD	TD-68-49-813	2605	3098	760	885	562	568	3/73	3/73	LP-131
		2838	3098	762	821	544	533	3/73	3/73	"
		2600	3200		1140	631	787		8/77	"
		2600	3194		1220	706	851		7/89	EUWD #49
		2600	3194		1190	640	827		7/90	EUWD #50
37TD	EUWD SOUTH	2690	2808	724	796	487	513	8/93	7/93	EUWD 93-11
	MEDINA OB. #1	2690	2924	620	575	312	338	"	"7/93	"
		2690	2884	581	515	313	289	"	7/93	"
		2690	3040	568	527	368	298	"	7/93	"
		2690	3168	524	559	410	324	"	7/93	"
		2690	3220	509	503	371	279	"	7/93-8/93	"AVG. 5 MEASUREMENTS
		2690	3291	503	448	363	235	"	8/93	"
		2690	3327	510	477	349	258	"	8/93	"USED ON MAP
		3040	3231	445	453	340	239	"	8/93	"
		3232	3406	444	447	298	234	"	8/93	"
43TD	TD-69-56-507	2160	2648	512	503	276	279	12/75	7/89	EUWD #49
44TD	TD-69-55-701	2190	2800	475	491	274	269	9/75	9/90	EUWD #50
		2190	2800		532	293	302		1/76	LP-131
45TD	TD-68-49-501	2250	2708	494	484	302	264	5/78	2/78	USGS FILES-SA
14YP	YP-69-51-702		1000		2430	1800	1816		7/85	EUWD #45
15YP	YP-69-51-703		1580		2740	2100	2064		7/85	"
16YP	YP-69-51-704		1640		3330	2800	2535		7/85	"
17YP	YP-69-51-705		1660		3450	3000	2630		8/85	"
18YP	YP-69-51-501		1050		3320	2380	2527		10/72	LP-131
19YP	YP-69-52-403	967	1175	3376	3090	2050	2343	3/74	7/89	EUWD #49
					3020	2100	2287		7/85	EUWD #45
					2940	2030	2223		7/90	EUWD #50
20YP	YP-69-51-1O4	130	240	981	920	503	612	2/75	5/89	EUWD #49
					824	450	535		3/85	EUWD #45
					858	467	562		6/90	EUWD #50
					836	454	545		6/91	EUWD #51
21YP	YP-69-51-112		250		1170	1100	811		3/85	EUWD #45
22YP	YP-69-51-115		570		885	560	584		3/85	EUWD #45
23YP	YP-69-51-102		391		639	390	387		3/85	EUWD #45
					669	392	411		6/90	EUWD #50
33YP	YP-69-53-701		2575		620	393	372		7/74	LP-131
34YP	YP-69-53-703		1990		763	484	486		4/74	"
39YP	YP-69-51-602	960	1180	3432	3320	2380	2527	10/72	10/72	CONTROL IS 18YP
8ZX	ZX-69-61-526		3488		3920	3300	3005		3/75	"

Table 3. Calculated (Ca) and measured (Ct) values of specific conductance and measured total dissolved solids (TDS) from selected area wells used for establishing relationships between Ca, Ct, and TDS. Calculated values are derived from geophysical logs.

Map I. D. Number	Other well identification	Depth interval from:	to:	Ca	Ct	TDSm	TDSest	Mo/Yr log recorded	Mo/Yr measured	Remarks
1AL	Tenneco #1 Smith	2306	2858	2124	2130	1600	1411	1/68	7/85	Control is 5AL
17TD	Tenneco #1 Carroll	2314	2698	917	759	518	602	10/69	7/70	Control is 6AL, 131 LP
29TD	TD-68-49-813	2605	3098	760	865	562	497	3/73	3/73	LP-131
		2838	3098	762	821	544	499	3/73	3/73	"
37TD	EUWD South	2690	2808	724	796	467	473	8/93	7/93	EUWD #93-11
	Medina OBV. #1	2690	2924	620	575	312	403	"	'7/93	"
		2690	2984	581	515	313	377	"	7/93	"
		2690	3040	568	527	368	369	"	7/93	"
		2690	3168	524	559	410	339	"	7/93	"
		2690	3220	509	503	371	329	"	7/93-8/93	"Avg. 5 measurements
		2690	3291	503	448	363	325	"	8/93	"
		2690	3327	510	477	349	330	"	8/93	"Used on map
		3040	3231	445	453	340	286	"	8/93	"
		3232	3406	444	447	298	285	"	8/93	"
43TD	TD-69-56-507	2160	2648	512	503	276	331	12/75	7/89	EUWD #49
44TD	TD-69-55-701	2190	2800	475	491	274	306	9/75	9/90	EUWD #50
45TD	TD-68-49-501	2250	2708	494	484	302	319	5/78	2/78	USGS files, SA
19YP	YP-69-52-403	967	1175	3376	3090	2050	2250	3/74	7/89	EUWD #49
20YP	YP-69-51-1O4	130	240	981	920	503	645	2/75	5/89	EUWD #49
39YP	YP-69-51-602	960	1180	3432	3320	2380	2287	2/75	10/72	LP-131 (WELL 18YP)

Table 3. Continued - Explanation of Remarks and symbols for Tables 1 , 2, & 3.

EUWD 92-03	- basic well data taken from EUWD 92-03, 1992
EUWD 92-03, recalculated	- basic well data taken from EUWD 92-03 and log values reviewed and specific conductance recalculated
sonic added	- sonic log acquired since completion of EUWD 92-03 and specific conductance recalculated
additional well	- well with additional data added which was not part of EUWD 92-03
EUWD #45	- measured water quality data taken from EUWD #45, 1987
EUWD #49	- measured water quality data taken from EUWD #49, 1990
EUWD #50	- measured water quality data taken from EUWD #50, 1991
LP-131	- measured water quality data taken from TX Dept. Water Res., LP-131, 1980
logs added	- logs acquired and added to well shown in EUWD 92-03
"	- same as previous entry
"recalculated	- source for well data same as previous entry, specific conductance recalculated
other remarks	- as stated

Ca = Calculated specific conductance in microseimens per centimeter (uS/cm) - from geophysical logs

Ct = Measured specific conductance in microseimens per centimeter (uS/cm)

TDSm = Measured total dissolved solids in mg/L

TDSest. = Estimated total dissolved solids in mg/L