Hydrologic Atlas No. 9

Water Quality in the Rustler Aquifer

by
Eric Brown
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by Eric M. Brown, Environmental Specialist
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INTRODUCTION

The Rustler aquifer underlies the Delaware Basin in West Texas and Southwestern New Mexico. During the Permian age, deposition of predominantly carbonate sediments within the Delaware Basin, covered by a shallow sea and ringed by a reef, formed the Rustler Formation. The aquifer, underlying most of Reeves County, is also present in parts of Loving, Pecos, and Ward counties, and extends into extreme southeastern New Mexico. In addition, it underlies a small section of Brewster and Jeff Davis counties.

The formation is primarily composed of dolomite and anhydrite with minor amounts of limestone, sandstone, and shale. It has a basal zone of sand, conglomerate, and shale. In some areas the Rustler is reported to be cavernous. The aquifer crops out in the Rustler Hills in eastern Culberson County from where it downdips southeasterly at about 100 feet per mile. In Reeves County the aquifer dips toward the center of the county from both the east and west, probably as a result of water from deeper formations locally dissolving evaporites in the Rustler Formation and causing the formation to subside (Ogilbee et al, 1962). In Loving, Pecos, and Ward counties the aquifer is present only as downdip. Although the formation is present in Brewster and Jeff Davis counties, the Texas Water Development Board (TWDB) presently has no Rustler wells on record for these counties. The map in Figure 1 illustrates the aquifer's extent, outcrop, downdip, and location of sampled wells used in this atlas.

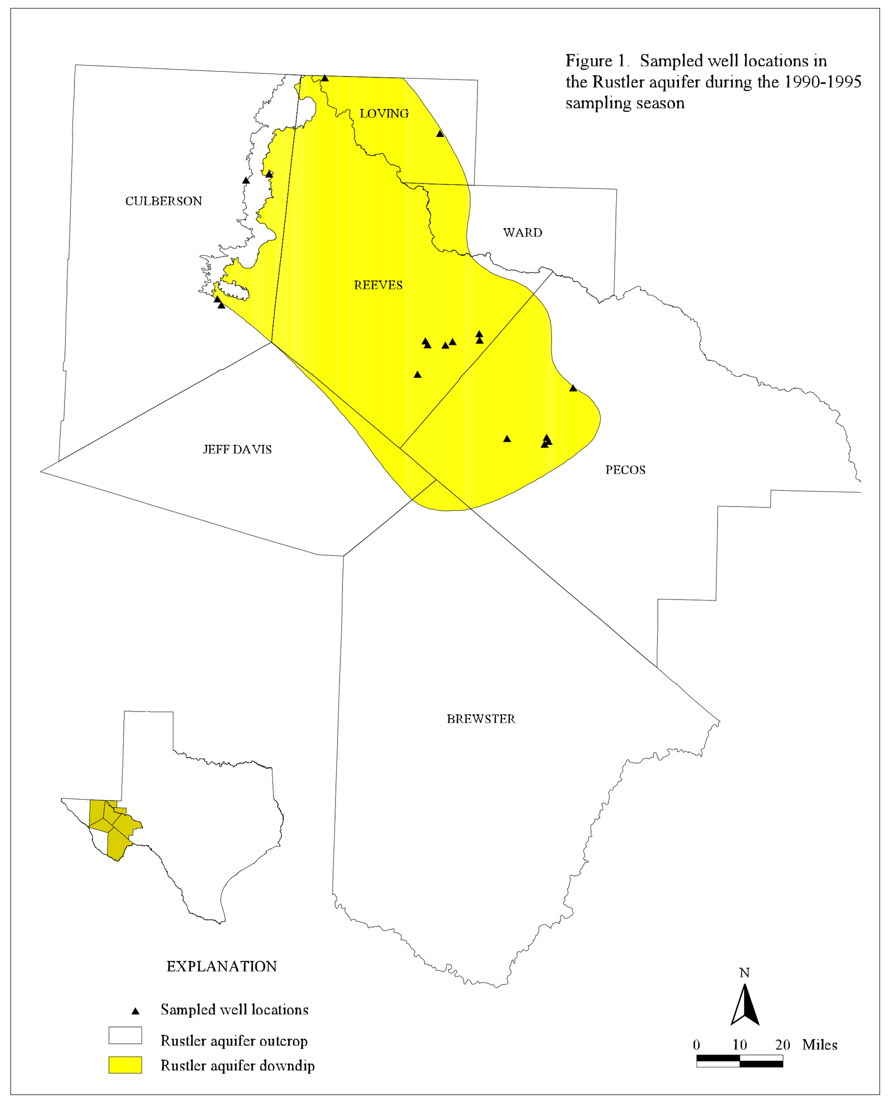

Figure 1 Sampled well locations in the Rustler aquifer during the 1990-1995 sampling season

Thickness across the formation ranges from 200 to 500 feet. Well depths range from 80 feet to 4,700 feet, with the deepest wells located in the subsurface portions in Pecos, Reeves, and Ward counties. Small to moderate amounts of slightly saline to brine water is available throughout most of the aquifer.

The aquifer is recharged primarily by rainfall and seepage from streams in the Rustler Hills area of Culberson County. Rainfall over this area averages about 9 inches. Discharge occurs through springs and wells. Artesian conditions exist over most of the aquifer's extent.

The TWDB sampled 18 Rustler wells (one twice—for a total of 19 samples) from 1990 through 1995 (15 in 1995). TWDB maintains an ongoing program to monitor the ambient water-quality in major and minor aquifers throughout the state and to determine any changes that may have occurred over time. The author sampled Rustler wells in Pecos and Reeves counties and wishes to thank the other environmental specialists who collected samples: John Asensio, Merrick Biri, Doug Coker, Dennis Jones, and Ron Mohr. Special thanks to the landowners who permitted their wells to be sampled and geologists Phil Nordstrom and Janie Hopkins who edited the atlas. All illustrations were created with ArcView by the author.

WATER QUALITY

Most working wells completed in the Rustler aquifer are used for irrigation and livestock. Wells sampled from 1990 to 1995 included 1 domestic, 10 irrigation, 1 industrial (oil-recovery), and 6 stock. Of the 18 wells sampled, 14 are completed in the downdip portion of the aquifer. Sampled wells range in depth from 80 to 3,300 feet.

High yield and high use wells are preferred because they tend to provide water more characteristic of the aquifer, such as the 10 irrigation wells sampled in this study. Regardless of the type of well, environmental specialists took steps to ensure each well was producing a good sample either by making arrangements to have the well pumping on arrival, or by purging the casing and monitoring certain indicator parameters before drawing a sample. Environmental specialists take field measurements and use appropriate sampling techniques as described in the TWDB *Field Manual for Ground Water Sampling* (Nordstrom and Beynon, 1991) for dissolved inorganic constituents, nutrients, and, for the first time in this aquifer, radioactivity. Constituent levels as determined by the Texas Department of Health Laboratory are discussed, and areas in which key constituents are in excess of maximum contaminant levels (MCLs) are illustrated in maps where appropriate. The primary and secondary MCLs, as set by the Texas Natural Resource Conservation Commission (TNRCC), are listed in Table 1.

Field Measurements

The ground water temperature of the Rustler samples ranged from 19° to 30°C and averaged 26°C. The average pH of all Rustler analyses was 7.0. The range was from 6.4 to 7.5. Secondary drinking water standards indicate that the pH should be greater than 7.0 because acidic water (less than 7.0) will act as a solvent to release metal ions to the water. The specific conductance for the entire aquifer ranged from 1,559 to 4,130 micromhos and averaged 2,614 micromhos. The average total alkalinity as determined in the field was 145 mg/l, with a range of 37 to 230 mg/l as $CaCO_3$; average bicarbonate ion concentration, calculated from mean total alkalinity, was 178 mg/l. The negative Eh average of -120 mV (range: -377 to +177 mV) indicates that the formation tends to have reducing conditions.

Constituent	Symbol	MCL
Primary Constituent Levels		
Antimony	Sb	6 µg/l
Arsenic	As	50 µg/l
Barium	Ba	2,000 µg/l
Beryllium	Be	4 µg/l
Cadmium	Cd	5 µg/l
Chromium	Cr	100 µg/l
Fluoride	F	4.0 µg/l
Lead (EPA Lead Rule)	Pb	5 µg/l
Mercury	Hg	2 µg/l
Nickel	Ni	100 µg/l
Nitrate (as N)	NO_3 (N)	10.0 mg/l
Selenium	Se	50 µg/l
Thallium,	Tl	2 µg/l
Gross Alpha	α	15 pCi/l
Gross Beta	β	50 pCi/l
Radium	Ra^{226} + Ra^{228}	5 pCi/l
Secondary Constituent Levels		
Chloride	Cl	300 mg/l
Copper	Cu	1,000 µg/l
Dissolved-Solids	TDS	1,000 mg/l
Fluoride	F	2.0 mg/l
Iron	Fe	300 µg/l
Manganese	Mn	50 µg/l
pH	pH	≥7.0
Silver	Ag	100 µg/l
Sulfate	SO_4	300 mg/l
Zinc	Zn	5,000 µg/l

Table 1. Drinking water standards for selected inorganic constituents and radioactive species as set by the TNRCC.

Dissolved Inorganic Constituents

The dissolved-solids content is the main factor limiting or determining the use of ground water. These solids primarily consist of mineral constituents dissolved from the host rock, although another natural source, such as adjacent aquifers or human-affected sources such as oil-field brines, can also contribute certain dissolved constituents. Table 2 describes four classes of ground water classified according to dissolved-solids content, as defined by the Texas Ground Water Protection Committee.

Class	Quality*	Examples of Use
Fresh	0 - 1,000	Drinking and all other uses
Slightly Saline	>1,000 - 3,000	Drinking if fresh unavailable; for livestock, irrigation, and industrial use
Moderately Saline	>3,000 - 10,000	Industrial, mineral extraction, oil and gas production; potential/future drinking and limited livestock watering and irrigation if fresh or slightly saline water is unavailable
Very Saline to Brine	>10,000	Mineral extraction, oil and gas production

* Concentration range of dissolved-solids in milligrams/liter
Table 2. Ground-water classification system.

Table 3 lists average concentrations and ranges of dissolved-solids and other inorganic constituents from the Rustler aquifer. None of the constituents had results reported as below detection levels (flagged with "<").

Constituent	Average*	Range*	# Above MCL
Bicarbonate	185	116 - 281	
Calcium	511	183 - 675	
Chloride	160	7 - 349	6**
Diss. Solids	2,798	1,456 - 3,787	18**
Fluoride	2.06	0.50 - 4.00	9**
Hardness	1,884	641 - 2,574	
Magnesium	146	44 - 220	
Potassium	12	3.60 - 25	
Silica	20	15 - 37	
Sodium	120	10 - 237	
Strontium	7.12	1.12 - 10	
Sulfate	1,716	489 - 2,352	18**

* Expressed in milligrams/liter ** secondary MCL
Table 3. Major anions and cations in Rustler aquifer ground water.

The averages and ranges above exclude a 1000-foot deep well in Loving County. This well was left out of the calculations because of its extremely high anion and cation levels which skewed the averages and provided an inaccurate interpretation of average water quality in the Rustler. For example, this well had a dissolved-solids content of 89,715 mg/l, a sodium content of 30,500 mg/l, and a potassium content of 702 mg/l. These high levels were unique compared to the rest of the sample results, as is evident in the ranges for each constituent, and are probably indicative of oil-field contamination in this well.

The dissolved-solids average of 2,798 mg/l reflects the normally saline character of the aquifer. Of the 18 wells sampled, all had dissolved-solids levels above the secondary MCL of 1,000 mg/l. These wells were located over the entire area of the aquifer, both in the outcrop and downdip (Fig. 2).

Chloride, naturally dissolved from rocks and soils, can also be introduced into ground water by human activities, as it is present in sewage, oil-field brines, industrial brines, and seawater (a possible contaminant of freshwater aquifers in areas of heavy pumpage). In large amounts in combination with sodium, chloride gives a salty taste to drinking water and can increase the corrosiveness of the water. Of the 1990 - 1995 samples, chloride levels were above the secondary MCL of 300 mg/l for 6 of the wells (Fig. 2). A high chloride level usually coincides with high dissolved-solids content; all 6 of these wells had corresponding dissolved-solids readings over 1,000 mg/l.

Fluoride is dissolved in small amounts from most rocks and soils. In drinking water it helps to inhibit tooth decay, but high levels can cause mottling of teeth. Fluoride concentrations throughout the entire aquifer were below primary MCLs, but 9 wells contained fluoride in excess of the secondary MCL of 2.0 mg/l.

Sulfate is formed by the dissolution of sulfur from rocks and soils containing sulfur compounds such as gypsum and anhydrite, the latter being a predominant part of the Rustler formation. Sulfate in large amounts in combination with other ions gives drinking water a bitter taste. All of the wells recently sampled contained sulfate in excess of the secondary MCL of 300 mg/l.

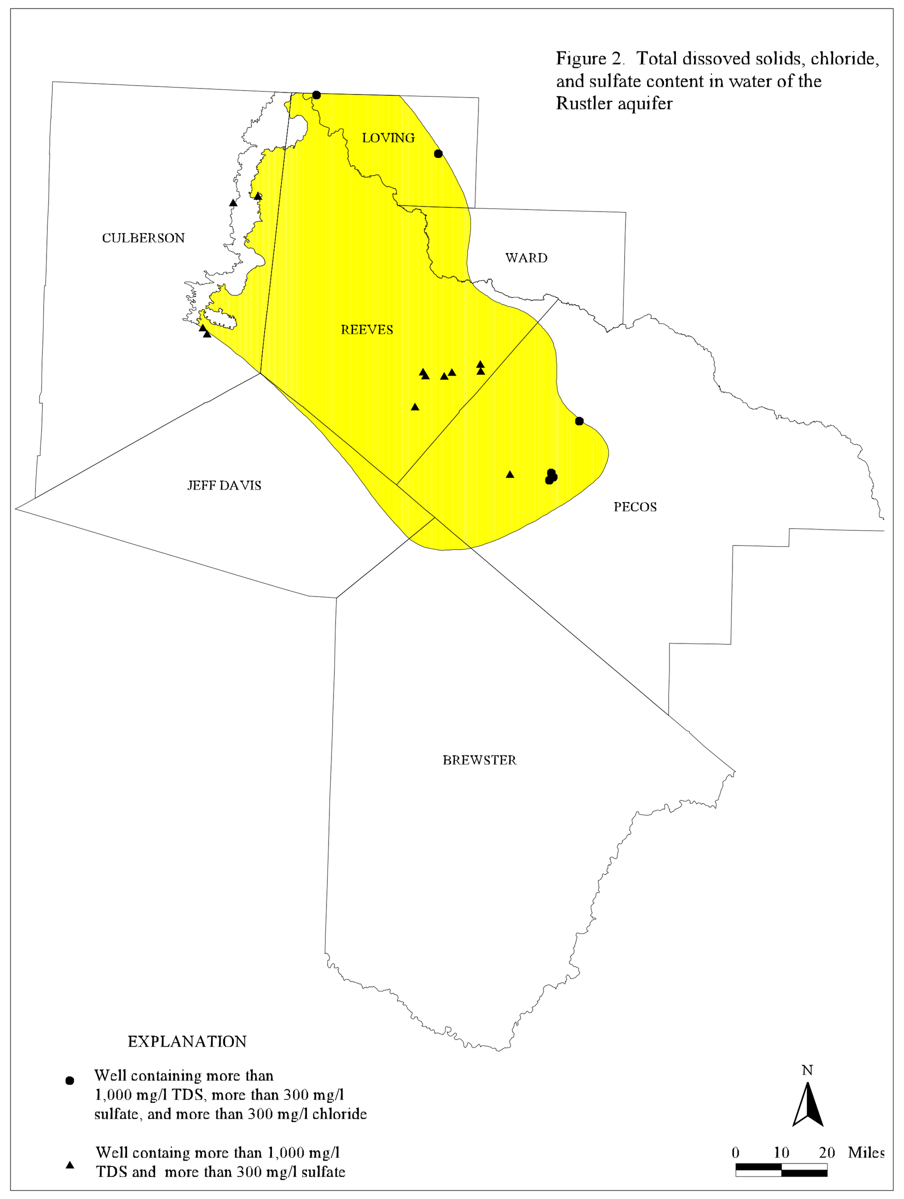

Figure 2 Total dissolved solids, chloride, and sulfate content in water of the Rustler aquifer

Table 4 lists averages and ranges of dissolved trace metal constituents in the Rustler aquifer, for the most part detected in insignificant amounts. A majority of the analyses for several of the constituents were below lab detection levels. Five of these constituents— arsenic, beryllium, cadmium, lead, and thallium— had 100% of their results below detection levels; chromium, mercury, and silver had all but one analysis below detection levels. *Please note*: Each average for the corresponding constituent reflects values above detection limits, that is, values that do not have a "<" sign. For all constituents the number of samples tested for a particular constituent is in parentheses. The well suspected of contamination in Loving County was left in this data set because levels of dissolved metals did not appear to be unusually high compared to the other wells.

Constituent (No. of samples)	Average*	Range*	# Above MCL	# Below detection level
Aluminum (11)	57	3 - 166		8
Antimony (16)	3.90	< 2.0 - 5.50		13
Arsenic (19)	NA	< 1.0 - <10		19
Barium (19)	14.4	< 6.0 - 30		4
Beryllium (16)	NA	< 1.0 - < 8		16
Boron (17)	475	183 - 940		0
Bromide (15)	0.39	< 0.01 - 0.90		0
Cadmium (19)	NA	< 0.50 - <10		19
Chromium (16)	5.80	< 2.0 - < 64		15
Cobalt (12)	2.47	2.3 - < 64		9
Copper (17)	13.1	< 2.0 - < 48		14
Iron (19)	1,307	<6 - 8,360	8**	2
Lead (19)	NA	< 2.0 - < 50		19
Lithium (15)	125	10 - 200		2
Manganese (19)	14	1.10 - 52	1**	8
Mercury (10)	0.20	< 0.13 - < 2.0		9
Molybdenum (16)	9.0	< 2.0 - < 50		14
Nickel (9)	46	< 20 - < 160		6
Selenium (19)	15	< 2.0 - 40		14
Silver (15)	27	< 2.0 - 27		14
Thallium (16)	NA	< 2.0		16
Vanadium (13)	6.50	< 2.0 - < 64		10
Zinc (18)	193	< 5 - 698		9

*Expressed in micrograms/liter (µg/l) ** Secondary MCL
Table 4. Dissolved trace metal constituents in Rustler ground water.

Boron is a minor constituent in most natural waters. Although it has no drinking water standard, knowledge of its concentration in ground water is important because it determines the suitability of the water for irrigation. Concentrations as high as 1,000 µg/l are permissible for irrigation of boron-sensitive crops such as deciduous fruit and nut trees; as high as 2,000 µg/l for irrigation of semi-tolerant crops such as most grains, cotton, and potatoes; and as much as 3,000 µg/l for tolerant crops such as alfalfa and most root vegetables. None of the wells sampled contained boron in excess of 1,000 µg/l.

Iron, dissolved from rocks and soils, occurs naturally at low levels in ground water. Higher levels can often be traced to iron casing and other equipment used in well construction, or attributed to natural causes depending on the geology of the water-bearing formations. Manganese, found naturally in ground water, and typically at low levels, can also occur naturally at high levels, often in conjunction with high iron levels. Figure 3 illustrates well locations where iron and manganese exceeded their secondary contaminant levels of 300 µg/l and 50 µg/l, respectively. Eight wells contained iron levels in excess of the secondary MCL. One well in Loving County, previously mentioned as being suspected of contamination, contained both iron and manganese in excess of secondary MCLs.

Nutrients

Of the four nutrients analyzed in each well, only nitrate and nitrite have drinking water standards. Nitrate, an end product of the aerobic stabilization of nitrogen, particularly organic nitrogen, is a potential pollutant in any agricultural area. It is to be expected at high concentrations where fertilizers are used and in decayed animal and vegetable matter. Concentrations are also commonly higher in leachates from sludge and refuse disposal and in industrial discharges. Nitrite, formed by the action of bacteria upon ammonia and organic nitrogen, when detected in potable water in considerable amounts, is an indication of sewage/bacterial contamination and inadequate disinfection (De Zuane, 1990). In such reducing environments, nitrite is not oxidized to nitrate. However, in the oxidizing environments common in most aquifers, nitrites are converted into nitrates, and their values are lower. In this study, none of the wells sampled contained nutrients in excess of drinking water standards.

Constituent*	Average	Range	# Above MCL	# Below detection level
Ammonia (as N) (19)	0.22	< 0.01 - 0.84		2
Nitrite (as N) (19)	0.02	< 0.01 - 0.06		15
Nitrate (as N) (18)	3.14	< 0.01 - 26		2
Kjeldahl (19)	0.56	0.08 - 1.50		0

* Expressed in milligrams/liter
Table 5. Dissolved nutrients in Rustler ground water.

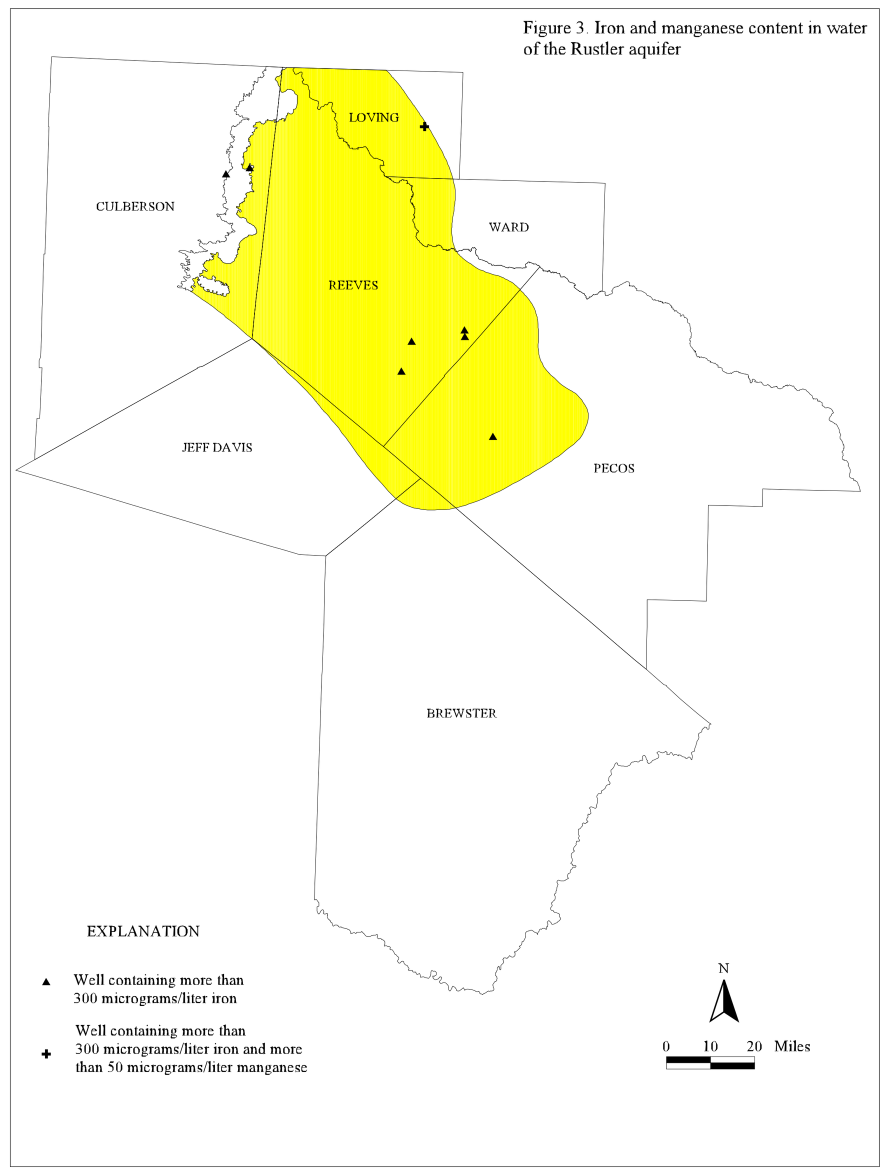

Figure 3. Iron and manganese content in water of the Rustler aquifer

Radioactivity

Gross alpha (α) is the total radioactivity, measured in units of picocuries per liter (pCi/l), due to alpha particle emission. Alpha-emitting isotopes in natural waters are primarily isotopes of $radium^{226}$ and $radium^{228}$ and usually occur in deep aquifers or in areas affected by uranium or phosphate mining. Gross beta (β) radiation is the total radioactivity due to beta particle emission. Natural β-emitting isotopes occur in the uranium and thorium disintegration series, among other natural sources. Radium is derived from igneous rocks such as granites, uranium ores, certain shales and sandstones, and volcanic rocks. The dominant radium isotopes found and detected in natural waters are $radium^{226}$ and $radium^{228}$. In these analyses, 13 of the samples (12 wells) exceeded primary MCLs for one or more type of radioactive elements. Figure 4 illustrates the location of the wells. All of these wells were located in the downdip, and therefore deeper, portion of the aquifer in Loving, Pecos, and Reeves counties. Note: The primary MCL for $radium^{226}$ and $radium^{228}$ is 5 pCi/l for the sum of both. In this study, two wells exceeded this standard.

Constituent*	Average	Range	# Above MCL	# Below detection level
Gross alpha (17)	84	5.60 - 277	13	
Gross beta (17)	66	< 6.0 - 396	8	1
$Radium^{226}$ (2)	120	30, 209	2	
$Radium^{228}$ (2)	20	2.8, 37	1	

* Expressed in picocuries/liter
Table 6. Radioactivity in Rustler ground water.

Alpha particle radiation cannot penetrate human skin, but is very dangerous when the alpha emitting particle is ingested. Beta particle radiation can penetrate human skin. Both types of radioactivity are very harmful to tissue in internal organs and damage depends on time and dosage of the radiation. Depending on these factors, the tissue may recover or develop cancerous cells or tumors. Radium, in excessive concentrations, can cause bone and bone marrow cancers.

Uranium-rich and deep aquifers are both known to contain natural amounts of radioactivity, although the Rustler does not contain uranium nor is it particularly deep. A possible explanation for the increased radioactivity found in this aquifer would be the migration of water from deeper formations. This is only a hypothesis and further research is needed to confirm the source of the radioactivity.

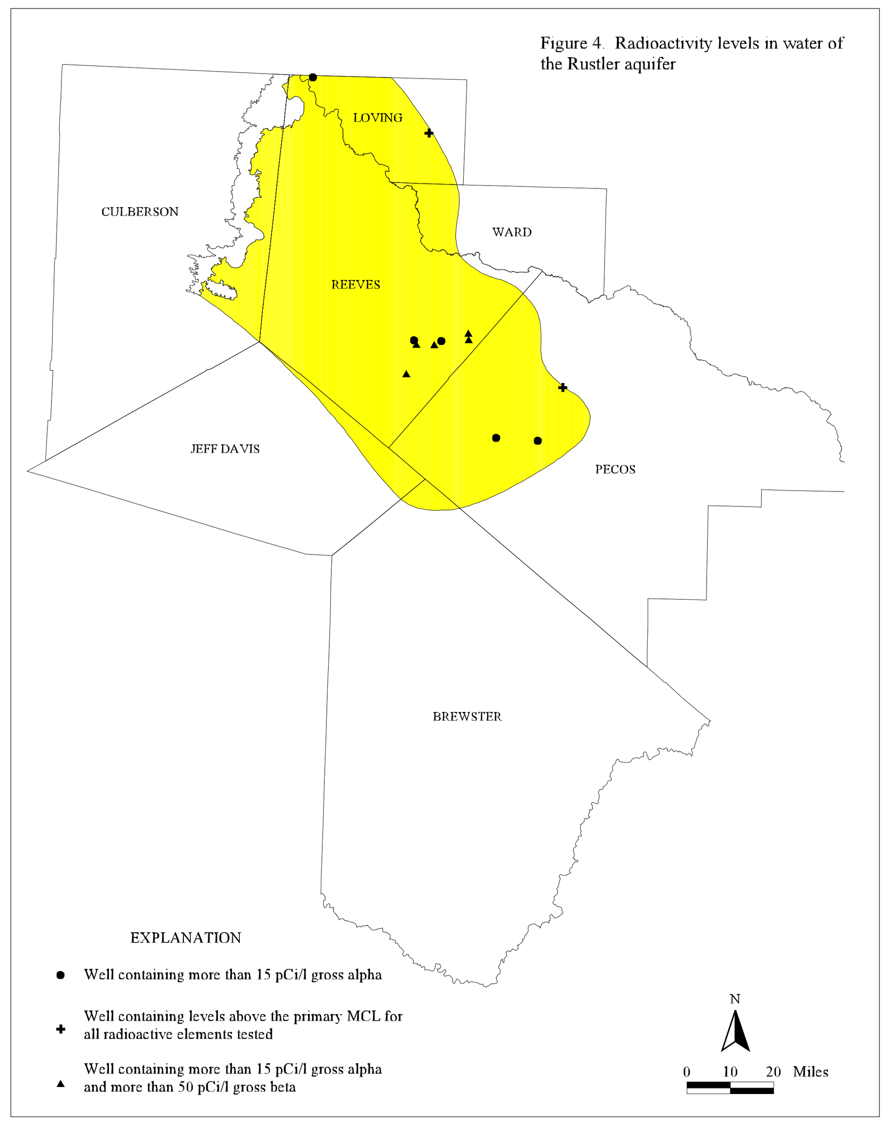

Figure 4. Radioactivity levels in water of the Rustler aquifer

COMPARISON TO PREVIOUS WORK

Reviewing past studies show findings similar, but not as detailed, to those in this report. Armstrong and McMillion (1961) reported levels of dissolved-solids ranging from 1,730 mg/l to 2,580 mg/l in Pecos County; sulfate and calcium occurred at high levels; and chloride at low. Hydrogen sulfide gas also dissipates from the water (Armstrong and McMillion,1961). In Reeves County, water from the basal zone was very saline, over 10,000 mg/l, but quality improved in water from the upper portion of the aquifer, where dissolved-solids ranged from 1,000 mg/l to 4,000 mg/l (Ogilbee et al., 1962). Ogilbee (1962) also reported Rustler water in Reeves County to be true "gyp" water, because of the solution of gypsum and anhydrite. Richey et al. (1985) stated that Rustler water in Pecos and Reeves counties was usually very saline and moderately saline in Ward County. White (1971) reported Rustler water to contain elevated levels of sodium and chloride in Ward County. No reference to radioactivity was mentioned in any of the reports; water-quality data focused on major anions and cations.

Historical data taken from balanced analyses in the TWDB ground-water database was examined to assess water-quality changes over time. Query language was used to calculate averages of chloride, dissolved-solids, fluoride, hardness, and sulfate during the last five decades and the present partial decade (Table 7). Averages do not reflect the same sample population for each time period; although the same wells were often sampled more than one decade, few were sampled in more than one. Furthermore, the choice of decades as the time period most appropriate for the calculation of averages is arbitrary, as sampling events were not timed to correspond with any certain time period, and analyses are few and sporadic because of the lack of any widespread sampling effort until recently.

Constituent*	1950 - 1959	1960 - 1969	1970 - 1979	1980 - 1989	1990 - 1995
Chloride	164	87	122	169	160
Diss. Solids	3,401	1,913	1,677	2,388	2,798
Fluoride	2.70	1.40	2.00	1.70	2.06
Hardness	2,285	1,299	1,063	1,585	1,884
Sulfate	2,188	1,132	942	1,405	1,716

Table 7. Comparison of averages of dissolved constituents in the Rustler aquifer.

Because of the small number of samples, identifying true trends in water-quality is hampered. Since 1970, chloride, dissolved-solids, hardness, and sulfate levels have all increased. Any apparent trends could possibly be explained by collection, sampling, transportation, and testing methods. Before 1989, wells were sampled without specific guidelines, therefore, reliability of collection and transportation methods are questionable in some cases. In addition, sampling and testing techniques have improved over the decades, and the purpose of the TWDB monitoring program has broadened in scope to include a representative sampling of wells throughout the entire aquifer.

Another way of assessing change in water-quality over time is by examining analyses from wells sampled more than once. One well has been sampled 6 times, from 1965 to 1995, and is located in Pecos County.

	Chloride	Dissolved Solids	Fluoride	Hardness	Sulfate
1965	315	1,496	2.8	750	560
1974	325	1,596	2.6	810	620
1975	317	1,581	2.5	810	600
1979	314	1,679	2.1	829	686
1985	314	1,638	2.1	834	646
1995	329	1.633	1.8	798	630

All parameters, with the exception of fluoride, deteriorated slightly or remained stable over the time period. A number of explanations could be discussed, but the most likely is the improvement of sampling and testing procedures, or that significant deterioration of the water-quality has not occurred over the 30-year period.

CONCLUSIONS

The overall water-quality of the Rustler aquifer is poor. Sampled well analyses contained constituents that exceeded both primary and secondary standards. A high level of radioactivity is the most widespread water quality problem when primary standards are considered. Previous studies, likely due to the unavailability of testing equipment, did not include discussions on radioactivity levels. Further study on the radioactive sources and levels is encouraged.

In regards to secondary drinking water standards, the Rustler aquifer has a widespread dissolved-solids and sulfate problem. All 18 wells had results exceeding secondary MCLs for both constituents. Several wells had high chloride and fluoride levels and also contained iron in excess of the secondary standard. Based on these results, the Rustler aquifer is adequate for irrigation and other non-consumptive uses.

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