P-373 SEPTEMBER 1959

SOME RELATIONS AMONG — *Irrigation Water Quality, Soil Characteristics and Management Practices* — IN THE TRANS-PECOS AREA

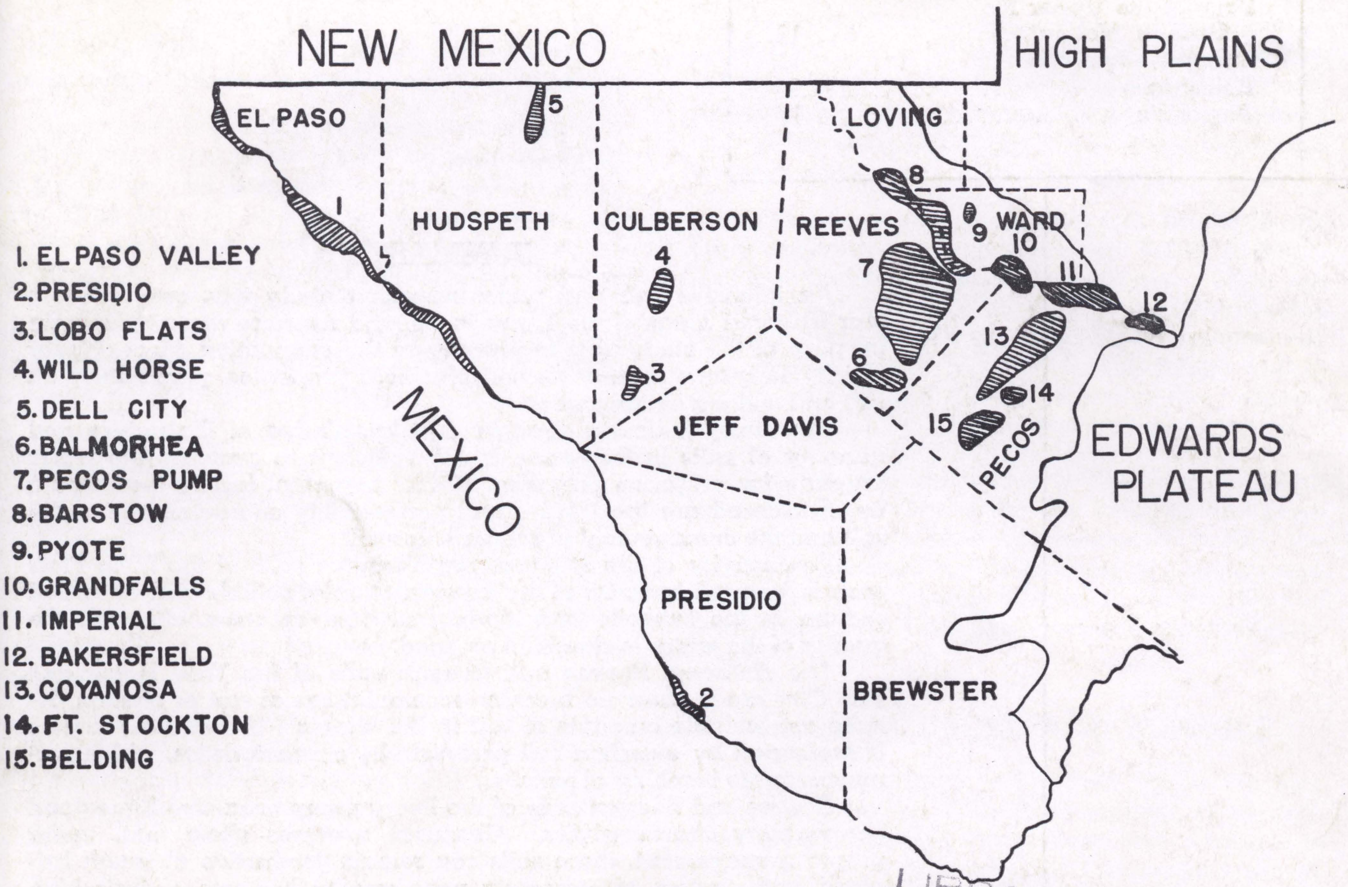

Figure 1. Map of the Trans-Pecos land resource area showing the approximate locations of the irrigated areas.

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SUMMARY

An intensive soil and water sampling study was conducted in four irrigated areas of the Trans-Pecos land resource area. The main purpose of the study was to investigate the cumulative effect of poor quality irrigation waters on soil chemical properties, particularly on salt and sodium accumulation.

The study indicates strongly that knowledge of the nature and quantity of salts in the water is not sufficient to evaluate the water properly for irrigation purposes. Other important factors that should be considered are the texture and permeability characteristics of the soil and the management practices followed.

Productivity of the fine-textured Verhalen soils of the Lobo Flats area is lowered because of the accumulation of soluble and adsorbed sodium in the subsoils and inadequate root aeration, although the quality of the water is classified as good.

The Anthony, Reeves and Reagan soils of the Wild Horse and Dell City areas show no harmful accumulations of salt or sodium despite appreciable amounts of salt in the waters. Use of these waters is facilitated by excellent soil permeability characteristics, which permit adequate leaching of salts.

Reeves and Reagan soils of the Pecos pump area also have good permeability characteristics. Chemical analyses show that, under proper management, these soils can remain productive although irrigated with waters of extremely poor quality because of their high content of salt.

X-ray and D.T.A. analyses and laboratory permeability studies indicate that soils of the Lobo Flats, Wild Horse, Dell City and Pecos pump areas are similar mineralogically—the clay content is illite or degraded mica. Chief differences are in texture and profile characteristics.

The low-swelling characteristics of these soils is contrasted sharply with the high-swelling montmorillonite soils of the El Paso Valley. Poor quality waters which are usable in these four areas cannot be applied continuously to soils of the Upper Rio Grande Valley without disastrous results—reduction in permeability, and salt and sodium accumulation.

The importance of proper management practices for salinity control in each area is emphasized.

Some Relations Among Irrigation Water Quality, Soil Characteristics and Management Practices in the Trans-Pecos Area

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WITH THE EXCEPTION of the Rio Grande and Pecos River Valleys, the development of irrigated crop production in the Trans-Pecos area has taken place only within the past 25 years. Nearly 300,000 of the approximately half-million acres developed for irrigation have been in production less than 15 years. Further expansion is limited only by the supplies of under-ground water suitable for irrigation. A map of the Trans-Pecos region with the approximate locations of the 15 separate areas is shown in Figure 1.

Of primary importance to the continued productivity of these areas is the quality of water available for irrigation. All irrigation waters contain soluble salts. The amounts and kinds of salts present are an important factor determining the suitability of the water for crop production. Recent publications of the Texas Agricultural Experiment Station (2,5) emphasize, however, that water quality, soil physical characteristics and management practices are important in the control of soil salinity.

Waters used for irrigation in the Trans-Pecos area vary widely in total salt content and salt composition (2). Many are so saline as to be considered unusable by water quality standards established by the U. S. Salinity Laboratory at Riverside, California (6). The effect of continued application of poor quality waters on salt accumulation and crop production in certain of these irrigated areas is of utmost importance.

This publication reports results of soil and water investigations in selected areas of the Trans-Pecos and shows some relations among water quality, soil physical and chemical conditions and management practices.

IRRIGATED AREAS AND SOIL TYPES

Fifteen separate areas on widely different soil types make up the irrigated cropland of the Trans-Pecos region. Table 1 lists these areas, the approximate acreage now or formerly under cultivation, with soil and irrigation information.

The first six areas are located on alluvial soils of the Rio Grande and Pecos River Valleys. They include soils of the Gila, Imperial, Pima, Glendale, Vinton and Brazito series. These soils generally are highly stratified in the surface horizons, and vary from coarse sands (Brazito) to heavy clays (Imperial), with a preponderance of finer-textured, slowly drained soils. No detailed soils maps of the region have yet been released, and published data are limited to a USDA reconnaissance soil survey compiled in 1928 (1). Most of these soils are highly productive with good quality irrigation water. Inadequate drainage and lack of good quality water have limited crop yields along the Pecos River, where large areas are only infrequently under cultivation.

The most highly productive soils of the Trans-Pecos region are the well-drained loams and silt loams of the Reagan and Reeves series. These are extensive upland soils in Pecos, Reeves and Culberson counties, and comprise the largest, most uniform cultivated areas in far West Texas. Although low in organic matter and natural fertility, they respond well to applied fertilizers under irrigation.

Isolated areas of finer-textured upland soils (Verhalen and Balmorhea series) are found at Van Horn and Balmorhea. They are inherently fertile, but very slowly permeable, and generally of lower productivity than irrigated soils of coarser texture. One of these areas, Lobo Flats, is included in the studies reported.

WATER SOURCES AND SUPPLIES

Both underground and surface waters are used for irrigation in the Trans-Pecos region. In no area, however, have surface waters alone been adequate to supply irrigation demands over an extended period. A recent 10-year drouth (1947-56) along the Rio Grande watershed forced El Paso Valley farmers to drill wells and tap underground sources. Only rarely does the Pecos River supply enough water for cropland in the Barstow, Imperial, Grandfalls and Bakersfield areas, and this water at best is of very poor quality because of its high salt content (Appendix Table O). Springs at Balmorhea and Fort Stockton are inadequate to satisfy irrigation needs.

Underground waters are pumped in all 15 irrigated areas, and in many locations are the only waters available (Table 1). These sources likewise are

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TABLE 1. IRRIGATED AREAS AND SOILS OF THE TRANS-PECOS LAND RESOURCE AREA WITH RELATED INFORMATION[1]

Area	Approximate irrigated acreage	Pump or surface irrigation	Present pumping depths, feet	Nature and texture of surface soils
		ALLUVIAL SOILS		
El Paso Valley	90,000	Both	90-130	Stratified alluvial sands, loams and clays
Presidio	6,000	Both	16-25	Stratified alluvial loams and clays
Barstow	40,000	Both	100-150	Alluvial loams and clays
Grandfalls	13,000	Both	100-150	Alluvial loams and clays
Imperial	15,000	Both	100-150	Alluvial loams and clays
Bakersfield	9,000	Both	150-200	Alluvial loams and clays
		UPLAND SOILS		
Pecos	160,000	Pump	200-450	Silt loams and loams
Coyanosa	80,000	Pump	200-250	Loams and clay loams
Belding	18,000	Pump	150-200	Loams and clay loams
Ft. Stockton	7,000	Both	200-300	Loams
Van Horn (Lobo Flats)	20,000	Pump	200-250	Clay loams and clays
Van Horn (Wild Horse)	20,000	Pump	250-300	Sandy loams and clay loams
Dell City	25,000	Pump	60-150	Silt loams
Balmorhea	10,000	Both	250-300	Sandy loams and clays
Pyote	4,000	Pump	150-200	Sands and loamy sands
Total	517,000			

[1]Compiled in 1957.

limited. Static underground water levels have been dropping steadily in the Van Horn, Pecos and Fort Stockton areas because of over-expansion of acreage and limited underground supplies, according to information supplied by local work units of the USDA Soil Conservation Service. Most of this pump water is believed to have its source as rainfall in the Davis Mountains. This supply is limited. Farmers in these areas should recognize this and adopt more realistic acreage controls and water conservation practices. Only at Dell City have underground water supplies of acceptable quality been adequate to meet irrigation needs.

WATER QUALITY

Of more immediate concern even than water supply is the problem of water quality in most Trans-Pecos irrigated areas. Soluble salts applied to the soil in irrigation waters present a constant hazard to crop production.

Basically those salts affect crop yields in two ways. First, excessive amounts of soluble salts in the soil limit plant growth in effect by rendering the soil water less available to the plant. Plant roots simply cannot extract sufficient water for growth needs when large amounts of salt are present in the

TABLE 2. AVERAGE SALT CONTENT OF PUMP WATERS USED FOR IRRIGATION IN THE TRANS-PECOS AREA

Area	Total salt content		Milliequivalents per liter							Na, %	S.A.R.[2]
	P.P.M.	T.A.F.[1]	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3		
Imperial-Girvin[3]	4030	5.48	28.0	28.5	21.4	1.0	38.7	39.3	0.2	35.8	5.61
Belding-Upper Coyanosa	1153	1.57	8.8	4.9	5.2	0.4	12.6	6.6	2.3	43.6	3.98
Bakersfield[3]	2425	3.30	17.6	14.3	9.3	0.4	28.3	12.2	1.8	42.3	5.13
Lower Coyanosa[3]	1139	1.55	9.7	5.5	5.1	0.3	9.5	9.8	1.1	47.1	4.22
Pecos pump[3]	2793	3.80	21.8	9.3	16.1	0.7	28.5	16.7	1.9	45.5	6.84
Dell City	1462	1.99	6.1	9.9	11.9	0.3	9.8	17.0	3.9	21.6	2.01
Wild Horse (Van Horn)	1396	1.90	17.3	2.2	6.3	0.3	14.5	8.0	4.1	66.3	6.46
Lobo Flats (Van Horn)	375	0.51	5.5	0.1	1.3	0.1	5.3	0.7	4.1	78.6	4.78
Rio Grande Valley areas[3]											
Mesilla Valley	1536	2.09	13.9	4.0	5.3	0.5	13.1	7.7	2.1	58.6	6.46
Ysleta	1756	2.39	15.8	6.2	5.3	0.6	17.6	8.8	3.8	57.8	6.58
Clint-Socorro	2903	3.95	31.6	6.9	7.4	0.8	27.5	15.6	4.0	67.6	11.83
Fabens-Tornillo	2168	2.95	18.8	5.0	7.4	0.6	21.5	8.6	4.4	59.1	7.55
Hudspeth county	3925	5.34	41.3	10.2	14.2	1.1	44.8	19.0	4.7	61.8	11.83
Presidio	2095	2.85	18.8	6.1	7.4	0.2	14.0	17.4	1.5	57.8	7.23

[1]T.A.F. = Tons of salt per acre-foot of water.

[2]$\text{S.A.R.} = \dfrac{\text{Sodium}}{\sqrt{\dfrac{\text{Calcium} + \text{magnesium}}{2}}}$ expressed in equivalent quantities.

[3]Individual wells in these areas may vary widely from the average analysis.

soil. Crops may be in need of water although the soils appear moist (5,6). Paradoxically, plants are slow to wilt on saline soils even when suffering badly for water.

Second, crop yields can be affected indirectly by large amounts or percentages of sodium in irrigation water. Excess sodium affects plant growth directly by its toxic action, and it also has a detrimental effect on soil physical properties. It causes reductions in permeability, crusting, clodding and even "sealing up" under certain conditions. These effects are more adequately discussed in Texas Station Bulletin 876 "Salinity Control in Irrigation Agriculture" (5).

Experiment Station personnel, in cooperation with the USDA Soil Conservation Service and Bureau of Reclamation, have collected and analyzed hundreds of irrigation water samples in the past several years. These data should be of particular interest to farmers and technicians in each area, for they present a reasonable evaluation of waters now being used for irrigation. Average values for the amount and kinds of salt in waters of the major cultivated areas are given in Table 2. A more complete summarization of water analyses is presented in the appendix tables.

It is apparent that the total salt content and kinds of salt present in the waters vary considerably from location to location. The appendix tables show that in certain irrigated areas the quality of the water differs greatly even from farm to farm. This can be attributed to several factors, including the source of the water and depth of wells. In the river valleys particularly, the highly stratified nature of the alluvial fill is largely responsible for local variations in pump water quality. Waters are channeled underground through sand and gravel strata which are highly variable in extent and direction.

The question arises: "What determines whether a particular water is usable or unusable—good, bad or marginal?" The answer is not a simple one. It involves the kinds and amount of salt in the water, and must take into consideration the physical characteristics of the soil and management practices. This publication attempts to show the relation between these factors, and why this relation, rather than water quality alone, determines the suitability of a water for irrigation.

SALT ACCUMULATION IN SOILS

Usually, it is not the salt content of the irrigation water itself that limits crop yields, it is the *accumulated* salt in the soil. The salt content of irrigated soils often is many times that of the applied irrigation water. Water evaporates from soil surfaces, leaving the salt behind to accumulate. Leaching, the process of passing water through the soil to remove salts in drainage waters, is now the only known method of controlling salt.

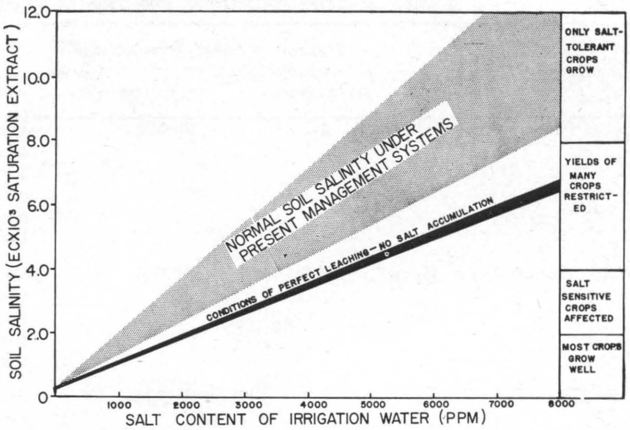

Figure 2. Soil salinity as affected by management systems and salt content of irrigation waters. Data obtained from Lysimiter studies at Substation No. 17, El Paso.

Under conditions of essentially perfect leaching, i.e., practically no salt accumulation in the soil, fair yields of salt-tolerant crops such as cotton or barley can be produced with waters containing up to 6,000 ppm (parts per million or pounds of salts per million pounds of water) total salt (8 tons of salt per acre-foot of water). Figure 2 explains this diagrammatically. If vertical lines are drawn from any particular salt content of irrigation water, their intersection with horizontal lines would give the relation between salt content of the water and soil salinity, expressed as conductivity of the saturation extract.

Conductivity is the ability of water to conduct electrical current (expressed as EC$\times10^3$ millimhos/cm). The higher the conductivity of the soil water the more salt in the soil.

The saturation extract is water extracted from soil pastes under suction. The solid diagonal line shows what the salt content of the soil would be under conditions of essentially perfect leaching when irrigated with waters containing 0 to 8,000 ppm total salt. The large shaded area shows the amounts of salt normally present in field soils irrigated with

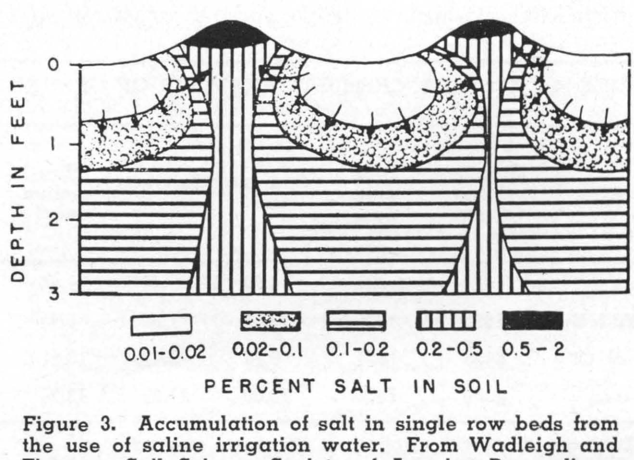

Figure 3. Accumulation of salt in single row beds from the use of saline irrigation water. From Wadleigh and Fireman, Soil Science Society of America Proceedings. 1948.

TABLE 3. DESCRIPTION OF TRANS-PECOS IRRIGATED SOILS INCLUDED IN THE STUDY

Area	Years under irrigation[1]	Approximate irrigated acreage	Description of soils	Soil series
Lobo Flats (Van Horn)	5-7	20,000	Imperfectly drained clays and clay loams underlain by gravelly strata at depths of 6 to 8 feet. Carbonate deposits below second foot. Naturally fertile but not highly productive. Cotton yields average about 1½ bales per acre.	Verhalen
Wild Horse (Van Horn)	5-7	20,000	Deep permeable sandy loams and loams. Good internal drainage. Carbonate deposits below second foot. Low in natural fertility. Cotton yields average 1½ to 2 bales per acre.	Anthony, Reagan
Dell City (Salt Flats)	6-8	25,000	Silts and silt loams, generally shallow, underlain by soft caliche at depths of 1 to 2½ feet. Internal drainage excellent. Low in natural fertility. Cotton yields average 1½ to 3 bales per acre.	Reagan, Reeves
Pecos	15-20	160,000	Similar to Dell City soils but somewhat deeper. Caliche at depths of 2½ to 4 feet. Internal drainage excellent. Low in natural fertility. Cotton yields average about 2½ bales per acre.	Reagan, Reeves

[1]When sampled in 1956.

these waters under present management systems. It will be seen that a considerable amount of salt accumulation invariably occurs, and it is this accumulated salt which limits plant growth and crop yields. For example, soils irrigated with water containing 6,000 ppm salt would have conductivities of 6.0 to 11.0 millimhos/cm. in the saturation extract, as compared with a conductivity of about 5.0 with perfect leaching.

It is in this respect that the other two factors—soil physical conditions and management practices—become of vital importance. Seldom if ever can conditions of perfect leaching and no salt accumulation be attained in the field with the usual systems of management. With furrow-type irrigation, much of the salt moves laterally into the beds and accumulates there. The salt content of the soil in and under the beds always is much higher than that of the soil in the furrows. Figure 3 shows the manner in which salt accumulates using furrow irrigation and saline water. Even with waters low in total salt, gradual accumulation of salt builds up in the beds. The higher the salt content of the waters, the more quickly this accumulation takes place.

Inefficient management practices accelerate the build-up of salts in surface soils. Since salts can be removed only by leaching out in drainage waters, efficient management lies in the art of applying enough water periodically to leach out accumulated salt without excessive waste of water. The saltier the water, the more water must be applied to control salt in surface soils (5,6).

Soil physical characteristics play a vital role in leaching and salt removal. It is relatively easy to leach salt from freely permeable soils, but much more difficult to leach finer-textured soils (clays and clay loams). In addition, all soils swell when wet. This ability to swell is highly variable, however. Some soils swell excessively and even seal up entirely un-

TABLE 4. AVERAGE CHEMICAL ANALYSES OF GROUND WATERS USED FOR IRRIGATION IN THE VAN HORN, DELL CITY AND PECOS AREAS[1]

Area	Conductivity, EC x 10^6	Total salt, ppm	Sodium, me/l	Calcium, me/l	Magnesium me/l	Potassium, me/l	Carbonate + bicarbonate, me/l	Chloride, me/l	Sulfate, me/l	Sodium, %	S.A.R.	Residual sodium carbonate,[2] me/l
Lobo Flats	454	295	4.60	.40	1.45	.44	3.47	3.57	.40	66.8	4.78	1.62
Wild Horse	1960	1270	12.31	1.80	5.45	.30	4.38	13.40	3.24	62.0	6.46	0
Dell City	2495	1624	6.80	9.47	13.51	.30	3.55	12.46	15.43	22.6	2.01	0
Pecos	4390	2850	23.80	11.30	13.00	.61	2.06	25.16	21.24	48.9	6.84	0

[1]Average of waters applied at locations studied.
[2](Carbonate + bicarbonate) — (calcium + magnesium) me/l

der certain conditions. Other soils swell only slightly, and always retain some degree of permeability. Excessive sodium in soils greatly accentuates this capacity to swell, and is the cause of "sealing up" which occurs at times on soils of the El Paso Valley. High sodium waters increase the danger of sodium accumulation in soils. When this occurs, the use of soil amendments is justified (5).

Soil permeability, therefore, is a vital factor when irrigating with poor quality water. Loss of permeability means accumulation of salt and sodium with consequent reductions in crop yields. The establishment and maintenance of sufficient permeability are the key to irrigation with saline waters. Farmers tilling soils which tend to shrink and swell excessively should guard constantly against a reduction in permeability. Such reductions can be brought about by excess sodium, and by over-tillage, plow pan or hard pan formation, loss of soil organic matter or gradual structural breakdown.

Conversely, farmers tilling soils which do not swell appreciably are extremely fortunate. These soils can be irrigated satisfactorily with waters of such poor quality that soon would completely salt-out swelling-type soils. On slightly swelling soils, high sodium waters (60 to 80 percent sodium) often can be applied without serious detrimental effects, particularly if the soils contain gypsum. Results of the study reported following bear out these conclusions.

EXPERIMENTAL INVESTIGATIONS

To determine the cumulative effect of irrigation waters and management practices on soil conditions, four recently developed irrigated areas were chosen for study—the Lobo Flats and Wild Horse areas near Van Horn, the Dell City area and the Pecos pump area. These were selected because they represent wide variations in soil texture as well as considerable differences in the salt content of pump waters. Soil texture and water quality within each area are fairly uniform, however. Table 3 gives a brief description of the soils and Table 4 gives the average salt composition of the irrigation waters applied at the locations studied.

On the basis of presently accepted water quality standards (6), only the waters at Lobo Flats are rated as of good quality (Figure 4). Waters of this area have a low total salt content (expressed as conductivity) and the sodium hazard (S.A.R.—sodium adsorption on ratio – See Table 2) is not serious although the waters contain residual sodium carbonate [(calcium plus magnesium) minus (carbonate plus bicarbonate) expressed in equivalent quantities]. The presence of residual sodium carbonate theoretically increases the danger of sodium accumulation.

The waters at Wild Horse, Dell City and Pecos are of progressively poorer quality primarily because of increasing total salt content. Pump waters at Dell City and Pecos are classed as very high salinity waters (Figure 4) and "are not suitable for irrigation under ordinary conditions but may be used occasionally under special circumstances. The soils must

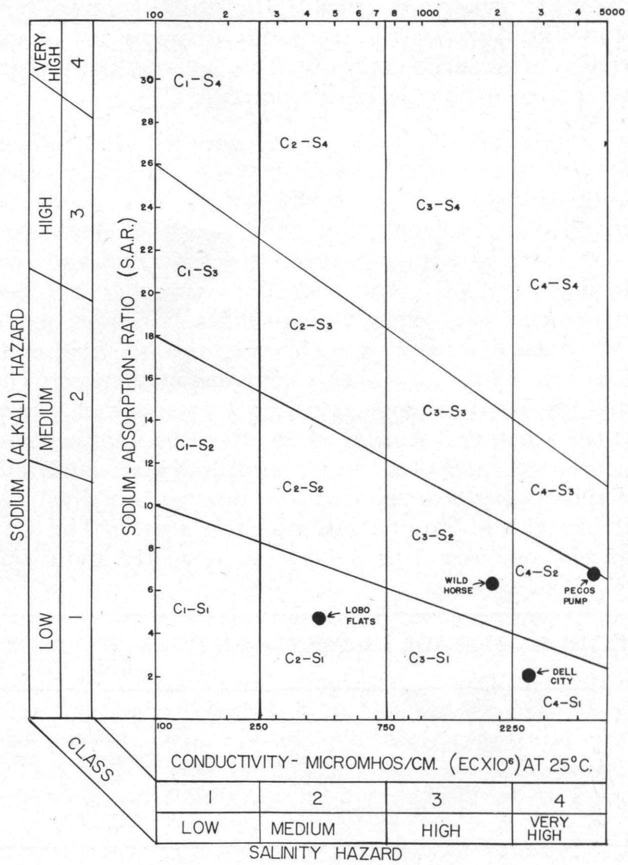

Figure 4. Diagram for the classification of irrigation waters. USDA Agriculture Handbook 60. 1954.

LOW-SALINITY WATER (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

MEDIUM-SALINITY WATER (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

HIGH-SALINITY WATER (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

VERY HIGH SALINITY WATER (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, excess irrigation water must be applied to provide considerable leaching, and very salt-tolerant crops should be selected.

LOW-SODIUM WATER (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops, such as stone-fruit trees and avocados, may accumulate injurious concentrations of sodium.

MEDIUM-SODIUM WATER (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

HIGH-SODIUM WATER (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management—good drainage, high leaching and organic matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

VERY HIGH SODIUM WATER (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

be permeable, drainage must be adequate, irrigation water must be applied in excess and highly salt-tolerant crops should be selected." This classification assumes average conditions with respect to soil texture, drainage, infiltration rates, quantity of water used and salt tolerance of crops. The study reported here shows how greatly the suitability of water for irrigation is affected by exceptional soil permeability characteristics and management practices.

Soils of the areas were sampled as follows. Several sites were chosen in each area, at which both cultivated and nearby virgin soils could be sampled. Five soil cores to a depth of 48 inches were taken at each site, three from irrigated and two from virgin soil. Each core was sampled at 1-foot increments and detailed chemical analyses were made of all samples, together with water samples from each location. This gave direct comparisons between virgin and irrigated soils as affected by water of a particular quality. A total of 38 sites was sampled and nearly 800 soil and water samples were analyzed. Table 5 gives average chemical analyses obtained for irrigated and virgin soils of each area. The bar graphs (Figures 5 to 8) give some of the more important information in a form more suitable for comparisons.

Lobo Flats Area

Soils of the Lobo Flats area are mostly deep reddish-brown clays and clay loams (Verhalen series), very slowly permeable. Cotton has been the principal crop grown under a furrow-type surface irrigation. Irrigation runs are not excessively long, and most fields have been leveled to uniform grades. Although soil fertility is high, crop yields have not been exceptionally good, averaging about 1½ bales of cotton per acre.

Figure 5 shows graphically the effect of approximately 5 years' irrigation on salinity, pH, soluble sodium and exchangeable sodium in these soils. (pH is a measure of the acidity or alkalinity of a soil. A pH value of 7.0 is neutral. Below 7 the soil is acid, above 7 it is alkaline. Exchangeable sodium is sodium adsorbed (held) on the surface of the clay particles.) All four of these chemical conditions tend to become progressively more serious with increasing depth in the profile. This apparently is because of the low permeability of these soils, and of the fact

TABLE 5. AVERAGE CHEMICAL ANALYSES OF VIRGIN AND CULTIVATED SOILS FROM THE LOBO FLATS, WILD HORSE, DELL CITY AND PECOS AREAS

Area	Irrigated or virgin	Depth, inches	pH soil paste	Conductivity saturation extract, EC x 10^6	Soluble calcium	Soluble sodium	Exchangeable sodium	Cation exchange capacity	Exchangeable sodium, %	Gypsum content, T.A.F. of soil	$CaCO_3$ equivalent, %
					Milliequivalents/100 g. soil						
	Irrigated	0-12	7.85	740	0.06	0.31	2.73	25.1	10.8	2.0	12.8
	Virgin		7.93	650	0.09	0.19	1.58	22.7	6.9	2.1	11.5
	Irrigated	12-24	7.94	1300	0.09	0.55	5.05	28.8	17.5	2.8	17.6
Lobo Flats	Virgin		7.96	1430	0.14	0.68	4.00	25.1	15.9	2.9	16.3
	Irrigated	24-36	8.02	2960	0.29	1.36	5.58	25.6	21.7	5.7	19.1
	Virgin		8.00	2700	0.28	1.42	5.38	25.9	20.7	4.7	19.5
	Irrigated	36-48	8.03	4000	0.45	1.94	4.92	19.1	25.6	9.4	18.3
	Virgin		8.02	3445	0.45	1.73	6.09	24.1	25.2	5.3	19.7
	Irrigated	0-12	8.15	1190	0.08	0.26	1.58	18.5	8.5	2.2	7.2
	Virgin		8.06	480	0.08	0.26	0.49	19.3	2.5	2.4	6.7
	Irrigated	12-24	8.00	1650	0.22	0.32	1.43	18.5	7.7	2.7	13.1
Wild Horse	Virgin		7.97	500	0.14	0.06	0.42	18.6	2.2	3.3	13.3
	Irrigated	24-36	8.07	1780	0.27	0.40	1.95	18.0	10.7	3.8	18.2
	Virgin		7.99	730	0.13	0.11	0.58	16.1	3.6	2.9	20.2
	Irrigated	36-48	8.13	1670	0.21	0.36	2.25	13.9	16.1	3.2	22.7
	Virgin		8.04	1140	0.21	0.18	0.75	14.9	5.0	2.9	23.8
	Irrigated	0-12	7.83	3965	0.74	0.64	1.21	16.1	7.4	18.8	16.9
	Virgin		7.91	5040	0.64	1.76	2.70	13.0	20.6	19.4	16.7
	Irrigated	12-24	7.86	3230	0.70	0.44	0.90	9.7	9.2	23.5	17.3
Dell City	Virgin		8.09	7035	0.70	2.50	1.65	10.6	15.5	24.0	18.0
	Irrigated	24-36	7.86	3200	0.69	0.29	0.68	7.7	8.7	27.1	19.4
	Virgin		8.35	8565	0.72	2.81	1.86	6.9	26.8	26.6	20.2
	Irrigated	36-48	7.91	3085	0.63	0.24	0.73	6.3	11.5	22.5	18.6
	Virgin		8.26	8300	0.67	1.98	1.50	7.1	21.10	23.9	24.3
	Irrigated	0-12	7.60	5525	1.75	2.17	2.63	20.5	12.7	8.7	16.1
	Virgin		7.66	1915	0.50	0.28	0.99	19.9	4.9	5.3	14.1
	Irrigated	12-24	7.64	5595	1.82	2.71	2.71	19.1	14.1	10.8	20.9
Pecos	Virgin		7.60	2190	0.66	0.28	1.02	18.3	5.5	5.9	20.6
	Irrigated	24-36	7.63	5580	1.87	2.15	2.36	18.4	12.7	13.9	21.0
	Virgin		7.59	2770	0.75	0.34	1.10	18.3	6.0	10.8	19.7
	Irrigated	36-48	7.62	5165	1.88	1.94	2.12	15.6	13.5	19.9	18.0
	Virgin		7.60	3285	0.92	0.37	1.24	17.8	6.9	16.4	18.6

that sufficient water for adequate leaching of salts has not been applied, judging from the similar condition of virgin soils that have never been irrigated. Both soluble and exchangeable sodium are seriously high at the third and fourth feet of depth. This condition alone could limit root growth and water penetration at these depths. Coupled with low intake rates and inadequate root aeration, the reasons for only fair crop yields on these fertile soils become apparent. Root penetration is necessarily shallow, and crops suffer from drouth because the roots are unable to penetrate to normal depths.

The extremely fine texture and low permeability of these soils have created a condition difficult to improve. Although the waters are very low in total salt, their high percentage of sodium has brought about a virtually impermeable situation in the subsoils which must be improved before suitable crop yields can be obtained. It seems likely that continuous small additions of gypsum or sulfuric acid to the waters should gradually alleviate the excessive sodium situation in the subsoils by lowering the ratio of sodium to calcium in the water. This improvement could not be brought about quickly, however, and might require several years to accomplish.

Use of high double beds also might improve cotton yields by supplying a greater area of soil suitable for root penetration. There is need for both basic and applied agronomic research in this area. The more shallow-rooted crops of moderate salt tolerance — sorghums, grasses and certain vegetables — should do well on these soils despite unfavorable subsoil conditions.

Continued application of these waters, which are classed as suitable for irrigation, has tended to aggravate adverse soil conditions primarily attributable to fine texture and low water permeability. Although perhaps an exceptional case, it emphasizes the fact that water quality alone is inadequate to characterize a particular situation. In this area, the attainment of higher crop yields eventually will depend on proper management practices which may include use of amendments, modified planting beds, heavier water application rates and selection of more shallow-rooted crops.

Wild Horse Area

Cropping systems and management practices in this area are similar to those at Lobo Flats. These soils are generally of much coarser texture, however —deep, reddish-brown sandy loams and loams of moderate fertility, but with good permeability and internal drainage characteristics (Anthony and Reagan series). Smaller acreages of fine-textured soil in this area are similar to the soils of Lobo Flats, with similar chemical characteristics. Here, also, cotton yields have not been exceptionally good, but this apparently is because of low inherent fertility, loss of

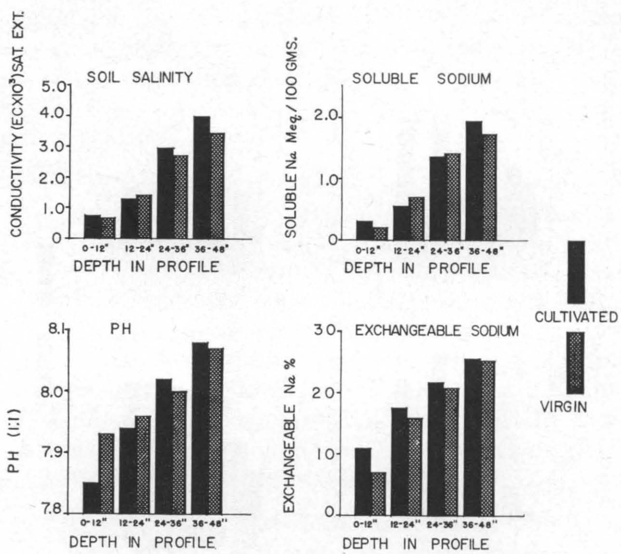

Figure 5. Effect of 5 to 7 years' irrigation and cultivation on certain chemical characteristics of Verhalen soils of the Lobo Flats area.

fertilizers by leaching and other factors associated with open, permeable soils, such as drouthiness and uneven water distribution.

Pump waters here contain considerably more salt than those of Lobo Flats, but (according to classification, Table 4) are usable on soils of good permeability with proper precautions against sodium accumulation. These waters contain considerable sodium, chloride and bicarbonate, but are very low in calcium and sulfate. The significance of this unbalanced salt condition is not now fully understood, but is worthy of notice. The waters, however, do not contain residual sodium carbonate.

Results of the soil analyses from this area are given in Table 5 and Figure 6. This figure shows

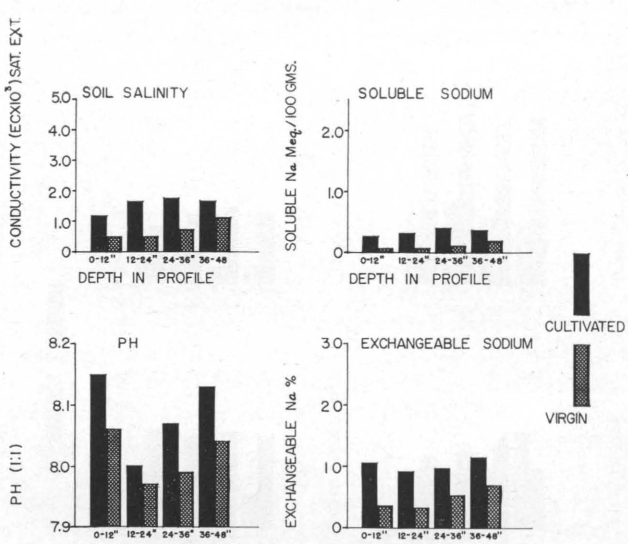

Figure 6. Effect of 5 to 7 years' irrigation and cultivation on certain chemical characteristics of Anthony and Reagan soils of the Wild Horse area.

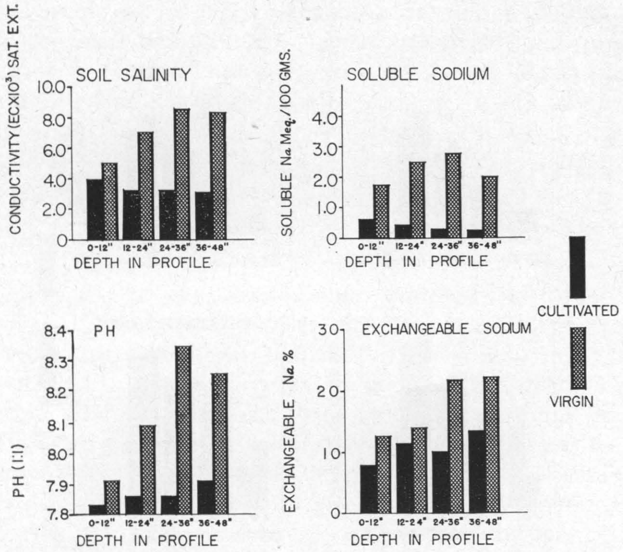

Figure 7. Effect of 6 to 8 years' irrigation and cultivation on certain chemical characteristics of Reagan and Reeves soils of the Dell City area.

that the chemical situation here is different from that of the Lobo Flats area. Although the waters contain nearly four times as much salt and a high percentage of sodium, there is no evidence of serious accumulation of either salt or sodium in these soils. This can be attributed almost entirely to excellent soil permeability and adequate leaching, as indicated by the uniformly low salt and sodium conditions throughout the profile.

Continued application of these waters has increased the amounts of salt and sodium above that in the virgin profiles, but these increases are not serious. Chemical equilibrium between waters and soils already appears to have been established. The presence of some gypsum in these soils has evidently aided in the control of sodium. The somewhat higher alkalinity of the irrigated soils (pH) is difficult to explain because of their low sodium content. This presents the possibility of deficiencies of certain trace elements, and this aspect of soil fertility merits investigation.

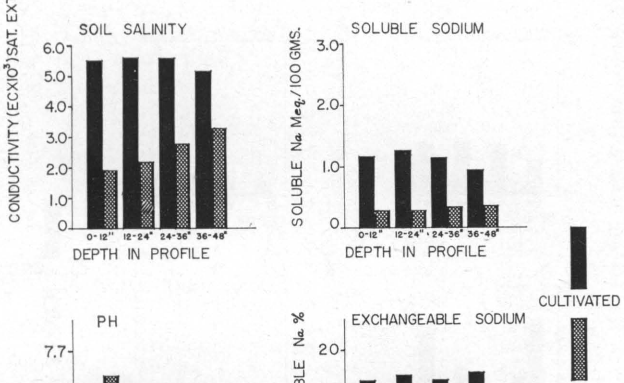

Figure 8. Effect of 15 to 20 years' irrigation and cultivation on certain chemical characteristics of Reagan and Reeves soils of the Pecos pump area.

Apparently, salt and sodium accumulation will not constitute a problem in this area in the near future. Pump waters here are definitely acceptable on these soils of ready permeability. Here, again, proper management probably will provide the means of higher crop production. Irrigation runs should be shortened and fields leveled for more uniform water application. On the sandier soils, sprinkler irrigation may be the only answer to better water distribution. Appreciable amounts of fertilizer should be applied, but in split applications to avoid excessive leaching losses.

With good management, these soils should produce excellent yields of most crops with some degree of salt tolerance. This area should be ideal for certain vegetables and melons under sprinkler irrigation.

Dell City Area

Soils of the Dell City area (Reeves and Reagan series) are largely gray silts and silt loams, underlain at depths of 1 to 3 feet by a soft marl or caliche which contains appreciable amounts of gypsum. These soils are not exceptionally fertile, but are well drained and respond to fertilizer applications.

The average salt content of the waters is relatively high (Table 4). They are exceptionally well balanced with respect to sodium, calcium, magnesium, chloride and sulfate, however, and have a favorably low sodium percentage.

Results of this study (Figure 7) show that 6 to 8 years' application of these waters have definitely improved chemical conditions in the irrigated soils over those in the virgin soils. Apparently this area was salinized at some previous period by high water tables. The entire area may at one time have been covered by the salt lake which now borders the eastern side. This would explain the high gypsum content of the soils and underlying caliche. Continued irrigation apparently has lowered the pH, total salt and sodium status throughout the entire soil profile.

Excellent soil permeability and internal drainage characteristics are indicated by the uniformly low salt and sodium content through the 0 to 4-foot depths. Exchangeable sodium, while not serious, is unusually high considering the low sodium percentage of the waters and high gypsum content of the soils. This may indicate that final equilibrium between soils and waters has not yet been established.

This area is an excellent example of the relation of soil permeability to the suitability of water for irrigation. On less permeable soils, such waters undoubtedly would cause serious problems of salt accumulation. Current management practices in the area also aid in controlling salinity. Cotton is planted in the furrow and large amounts of water are applied, both of which contribute to adequate leaching of soluble salts.

Planting of crops on raised beds here would require careful management to avoid excessive salt accumulation in the beds. Double row (cantaloupe) beds probably could be used on the more level land where good distribution of water could be obtained. Such beds might facilitate seedling emergence by reducing the crusting problems encountered in furrow planting.

With proper management, this area should continue to produce good yields of most salt-tolerant crops. The permeable nature of the soils requires that adequate nitrogen be applied each year for maximum crop yields, and to offset fertilizer leaching losses.

Pecos Pump Area

Soils and management practices in this extensive irrigated area are similar to those at Dell City. These gray-colored silts and silt loams (Reagan series) are considerably deeper, however, and are underlain by normal caliche deposits at depths of 3 to 4 feet. This caliche consists mainly of relatively insoluble calcium and magnesium carbonates. The topography is rolling and little attempt has been made to level the land. Fields usually are furrow-irrigated down the slopes. Runs are relatively long (1,000 to 3,000 feet) and much runoff occurs as tail water. Although this system is inefficient and wasteful of water, it has some advantages where salty waters are applied. Cotton is seeded in the furrow and heavy water applications aid in preventing salt accumulation.

The total salt content of these pump waters is so high that most farmers are well aware of the dangers of accumulated salt. Salt content averages about 4 tons per acre-foot, and, according to some classification (6), these waters should not be used continuously for irrigation (Figure 4). Yet during 15 to 20 years' irrigation, average cotton yields in this area have been increasing steadily.

Results of this study (Figure 8) show the salt content and sodium status of the irrigated soils are much higher than those in the virgin state. Soil salinity, particularly, is high enough to cause serious concern. At this salt level, only relatively salt-tolerant crops, such as cotton, can be grown successfully, and there is constant danger of reductions in yields from mismanagement and salt accumulation.

Soil conditions hardly could be otherwise from continued use of waters of such poor quality. It is surprising to find salinity levels as low as they are. One finding of considerable significance was the relatively uniform salt and sodium condition existing throughout the 4-foot profile. Here, as at Dell City and Wild Horse, is an indication of excellent internal drainage, and herein lies the reason why these soils have not become salted out and unproductive from continued irrigation.

As mentioned previously, furrow planting and heavy water application rates definitely aid in controlling salinity. It is doubtful if successful plantings on raised beds could long be continued here without considerable land leveling and much better control of irrigation water. Farmers wisely have selected probably the best management system possible for continued use of these waters on this sloping land. Information is needed, however, regarding the most efficient irrigation grades and lengths of run for maximum conservation of water.

Although soluble sodium does not appear to be a problem of these soils at this time, exchangeable (adsorbed) sodium is serious enough to merit careful consideration. The soils contain approximately 15 percent exchangeable sodium, which is unusually high in view of the gypsum content of the soils and the high calcium and magnesium content of the waters. The possibility of reductions in crop yields is a real danger at slightly higher accumulations of adsorbed sodium. Periodic sampling and analysis of both soils and waters are recommended for this area to guard against excessive salt and sodium conditions.

Such additional problems as excessive use of water, unequal water distribution, loss of tail water and fertilizer leaching losses are serious and must be minimized if the area is to remain productive.

RELATION OF SOIL PERMEABILITY TO MINERALOGICAL COMPOSITION

Investigations into the mineralogical nature of the soil material in the four areas discussed were conducted in conjunction with the field and laboratory studies previously reported. Both X-ray diffraction and differential thermal analyses show the colloidal (clay) fraction of the soils of all four areas are largely illite or degraded mica. This type of clay is of a relatively low-swelling nature as compared with clay material from soils of the El Paso Valley which is largely montmorillonite or swelling-type clay.

Further verification of the physical characteristics of these soils was obtained from laboratory permeability measurements. A series of columns containing soil from each area were first leached thoroughly with saline water containing from 0 to 95 percent sodium. After drying, the soils were re-packed into the columns and the permeability to distilled water measured. By this procedure, maximum swelling at different exchangeable sodium contents was induced. Reductions in soil permeability were directly proportional to the amount of swelling which occurred. The effect of added gypsum on soil permeability also was evaluated. Results of these tests are shown in Figure 9.

It is apparent that the permeability characteristics of all soils were similar, with the exception of the soil from the El Paso Valley. This soil showed a rapid reduction in permeability with increasing amounts of sodium in the irrigation water. It sealed up entirely when the sodium content of the water exceeded 55 percent. Soils from the Lobo Flats, Wild Horse, Dell City and Pecos areas did not seal up even after leaching with waters containing up to 95 percent sodium. This verifies the mineralogical determinations and emphasizes the low-swelling nature of these soils. The presence of gypsum in these soils served to improve their permeability somewhat, probably by lowering the amounts of exchangeable sodium. This indicates the value of gypsum when present in these soils.

Soils from Lobo Flats, Dell City and Pecos showed remarkably similar permeability characteristics, differing only in the rate of water movement. They showed low to moderate permeability which gradually but slowly decreased under the effect of increasing amounts of sodium in the irrigation water. The low but constant permeability of the fine-textured soil from Lobo Flats indicates that the adverse sodium status of these field soils may be improved by the use of amendments and heavier water applications.

SOILS OF THE UPPER RIO GRANDE VALLEY

Because of the highly stratified nature of these alluvial soils, and the difficulty of obtaining virgin soil samples, a field study similar to those previously reported was not possible in this area. These soils vary from coarse sands to fine clays, and present a

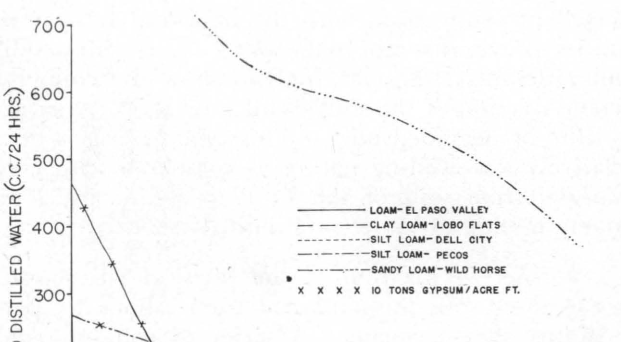

Figure 9. Effect of the sodium percentage in irrigation water and soil gypsum on the permeability and swelling characteristics of Trans-Pecos soils.

difficult problem for efficient irrigation because of the rapidly variable soil permeability, even within the same field.

Evidence of the montmorillonite clay mineral present and the excessive swelling tendency of these soils under adverse conditions has already been presented (Figure 9). These soils require careful management to avoid deterioration of soil structure, puddling, clodding and occasional sealing up, which result from the accumulation of sodium.

The physical and chemical conditions of these soils rapidly become worse when good quality river water is scarce and saline underground waters must be applied. Ground waters vary from good to completely unusable, depending partly on their location in the Valley (Tables I-N, appendix). Sodium percentages of these waters are high enough (45 to 75 percent) to create a definite sodium hazard because of the swelling nature of the soils. Use of saline ground waters on the finer-textured soils causes rapid sult from the accumulation of sodium.

Studies of the effect of saline pump water on these soils have been made at the Texas Agricultural Experiment Station at El Paso. Results of these studies have been summarized in previous publications (3,4). Use of various soil amendments on the fine-textured soils have not aided in preventing either salt or sodium accumulation (4). These soils showed rapid salt and sodium accumulation after only 1 year's application of saline water. Leaching with good quality project water gave gradual improvement in the physical and chemical conditions of the soil without the use of amendments. This indicates that only good water should be applied to these soils. (Project water is Rio Grande water stored and released from Elephant Butte Dam in New Mexico. See appendix Table O.)

Waters of higher salt content (up to 3,000 ppm total salt) can be applied to the coarse-textured soils with good under-drainage, but some reduction in yields of cotton and other salt-tolerant crops always results, even with efficient management. The use of double-row beds is recommended when saline waters must be applied (3,5). The double-row (cantaloupe) bed has given highest yields and best control of salinity. Flat and furrow plantings have not given good control of salinity. Low crop yields in this instance were attributable partly to losses from seedling diseases and inadequate root aeration. The single-row bed was unsuitable when saline waters were applied because of excessive salt accumulation in the seedling root area.

Soils of the El Paso and Mesilla Valleys normally are productive so long as project water is available or good quality pump waters are applied. Conservation of project water merits greater consideration because of the adverse effects of saline pump waters on these soils.

ACKNOWLEDGMENTS

Some of the information presented in this publication is based on research conducted at the U. S. Salinity Laboratory Riverside, California, and on the findings of other research workers.

The authors acknowledge the many helpful suggestions of the following in reviewing the manuscript: L. V. Wilcox and H. E. Hayward of the U. S. Salinity Laboratory; C. L. Godfrey and M. E. Bloodworth of the Texas Agricultural Experiment Station: W. F. Bennett of the Texas Agricultural Extension Service; and R. E. Fox and Lawrence Freeman of the USDA Soil Conservation Service.

R. E. Fox, D. W. Carson and Lawrence Freeman of the SCS assisted in selecting the experimental sites and in taking samples. Mineralogical determinations were made by George Kunze and Eli Whitely of the Texas Agricultural Experiment Station.

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APPENDIX

Table A. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE IMPERIAL-GIRVIN AREA, 1958

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
34	4290	5.84	31.7	20.1	7.4	0.9	30.2	30.6	0.3	52.7
35	4550	6.19	35.0	22.0	16.1	1.0	33.5	31.0	0.2	47.2
36	4028	5.48	25.5	21.0	11.8	0.9	25.3	30.1	0.1	43.1
37	4094	5.57	26.8	18.0	13.7	0.9	25.9	30.5	0.2	45.1
38	3902	5.31	26.0	19.1	13.0	0.9	26.3	30.1	0.1	44.1
39	3315	4.51	23.0	18.0	14.4	1.2	31.1	23.5	1.6	40.6
High	6495	8.84	66.7	26.7	10.5	2.0	70.1	28.0	2.9	63.0
Low	845	1.15	5.7	3.0	3.2	0.2	7.2	3.7	1.0	47.1
Average[1]	4030	5.48	28.0	18.5	11.4	1.0	28.7	29.3	0.2	47.5

[1]Average of 10 wells.

Table B. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE BELDING-UPPER COYANOSA AREA, 1958

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
3.	1360	1.85	9.7	6.2	5.8	0.5	15.3	4.1	3.8	43.7
5.	1264	1.72	9.0	5.7	5.4	0.4	13.8	3.4	2.6	43.9
11	1368	1.86	10.0	6.7	5.7	0.5	13.9	5.3	2.1	43.7
15	1433	1.95	12.1	5.9	5.7	0.5	15.5	5.6	2.2	50.0
24	1036	1.41	6.5	5.5	5.3	0.3	10.3	3.9	2.1	36.9
27	838	1.14	6.3	4.3	3.7	0.2	8.9	3.7	1.9	43.3
High	1485	2.2	12.1	5.5	5.7	0.6	15.5	5.4	2.2	50.6
Low	588	0.80	4.0	3.6	3.2	0.2	7.1	2.4	1.9	36.4
Average[1]	1153	1.57	8.8	4.9	5.2	0.4	12.6	4.6	2.3	43.6

[1]Average of 48 wells.

Table C. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE BAKERSFIELD AREA, 1958

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
44	1528	2.08	10.5	6.6	8.9	0.3	16.9	5.0	2.7	39.9
50	1690	2.30	9.5	11.5	5.0	0.3	17.4	8.1	1.8	36.1
56	933	1.27	6.0	4.6	5.4	0.2	10.3	4.4	2.3	37.0
58	2991	4.07	21.0	10.0	8.4	0.4	30.1	9.2	2.5	52.8
60	2859	3.89	18.1	16.4	11.3	0.4	32.2	12.7	0.6	39.2
65	3572	4.86	25.0	29.8	6.9	0.5	47.1	14.5	0.6	40.2
High	5527	7.52	38.2	34.3	18.4	0.8	68.0	20.5	0.4	41.7
Low	684	0.93	4.9	2.2	4.4	0.2	6.6	3.9	1.4	41.9
Average[1]	2425	3.30	17.6	14.3	9.3	0.4	28.3	12.2	1.8	42.3

[1]Average of 24 wells.

Table D. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE LOWER COYANOSA AREA, 1958

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
82	838	1.14	6.0	4.4	4.3	0.2	6.6	8.6	1.8	40.3
84	1168	1.59	8.2	5.0	5.6	0.2	7.0	12.4	0.5	43.2
91	3116	4.24	32.4	10.6	14.5	0.8	29.8	25.0	1.1	55.6
96	625	0.85	5.2	2.5	3.2	0.1	4.2	5.5	1.2	47.3
104	551	0.75	4.6	3.0	2.9	0.2	5.5	3.4	1.8	43.0
114	706	0.96	4.6	3.2	3.5	0.2	9.1	3.0	1.9	40.0
High	3248	4.42	40.0	11.9	7.2	0.8	30.1	23.7	1.9	66.8
Low	522	.71	4.6	1.6	2.7	0.2	6.0	2.4	1.9	50.5
Average[1]	1139	1.55	9.7	5.5	5.1	0.3	9.5	9.8	1.1	47.1

[1]Average of 41 wells.

Table E. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE PECOS PUMP AREA, 1958

Sample no.	Total salt content P.P.M.	Total salt content T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	Na, %
			Milliequivalents per liter							
68	2859	3.89	19.8	9.5	17.4	0.7	29.1	17.6	2.0	41.8
77	3447	4.69	21.7	10.2	19.9	0.8	36.7	12.9	1.8	41.2
86	3248	4.42	27.3	9.9	20.9	0.8	36.0	16.1	1.9	46.3
104	3182	4.33	23.5	8.3	16.9	0.6	31.0	16.4	2.0	47.7
117	2403	3.27	30.0	8.0	13.5	0.6	25.2	21.5	2.0	57.6
125	2271	3.09	18.4	9.4	12.4	0.7	22.2	13.8	1.7	45.0
High	5586	7.60	56.0	20.8	27.8	1.0	68.5	29.3	2.1	53.0
Low	2175	2.96	20.0	7.9	12.7	0.6	21.4	15.6	1.8	48.5
Average[1]	2793	3.80	21.8	9.3	16.1	0.7	28.5	16.7	1.9	45.5

[1]Average of 96 wells.

Table F. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE DELL CITY AREA, 1957

Sample no.	Total salt content P.P.M.	Total salt content T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	Na, %
			Milliequivalents per liter							
22	1051	1.43	3.8	8.0	8.7	0.3	6.8	10.5	3.8	18.3
23	1624	2.21	7.8	11.0	13.5	0.3	10.4	17.5	4.2	23.9
24	1073	1.46	3.5	8.5	9.5	0.3	7.4	10.6	4.0	15.9
25	1205	1.64	4.2	9.9	11.2	0.3	7.6	15.0	4.0	16.4
27	1948	2.65	8.9	12.0	13.4	0.4	14.5	17.5	3.3	25.6
33	1756	2.39	8.4	10.5	14.9	0.3	12.0	19.2	4.3	24.6
High	6365	8.66	57.6	16.9	36.4	0.8	65.6	33.0	4.5	51.6
Low	904	1.23	3.5	8.2	9.5	0.3	7.0	12.1	3.2	16.3
Average[1]	1462	1.99	6.1	9.9	11.9	0.3	9.8	14.0	3.9	21.6

[1]Average of 32 wells.

Table G. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE WILD HORSE AREA (VAN HORN), 1957

Sample no.	Total salt content P.P.M.	Total salt content T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	Na, %
			Milliequivalents per liter							
15	2014	2.74	17.0	2.5	11.5	0.3	20.4	8.9	3.5	54.3
16	1918	2.61	15.3	4.3	9.7	0.4	20.0	6.5	4.0	51.5
19	875	1.19	9.9	0.8	7.3	0.2	9.4	3.9	4.5	54.4
20	845	1.15	9.8	0.4	8.1	0.3	8.4	4.7	5.6	52.7
[illegible]	1948	2.65	17.1	4.2	9.5	0.4	19.6	7.6	3.8	54.8
27	830	1.13	7.2	1.4	4.7	0.2	8.9	2.4	2.3	53.3
High	2050	2.79	18.3	4.1	8.6	0.4	20.6	7.0	4.4	58.3
Low	712	0.97	9.0	0.3	7.0	0.2	8.6	4.1	4.7	54.5
Average[1]	1396	1.90	17.3	2.2	6.3	0.3	14.5	8.0	4.1	66.3

[1]Average of 14 wells.

Table H. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE LOBO FLATS AREA (VAN HORN), 1957

Sample no.	Total salt content P.P.M.	Total salt content T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	Na, %
			Milliequivalents per liter							
10	375	0.51	5.0	0.1	1.6	0.1	3.0	0.8	3.8	73.5
12	360	0.49	5.5	0.2	1.8	0.1	3.4	0.7	4.1	72.4
13	559	0.76	7.1	0.1	1.1	0.1	4.4	0.4	5.4	84.5
17	323	0.44	5.0	0.1	1.3	0.1	2.8	1.5	2.8	76.9
18	243	0.33	4.0	0.2	1.0	Trace	3.8	0.3	1.9	75.5
20	331	0.45	5.0	0.2	1.3	0.1	2.8	1.0	2.8	75.8
High	617	0.84	8.3	0.1	1.4	0.1	4.5	0.9	4.8	83.8
Low	220	0.30	4.0	Trace	1.1	0.1	2.7	0.4	2.1	75.4
Average[1]	375	0.51	5.5	0.1	1.3	0.1	3.3	0.7	2.1	78.6

[1]Average of 15 wells.

Table I. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (MESILLA VALLEY AREA), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
43	978	1.33	9.0	3.1	4.4	0.6	9.0	5.4	2.4	52.6
51	1455	1.98	13.1	3.4	6.3	0.7	12.3	8.3	2.1	55.7
65	1308	1.78	12.5	2.0	4.9	0.3	11.1	6.5	1.9	63.4
70	1529	2.08	14.9	3.6	5.4	0.5	13.5	8.2	1.8	61.1
71	2014	2.74	17.2	6.0	6.8	0.6	16.4	11.8	2.0	56.2
84	1544	2.10	16.8	5.4	4.3	0.4	16.6	6.0	2.4	62.5
High	3014	4.10	29.4	8.2	10.1	1.2	27.8	19.4	2.2	60.1
Low	691	0.94	4.2	1.9	2.5	0.3	3.1	3.1	1.6	47.2
Average[1]	1536	2.09	13.9	4.0	5.3	0.5	13.1	7.7	2.1	58.6

[1]Average of 28 wells.

Table J. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (YSLETA AREA), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
4	1756	2.39	13.0	7.6	7.3	0.7	17.0	7.3	4.3	45.4
7	1918	2.61	19.5	8.8	6.8	0.8	20.3	10.7	4.5	54.3
22	1301	1.77	9.9	6.1	5.3	0.4	13.2	6.2	3.0	45.6
59	1528	2.08	16.1	5.5	3.5	0.5	14.1	6.3	5.1	62.9
84	1492	2.03	12.0	5.0	7.6	0.6	11.8	7.7	4.4	47.6
95	1882	2.56	18.0	4.5	3.9	0.5	18.8	4.6	4.2	66.9
High	4807	6.54	35.0	23.1	11.2	2.1	56.9	11.6	2.8	49.0
Low	970	1.32	9.4	2.4	3.5	0.4	8.8	5.2	3.1	59.9
Average[1]	1756	2.39	15.8	6.2	5.3	0.6	17.6	5.8	3.8	57.8

[1]Average of 65 wells.

Table K. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (CLINT-SOCORRO AREA), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
104	2793	3.80	27.0	7.0	8.0	1.0	24.2	15.2	2.9	62.8
121	2925	3.98	33.0	7.0	7.3	0.9	24.6	17.7	4.8	68.5
133	3248	4.42	33.0	11.0	6.5	1.1	37.0	9.6	3.1	63.9
135	3182	4.33	33.9	5.6	8.5	0.9	33.8	11.2	4.0	69.3
142	2212	3.01	24.0	5.0	4.9	0.8	22.2	6.4	5.5	69.2
154	3087	4.20	30.0	8.5	7.4	0.9	28.6	11.1	5.0	64.1
High	4226	5.75	42.0	12.8	7.6	1.2	39.4	23.9	2.4	66.0
Low	1705	2.32	16.9	3.4	4.7	0.8	16.8	6.6	2.6	65.5
Average[1]	2903	3.95	31.6	6.9	7.4	0.8	27.5	15.6	4.0	67.6

[1]Average of 40 wells.

Table L. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (FABENS-TORNILLO AREA), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
220	1933	2.63	17.6	5.5	6.8	0.7	18.2	8.4	3.8	57.5
234	1720	2.34	14.9	6.6	6.3	0.6	16.9	5.8	3.6	52.5
237	3638	4.95	31.0	6.9	15.8	1.4	35.6	17.3	1.2	56.3
256	1235	1.68	12.0	3.1	3.5	0.4	9.8	4.2	4.6	63.2
280	1168	1.59	10.0	3.6	3.5	0.4	8.6	5.9	2.1	57.1
285	2337	3.18	20.0	10.4	5.9	0.8	22.9	8.4	4.0	53.9
High	4226	5.75	43.0	5.5	13.8	1.4	42.4	16.0	4.4	67.5
Low	1073	1.46	9.8	4.4	5.0	0.3	12.4	4.4	3.1	50.3
Average[1]	2168	2.95	18.8	5.0	7.4	0.6	18.5	8.6	4.4	59.1

[1]Average of 123 wells.

Table M. ANALYSIS OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (HUDSPETH COUNTY), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
77	2470	3.36	28.0	5.4	7.3	0.8	24.5	11.3	5.3	67.5
79	3638	4.95	33.0	15.0	8.6	1.0	35.8	14.7	4.7	57.3
84	3902	5.31	40.0	13.5	13.7	0.9	46.5	14.4	3.9	58.7
87	5130	6.98	56.0	16.0	12.5	1.2	64.4	13.7	4.5	65.3
95	2043	2.78	17.4	7.8	7.9	0.5	20.0	8.8	4.2	51.8
99	3116	4.24	41.0	5.6	7.2	1.0	34.3	10.9	4.8	74.8
High	7150	9.73	71.0	26.7	12.4	2.2	77.9	30.7	4.3	63.2
Low	1880	2.56	19.2	5.0	6.4	0.4	19.8	8.7	4.9	61.9
Average[1]	3925	5.34	41.3	10.2	14.2	1.1	44.8	19.0	4.7	61.8

[1]Average of 56 wells.

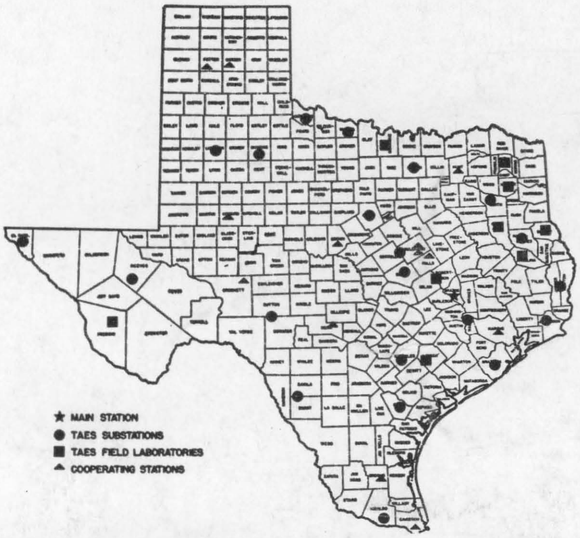
Table N. ANALYSES OF PUMP WATERS USED FOR IRRIGATION IN THE UPPER RIO GRANDE VALLEY (PRESIDIO AREA), 1956

Sample no.	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
10	2072	2.82	16.0	9.0	6.7	0.3	16.1	13.5	2.7	50.0
12	2587	3.52	22.5	8.0	7.7	0.1	18.1	16.2	1.4	58.7
13	2070	2.82	18.5	5.3	7.6	0.1	14.2	15.8	1.4	58.7
17	1036	1.41	7.0	2.5	4.2	1.1	5.8	7.9	1.3	47.3
19	2918	3.97	22.5	15.1	10.0	0.4	25.4	22.2	1.0	46.9
21	1940	2.64	14.0	6.0	8.1	0.3	14.6	13.5	2.5	49.3
High	3116	4.24	27.6	10.4	12.9	0.8	21.6	24.3	2.4	53.4
Low	1030	1.40	7.0	2.4	3.8	0.2	6.6	7.1	1.4	52.2
Average[1]	2095	2.85	18.8	6.1	7.4	0.2	14.0	17.4	1.5	57.8

[1]Average of 12 wells.

Table O. ANALYSES OF SURFACE AND SPRING WATERS USED FOR IRRIGATION IN THE TRANS-PECOS AREA

Source	Total salt content		Milliequivalents per liter							Na, %
	P.P.M.	T.A.F.	Sodium Na	Calcium Ca	Magnesium Mg	Potassium K	Chloride Cl	Sulfate SO_4	Bicarbonate HCO_3	
Rio Grande El Paso (May 1956)	1368	1.86	11.8	6.9	2.4	0.1	6.6	11.3	3.3	55.7
Rio Grande El Paso (Dec. 1956)	2836	3.86	34.1	6.9	3.2	0.8	19.8	19.5	5.4	76.0
Rio Conchos Ojinaga (May 1956)	1220	1.66	8.1	9.8	1.3	0.2	4.5	11.3	2.6	41.7
Rio Conchos Ojinaga (Dec. 1956)	985	1.34	6.7	7.7	0.9	0.1	2.9	8.8	3.6	43.5
Pecos River (Red Bluff Reservoir) (April 1959)	3895	5.30	37.0	16.0	14.2	0.5	38.7	25.0	1.3	54.7
Balmorhea Lake (1956)	2278	3.1	17.0	7.2	7.4	0.4	17.6	10.5	3.8	53.1



Location of field research units of the Texas Agricultural Experiment Station and cooperating agencies

State-wide Research

★

The Texas Agricultural Experiment Station is the public agricultural research agency of the State of Texas, and is one of ten parts of the Texas A&M College System

ORGANIZATION

IN THE MAIN STATION, with headquarters at College Station, are 16 subject-matter departments, 2 service departments, 3 regulatory services and the administrative staff. Located out in the major agricultural areas of Texas are 21 substations and 9 field laboratories. In addition, there are 14 cooperating stations owned by other agencies. Cooperating agencies include the Texas Forest Service, Game and Fish Commission of Texas, Texas Prison System, U. S. Department of Agriculture, University of Texas, Texas Technological College, Texas College of Arts and Industries and the King Ranch. Some experiments are conducted on farms and ranches and in rural homes.

OPERATION

THE TEXAS STATION is conducting about 400 active research projects, grouped in 25 programs, which include all phases of agriculture in Texas. Among these are:

- Conservation and improvement of soil
- Conservation and use of water
- Grasses and legumes
- Grain crops
- Cotton and other fiber crops
- Vegetable crops
- Citrus and other subtropical fruits
- Fruits and nuts
- Oil seed crops
- Ornamental plants
- Brush and weeds
- Insects
- Beef cattle
- Dairy cattle
- Sheep and goats
- Swine
- Chickens and turkeys
- Animal diseases and parasites
- Fish and game
- Farm and ranch engineering
- Farm and ranch business
- Marketing agricultural products
- Rural home economics
- Rural agricultural economics
- Plant diseases

Two additional programs are maintenance and upkeep, and central services.

Research results are carried to Texas farmers, ranchmen and homemakers by county agents and specialists of the Texas Agricultural Extension Service

AGRICULTURAL RESEARCH seeks the WHATS, the WHYS, the WHENS, the WHERES and the HOWS of hundreds of problems which confront operators of farms and ranches, and the many industries depending on or serving agriculture. Workers of the Main Station and the field units of the Texas Agricultural Experiment Station seek diligently to find solutions to these problems.

Today's Research Is Tomorrow's Progress