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# Salinity Trend in the Lower Rio Conchos, Chihuahua

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**ABSTRACT**—Salinity has been recognized as a major concern to agricultural production in northern Mexico because of its potential impairment to soils. Streams within the lower Rio Conchos basin have increased their salt content in the past decades as a result of various factors, among them water management and drought. In order to estimate the contribution of each of these sources of water salinity and their impact to soil salinity, selected samples of the river, springs, and adjacent lands were collected and analyzed. These data, supplemented with previously reported salinity and flow values, were used to obtain a trend and seasonal variation of salinity in the river at its confluence with the Rio Grande. An increasing trend in the river water salinity for the past 20 years is noticeable. More data are necessary to verify this trend and to account for a cyclic nature of precipitation of the area (e.g., summer monsoon; drought every five to seven decades) and its impact to soil salinity.

**RESUMEN**—La salinización de la tierra es un problema que, de no atenderse debidamente, puede perjudicar la producción agrícola del norte de México, debido a que afecta la productividad de los suelos. Ríos dentro de la cuenca del río Conchos han aumentado su salinidad en las últimas décadas como resultado de sequías y manejo de la cuenca, entre otros factores. Muestras de aguas y suelos de la cuenca baja de este río se analizaron para estimar el nivel de salinidad existente. Los resultados de este estudio se aunaron a datos existentes del río Conchos a su confluencia con el río Bravo del Norte, y juntos se utilizaron para estimar la tendencia de la salinidad en esta parte de la cuenca. La salinidad del río en los últimos 20 años muestra un aumento gradual, aunque ligero. Mas datos son necesarios para poder determinar si esta tendencia es cíclica o lineal, si su variación se puede explicar por medio de la precipitación (esta última de tipo monzón, con sequías periódicas cada cinco a siete décadas), así como su posible impacto a la salinidad del suelo.

The Rio Conchos of northern Mexico is located almost entirely within the state of Chihuahua and joins the Rio Grande (Rio Bravo del Norte) at Ojinaga-Presidio. An increase in salinity has been observed in the Rio Grande, with an average annual salinity increase in the river segment upstream of Amistad Dam of 15 to 18 mg/L (Miyamoto et al. 1995). The lower Rio Conchos has increased its salt content in the past decades as a result of various factors, among them the inflow of irrigation drain returns upstream, increase in population in urban areas, industrial and domestic waste inflows and, from 1992 to 2002 (maybe longer), drought. Quantifying the increase in salinity of the Rio Conchos is the purpose of this study.

Flow and salinity data for the Rio Conchos are scarce; the majority of it corresponds to data reported by the International Boundary and Water Commission (IBWC) at the confluence of the Rio Conchos with the Rio Grande. Knowing how much of this salinity is contributed by each source (e.g., salt flushing, evaporation, dissolution of geologic material, irrigation) would help to better manage the water resources of the basin. Water total dissolved solid values of up to 2000 mg/L have been reported for irrigation drain input to the Rio Conchos upstream from the town of Julimes (Gutierrez and Borrego 1999). Other sources of salinity have been identified but have not been quantified; these include sewage from cities along the river, groundwater brine inflow, and hot springs.

Soil salinity data are also scarce. The background soil salinity investigated here was; however, limited to that occurring in a non-urbanized, non-irrigated part of the Rio Conchos basin that could be used as background in future studies.

Salinity has been recognized as a major concern to agricultural production in northern Mexico because of its potential impairment to soils. Irrigated lands in the semi-arid regions of northern Mexico are a major agricultural producer for several crops including corn, alfalfa, peanuts, cotton, and sorghum. Sadly, as much as 81% of the irrigated land in northern Mexico has been affected by salinization of one type or another (Gonzalez-Casillas et al. 2001). Although most of the crops grown in these irrigation districts are salt tolerant, the yield of some crops can be significantly reduced under increased salinity (Gonzalez-Meraz and Pulido-Madrigal 2000). The response of riparian areas to higher salinity is also an important matter within the Chihuahuan Desert. Higher salinity may adversely effect both the riparian vegetation and the wildlife that rely on it for food and water supply. A decrease in the river water flow, lowering of water tables, and higher salt content of soils within the riparian area may be detrimental to native riparian vegetation by encouraging the growth of plants such as tamarix—an intrusive, non-native species better fitted to withstand drier conditions.

**WATER AND SOIL SAMPLE COLLECTION**—Water and soil samples were collected in March of 2004 at selected locations in the lower Rio Conchos basin near the Luis L. Leon Reservoir (also known as El Granero), as shown in Fig. 1. Parameters measured *in situ* included pH and electrical conductivity. Water samples (Ca, Na, and Mg) and soil saturation extract samples (Ca, Sr, B, Ba, Al, Fe, Na, and Mg) were analyzed in the laboratory using a Liberty 150 AX Turbo induction coupled spectrometer (ICP). Sulfates and chlorides of water samples were also measured following standard methods (Clescerl et al. 1999).

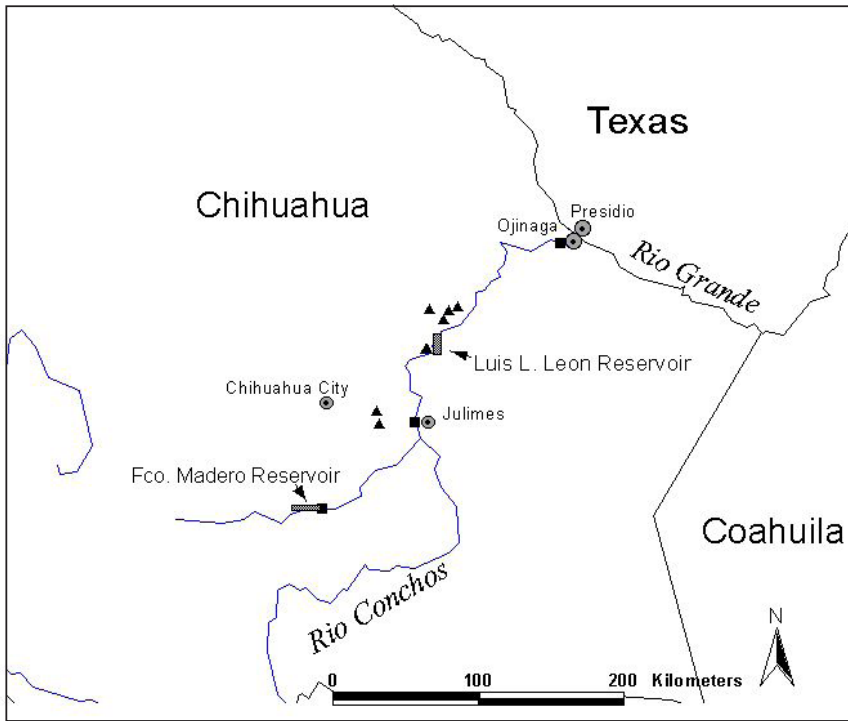


FIG. 1—Study area showing the approximate location of water (squares) and soil (triangles) samples.

Additional water salinity data (INEGI 1983; Gutierrez and Borrego 1999; Gutierrez and Carreon 2004; IBWC 2004; and TCEQ 2004) from the Rio Conchos and Rio Grande were used to supplement our data. The soil salinity data were supplemented with data from INEGI (1984). Water quality sampling at the Rio Conchos station (IBWC) was interrupted in 1998 (S. Waggoner, pers. comm.), which precluded the ability of this study to extend the Rio Conchos station's water salinity analysis beyond this date.

**RESULTS—Water Salinity**—This study focused on changes taking place in the lower Rio Conchos basin over the past 20 years. Water salinity data available from IBWC (2004) were utilized for this historical analysis. Flow data are included in the analysis since the salinity is expected to be a function of the flow. The correlation between flow and salinity was determined for the years comprised in this study using Microsoft Excel 2002. The correlation coefficient obtained for the Rio Grande was  $-0.26$  and for the Rio Conchos  $-0.46$ . The small value obtained for both correlation coefficients indicates

that the flow: salinity relationship is not linear. Rather, the relationship seems to be a complex function of several factors besides flow, including water storage in reservoirs, and irrigation practices upstream.

The Rio Conchos and the Rio Grande flows are shown in Fig. 2. Although the Rio Conchos has historically provided most of the water carried by the Rio Grande at their confluence, there have been times when the contribution from the Rio Grande was significant (e.g. 1987, 1995). Likewise, the salinity of the Rio Grande upstream of the confluence of the Rio Conchos has been higher than that of the water delivered by the Rio Conchos. The latter is of better quality, for which the decreased inflow of the Rio Conchos during the 1990s drought years resulted in low-flow, high-salinity conditions in the downstream Rio Grande segment. The drought of the Rio Conchos basin began in 1992. By May of 2000, the drought continued but rains within the Rio Conchos basin approached long term median values (Vasquez-Montes et al. 2000).

River salinity data for the past 20 years revealed a gradually increasing trend. The data are highly scattered, and even when grouped quarterly to reflect seasonal variations, coefficient of determination ( $R^2$ ) for the best fitted lines remained small. The resulting best fit lines for each quarter are shown in Fig. 3 for the Rio Grande and in Fig. 4 for the Rio Conchos. In both figures, the salinity values are more scattered in the last ten years. According to the slope of these lines, the salinity shows a sudden increase for the Rio Conchos and a more gradual increase in the Rio Grande. The four trend lines obtained for the Rio Conchos are very similar among themselves, indicating that in spite of the large difference in flows between dry and wet months, the salinity does not fluctuate as much. In contrast, the trend lines obtained for the Rio Grande vary considerably between the rainy months and the dryer months. The salinity values are higher for the Rio Grande in the dryer months (October to March) and are at their lowest during the rainy season, reaching a salinity value close to that of the incoming Rio Conchos. More data are; however, necessary to verify these trends and to account for the above mentioned cyclic nature of precipitation of the area.

Additional water samples were collected in March of 2004 from the Rio Conchos by the town of Julimes and from a hot spring within this town. The amount of water flowing out of the hot spring is relatively small but it was sampled as it might represent the chemical composition of underground inflows to the river. A sample from the Fco. Madero Reservoir is included for comparison purposes, as this water represents water free from the effects of irrigation. The results are shown in Table 1. The salinity concentrations of river and hot spring are similar, opposing the assumption that the hot springs significantly affect the river's composition. An increase in concentrations

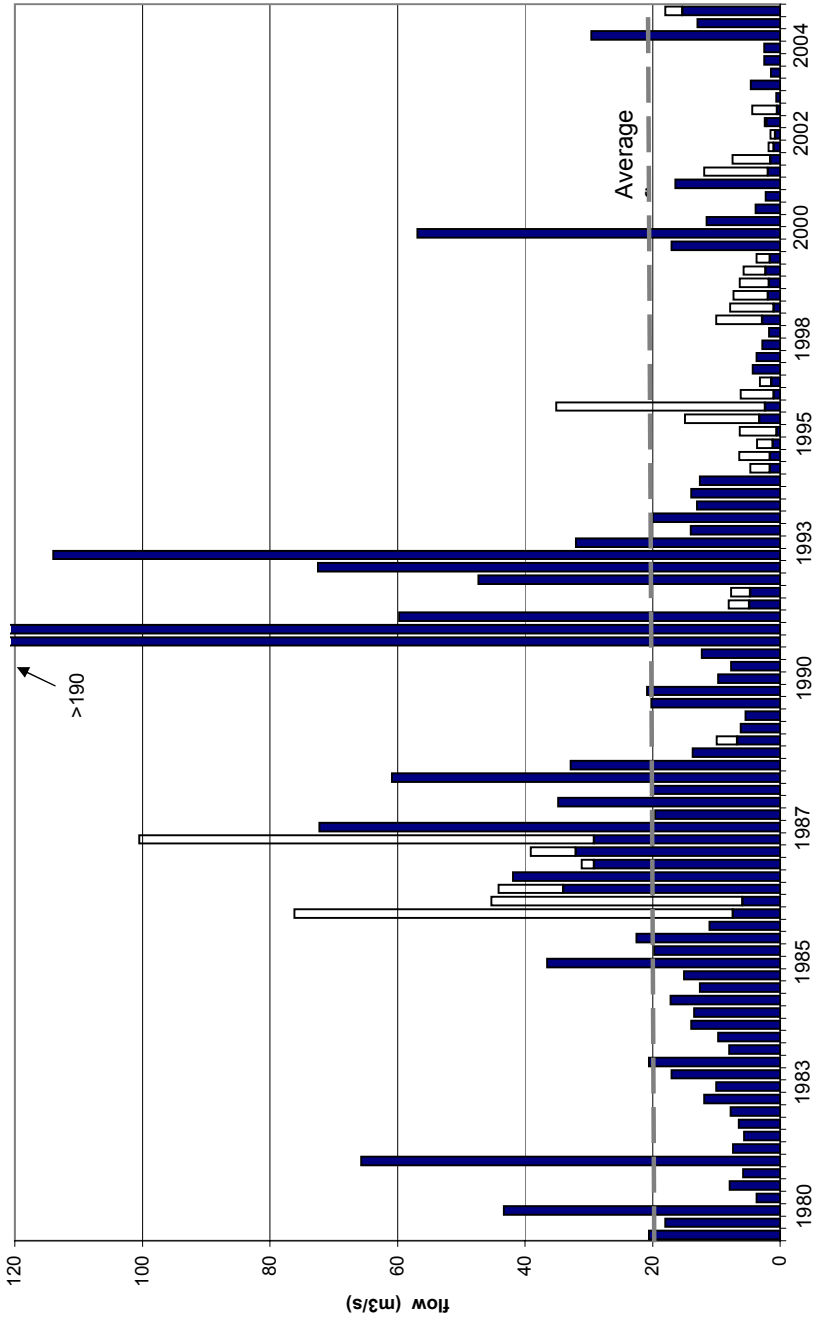


FIG. 2.—Flow of the Rio Conchos (dark bars) and average flow for the 1968–1993 period at its confluence with the Rio Grande. Light color bars represent the Rio Grande flow before the confluence of the Rio Conchos. The data are instantaneous measurements taken at irregular intervals and reported by IBWC.

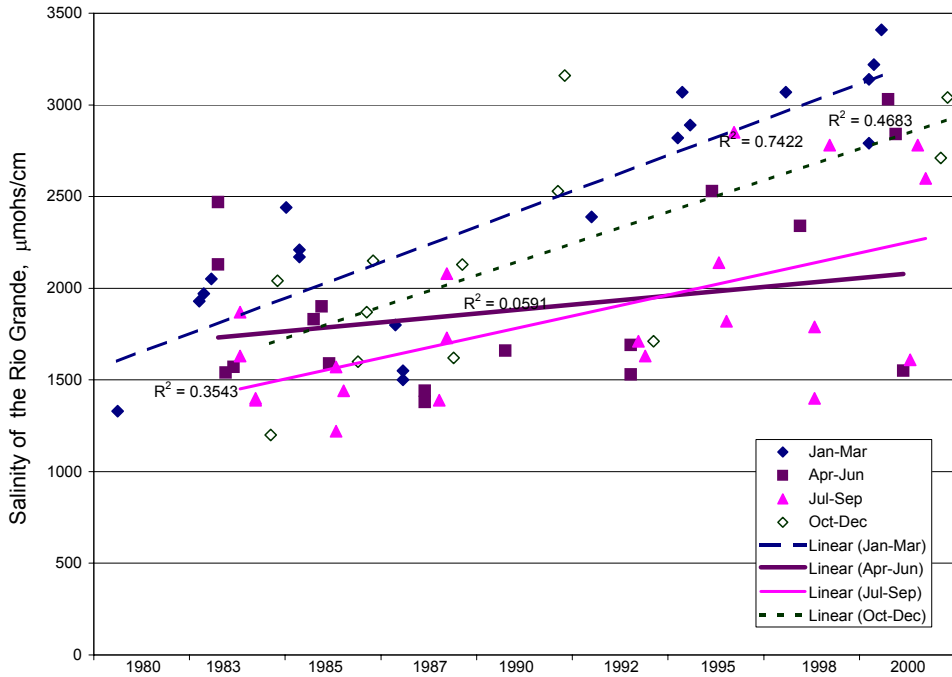


FIG. 3—Salinity of the Rio Grande above the Rio Conchos near Presidio TX for selected years and trend lines for each quarter (seasonal variations).

with time can be observed for both Ca and Na in river water. Calcium is naturally present in the soil and a combination of irrigation practices and decreasing pH in the river may explain its increase. A previous study shows a much higher increase in Ca near the Luis L. Leon reservoir (Gutierrez and Borrego 1999), that were attributed to gypsum-rich geologic units that occur in that area (Gutierrez and Carreon 2004). Na was expected to increase with time but the 2004 sample at Julimes showed a decrease in concentration. This decrease in Na (an ion occurring mainly in irrigation waste) may have resulted from the sample being taken in March, a month in which fields are not irrigated.

*Soil Salinity*—Prior to collecting the samples, soil sampling locations were identified using satellite images. The targeted locations were those showing a higher salinity in natural, non-irrigated land and yet accessible by road. The reason for these criteria was to obtain the worst case of soil salinity due to natural sources within the lower Rio Conchos basin. Field determinations included electrical conductivity and pH of the saturation solution, sediment color, and a horizontal location using a hand-held ground position system receiver. All of the analytical procedures followed standard procedures (Clescerl et al. 1999; Rhoades 1992).

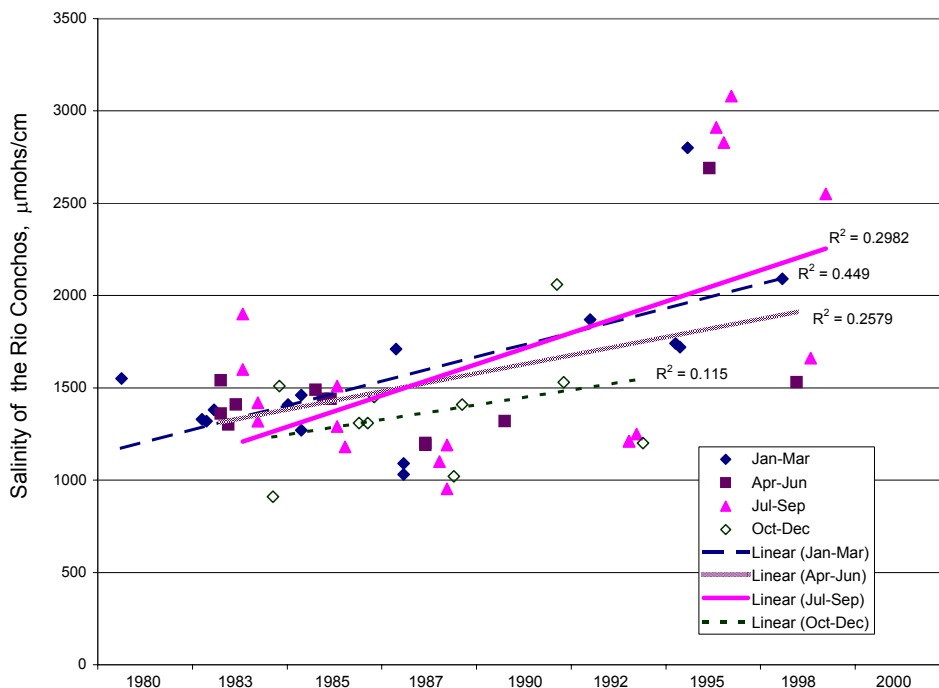


FIG. 4—Salinity of the Rio Conchos near Ojinaga, Chihuahua, for selected years and trend lines for each quarter (seasonal variations).

TABLE 1—Water quality of selected samples within the lower Rio Conchos basin.

Location, year*	pH	EC µS/cm	Hardness	HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>-2</sup>	Mg	Ca	Na
Rio Conchos, Julimes, 2004	7.3	n.r.**	n.r.	n.r.	96	358	35.8	193	20
Rio Conchos, Julimes, 1997	7.9	1920	400	n.r.	n.r.	n.r.	23.9	143	275
Rio Conchos, Julimes, 1983	8.1	1450	254	n.r.	57	281	30.5	51	159
Hot Springs at Julimes, 2004	6.7	n.r.	n.r.	256	66	253	26.8	139	46
Fco. Madero Reservoir, 2004	8.3	n.r.	n.r.	n.r.	1	4	8.4	42	1
Fco. Madero Reservoir, 1997	8.2	292	120	n.r.	n.r.	n.r.	5.2	28	15
Fco. Madero Reservoir, 1983	8.4	430	146	189	21	52	12.2	38	39

\* June, except for 2004 samples, which were taken in March

\*\* n.r. = not reported



Soil samples were collected at two depths, one near the surface and the other one from 5 to 10 cm depth. These samples are referred to as “S” and “U” respectively. At one location (sample No. 4), three samples were collected near each other to determine the variability for nearby samples; that is, two additional samples were collected at 0.5 m on either side of sample 4 (samples 4.1 and 4.2).

The results obtained for soil salinity analyses are shown in Table 2. The 2004 sampling coincided with several days of heavy rains in the area. As a result, the salinity of the surface portion of the soil (S) was less than that at depth (U) for most samples, as observed in Table 2. Samples 1, 2, and 5 showed a higher concentration in one or more elements. The samples 4, 4.1, and 4.2 showed little variability, except for the deeper sample of 4.1, which was two to five times more concentrated in all elements. The salinity of the samples, expressed as electrical conductivity, varied between 0.15 and 0.85 dS/cm and pH values were less than 8.5, for which these soils are classified as “normal soils.” The border line value for saline soils is 4.0 dS/cm conductivity, and pH of 8.5. Thus, the salinities of the soils sampled do not pose a threat to plant growth. Adjacent to this area there is a closed basin that is easily identified in the satellite images because of the high salt content of the soils. The soils at the center of this closed basin have been identified as sodic and have a conductivity value of 6 and a pH of 9 at 16 cm depth (INEGI 1984). Within the lower Rio Conchos basin, however, salts do not build up as much and the minor amounts of salts found correspond to weathering of salt-laden deposits within the basin. The sampled soils are classified as aridisols, their vegetation consists of short desert shrub and its land use is appropriate for cattle grazing (INEGI 1988). The high Ca concentration in water of nearby streams and springs reflects the interaction with gypsum-rich geological units that occur in this part of the basin.

CONCLUSIONS—The lower Rio Conchos basin lacks enough water quality monitoring data to assess the salinization process in an in-depth manner. Using available water quality data, an increasing trend in salinity was observed for both the Rio Grande and Rio Conchos. Soil salinity within this basin is mostly due to the natural weathering of salt deposits that are common locally and, to a lesser extent, the influence of upstream irrigation drain returns. The salinity of soils sampled was found to be low enough to be non-threatening to plant growth. Gypsum deposits occurring in this part of the basin seem to alleviate potential soil sodicity problems as sodium content decreases once calcium and sulfate-laden waters enter the Rio Conchos near the Luis Leon Reservoir. The seasonal and drought periodicity affect the salt content of the river

TABLE 2—Electrical conductivity and concentration of selected elements in soil saturation extracts.

Sample	Conductivity dS/m	Ca ppm	Na ppm	Al ppm	Sr ppm	Ba ppm	B ppm	Mn ppm	Fe ppm	Mg ppm
1S	0.241	98.9	n.d.	3.1	85.7	0.3	35.4	0.1	1.6	4.0
1U	0.253	132.3	65.8	3.4	222.2	0.5	210.0	1.0	1.8	9.9
2S	0.290	116.6	0.4	3.6	79.7	0.4	88.9	0.1	0.2	6.2
2U	0.355	103.3	5.5	3.5	68.3	0.3	116.3	0.0	0.1	3.4
3S	0.207	77.8	7.2	0.3	53.7	0.1	17.8	0.0	0.3	5.4
3U	0.238	84.7	6.3	3.3	62.1	0.1	47.1	0.1	0.6	4.3
4S	0.385	123.8	2.2	4.1	40.9	0.2	26.5	0.1	0.1	4.5
4U	0.328	70.7	3.6	1.6	29.4	0.1	37.7	0.0	0.1	3.0
4.1S	0.350	86.4	3.6	3.4	44.1	0.2	27.3	0.1	0.2	6.8
4.1U	0.456	208.1	15.1	7.4	95.8	0.3	76.5	1.0	1.1	9.6
4.2S	0.295	79.8	1.5	3.9	32.8	0.1	25.0	0.1	0.1	5.9
4.2U	0.323	95.1	0.0	5.2	43.7	0.2	30.7	0.1	0.6	6.7
5S	0.527	349.1	1.4	7.6	80.7	0.2	26.6	0.0	0.0	4.9
5U	0.846	217.8	7.9	13.4	128.4	0.5	17.8	0.1	0.7	10.4
6S	0.157	59.9	17.5	2.5	70.1	0.2	36.1	0.3	0.8	7.1
6U	0.250	126.0	32.9	5.8	121.1	0.3	55.7	0.5	0.4	12.0
7S	0.326	86.7	n.d.	2.1	33.8	0.1	21.4	0.1	0.5	10.3
7U	0.330	100.4	13.2	1.5	66.0	0.1	70.1	0.0	0.5	6.0

water although the relationship is far from being a simple linear one. More studies and a long-term monitoring are needed to fully determine the impact of water salinity to soils within the basin.

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