New Mexico Bureau of Mines and Mineral Resources

Open-File Report 346

RECHARGE AT THE WHITE SANDS HAZARDOUS-WASTE FACILITY, OTERO COUNTY, NEW MEXICO

by

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October 1988

REVISED OCTOBER 1991

PREFACE TO REVISION

Due to an error in calculating soil-moisture content, the soil-water chloride, and thus recharge rate, originally reported for the White Sands site are incorrect. The error arose when the lab assistant mistakenly calculated moisture as simply the wet sample weight minus the dry sample weight. It should have been calculated using wet weight minus dry weight, divided by the dry weight minus the average jar weight. Fortunately, raw data were preserved and a recalculation of the values was possible. This revised version includes 1) a new Table 2 giving corrected moisture and chloride values, 2) new profiles (Figure 3) based on the corrected values, 3) a revised average soil-water-chloride content (Clsw) and 4) a new recharge rate recalculated from the corrected values. All changes are within the Results and Discussion sections of the report.

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October 1991

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INTRODUCTION

In the period 1977–1981, the U.S. Army operated a hazardous-waste facility in sec. 6, T22S, R6E, at White Sands Missile Range (WSMR), Otero County, New Mexico (Figure 1). Containers with more than 100 different hazardous chemicals were buried in six 10-ft deep cells. In 1988 it was realized that the potential for migration of the hazardous waste to water-supply wells or the surface was not sufficiently understood. Thus, EPA required that the site either be shown to be suitable or the waste exhumed and transferred to an approved site.

In September, 1988, the U.S. Geological Survey began a hydrogeologic investigation of the site. As a part of this, a recharge study was conducted by the Bureau. The purpose of the recharge study was to determine an average long-term rate at which water (and potential contaminants) might move toward the water table at the site, under the influence of precipitation. This report gives the results of the Bureau's investigation of moisture/solute flux using the natural tracer chloride.

REGIONAL SETTING

The Army facility lies approximately 10 mi east of the WSMR Post Headquarters in the north/south-trending Tularosa Basin of the Rio Grande rift (Figure 1). It is situated between the Organ Mountains (12 mi to the west) and the Sacramento Mountains (26 mi to the east).

The Tularosa Basin is a typical Southwestern alluvial basin. The surface is characterized by the Dune Land/Doña Ana soil complex, which is classified as highly

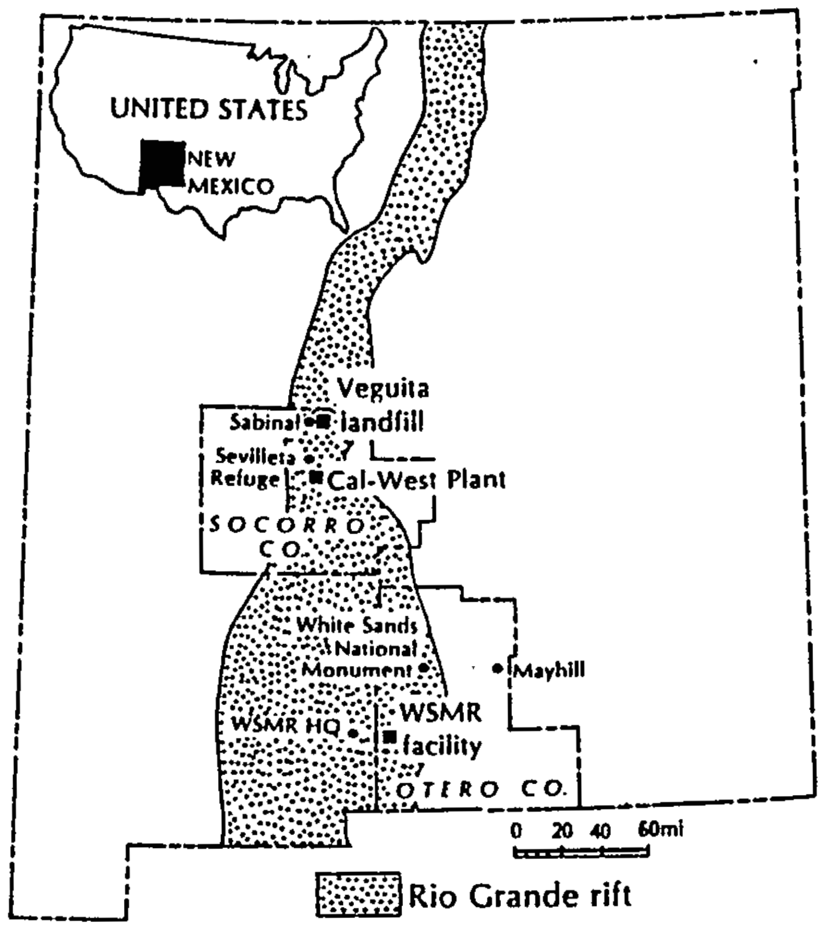

Figure 1. Location of White Sands and other waste-disposal sites studied in Rio Grande Rift (solid boxes) and sources of climatic data (solid circles).

permeable (Neher and Bailey, 1976). The facility is underlain by bolson-fill deposits. These consist of interbedded gravel, sand, silt, and clay of Quaternary age (Myers and Pinckley, 1987). Lithology of the sediments cored is given in Figure 2.

The climate is arid to semiarid with precipitation in the Tularosa Basin ranging from approximately 8-16 in/yr (Table 1).

Table 1. Selected climatic data for White Sands and adjacent sites studied in Rio Grande rift; see Figure 1 for locations.

Station	Lat. (N)	Long. (W)	Elev. (ft)	Pcp. (in)	Yrs. of Record	Source
Mayhill	32°54'	105°28'	6,538	18.95	44	A
Sabinal	34°27'	106°48'	4,700	8.18	4	B
Sevilleta Wildlife Refuge	34°17'	106°55'	4,921	7.9	?	C
WSMR HQ	(32°20')	(106°30')	4,100	16.0	?	D
White Sands National Monument	(32°45')	(106°11')	3,995	7.61	22	E

[1] Lat/long in parens are approximate from available maps

[2] A = Maker and others, 1972; National Atmospheric Deposition Program, 1988
B = Gabin and Lesperance, 1977
C = Phillips and others, 1984; McCord and Stephens, 1987
D = Wilson and Myers, 1981
E = Maker and others, 1972; Gabin and Lesperance, 1977

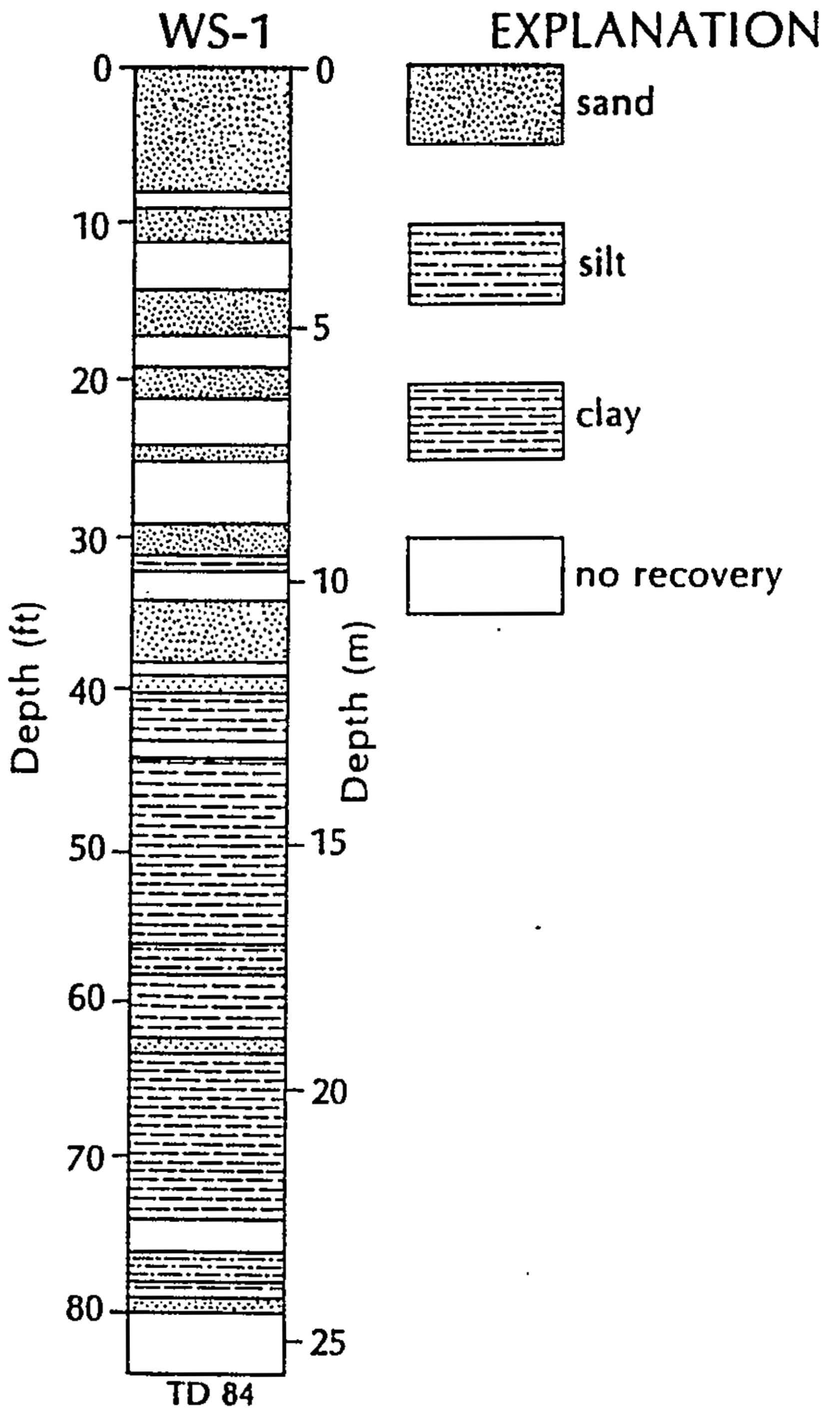

Figure 2. Lithologic log for hole at White Sands hazardous-waste facility.

Data on evaporation are sparse, but it commonly exceeds precipitation, in cases by as much as ten times. Gabin and Lesperance (1977) reported potential evaporation of 50.26 in for White Sands National Monument, resulting in a net water deficit (precipitation minus potential evaporation) of 42 in.

In 1986 ground-water depth ranged from 229 to 236 ft in three test wells at the facility (Myers and Pinckley, 1987). Water-table gradient is quite flat as might be expected in this basin-floor location. Wilson and Myers (1981, Plate 1) showed a gradient of 5-10 ft/mi in nearby T23/24N, R6E.

The site lies several miles beyond the eastern extent of freshwater, defined as that having a total-dissolved-solids content of <1,000 mg/L (Wilson and Myers, 1981, Plate 3). Chloride content of fresh ground water is on the order of 10's of mg/L, whereas that of the saline water is on the order of 1,000's to 10's of 1,000's of mg/l (Wilson and Myers 1981, Plate 2).

METHODS

Recharge was determined by the chloride mass-balance method. In this relatively simple and inexpensive procedure, it is assumed that

$$P \cdot Clp = R \cdot Clsw$$ (Allison and Hughes, 1978) where,

P = average annual precipitation (in/yr), Clp = annual chloride input via precipitation (mg/L), R = recharge rate (in/yr), Clsw average soil-water chloride content below the root zone (mg/L). Rewritten for recharge this becomes

$$R = (P \cdot Clp)/Clsw.$$

P and Clp are either obtained from the literature or by measurements made on site. Clsw is determined from samples of the entire unsaturated zone or 100 ft, whichever is less.

Preliminary tests suggest the general lab procedures used are valid (McGurk and Stone, 1985). The method has been widely used in arid settings (Allison and others, 1985; Stone, 1986a).

SAMPLING

Samples of the unsaturated zone were taken by means of coring with a hollow-stem auger rig. More specifically, a CME-55 continuous sampling system with a 5-ft split barrel was hired for the work. Each 5-ft core was subsampled at 1-ft intervals for the recharge study. Samples were taken in 1-oz screw-top, plastic jars. To prevent moisture loss these were also sealed with plastic electrical tape, placed in zip-top plastic bags, and stored out of the sun.

In the cae of incomplete recovery, it was assumed for consistency that the partial core was obtained, then the barrel became plugged. Thus, the core obtained was routinely assigned to the upper part of the interval drilled. For example, if only 3 ft were recovered in the interval 10–15 ft, the core was assigned to a depth of 10–13 ft.

ANALYSIS

Before recharge can be calculated, Clsw must be determined. This involves several steps. First, moisture content of each sample is determined gravimetrically. In other words, each sample is weighed as it comes from the field, oven dried to remove moisture, then weighed again. The weight loss is attributed to moisture content. Next, samples are shaken gently with a known volume of deionized water to remobilize the salt (chloride). The resulting solution is decanted off and its chloride content measured with a pH meter and chloride electrode. The chloride content of the original soil water (Cl) in each sample is calculated using

$$Cl = (Cle \cdot W/Sd)/(Sw\text{-}Sd/Sd\text{-}J) \cdot Db$$

where, Cle = chloride content of the extract (mg/L), W = weight of water added in extraction (g), Sd = dry weight of the sample (g), Sw = wet weight of the sample (g), i = weight of the jar (g) and Db is the bulk density of the sample.

Once Cl values are calculated for each sample, they are plotted versus depth. A typical plot is characterized by a chloride peak near the surface corresponding to the root zone. Plants take up water but leave salts behind. This accumulates over time to produce the chloride peak. Ideally, for every volume of water that comes in, through percipitation/ infiltration, an equivalent volume of water moves downward by piston flow. In most storms there is rarely enough precipitation to displace any water out of the root zone. However, the more intense storms do result in deep percolation/displacement. This shows up as lower chloride values below the peak. Only these are used to determine Clsw.

RESULTS

Although recovery was incomplete and coring was halted short of the projected 100-ft total depth, a sufficient number of samples was obtained to evaluate recharge (Table 2 and Figure 3). Moisture content varies with lithology, but generally fluctuates around 0.15 g/g

Table 2. Results of chloride analyses, White Sands hazardous-waste facility.

Sample No.	Sample Depth (ft)	Moist. Content (g/g)	Dry Wt. Soil (g)	Wt. Wtr. Added (g)	Cl in Extract (ppm)	Cl in Soil Wtr. (mg/l)
1	1	0.13	47.16	81.10	3.10	58.0
2	2	0.15	43.78	81.56	15.00	263.9
3	3	0.13	44.87	80.63	580.00	11,777.4
4	4	0.15	42.59	81.02	980.00	17,217.3
5	5	0.11	43.15	80.96	420.00	10,139.9
6	6	0.10	46.62	81.42	440.00	11,350.0
7	7	0.07	51.13	80.95	210.00	7,132.5
8	8	0.03	51.56	81.05	100.00	8,180.7
9	10	0.01	52.50	80.62	48.00	7,829.6
10	11	0.03	47.33	81.67	88.00	7,453.1
11	15	0.07	49.13	81.22	200.00	6,740.7
12	16	0.22	44.78	80.17	220.00	2,557.0
13	17	0.08	51.20	80.92	300.00	8,388.2
14	20	0.12	46.12	80.94	580.00	12,306.2
15	21	0.01	50.77	80.19	68.00	27,911.8
16	25	0.02	49.54	80.24	74.00	10,559.2
17	30	0.03	54.42	80.83	180.00	12,977.2
18	31	0.08	52.11	80.58	140.00	4,033.7
19	32	0.36	32.32	80.21	380.00	3,676.9
20	35	0.08	45.10	80.87	90.00	2,930.8
21	36	0.10	43.58	80.23	100.00	2,638.7
22	37	0.12	48.31	80.67	180.00	3,573.5
23	38	0.03	49.38	81.31	24.00	2,083.4
24	40	0.04	45.42	79.90	9.60	552.7
25	41	0.24	39.71	80.12	25.00	303.1
26	42	0.24	35.29	80.89	24.50	327.4
27	43	0.16	34.06	80.83	15.50	326.6
28	45	0.10	43.94	80.26	12.50	341.5
29	46	0.10	45.64	80.00	11.50	288.5
30	47	0.10	46.30	79.78	10.00	241.1
31	48	0.22	37.12	80.64	16.00	223.3
32	49	0.27	36.27	80.88	20.00	235.6
33	50	0.31	32.89	79.73	21.00	231.6
34	51	0.30	34.37	80.23	22.00	230.1
35	52	0.29	35.78	80.39	23.00	248.9
36	53	0.20	35.15	81.04	16.00	255.5
37	54	0.17	38.76	79.69	19.00	327.2
38	55	0.22	32.57	79.69	19.00	295.0
39	56	0.26	32.17	80.68	13.50	184.4
40	57	0.06	48.01	81.23	6.80	259.0
41	58	0.06	49.48	79.86	3.20	133.4
42	59	0.21	39.17	80.20	13.50	190.8
43	60	0.20	37.16	79.47	11.00	167.4

Sample No.	Sample Depth (ft)	Moist. Content (g/g)	Dry Wt. Soil (g)	Wt. Wtr. Added (g)	Cl in Extract (ppm)	Cl in Soil Wtr. (mg/l)
44	61	0.28	35.59	79.52	14.90	167.0
45	62	0.36	32.84	79.55	19.00	182.0
46	63	0.09	47.43	79.80	7.50	206.3
47	64	0.15	35.30	79.69	8.10	173.3
48	65	0.20	35.94	79.99	11.00	172.3
49	66	0.25	33.74	79.85	11.20	150.1
50	67	0.25	36.36	81.17	14.00	173.1
51	68	0.31	32.99	79.84	15.00	163.4
52	69	0.20	35.41	81.84	10.00	162.9
53	70	0.22	35.60	79.86	11.00	155.9
54	71	0.18	32.89	80.15	7.20	137.0
55	72	0.14	36.75	79.49	6.30	140.8
56	73	0.11	40.72	78.89	5.40	133.5
57	74	0.11	44.72	81.60	6.00	144.4
58	77	0.13	40.30	79.58	6.80	151.1
59	78	0.16	40.59	80.43	7.20	126.9
60	79	0.31	32.34	80.84	11.00	123.7
61	80	0.03	55.68	80.49	3.50	248.8

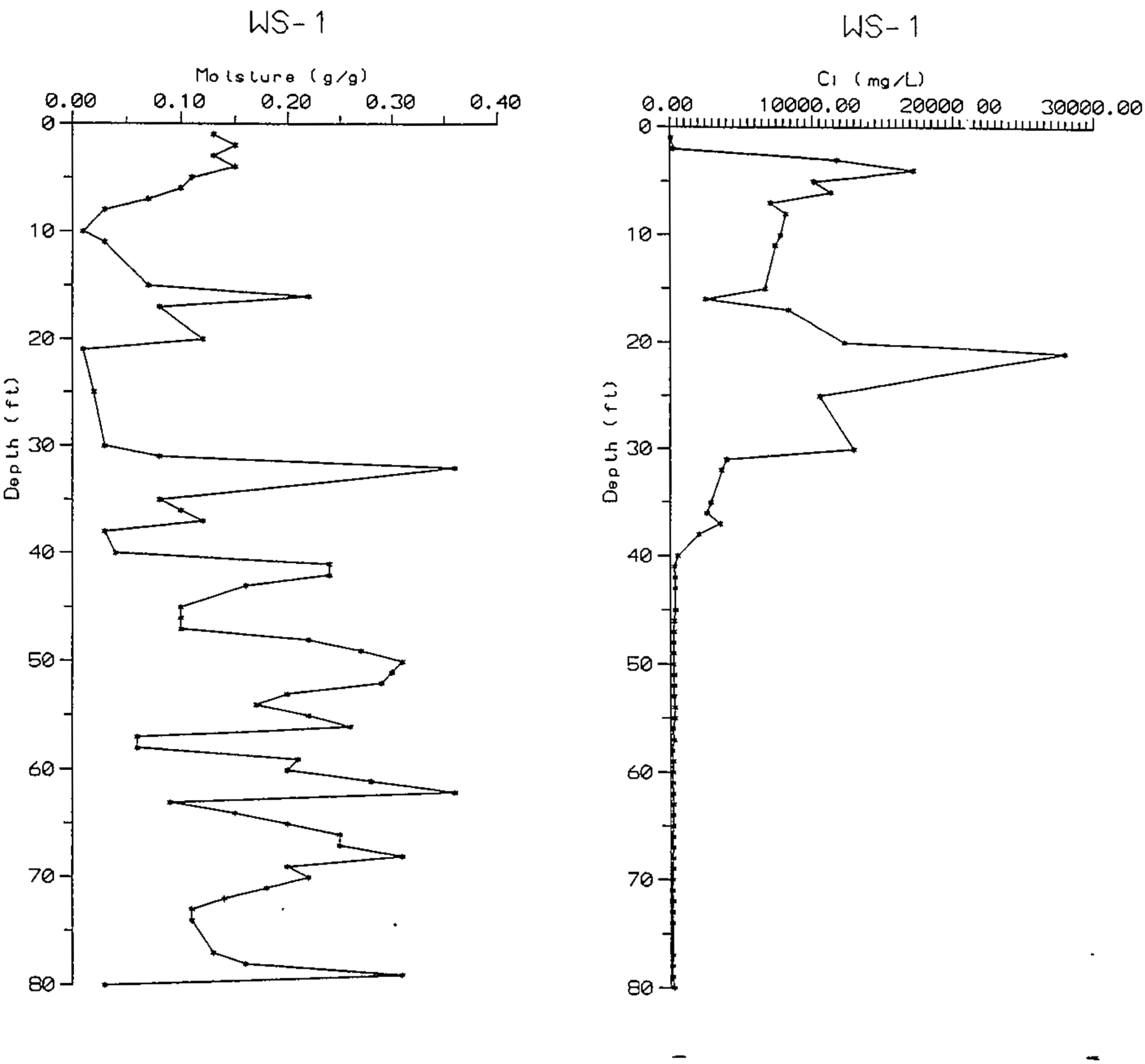

Figure 3. Results for White-Sands site.

(Figure 3). Values in excess of 0.3 g/g are associated with clay intervals (Figure 3 and Appendix). The chloride profile is typical in that it shows higher values near the surface and lower values at depth. The low-chloride interval between the peaks may represent a period of increased recharge. This may correspond to a time of standing water in the playa. Chloride values are generally higher than at other Rio Grande Valley sites (Figure 1 and Table 2; Stone, 1988a, b), with many >10,000 mg/L and maxima of 17,217 mg/L (4 ft) and 27,912 mg/L (21 ft).

Ideally, on-site measurements of P and Clp are used. The USGS already maintains a rain gage at the waste facility and plans to save samples for analysis on a regular basis during their study. In the meantime, the next best source of such data is the Jornada del Muerto Basin, just across the mountains to the west and north. Unfortunately, unpublished P and Clp data collected there in conjunction with an ecological study of Jornada Playa (near NMSU College Ranch) are too incomplete to use. Thus, recharge calculations were made using a Clsw of 218 mg/L for the interval 40-80 ft and published P and Clp values from the two closest stations for which such data are reasonably complete. These include Mayhill (approximately 75 mi to the northeast) and the Sevilleta Wildlife Refuge (approximately 135 mi to the north northwest). Using a P of 17.5 in/yr and a Clp of 0.286 mg/L, both from Mayhill (National Atmospheric Deposition Program, 1988a, b), recharge at the White Sands waste facility is 0.023 in/yr. Using a P of 7.6 in/yr from White Sands National Monument and a Clp of 0.37 mg/L from the Sevilleta Refuge (Phillips and others, 1984), recharge is 0.013 in/yr.

DISCUSSION

As expected from the mass-balance equation, the recharge rate obtained depends on the values used for P, Clp,and Clsw. As Clsw is constant and Clp is similar for the two stations, P is the critical parameter. P at Mayhill is more than twice that in the Tularosa Basin (see Table 1). This difference is no doubt due to Mayhill's location on the rainy side of the Sacramento Mountains. By contrast, the Sevilleta Refuge's basin setting and precipitation (7.9 in/yr, Fred Phillips, oral communication, October, 1988) are believed to be quite comparable to those at the waste facility. Thus the recharge rate obtained using Mayhill P and Clp data is rejected and that using Sevilleta values for these parameters (0.013 in/yr) is offered as a reasonable approximation, until on-site measurements are available.

The results of this study should not be taken to mean that any material lying at or near the surface will migrate toward the water table at a rate of 0.013 in/yr. This may serve as an ideal scenario, but is rarely attained for several reasons. First, the recharge rate calculated is a long-term average; lower (or higher) rates operate at any given time, depending on various climatic and site factors. Secondly, the rate only applies to highly soluble material that moves as the soil water does. Thirdly, movement of soil water is not strictly vertical (piston flow), as would be ideal for mass-balance calculations. There is often some lateral component of movement, in response to topographic effects (McCord and Stephens, 1987) and texture of the sediments (Winograd, 1974). Finally, the recharge rate obtained is only an estimate, because P and Clp were not availble for the site. If either of these were greater than assumed, the recharge value obtained would be greater and vice versa.

However, mass-balance recharge results have compared favorably with those of other methods (Phillips and others, 1984; Stone, 1986b). The value obtained also seems reasonable in view of the geology and vegetation at the site (Figure 2), climatic data for the region (Table 1), and previous experience with the method (Allison and others, 1985; Stone, 1986a, 1988a, b, and 1991). Although the recharge tate is among the lowest obtained in New Mexico (Stone, 1986b), it is of the same order of magnitude as other Rio Grande rift sites (Table 3). It amounts to only 0.17% of the precipitation value assumed for the area (7.6 in/yr at White Sands National Monument).

It should be noted that the multiple chloride peaks, do not alter the recharge rate calculated. Only values below the peaks are used to determine Clsw.

Table 3. Comparison of results at White Sands with those from other Rio Grande Rift sites. Data for Veguita and Cal-West from Stone (1988a, b).

Site	P (in/yr)	Clp (mg/L)	Climate Station	Clsw (mg/L)	R (in/yr)	% of P
White Sands	7.9	0.37	Sevilleta	218	0.01	0.17
Veguita Landfill	8.18	0.37	Sabinal, Sevilleta	121	0.02	0.24
Cal-West Metals	9.35	0.37	Sevilleta, Socorro	89	0.04	0.43

ACKNOWLEDGMENTS

This study was funded by the USGS - Water Resources Division, Albuquerque, New Mexico. Assistance with contract preparation, locating background information and sample collection by Cynthia Abeyta (USGS, Albuquerque) and Robert Myers (USGS, Las Cruces) is most appreciated. Lori Lesser and Sharon Boyd (undergraduate student assistants, New Mexico Tech) performed lab analyses and/or did computer work.

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APPENDIX

Brief Field Description of Core

Hole WS-1: outside fence on north side of White Sands Missile-Disposal Facility; 59 ft northwest of Range Hazardous Waste USGS well TW2.

Spl	Depth (ft)	Description
1-7	0-7	Sand, reddish brown, limy
8	7-8	Sand, grayer, loose
	8-9	No recovery
9, 10	9-11	Sand, gray, loose, as above
	11-14	No recovery
11-13	14-17	Sand, redder, finer grained
	17-19	No recovery
14	19-20	Sand as above, clayey with carbonate nodules
15	20-21	Sand, light pinkish gray, clean
	21-24	No recovery
16	24-25	Sand, fine grained as above
	25-29	No recovery
17	29-30	Sand as above with gravel at base
18	30-31	Sand as above, fine grained, limy
19	31-32	Clay, brown
	32-34	No recovery
20-23	34-38	Sand, yellowish pink, fine with silt and clay
	38-39	No recovery
24	39-40	Sand, light pinkish gray, very fine-fine grained

Spl	Depth (ft)	Description
25	40-41	Clay, reddish brown with selenite crystals
26, 27	41-43	Clay as above but some green, silty
	43-44	No recovery
28-30	44-47	Clay, reddish brown, sandy and limy
31-39	47-56	Clay, green, rusty in places, silty
40, 41	56-58	silt--very fine sand, reddish yellow
42-45	59-62	Clay as above, browner toward base
46	62-63	Sand, very fine grained, silty, yellow
47-57	63-74	Clay, brown, silty to pure, limy near base
	74-76	No recovery
58, 59	76-78	Silt--very fine sand, cream colored, limy
60	78-79	Clay, greenish brown
61	79-80	Sand, yellow, very fine, well sorted
	80-84	No recovery, tools stuck

TOTAL DEPTH = 84 ft; water table not encountered.