Outerbasin, Annulus and Playa Basin Infiltration Studies

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ABSTRACT

Infiltration within a playa lake basin and its surrounding outerbasin area determines playa usage. One playa was the site of four infiltration experiments with infiltrometers ranging in size from 5- to 350-inch diameter. First-minute infiltration rates (182, 116, 10.6 and 2.1 inches per hour) were dependent on infiltrometer diameter and experimental method utilized. In two experiments, outerbasin and annulus infiltration were evaluated in addition to playa basin infiltration. For these experiments, playa basin infiltration rates significantly exceeded those of their outerbasin counterparts. The implications are that environmental pollution can occur if the playas are not properly managed.

KEYWORDS: playas, infiltration, cracking soils

Within the southern High Plains of the United States, the most significant geomorphic features in the flat topography are numerous shallow depressions (playas). There are approximately 30,000 playa basins (Wood and Osterkamp, 1984) on the Southern High Plains, with 1,006 playas in Lubbock County, Texas alone (Blackstock, 1979). Since there is very limited regional riverine development, playas provide runoff catchment basins for these topographically closed drainage areas. The playa basins are comprised of clayey soils [Randall clay (fine, montmorillonitic, thermic Typic Haplusterts)]; whereas outerbasin soils are typically fine sandy loams or clay loams. Between the playa basin and outerbasin soil is an indefinite area of soil referenced to as the annulus. These playa basins are utilized for wildlife management, urban stormwater management, feedlot waste storage, as well as for irrigation water (Urban, 1994). In spite of their varied uses and economic importance, only limited research efforts have been directed toward a detailed understanding of their infiltration characteristics. Their potential as the focus point for Ogallala recharge adds emphasis to the need to understand basin infiltration characteristics.

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A review article by Mullican et al. (1994) traced the changing perception of the role of playas from closed drainage areas to areas of Ogallala aquifer recharge. Work by Theis (1937) suggested recharge of the Ogallala was a regional, steady-state process. Theis mentioned that sand dune areas were "more favored" for recharge. Mullican et al. (1994) mentioned "zonal" recharge in which the Ogallala recharge varied on the "basis of surface geologic units." Their third scenario for recharge is "modified zonal or playa." This focused recharge was suggested by White et al. (1946) as occurring in the playa basin. Wood and Osterkamp (1984) suggested that focused recharge occurred in the annular area surrounding the playa basin.

To have focused recharge of the Ogallala aquifer, water must first infiltrate within the playa basin. This study is a summary of the four infiltration experiments at one representative Lubbock County playa located near Shallowater, Texas. Experiments began by characterizing the infiltration phenomenon with small diameter (5 inches) infiltrometers and increased in size to 350-inch diameter.

MATERIALS AND METHODS

A playa located 2 mi southwest of Shallowater, Texas was used for this set of experiments. The playa was approximately 17 A in size and served as runoff catchment for an approximately 11 mi^2 area. The soil on the playa floor was a Randall clay having 67.7% clay, 20.7% silt, and 11.6% sand as determined by the methods of Gee and Bauder (1986). This particular soil had a pH of 7.4, an electrical conductivity of 0.29 dS/m, and a sodium adsorption ratio of 0.14 as determined by the methods of U.S. Salinity Lab Staff (1954). Gravimetric soil water contents ranged from 0.16 to 0.19. Surrounding the playa basin was an annular zone which possesses properties of both the playa and outerbasin soils. It had cracking clays at the surface but a calcareous subsoil horizon. Annular surface area was of such a small extent that it was not mapped as a separate soil series. The outerbasin soil surrounding the annulus was a Lofton clay loam which was classed as a fine, mixed, thermic Vertic Argiustolls. All experiments were conducted during the summer months. No efforts were taken to avoid or select areas of large cracks.

Phase I (5-inch scale)

Infiltration was evaluated using 5-inch diameter cylinder infiltrometers (Haise et al., 1956). Infiltrometers were installed 30 ft apart along a transect from the Lofton clay loam outerbasin soil, through the annulus and playa basin, and back through the annulus and into the opposite outerbasin soil. Thirty-one infiltrometers were positioned within the playa basin with 12 inches the annulus and 38 inches the outerbasin area. Wholly within the playa basin, a second experiment utilized 90 double-ring infiltrometers (8-inch diameter outer ring and 5-inch diameter inner rings) (Bouwer, 1986). In both experiments, the 12-inch infiltrometer rings were driven 3 inches into the soil. A known quantity of Lubbock municipal water was added to each 5-inch ring within 10 seconds. Infiltration rates were measured by the change of water levels on plastic rules in the 5-inch ring as a function of time.

Phase II (80-inch scale)

Intermediate scale infiltration was evaluated using 80-inch diameter basin infiltrometers (U.S. Environmental Protection Agency, 1981). Three replicated basin infiltrometers (20-inch metal flashing, inserted 3 inches deep) were aligned approximately 15 to 25 ft apart along the same elevation within the playa basin, annulus, or outerbasin soils. Basin infiltrometers were gravity filled (1 to 1-1/2 hr duration) with Lubbock municipal water from a water tank. After filling with a known volume of water, decreasing water levels were measured, on one minute intervals, using a point gauge (0.001-ft increments).

Phase III (350-inch scale)

A further experiment expanded the diameter of the basin infiltrometer to approximately 350 inches. An infiltrometer was constructed from 20-gauge steel, 24 inches wide, and inserted to a depth of 6 inches. Soil was bermed on the outside of approximately 14 inches of the aboveground metal. Water from an adjacent well was pumped to the infiltrometer using 4-inch diameter aluminum pipe with volume measured using an in-line flow meter. A wooden splash box was placed in the center of the infiltrometer to minimize soil erosion. Water level was determined using a point gauge measuring device calibrated to 0.01 inch. The three replicate sites were randomly selected within the playa basin within the limitations allowed by the amount of available pipe. Water depth within the infiltrometer and inflow volume were measured every 5 minutes until the water completely covered the soil surface to 18-inch depth. The filling process took 61 to 67 minutes to accomplish. At this time, the water was shut off; the infiltration was determined at regular intervals for several days. Concurrent evaporation was determined using a class "A" pan.

RESULTS

Four experiments were conducted to document infiltration within and adjoining a Shallowater, Texas playa basin. The 5-inch diameter infiltration data presented in Fig. 1 represents rate of infiltration for the outerbasin, annulus, and playa basin soils for the first five minutes. First minute infiltration rates were approximately 116, 88, and 60 inches per hr for the playa, annulus, and outerbasin soils, respectively. Infiltration decreased to 24, 22, and 20 inches per hr within 5 minutes. Statistically, the infiltration interval and cumulative rates for the annulus were not significantly different from either the outerbasin or playa basin soils at the 5% level. The initial infiltration value was significantly greater for the playa basin than the outerbasin. Transect data presented in Table 1 correlates elevation, cumulative infiltration, and surface horizon sand, silt, and clay percentages. Elevation was significantly ($P=0.0015$) and negatively correlated ($r=-0.3499$) with infiltration. This indicated greater rates of infiltration within the playa basin than in the outerbasin soil. Infiltration was significantly ($P=0.0053$) and positively correlated ($r=0.3090$) with surface horizon clay content. This high infiltration for the playa basin soil was due to the cracking nature (macropores) of the clay profile which were less evident in the annulus and not present in the outerbasin soil. Ninety

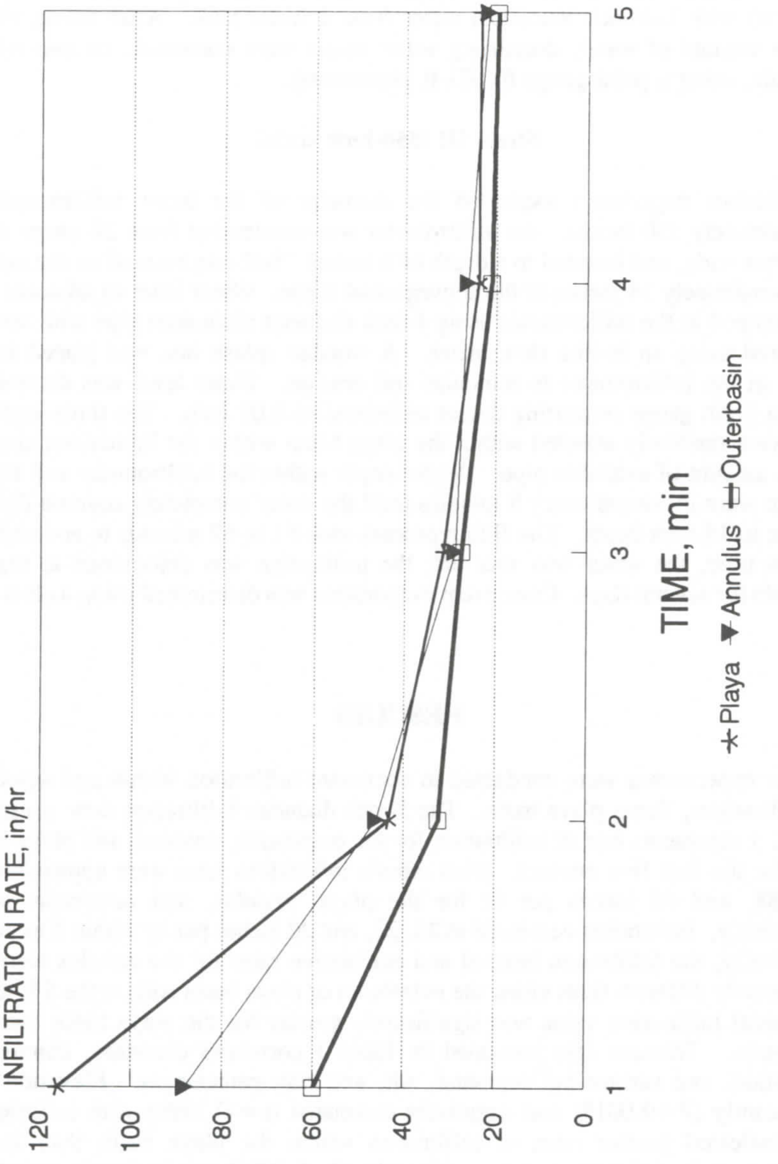

Fig. 1. Infiltration rate with time for 5-inch diameter cylinder infiltrometers.

Table 1. Correlation coefficient matrix and (probabilities) of selected soil and topographic parameters for 5-inch diameter cylinder infiltrometers along a transect.

Parameter	Cumulative Infiltration	Sand	Silt	Clay
Elevation	-0.3499 (0.0015)	0.8963 (0.0001)	0.3964 (0.0003)	-0.9013 (0.0001)
Cumulative Infiltration		-0.2893 (0.0093)	-0.1788 (0.1125)	0.3090 (0.0053)
Sand			0.2549 (0.0225)	-0.9390 (0.0001)
Silt				-0.5718 (0.0001)

additional double ring infiltrometers were placed within the playa basin. Infiltration rates for the first minute were 182 inches per hr for these infiltrometers. This playa basin infiltration rate was approximately 50% higher than reported for the cylinder infiltrometers (116 inches per hr). Since no efforts were taken to avoid large cracks,and these differences were caused by large cracks (>.5 inch) under 13 of the 90 rings.

Playa basin infiltration and soil parameter correlation coefficient matrixes are presented in Table 2 for both the cylinder and double ring methods. Elevation was correlated at (P=0.0813) with sand, silt (P=0.0067), and clay (P=0.0029) in the cylinder infiltrometers but not for the double ring infiltrometers (P=0.1695, 0.2298, or 0.9403), respectively.

Differences in significance are probably due to the distribution pattern of the infiltrometers. The cylinder infiltrometers were aligned on an east-west transect which emphasized elevation effects. The double ring infiltrometers were arranged in a grid pattern with less absolute elevational differences and varied not only east-west but also north-south in direction. Correlation values were anticipated to be less because of less elevational changes and variation was in two directions rather than one.

Infiltration rates were evaluated on larger 80-inch and 350-inch diameter scales. Three 80-inch diameter basin infiltrometers were evaluated in the outerbasin, annulus, and playa soils. The infiltration rates with time were presented in Fig. 2. Playa basin infiltration rates for the first-minute averaged 10.6 inches per hr compared to 5.5 and 3.2 inches per hr for the annulus and outerbasin soils, respectively. By 130 minutes, the rates had decreased to 2, 1, and 1 inch per hr for the playa basin, annulus, and outerbasin soils, respectively. These first minute infiltration rates are lower than those presented in Fig. 1. These differences were explained by the unmeasured, rapid infiltration period which occurred during infilling. For the 350-inch diameter infiltrometers, the infiltration rate during

Table 2. Correlation coefficient matrix and (probabilities) of selected soil and topographic parameters for 5-inch diameter infiltrometers within the playa basin.

Parameter	Sand	Silt	Clay	Infiltration
		Double Ring Infiltrometer		
Elevation	-0.1582 (0.1695)	0.1385 (0.2298)	-0.0087 (0.9403)	0.1027 (0.3741)
Sand		-0.4844 (0.0001)	-0.3439 (0.0022)	-0.1015 (0.3799)
Silt			-0.0504 (0.0001)	-0.0023 (0.9841)
Clay				0.0868 (0.4527)
		Cylinder Infiltrometer		
Elevation	0.3234 (0.0813)	0.4840 (0.0067)	-0.5255 (0.0029)	0.2371 (0.2071)
Sand		-0.0332 (0.8619)	-0.8698 (0.0001)	0.4922 (0.0057)
Silt			-0.4643 (0.0097)	0.2581 (0.1685)
Clay				-0.56349 (0.0012)

drainage was initially 2.1 inches per hr (Fig. 3). This rate decreased to 0.37 inch per hr within one day and was approximately 0.16 inch per hour after three days.

CONCLUSIONS

Four independent infiltration experiments were conducted adjoining to or within a playa basin. One commonality in these four experiments was the 1-minute infiltration rate within the playa basin. These values ranged from 2.1 inches per hr to 182 inches per hr. Those experiments with long infilling times such as the 350-inch diameter (1 hr infilling) and 80-inch diameter (1 hr plus infilling) infiltrometers had the lowest (2.1 and 10.6 inches per hr) first minute infiltration rates,

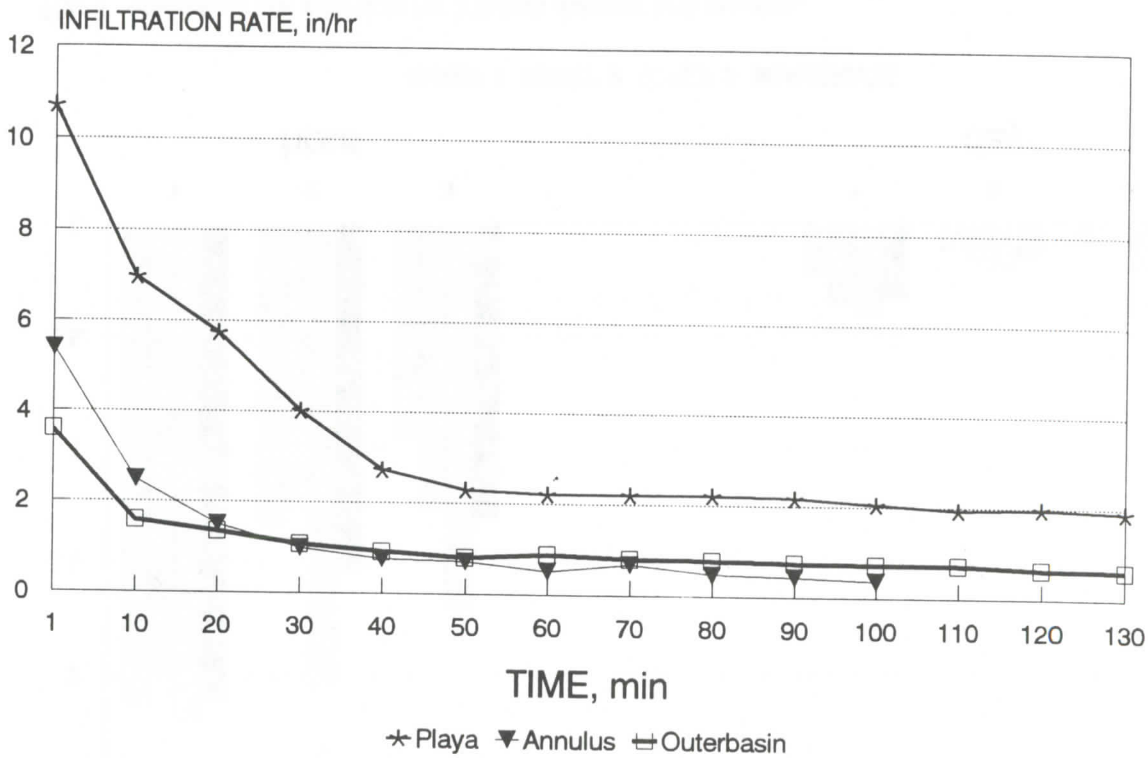

Fig. 2. Infiltration rate with time for 80-inch diameter basin infiltrometers.

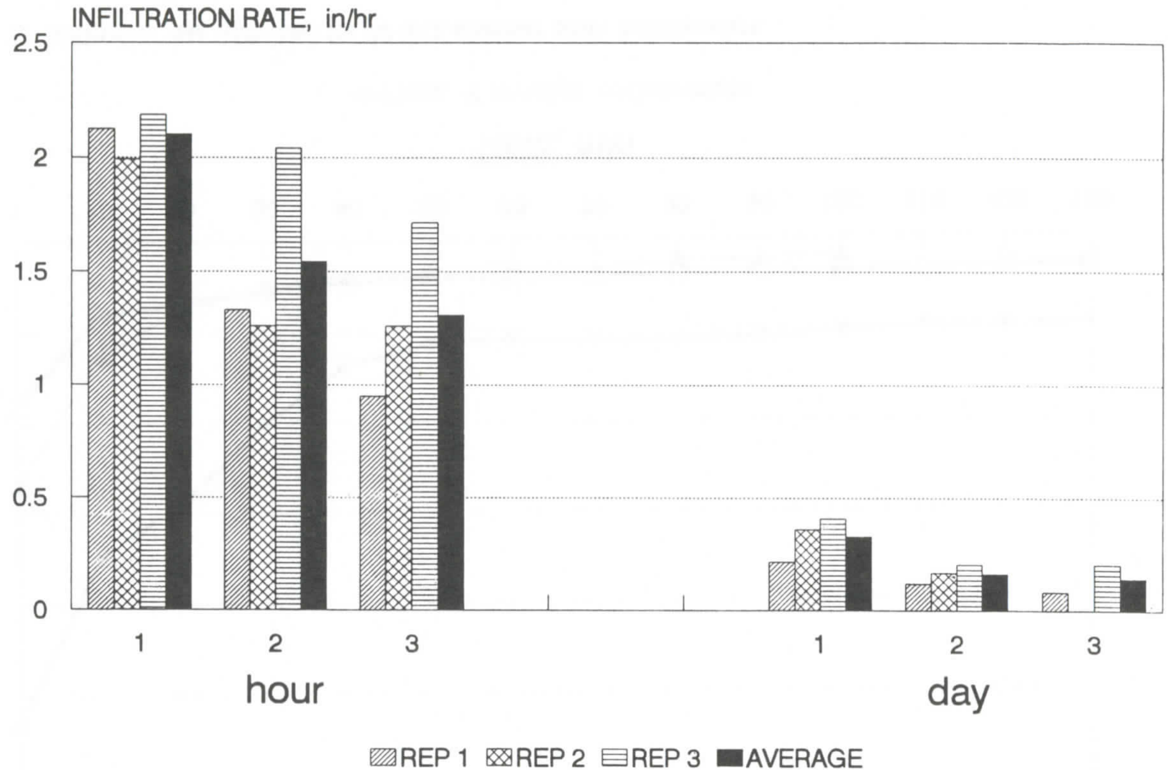

Fig. 3. Infiltration rate with time for 350-inch diameter infiltrometers.

respectively. Those infiltrometers with short infilling times of approximately 10 sec, double ring and cylinder infiltrometers, had the highest infiltration rates of 182 and 116 inches per hr, respectively. These differences were explained by infiltrometer and the unmeasured infiltration occurring during infilling.

In the cylinder and 80-inch diameter infiltration experiments, the high clay content playa basin had the greatest infiltration rate. The annulus had an intermediate initial infiltration rate with the lowest infiltration rate in the outerbasin soils. For both experiments, the playa basin had a significantly greater infiltration rate than the outerbasin soil. Annulus infiltration rate was not significantly different for either the playa or outerbasin soil in either study. Having the highest initial water entry into the soil occurring within the playa basin lends credence to the focused recharge through playas mentioned by Mullican et al. (1994).

The significance of this study is that large amounts of water can be transported through macropores in playa basin soils. This rapid flow presents environmental concerns as it provides the potential of movement from the soil surface to underlying groundwater for agricultural chemicals (Thomas and Phillips, 1979) (Graham et al., 1992). Therefore, the uses of playa basins should be evaluated in light of their contribution to the potential recharge of the Ogallala aquifer.

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