SIZE, DISTRIBUTION AND ORIENTATION PATTERN OF PLAYA LAKES IN NORTHWESTERN CASTRO COUNTY, TEXAS

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ABSTRACT

Playa basins and their associated ephemeral lakes are the most significant expression of surface hydrology on the Southern High Plains of Texas. A better understanding of the spatial characteristics of these lakes is critical for land use management planning. In Northwest Castro County, Texas playa lakes display a bidirectional linear orientation. Playa lake size was not a function of the east-west and north-south orientation. The bidirectional orientation pattern indicates a potential hazard for large area contamination from waste storage or disposal activities in the playa lake complex.

Key Words: Playa lakes, spatial characteristics

INTRODUCTION

Playa basins of the Southern High Plains are the most significant topographic expression on this otherwise featureless eolian plateau of Texas. These "pancake" shaped basins are typically 125 to 2000 acres in size and exhibit a maximum relief of 20 to 30 ft. Each drainage basin supports an ephemeral lake (playa lake) which is typically shallow and may vary in surface area from a fraction of an acre to more than 200 acres. The playa lakes are underlain by heavy textured soils. Within the Southern High Plains, the frequency of large playa lakes increases from south to north (Grubb and Parks, 1968) and the average size of the playa lakes increases from southwest to northeast (Allen, et al., 1972). This combination accounts for a larger per unit surface area in the northeast portion of the Southern High Plains. Estimates of the number of playa lakes on the Texas High Plains vary from 17,000 (Lehman, 1972) to 19,000 (Schwiesow, 1965) with totals ranging from 30,000 (Wood and Osterkamp, 1984) to 37,000 (Reddell, 1965) on the entire Southern High Plains region.

The origin of playa lakes has not been adequately explained. Reeves (1966) reviewed five theories on the origin of these lake basins and concluded that most were probably eolian in origin. Supporting this theory is the work of Price (1972), who characterized the playa lakes of the Llano Estacado in eolian developmental terms as mature, oval, and oriented. The term "mature" refers to playa lakes that are neither expanding nor being filled by sedimentation. "Oval" refers to the shape of playa lakes and their average axis ratio of 1.0:1.3 (Price, 1972). The longer axis is normally oriented from NW to SE. Recently, Osterkamp and Wood (1987) proposed that playa lakes in the Southern High plains originate wherever water collects in a "surficial depression." They present evidence for this mode of occurrence from hydrologic, geomorphic, and geological perspectives. In a subsequent publication, Wood and Osterkamp (1987) used mass balance arguments to document their theory of playa lake origin. Finley and Gustavson (1981) described lineament orientation of playa lakes and report a preferred orientation of 300 to 320 degrees (360 degrees = N). They attribute this geomorphic orientation to control exerted by geologic structure. The geologic joints provide paths of weakness which may encourage increased surface drainage. This increased surface drainage model agrees with the theory and models of Osterkamp and Wood (1987) and Wood and Osterkamp (1987). Osterkamp and Wood (1987) present diagrams with playa lake orientations of 75 degrees west [comparable to 285 degrees of Finley and Gustavson], 45 degrees, and 40 degrees west [comparable to 315 and 320 degrees of Finley and Gustavson].

RATIONALE

Playa lakes represent the hydrologic storage basin for most surface runoff in the region. Aronovici, et al., (1971) report that playa lakes impound 2 to 3 million acre-feet of water annually. Until recently, it was believed that playa lakes held surface water until it evaporated. Reddell (1965) reported that 90% of the accumulated water was lost to evaporation. Based on this assumption, playa lakes have been used as impoundment reservoirs for feedlot runoff (Lehman, 1972). However, the current thinking is that playa lakes and the area immediately surrounding them are major recharge zones for the Ogallala aquifer (Zartman, 1987; Wood and Osterkamp, 1984). This interpretation of the fate of playa lake water is significant because it not only may provide a way to add to the life of the Ogallala aquifer; but, may also contribute to its contamination. Estimates of the volume of water accumulated annualy in playa lakes in the Texas and New Mexico portion of Southern High Plains range from 1.8 to 5.7 million-acre feet (Clyma and Lotspeich,1966). This is equivalent to 4 to 11.5 inches of recharge over the irrigated portion of the Texas High Plains. Recharge of the Ogallala through the playa lake model may necessitate alteration of some current utilization methods (feedlot waste impoundment) and influence other development decisions (DOE, 1986). Since playas contribute to the recharge of the aquifer, what enters the playa influences the groundwater.

This project was initiated to evaluate the spatial relationships of playa lakes in northwestern Castro County, Texas. The specific interest in this study was generated by the possible development of a high-level nuclear waste repository site. Potential concerns were for the quantity, quality and direction of excavated salt movement during site development and radioactive nuclide movement following site activation. Average size of playa lake, distribution, and orientation of closest playa were evaluated. In order to obtain a better understanding of the spatial relationships and the potential utilization of playa lakes, this study proposes to determine the possibility for contamination of the aquifer from feedlot wastes or pesticides. A single axis, linear orientation would indicate the predominate surface drainage direction. Secondary orientations may reflect the impacts of subsurface geological connections.

MATERIALS AND METHODS

The study area encompasses 279 square miles primarily covering northwestern Castro County, Texas. For purposes of this study, playa lakes were defined in terms of the fine textured soils (Randall clay) which typically occupy the lowest elevational positon in a playa basin and upon which these ephemeral water bodies develop following a precipitation event. The criteria for designation was the location and area of soil mapped as a Randall clay (fine, montmorillonitic, thermic Udic Pellustert) in the Soil Conservation Service county Soil Survey Reports for Castro, Deaf Smith and Parmer counties (Burns, 1974; Geiger, et al., 1968; Burns, 1978).

Playa lake location was expressed in Universal Transverse Mercator (UTM) grid coordinates to the nearest 164 feet for the "center of mass" of each Randall clay mapping unit shown on 1:20,000 scale photomaps. Designated playa lakes were classified into one of five

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size classes based on the area of the Randall clay mapping unit. The classes were: #1 = less than 8 acres; #2 = 8 to 31 acres; #3 = 31 to 70 acres; #4 = 70 to 124 acres; #5 = greater than 124 acres. Location distribution by size class was examined through analysis of average size class within subsections of the study area. The area was divided into three north-south zones and three east-west zones. Each subsection encompassed approximately 31 square miles.

The distribution and orientation relationships of the designated playa lakes were evaluated using Fisher and geostatistical models. Geostatistical models used were similar to those presented by Vieira, et al. (1983:51-54). Spatial orientations of the playa lakes were modeled using linear, power, logarithmic and exponential equations. The spatial orientations were analyzed in five degree increments with tolerances of one degree from 270 degrees (west) through zero-degrees (north) to 90 degrees (east).

RESULTS AND DISCUSSIONS

Table 1 indicates the overall size class frequency distribution of the 188 playa lakes encountered on the study area. The spatial orientations of the playa lakes were best fit by non-linear models rather than linear ones, $r^2 = 0.9$ vs 0.8. However, most previous research has considered determination of the lineament (topographic features) rather than "best fit" of the data. The angle of orientation and linear equations modeling the playa lakes spatial orientation are presented in Table 2. Those angles with high r^2 values ($r^2 > 0.8$) are 270, 275, 350, 0, and 25. These indicate that the playa lakes are oriented; predominatly on an east-west (270, 275) and/or north-south direction (350, 0). The other direction having a high r^2 was 25 degrees, which would be a north-northeast to south-southwest orientation. These data are in apparent disagreement with the published information of Finley and Gustavson (1981). However, a closer examination of Plate 1 of their article, indicated that within the particular area of our study there are lineament orientations similar to those found using our geostatistical techniques and the area differs from the remainder of the Texas Panhandle as a whole.

Table 1. Playa lake size class distribution

Size Class	Number of Lakes	Percent
#1 = less than 8 acres	26	13.8
#2 = 8 to 31 acres	95	50.5
#3 = 31 to 70 acres	61	32.5
#4 = 70 to 124 acres	5	2.7
#5 = greater than 124 acres	1	0.5
Total	188	100.0

Linear equations such as those presented in Table 2 do not lend themselves to determination of lineament length. However, the length to the maximum number of pairs for each equation would be a realistic indication of the maximum length to which the equation could be extrapolated. For all of the preferred angles of orientation listed above, the lineament length was 15,000 to 20,000 yards. This indicates that the equation would be useful for predicting frequency of playa lakes for approximately an 8 to 11 mile distance in that direction. The values are similar to those presented by Finely and Gustavson (1981).

Table 2. Playa lake angle of orientation, linear model for orientation with r^2, maximum number of pairs, and lag distance for maximum number of playa pairs.

Angle, deg	Linear Equation	r^2	Maximum # of pairs	Lag Distance x 103 yd
270	$0.339+0.940X10^{-5}h$	0.89	59	15
275	$0.196+0.222X10^{-4}h$	0.91	69	20
280	$0.450-0.600X10^{-7}h$	0.14	60	20
285	$0.556+0.457X10^{-5}h$	0.16	65	20
290	$0.945+0.455X10^{-4}h$	0.66	60	20
295	$0.251+0.175X10^{-4}h$	0.65	57	22.5
300	$0.352+0.164X10^{-4}h$	0.61	55	20
305	$0.365+0.120X10^{-4}h$	0.60	47	20
310	$0.850-0.158X10^{-4}h$	0.16	53	20
315	$0.378+0.133X10^{-4}h$	0.49	69	15
320	$0.285+0.171X10^{-4}h$	0.67	41	20
325	$0.752-0.846X10^{-6}h$	0.10	54	15
330	$0.333+0.359X10^{-4}h$	0.57	45	20
335	$-0.900+0.681X10^{-4}h$	0.65	46	15
340	$0.203+0.374X10^{-4}h$	0.45	43	15
345	$0.468+0.165X10^{-4}h$	0.19	45	15
350	$0.287+0.264X10^{-4}h$	0.97	51	15
355	$0.449+0.134X10^{-4}h$	0.13	41	20
360/0	$0.145+0.332X10^{-4}h$	0.81	51	20
5	$0.822-0.151X10^{-4}h$	0.37	43	15
10	$0.195+0.269X10^{-4}h$	0.66	53	15
15	$0.518+0.205X10^{-5}h$	0.04	56	15
20	$0.596-0.847X10^{-5}h$	0.15	51	15
25	$0.308+0.276X10^{-4}h$	0.81	41	12
30	$0.263+0.158X10^{-4}h$	0.47	45	15
35	$0.940-0.299X10^{-4}h$	0.78	47	15
40	$0.442+0.172X10^{-5}h$	0.01	59	20
45	$0.519-0.113X10^{-5}h$	0.00	51	20
50	$0.467-0.519X10^{-5}h$	0.13	45	20
55	$0.602-0.651X10^{-5}h$	0.20	69	20
60	$0.411+0.479X10^{-5}h$	0.53	58	20
65	$0.420+0.301X10^{-5}h$	0.06	43	15
70	$0.462+0.119X10^{-4}h$	0.19	61	20
75	$0.627-0.237X10^{-5}h$	0.03	67	15
80	$0.267+0.118X10^{-4}h$	0.29	54	25
85	$0.462+0.214X10^{-5}h$	0.02	67	25
90	$0.339+0.940X10^{-5}h$	0.89	59	15

Playa lake size as a function of the east-west and north- south orientation is presented in Table 3. The playa lake sizes were not consistently significantly different with respect to direction. However, the only class 5 playa lake (>124A) occurred in the most northeastern section of the area. This would be as expected from the data of Grubb and Parks (1968) and Allen, et al. (1972).

Table 3. Playa lake size class distribution as a function of location.

Mean size class with standard error

	West	Central	East
North	2.00+/-0.11 (n=19) Ba*	2.04+/-0.12 (n=25) Ba	2.20+/-0.19 (n=20) Aa
Central	2.21+/-0.14 (n=29) Ba	2.27+/-0.16 (n=22) ABa	2.25+/-0.19 (n=20) Aa
South	2.71+/-0.19 (n=14) Aa	2.50+/-0.17 (n=22) Aa	2.29+/-0.17 (n=17) Aa

*Means with the same capital letter within a column are not significantly different at the 5% level using Duncan's Multiple Range Test. Means with the same lower case letter within a row are not significantly different at the 5% level using Duncan's Multiple Range Test.

CONCLUSION

The playa lakes of northwest Castro County, Texas are generally atypically oriented compared to other areas of the Southern High Plains. They have an average size of approximately 27 acres. The primary orientations of these playa lakes are east-west (275 degrees) and north-south (350 degrees). This criss-crossing orientation (275 and 350 degrees) pattern signifies a potential for contamination of the whole area if surface contaminants were to enter the playa lake complex. Land use planners and managers should be encouraged to exercise extreme caution concerning future decisions involving waste storage or disposal activities in this part of the Southern High Plains.

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