UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

Runoff from a paved small watershed at White Sands Missile Range, New Mexico

By

W. C. Ballance and J. A. Basler

67-9

Open-file report

Prepared by the U.S. Geological Survey in cooperation with the U.S. Army, White Sands Missile Range, N. Mex., and the Esso Research and Engineering Co.

July 1966

Contents

Illustrations

Tables

Runoff from a paved small watershed at White Sands Missile Range, New Mexico

By

W. C. Ballance and J. A. Basler

Introduction

During the spring of 1964 a small watershed paving project was begun in the re-entrant near the Headquarters area of the White Sands Missile Range by the U.S.Geological Survey in cooperation with the U. S. Army at White Sands Missile Range and the Esso Research and Engineering Company. The re-entrant is bordered on the south and west by the Organ Mountains, on the north by the San Augustin Mountains and merges with the Tularosa Basin on the east (fig. 1). The project area is about 25 miles east of Las Cruces and about 40 miles north of El Paso, Texas.

The purpose of the watershed paving project is to determine the increase in surface-water runoff in an arid area caused by paving a small watershed. The results are to be used to determine the possibility of increasing the supply of potable water to the Headquarters of White Sands Missile Range.

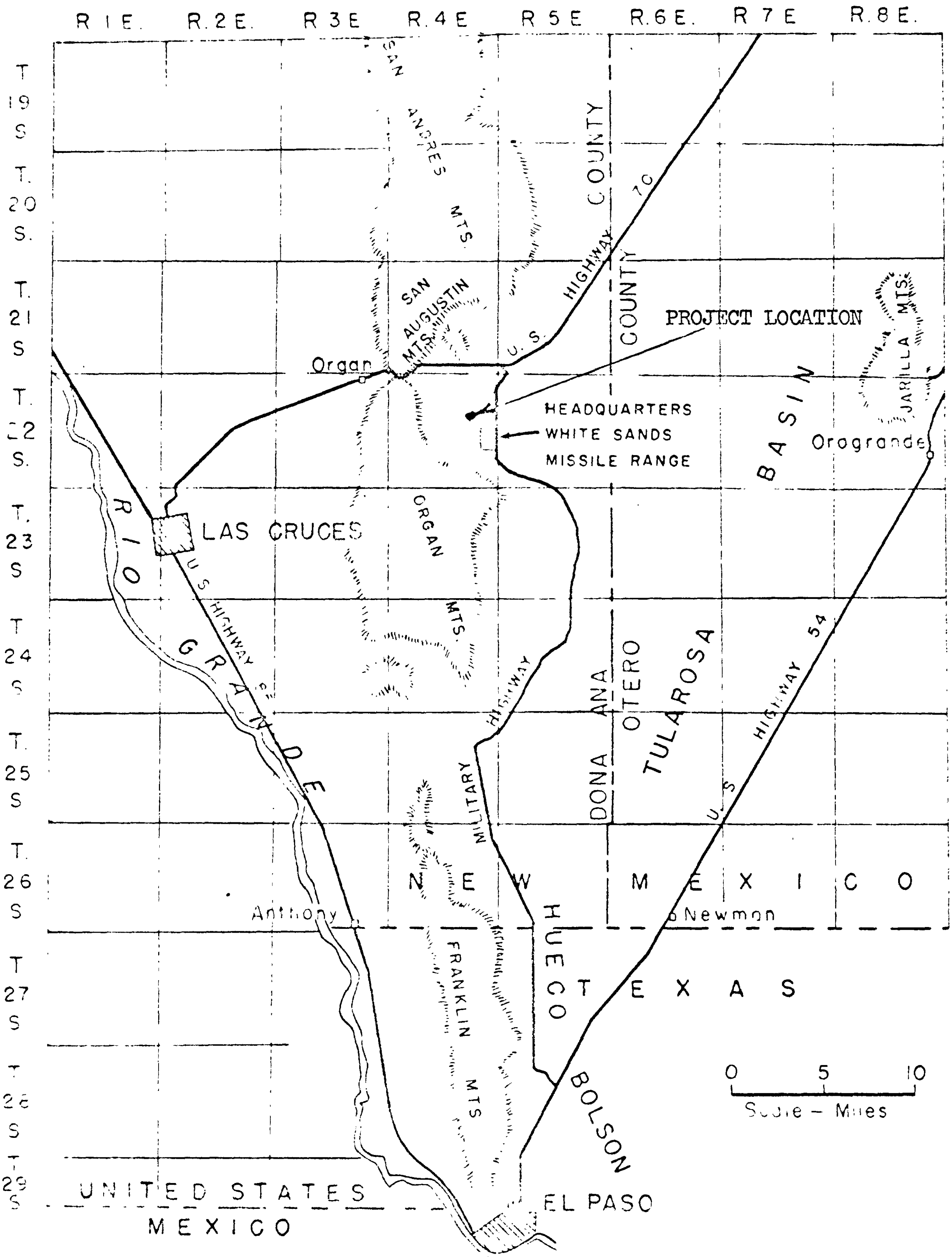

Figure 1.--South-central New Mexico with area of the Watershed Paving Project indicated.

Method of investigation

Two small adjacent watersheds of about 9 acres each were selected just northwest of the Headquarters area. One watershed was cleared of native shrub and covered 1/8-inch with an asphaltic material; the other watershed was not disturbed. Plate 1 is an areal view showing the paved area of the watershed project. A recording rain gage was installed in each of the areas to record the precipitation and a V-notch weir (plate 2) was installed in each area to measure the runoff. Recording gages were installed to monitor height of water and duration of flow at each of the weirs. Infiltration pits were constructed downstream from each of the weirs to collect the runoff and a recording gage was placed in each pit to record the gage height and infiltration rate.

Instrumentation of the two areas provided a means of determining the collection efficiency and the amount of water collected which can be attributed to the use of the asphalt coating.

Plate 1.--Areal view showing the paved area of the watershed project.

Plate 2.--V-notch weir and recorder shelter containing recording equipment.

Climate

The White Sands Missile Range area has an arid to semi-arid climate typical of the southwestern United States. Climatological data have been recorded by the Air Weather Service at White Sands Missile Range since 1947. The elevation of the Air Weather Station is 4,238 feet above sea level. Precipitation as snow or hail rarely occurs in the project area and if it does it is considered as equivalent rainfall. The average annual rainfall at this station and the project area is about 10 inches. The rainfall probably ranges from 18 to 20 inches on the Organ Mountains to the west of the project area where the land surface rises to more than 7,000 feet above sea level. A large part of the rainfall in the area occurs in heavy showers of local extent, generally in July, August and September. The relative humidity generally is less than 40 percent. During the summer months the temperature often rises above 100° F. There is no weather station reporting evaporation rates in the vicinity. However, records from Elephant Butte Dam on the Rio Grande to the northwest, El Paso to the south and Las Cruces across the Organ Mountains indicate the potential evaporation as represented by a class A evaporation pan may be as much as 100 inches of water per year.

Analysis of data

The data collected from May 1964 to May 1966 are analyzed in this report. Part of the record was lost due to malfunctioning of the instruments; however, sufficient data were collected to make some determinations on collection efficiencies attributed to coating the watershed with asphalt.

The data collected on the unpaved watershed indicated a collection efficiency of less than 3 percent. There were flows through the weir on the unpaved area only when the duration of the shower was long and the mean intensity of the shower was very high.

The data collected on the paved area is divided into two parts (table 1 and table 2). The first table gives the data when the rainfall was 0.10 inch and above. The second table gives the data when the rainfall was less than 0.10 inch.

The data from the paved area indicate that a larger percent of runoff will occur for a definite amount of precipitation if the duration of the shower is short rather than for a long period of time. That is, the efficiency at which an artificial watershed will harvest the rainfall of a particular shower depends not only on the amount of rainfall, but also on the average intensity of the shower.

Table 1.--Data on the watershed paving project at White Sands Missile Range, N. Mex. (rainfall 0.10 inch and above)

Date	Inches (rain-fall)	Duration in minutes	Volume on paved area (cu ft)	Flow through weir (cu ft)	Average intensity (inches per hour)	Collection efficiency (percent)
5-26-64	0.40	50	13,200	8,060	0.48	61
9-12-64	1.00	292	33,000	25,520	.20	77
12- 2-64	.40	150	13,200	8,220	.16	62
12- 4-64	.12	40	3,960	1,910	.18	48
1- 7-65	.46	285	15,180	8,984	.10	59
1-20-65	.20	315	6,600	3,650	.04	55
2- 6-65	.44	485	14,520	9,960	.06	68
6- 9-65	.10	150	3,300	1,060	.04	32
6-10-65	.14	100	4,620	2,355	.08	51
6-10-65	.10	15	3,300	1,230	.40	37
6-23-65	.22	6	7,260	5,810	2.20	80
8-14-65	.10	15	3,300	2,095	.40	63
8-22-65	.72	35	23,760	18,420	1.05	77
8-27-65	.22	6	7,260	4,532	2.20	62
8-27-65	.18	15	5,960	4,069	.72	68
9- 6-65	.48	45	15,840	12,105	.64	76
12- 9-65	.36	225	11,880	6,325	.10	53
12-11-65	.22	225	7,260	4,340	.06	60
1- 2-66	.10	85	3,300	1,488	.07	45
2- 8-66	.46	142	15,180	8,315	.19	55

Table 2.-- Data on the watershed paving project at White Sands Missile Range, N. Mex. (rainfall less than 0.10 inc)

Date	Inches (rain-fall)	Duration in minutes	Volume on paved area (cu ft)	Flow through weir (cu ft)	Average intensity (inches per hour)	Collection efficiency (percent)
9-12-64	0.06	40	1,980	720	0.09	36
9-13-64	.06	45	1,980	625	.08	32
9-24-64	.08	10	2,640	815	.48	31
10-25-64	.02	10	660	143	.12	22
1- 7-65	.02	15	660	170	.08	26
1- 8-65	.02	15	660	145	.08	22
2- 7-65	.06	38	1,980	1,470	.10	74
2- 7-65	.04	36	1,320	225	.07	17
2- 7-65	.06	105	1,980	660	.03	33
4-26-65	.04	9	1,320	390	.27	30
5-31-65	.08	20	2,640	1,125	.24	43
7-23-65	.06	5	1,980	1,055	.75	53
8- 1-65	.06	30	1,980	625	.12	32
8-14-65	.08	20	2,640	1,055	.24	40
8-28-65	.02	25	660	30	.05	4.5
9- 6-65	.08	5	2,640	1,070	.96	40

The amount of rainfall that is retained on the pavement as a film held by surface tension after each shower is constant. The retention constitutes a relatively large fraction of a small quantity of water if the shower is small. Therefore, a small shower on an already wet surface as a result of a previous shower will gain considerable in collection efficiency. Conversely, the influence of rainfall intensity on collection efficiency might be expected to predominate in the case of heavy showers, for which water holdup on the coating would be relatively unimportant. Generally, collection efficiency should be a function of both duration of rainfall and average intensity.

Other variables which have an important bearing on collection efficiency are air temperature, pavement temperature, and wind movement.

Comparisons of runoff in the lower ranges of rainfall, .09 inch precipitation or less, show an initial surface evaporation and surface retention loss. Therefore, the collection efficiencies of rainfalls having .09 inch precipitation or less rarely exceeds 40 percent and often results in only minute amounts of runoff. Examples are: August 28, 1965, when a rainfall of 665 cu ft resulted in a collection of only 30 cu ft, and February 7, 1965, when a rainfall of 1,320 cu ft resulted in a collection of 225 cu ft.

In the higher ranges of rainfall, the amount of precipitation overcomes the initial evaporation and surface retention loss and collection efficiencies exceed 75 percent under optimum conditions.

Cost of water collected from an asphalt-coated watershed

The cost to prepare a project for water harvesting and the cost per thousand gallons of water delivered depends on the terrain, storage facilities, and the magnitude and duration of precipitation on the area. The preparation of the area prior to the application of the asphalt normally will be a significant part of the cost. However, once the area is prepared, the life of the project could be extended indefinitely by recoating the area when needed.

The cost of preparing the land and applying the asphalt for this project follows:

Leveling (bulldozer to clear the brush and level the area)	$ 650.00
Asphalt (17,600 gallons at 11½ cents per gallon)	2,000.00
Application of asphalt	2,050.00
Total cost	$4,700.00

This resulted in an initial cost of $516.40 per acre.

The cost of instrumenting the project is not included.

To maintain the project it would be necessary to recoat the area with a thin coat of asphalt each 5 years and patch the eroded areas each 2½ years.

In order to arrive at the cost of the water collected from the project over a ten-year period, Esso Research and Engineering Company supplied the initial and repair cost summarized below.

Initial cost	$4,700.00
Maintenance after 2½ years	
Asphalt	200.00
Application of asphalt	160.00
5 percent rise in cost	18.00
Maintenance after 5 years	
Asphalt	950.00
Application of asphalt	1,350.00
Maintenance after 7½ years	
Asphalt	200.00
Application of asphalt	160.00
10 percent rise in cost	36.00
Total cost for first 10 years	$7,774.00

During the period from May 1964 through February 1966 about 36 cycles of precipitation and runoff were recorded. The total precipitation amounted to 7.26 inches or 239,600 cu ft of water on the coated area. 148,771 cu ft of water was measured through the weir. This amounted to a collection efficiency of 62 percent, and the average shower amounted to 0.20 inch.

The average annual precipitation in the project area (table 3) is 10 inches. Then with a collection efficiency of 62 percent, the project area would collect 6.2 inches of precipitation each year or 4.7 acre-feet (9.10 acres $x \frac{6.2}{12} = \frac{56.42}{12} = 4.7$ acre-feet).

About 47 acre-feet or 15,315,000 gallons of water will have been collected over a 10-year period.

The cost of the project for the first ten years of the project, summarized on page 17, is $7,774.00.

The cost per 1,000 gallons would be $7,774.00 divided by 15,315 or about 50 3/4 cents.

Table 3 .--Precipitation in inches by months at the Air Weather station, White Sands Missile Range, 1947-1964

Month	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964
Jan.		1.19	1.98	0.06	0.14	0.40	0.00	0.08	0.91	0.15	0.40	1.26	0.14	1.50	0.69	1.19	0.13	0.21
Feb.		1.06	.57	.28	.36	1.21	1.28	T	.03	.22	1.44E	.89	.85	.54	T	.43	.62	.20
Mar.		.46	.00	T	.28	1.34	.09	.31	.61	.00	.57	3.00	.12	.39	.72	.60	T	1.40
April		.00	.16	T	.80	1.37	.48	T	T	T	.02	.28	T	T	T	.39	.17	.06
May		.31	.78	.25	.10	.49	.17	.27	.04	.00	.61	.40E	.95	.21	.00	T	T	.23
June		1.51	.05	.11	T	.65	.60E	.15	.14	.63	T	1.21	.67	.81	1.79	.07	.05	T
July		.22	1.68	3.46	.04	1.42	1.35	1.21	3.55	.70E	1.65E	1.85	1.22	3.46	3.20	5.63	1.14	.69
Aug.	0.83	2.79	.09	.01	2.68	1.48	.24	1.28	.80	1.75E	3.20E	2.13	6.32	1.40	.97	.24	2.45	1.83
Sept.	.00	.41	3.85	1.20	.04	.26	.14	1.18	.14	.00	.32	5.76	T	.03	1.47	2.70	2.05	3.44
Oct.	.04	.36	2.05	1.04	.67	.00	.70	1.38	2.99	.40E	2.92	2.84	.64	1.46	.04	1.11	.44	.03
Nov.	1.35	.00	.00	.00	.19	.32	.02	.00	.05	T	.18	.40	.05	.01	2.40	.51	.59	.03
Dec.	1.77	1.56	.35	T	1.78	.38	.23	.05	.00	.64	T	T	.49	1.44	1.34	1.20	T	1.10
Total		9.87	12.06	6.41	7.08	9.32	5.30E	5.91	9.26	4.49E	11.31E	20.02E	11.45	11.25	12.62	14.07	7.63	9.22

E = Estimated

T = Trace

Discussion

The paving project has been installed about $2\frac{1}{2}$ years. Some of the pavement is in need of repair. Sand from the eroded areas fills the stilling basin and adversely affects the weir stage recorder, resulting in an error by recording less flow than actually occurred. Vegetation has penetrated the thin asphalt coating and cracks appear over a large part of the area. The yearly deterioration of the asphalt coating as it relates to collection efficiency has not been determined. However, a similar experimental project was conducted in Hawaii and the yearly deterioration of the asphalt and accompanying decrease in surface water run-off was noted.

In a 3-year (1959-61) test of an asphalt-lined catchment area near Holualoa, Hawaii, Chinn (1965) states that the rainfall on the catchment averaged 79.2 inches a year and the efficiency (ratio of runoff to rainfall) of the asphalt-lined catchment, under minimum maintenance conditions, decreased rapidly with time. It decreased from 93 percent in 1959 to 82 percent in 1960 and to 78 percent in 1961. The average for the 3-year period was 84 percent. The decrease in efficiency was due to (1) seepage loss through the cracks in the asphaltic membrane which formed as the membrane deteriorated with age, (2) interception of light rains by the vegetation which penetrated the membrane, and (3) interception by depressions in the catchment surface that lost water between storms.

The results of the paving project thus far indicate that water harvesting by paving large areas may be more economical in some areas than other means of obtainining additional potable water supplies.

About 3 miles west of the present project area the annual precipitation is about 15 inches. An area of 5.5 square miles treated with an impervious material and receiving 15 inches of annual rainfall would collect 2,774 acre-feet of water each year. This amount of water would meet the present water requirements at White Sands Missile Range. This water conceivably could be diverted to flow into the cone of depression in the well fields which provide a natural underground storage reservior. The result would be a rise of the water surface in the depressed area of the well field, a reduction in the cost of pumping water due to a decrease in lift, diminish the possibility of saline water encroachment and establish a more permanent ground-water supply.

Reference cited

Chinn, Salwyn S. W., 1965, Water Supply Potential from an Asphalt-lined Catchment near Holualoa Kona, Hawaii: U.S. Geol. Survey Water-Supply Paper 1809-P, p. 25, 16 figs., 3 tables.