DEPARTMENT OF AGRICULTURE

SURVEY REPORT

FLOOD CONTROL

QUEEN CREEK WATERSHED
Arizona

Part II, Appendix

SURVEY REPORT

RUN-OFF AND WATER-FLOW RETARDATION AND SOIL-EROSION PREVENTION FOR FLOOD-CONTROL PURPOSES

QUEEN CREEK WATERSHED
Arizona

PART II

APPENDIX

CONTENTS

PART II, APPENDIX

SUPPLEMENTARY INFORMATION

Page

MAPS

In Part I

Following page

In Part II

SUPPLEMENTARY INFORMATION

PHYSICAL FEATURES, QUEEN CREEK BASIN

127. Queen Creek watershed embraces about 563,500 acres (880 sq. miles). It extends, roughly, from Chandler, Maricopa County, to Superior, Pinal County, being practically 50 miles long and 25 miles wide. Ordinarily, the flood flows of Queen Creek and other drainages do not reach the Salt and Gila Rivers.

Physiography

128. This watershed consists largely of a nearly level alluvial plain, which is an eastern extension of the irrigated Salt River Valley and which slopes gradually upward for about 34 miles toward the east from an elevation of 1,160 feet to about 2,300 feet. To the southeast it is separated from Gila River Valley by a very low divide. Fringing this plain on the northeast and east are Goldfield, Superstition, and rugged Pinal Mountains, with a rather narrow intervening foothill zone below the Pinal Mountains, which consist of fans or outcrops of schist and intrusions covered with colluvial materials. These mountains rise abruptly to elevations of 4,500 and 5,000 feet. Santan Mountain—a low mountain mass—forms a part of the watershed's southwestern boundary. The rugged relief in the eastern part of this watershed is characterized by deep canyons and steep stream gradients which produce profound effects on both stream flow and drainage channels.

Natural Drainage

129. The principal drainage is Queen Creek. The component drainages are shown on map 1. Facts regarding these are given in table 4.

Table 4.—Component Subdrainages of Queen Creek Watershed, and Stream Gradients

Subdrainage	Length	Width	Area	Length and fall of main channel		
				Channel length	Total fall	Average fall per mile
	Miles	Miles	Sq.Miles	Miles	Feet	Feet
A Upper Queen Creek (above Black Point)	19	11	182	21	2,660	126.5
B Lower Queen Creek (below Black Point)	25	2	39	27	620	23.0
C Sand Tanks Wash	23	9	160	30	1,780	59.5
D Buchanan Wash	15	5	65	17	1,180	69.5
E Bulldog Wash	10½	7½	70	13	830	64.0
F Taylor basin	19	6	121	15	1,700	60.0
G Sonoqui Wash	14	6	79	15	180	12.0
H Agricultural area 1/	20	9	164	--	170	19.0

1/ Without drainageways.

130. Upper Queen Creek drainage receives tributaries from both directions perpendicular to the main axis of the watershed. In the first part of its course, Sand Tanks Wash flows as does Queen Creek on a steep gradient and through the foothill area before passing upon the plain. The Sand Tanks drainage area, as well as those of Buchanan and Bulldog Washes, includes independent streams of ephemeral flows which fan out on the plain. The drainageways of Taylor basin

originate in the southwestern fringe of Pinal Mountains, pass through the hilly section below, and disappear on the plain. Sonoqui Wash area includes drainages that carry the run-off from Santan and Goldmine Mountains.

Climate

131. The average annual rainfall of 10 inches on the lower part of the plain and which increases generally with elevation to about 25 inches in the Pinal Mountains (map 5), indicates three climatic zones, desert, semidesert, and subhumid. Over the watershed as a whole, there are two rainy seasons, summer (July to Sept.) and winter (Nov. to April). May, June, and October are usually dry, although small local rainfalls may occur.

132. The normal precipitation in this watershed, typical of dry regions, is characterized by infrequent heavy downpours (especially during July, Aug., and Sept.) and by comparatively general steady rains usually during the winter months (Nov.-Apr.).

Normal Precipitation in Relation to Soil Erosion

133. Owing to the fact that the vegetation on this watershed, for the most part, has deteriorated from its natural state and that the lands have suffered from erosion, the present conditions are such that during comparatively light rains soil erosion takes place. Rain water quickly concentrates on the ground surface, and even during light showers sheet and rill erosion may occur. Although during light rains the silt is moved comparatively short distances, usually charging the larger channels, it is moved farther down during the heavier rains. The heavier summer storms, particularly, cause destructive soil erosion, especially on denuded slopes. Heavy winter-type storms may also cause destructive soil erosion.

ANNUAL PRECIPITATION
QUEEN CREEK WATERSHED

U S DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
74 TH CONGRESS

MAP 5

SOURCE OF DATA U S WEATHER BUREAU
COMPILED L B LEOPOLD
APPROVED ARTHUR FIFE DATE 10-26-38

BASE DRAFTED BY C D MARINE
CARTOGRAPHIC SECTION SOIL CONSERVATION SERVICE
REGION EIGHT ALBUQUERQUE, NEW MEXICO

R-1259

Map 5

Temperature

134. Summer temperatures on the low plain commonly exceed 100° F. Average maximums for the warmest month (July) range from 95° to 102°, while on the higher areas the average maximums for the same month are somewhat lower. During the winter months the lowest temperatures on the plain occur during January—the average minimums for this month range from 34° to 39°; while in the mountains, for the same month, temperatures may fall to freezing and sometimes to about 20° below freezing (1,2).° Whenever the ground freezes (on the highest areas) the frost penetrates to shallow depths, and for only short duration. When the period between the last killing frost in the spring and the first in the fall is considered, the climates in this watershed afford long growing seasons—about 290 days in the agricultural area around Chandler and Gilbert and 161 days at Pinal Ranch near Oak Flat (elev. 4,500 ft.).

Snowfall and Hail

135. Although in 15 years of record, snowfall has been officially recorded only six times at or near Superior, snow is not unusual on the highest parts of the watershed. In the winter of 1935-36, a 1-foot snowfall occurred in the mountains near and above Pinal Ranch, above Superior (elev. 4,520 ft.). However, nearly all of it melted in 3 days. Because snow seldom stays on the ground for more than a few days, or until another storm occurs, the possibility of floods being caused by rain falling on snow is remote in this watershed. Hail, in relation to floods, is a negligible factor. The records of the monthly and annual rainfalls are summarized in table 5.

° Figures in parentheses refer to "Important Sources of Factual Information."

Table 5.—Precipitation—Monthly and Annual Averages, Queen Creek Watershed

Station	Elevation	Years of Record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average Annual	Minimum and year		Maximum and year	
	Feet		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Year	In.	Year
Phoenix	1,108	62	0.80	0.88	0.65	0.36	0.13	0.07	0.99	0.94	0.75	0.46	0.66	0.95	7.64	3.03	1924	19.73	1905
Peoria	1,150	9	1.16	0.73	0.58	0.18	0.14	0.06	0.95	0.99	0.49	0.74	0.69	1.04	7.75	4.76	1895	13.79	1889
Tempe Date Orchard	1,165	26	0.98	1.04	0.88	0.46	0.17	0.10	1.22	1.13	0.79	0.54	0.77	1.23	9.31	4.17	1921	22.15	1905
Goulds Ranch	1,195	12	1.04	0.57	0.75	0.42	0.18	0.07	0.80	0.97	0.84	0.33	0.64	0.97	7.58	3.93	1924	11.19	1918
Goodyear	1,203	12	0.51	0.90	0.78	0.30	0.14	0.15	1.30	1.02	0.72	0.52	0.72	0.94	8.00	4.30	1928	13.40	1919
Chandler	1,213	19	0.85	0.85	0.69	0.46	0.18	0.09	0.98	1.09	0.87	0.46	0.70	0.92	8.14	4.24	1929	13.21	1919
Mesa	1,245	40	0.98	0.85	0.86	0.42	0.13	0.12	1.14	1.10	0.77	0.48	0.77	1.03	8.65	4.19	1924	20.31	1905
Granite Reef	1,325	57	1.07	1.13	0.87	0.46	0.17	0.12	1.30	1.32	0.82	0.49	0.81	1.30	9.86	3.74	1925	20.95	1884
Casa Grande Ruin	1,422	7	1.05	0.83	1.00	0.46	0.12	0.30	1.48	1.82	0.35	0.78	1.01	1.62	10.82	6.35	1910	16.08	1914
Florence	1,500	32	1.08	0.99	0.96	0.39	0.19	0.10	1.45	1.58	0.90	0.47	0.80	1.36	10.27	5.25	1924	17.30	1930
Roosevelt	2,275	25	2.18	2.14	1.96	1.06	0.35	0.45	1.42	2.19	1.08	1.12	1.30	1.99	17.56	8.96	1924	33.27	1905
Boyce Thompson SW. Arboretum	2,800	13	1.37	2.20	1.56	0.99	0.33	0.33	1.36	2.55	1.52	0.57	1.34	1.84	16.00	6.45	1925	21.64	1930
Superior	2,990	15	1.58	2.22	1.72	1.08	0.30	0.35	2.21	3.06	1.48	1.07	1.49	2.18	18.74	10.56	1934	28.65	1931
Globe	3,440	32	1.56	1.59	1.26	0.71	0.40	0.39	2.69	2.48	1.39	0.98	1.30	1.81	16.56	8.01	1924	23.47	1914
Miami	3,603	16	2.45	1.78	1.63	0.98	0.63	0.57	3.20	2.73	1.54	1.03	1.34	2.27	20.15	14.87	1917	26.29	1919
Pinal Ranch	4,520	43	3.14	3.00	2.44	1.03	0.46	0.47	2.84	3.43	2.15	1.32	2.08	2.89	25.25	11.84	1903	58.45	1905

Sources: U. S. Weather Bureau records and unpublished rainfall records obtained at the Boyce Thompson Southwestern Arboretum, Inc.

136. For further information on rainfall, see "Hydrology."

Other Climatic Features

137. Other distinguishing characteristics of the Queen Creek climate are clear weather, recurrent droughts which may last for several years, and moderate, dry winds which usually prevail for 10 months generally from the west, and during December and January, from the east off the mountains. April is the month of most wind, and September, the least.

138. Few places in the United States have so much clear weather; at Phoenix 241 days in a year, on the average, are clear, 75 are partly cloudy, and 49 days are cloudy. As regards the moisture condition of the atmosphere, one may gain a clearer idea of the prevailing dryness if he studies the records of relative humidity taken at Phoenix, as follows:

Time of day Hour	Average annual Percent	Average for maximum month (January) Percent	Average for minimum month (May) Percent
6 a.m.	56	68	41
12 m.	29	35	18
6 p.m.	28	38	16

139. Evaporation. The dry atmospheric conditions, high temperatures, and clear weather result in a high annual rate of evaporation. Evaporation loss from a free water surface at Mesa (elev. 1,245 ft.) averages 77.5 inches annually, with the highest monthly average of 11.1 inches in June, and the lowest (2.8 in.) in January. The evaporation at Roosevelt (elev. 2,275 ft.), 25 miles north of Superior, averages as much as 81.72 inches, or nearly 7 feet, per year. As regards the higher evaporation at Roosevelt than at Mesa, it is possible to have a combination of wind and temperature at a higher elevation to result in greater evaporation than at a lower elevation.

Land Cover

140. The cultivated lands of this basin are utilized for growing such crops as cotton, alfalfa, small grains, citrus, truck crops, and forage crops (see figs. 3, 4, 5). The native vegetation, which varies according to climatic zones, includes desert shrubs (with annuals) of the low uncultivated areas, semidesert shrubs of the semidesert zone, and chaparral 1/ on the highest areas (map 6).

141. Although the composition of the native vegetation types has changed as the result of severe grazing use, the boundary lines of those types, in the main, remain about the same in the designation of the present vegetation types, which are shown on map 6. In order to make clear the effects of improper grazing on the original ground cover, the native vegetation types are described as follows:

Native Vegetation

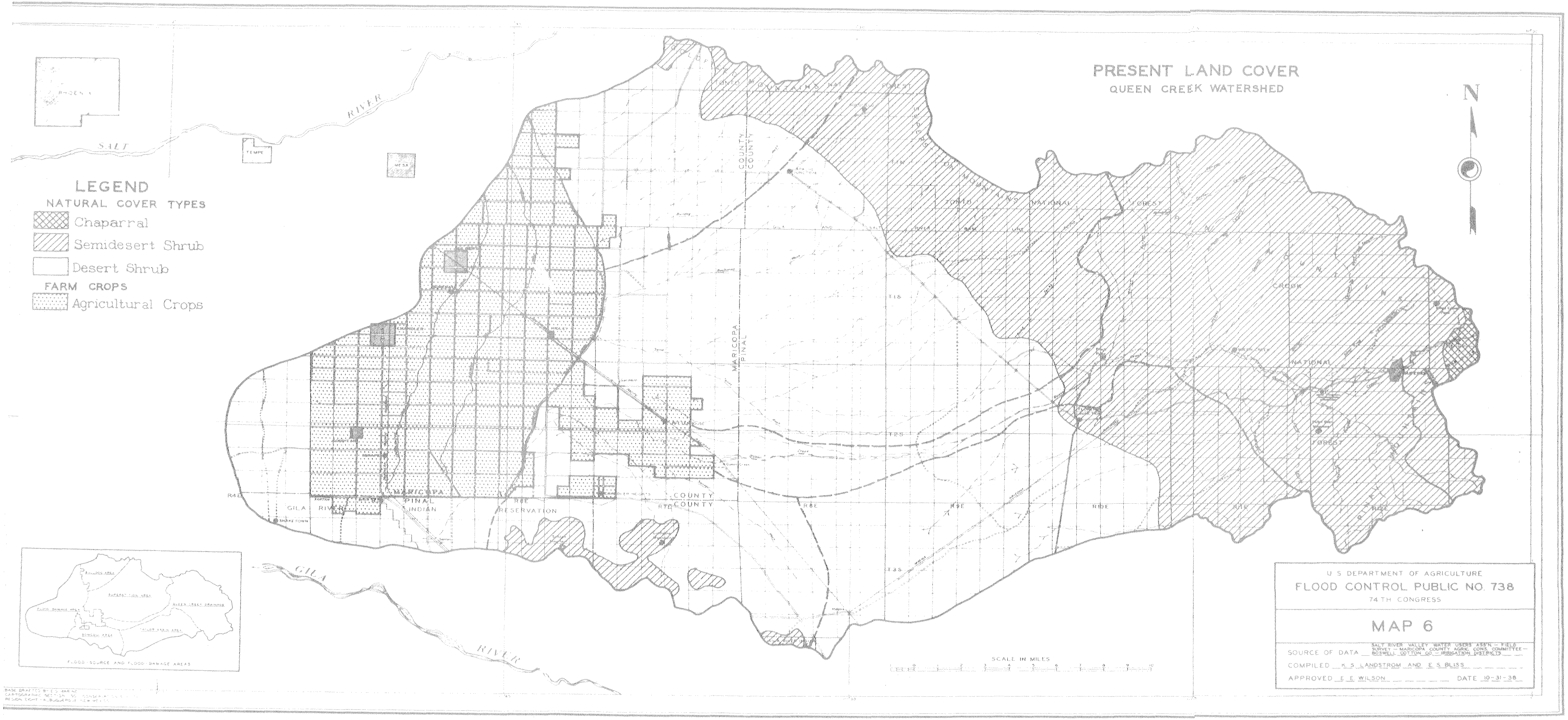
142. The vegetation in Queen Creek watershed, especially on the higher areas, constituted a protecting ground cover, for the most part treeless. On the plain grew creosotebushes, rabbitbrush, (Franseria deltoidea) a profusion of annuals, and some cacti and yuccas. In places where there was more soil moisture than elsewhere, grew tobosa and sacaton bunchgrasses. Trees marked the drainageways, including desertwillows, ironwoods, desert hackberries, and cottonwoods, flanked by mesquites.

143. In the higher semidesert zone (elev. 2,000 to 4,500 ft.), a good growth of bunchgrasses had become established between semidesert shrubs of such kinds as coffeeberry, paloverde, fairyduster, and twinberry (Menodora), which together gave good protection to the ground surface; while in the ravines shrubbery grew in abundance.

1/ Chaparral is a mixture of various kinds of brush growths, such as scrub live oaks, manzanitas, desert ceanothus, and mountain-mahogany.

PRESENT LAND COVER

QUEEN CREEK WATERSHED



U S DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

74TH CONGRESS

MAP 6

SOURCE OF DATA SALT RIVER VALLEY WATER USERS ASS'N – FIELD SURVEY – MARICOPA COUNTY AGRIC. CONS. COMMITTEE – BOSWELL COTTON CO. – IRRIGATION DISTRICTS

COMPILED K. S. LANDSTROM AND E. S. BLISS

APPROVED E. E. WILSON DATE 10-31-38

144. Above the semidesert zone (about 4,500 ft.) grew dense clumps of brush or chaparral, a mixed growth of scrub live oaks, some tree oaks, shrubs, and scattered junipers. Grasses grew between the shrubs and brush clumps. Oak Flat was covered largely with a rather dense stand of live oaks and junipers.

145. This original vegetation, through many centuries, had made possible the development of soils and allowed the accumulation of organic matter and soil nitrogen, which are important in plant growth. With such a protective cover of natural vegetation, the land surface did not suffer destructive erosion; hence, ordinarily, Queen Creek in its upper course ran clear even during normal flood flows. (7, 8, 9, 10, 11, 12.)

Effects of Land Uses on Native Vegetation

146. Overgrazing and drought have resulted in the disappearance of practically all the perennial grasses over the greater part of the watershed; and, with this protective ground cover gone, accelerated runoff has deprived the soils of considerable moisture for plant growth. Because of such induced drier soil conditions, together with the disappearance of the grasses, various kinds of desert shrubs of no forage value have encroached upon the semidesert areas, where formerly only a few had established themselves. Other changes in the land cover include the cutting of the juniper trees on the higher parts of the watershed for fuel and for use in the mines. The live oaks on Oak Flat met the same fate; only a few remain. Further, meadow areas which formerly grew trees and a profusion of herbaceous plants have become desert wastes as the result of clean wood cutting and overgrazing.

Vegetation in Relation to Erosion

147. Except the croplands, where soil erosion is not a problem, the vegetation on most of the watershed is in a deteriorated state, thus allowing greatly accelerated erosion. The relation of the present ground cover to erosion is briefly summarized in table 6.

Table 6.—Present Ground Cover in Relation to Soil Erosion 1/

Type of vegetation	Proportion of watershed	Character of vegetation	Condition of vegetation	Effectiveness in erosion control
	Percent			
Desert shrub	14 48.5	Shrubs Annual grasses Weeds	Deteriorated	Very low
Semidesert shrub	37.0	Shrubs Mixed grasses Weeds	Normal to deteriorated	Low to high
Chaparral	00.4	Scrub live oaks Shrubs Grasses	Deteriorated	Medium

1/ Total acreage of croplands equivalent to about 14 percent of watershed. Erosion slight.

Geology

148. The surface features of the Queen Creek basin, its stream channels, and soils have been influenced materially by, and are closely associated with, the geologic formations. The plain consists of valley-fill deposits, probably formed largely through water action. Ordinarily all the flow of the various drainageways of this watershed not lost by evaporation sinks into the valley-fill deposits, thus accounting for the fact that this basin has no through drainage.

149. In contrast to the plain, the Superstition Mountains and a large part of Pinal Mountains are of volcanic origin, with areas of crystalline

rock, limestone, and other sedimentary rocks, including some quartzite (map 7). The volcanic rocks consist largely of rather resistant dacite with some closely related rock (andesite), also areas of agglomerate—that is, compacted volcanic debris with various-sized fragments, as in areas around Picket Post Mountain. Probably caverns and cracks in Pinal Mountains, together with extensive mine workings at Superior, cause the disappearance of much of the surface flow of Queen Creek near the lower part of its mountain course. (3,4.)

150. The other mountains—Goldfield, Santan, and Goldmine—consist of old (Archaean) granitic rocks which disintegrate easily. The partly weathered granular material derived therefrom has been a potent factor in the formation of the porous soil mantles below these mountains, and at the present time contributes considerable erosion debris to those drainages that have their origin in these areas.

151. The intermediate foothill area below Pinal Mountains has developed on lavas, old Pinal schists, and also, geologically speaking, from rather recent sediments and gravelly deposits. Such an area does not occur below the Superstition Mountains, perhaps because this mountain faulted in comparatively recent geological time; and although probably eroded back, there remains a steep front, thus accounting for the steep stream gradients in the upper Superstition area.

Soils

152. Inasmuch as climate is generally recognized as a potent factor in the development of distinguishing characteristics that make possible soil classifications, the soils of Queen Creek watershed belong to three major, or zonal, groups: (a) Sirozem, or Desert, (b) Reddish

GEOLOGY
QUEEN CREEK WATERSHED

LEGEND

- VALLEY-FILL DEPOSITS
- ▨ CRYSTALLINE ROCKS GRANITIC AND METAMORPHIC
- ▨ VOLCANIC ROCKS PREDOMINANTLY DACITE
- ▨ SEDIMENTARY ROCKS LIMESTONE, SHALES, AND SANDSTONES

U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
74 TH CONGRESS

MAP 7

SOURCE OF DATA N. H. DARTON
COMPILED PARRY REICHE AND E. A. NIESCHMIDT
APPROVED ARTHUR FIFE DATE 10-17-38

BASE DRAFTED BY E. O. MARINE
CARTOGRAPHIC SECTION - SOIL CONSERVATION SERVICE
REGION EIGHT - ALBUQUERQUE, NEW MEXICO

Brown of the semidesert zone, and (c) Light Chocolate Brown and Brown of the highest, or subhumid, areas. Owing to rugged relief and rock exposures, a fourth and lesser group is also designated, including skeletal soils and bare rock (map 1).

Desert Soils

153. The Desert soils, which have developed from mixed materials deposited on the plain, range from those that are poorly developed (with uniform color, texture, and lime content from surface down) to those that have definite claypan, no free carbonate in the surface layer, and with a well-marked lime zone which occurs in some places as caliche. The poorly developed Desert soils occur on the alluvial plain (including the fertile agricultural area), also near drainageways, and on fans and colluvial deposits near the mountains. The better-developed Desert soils occur in playas, in basins, and on the older lower terraces. In general, all the Desert soils contain little organic matter, are light colored, and are free of alkali.

Reddish Brown Soils

154. The Reddish Brown soils of the semidesert zone occur on the higher fans, undulating areas of colluvial deposits, and on old higher terraces and areas of mountain pediments which have slight to moderate relief. On the whole, they are rather shallow yet fairly well developed, friable, and calcareous. Their subsoils are somewhat clayey textured, and well-cemented caliche occurs at lower depths.

Brown Soils

155. The Light Chocolate Brown and Brown soils of the high subhumid parts of the watershed occur in the Pinal Mountains area. For the most

part, these soils are shallow and are potentially fertile. In some places these brown soils have lime carbonate as seams and fine threads, and they contain medium quantities of organic matter. On the south exposures of Pinal Mountains, where the relief is strong, these brown soils are shallow, with no perceptible difference between topsoil and subsoil. Bare-rock slopes occur in some places, but aggregating only a small percentage of this whole brown-soil area. Distinct Brown soils (Shantung Brown) occur on Oak Flat. Here, too, are small areas (formerly cienegas) where the soils have developed under condition of water saturation and from which soils the free carbonates have been leached.

156. The darker-colored, or Brown, soils that occur above elevations of about 3,000 feet, where average annual rainfall varies from 20 to 25 inches, are noncalcic and in reaction are neutral and slightly alkaline, classed as Shantung Brown, or Noncalcic Brown.

Skeletal Soils

157. The skeletal soils—that is, thin accumulations or deposits of geologic soil-forming materials—occur on Superstition Mountains, in the Apache Leap area in Pinal Mountains, on Santan and Goldmine Mountains, and on a part of Goldfield Mountains. These soil areas are rough, stony, mountainous, and inaccessible, and, at best, support only scant vegetation, largely shrubs and some grass.

Erodibility of Soils

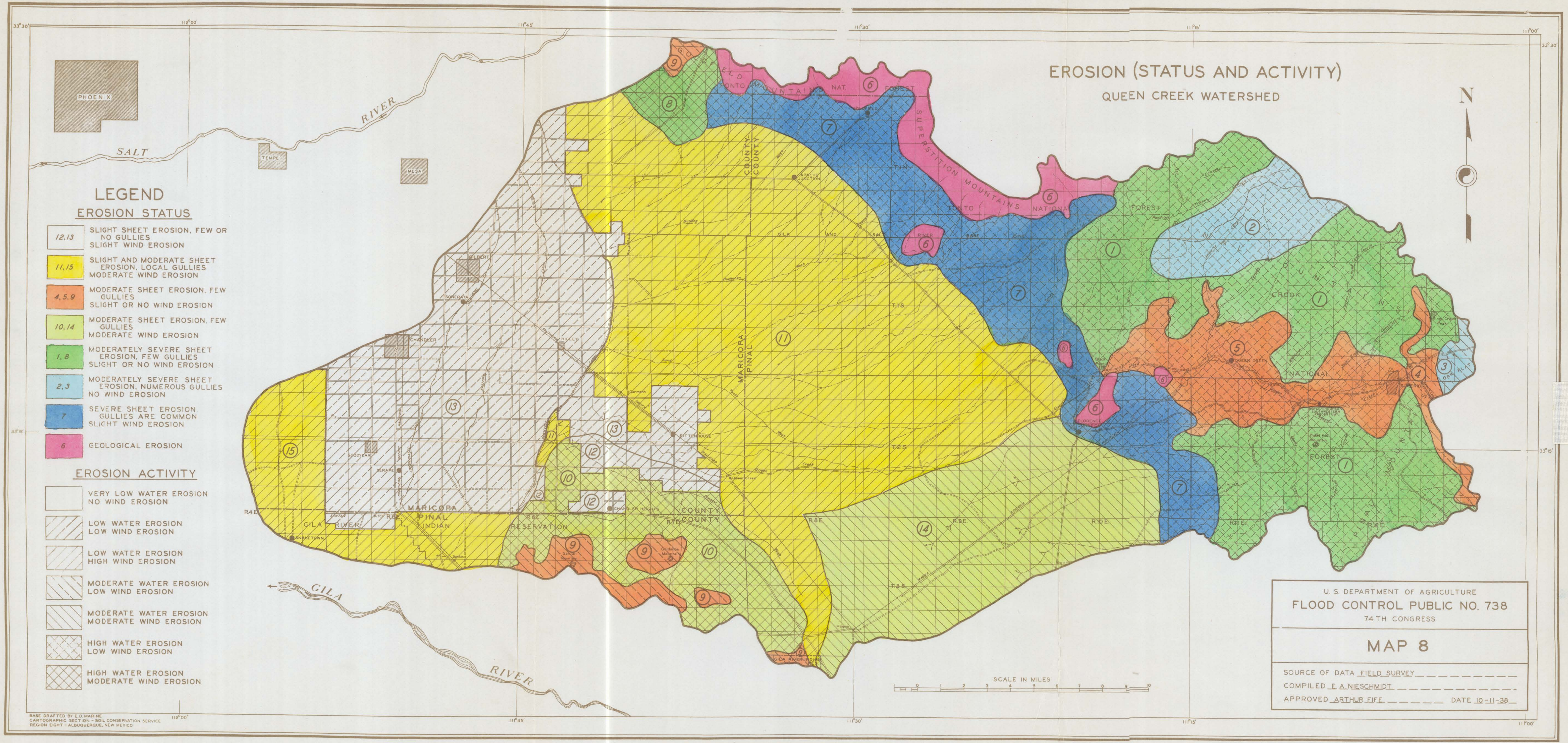
158. The Desert soils, which comprise about 60 percent of this basin, are medium to highly erodible. These soils occur largely on the plain, where, without remedial measures, future gullying and

channeling are likely to be most severe. The erodibility of soils, according to classes, is summarized in table 7.

Soil Erosion

159. As the result of overgrazing, together with the effects of roads, trails, cow paths, and highway and railway culverts, the lands on the entire Queen Creek watershed have suffered from erosion. On only a few small areas can one find any soil still in its original condition—that is, with its topsoil intact and with native vegetation. Among the evidences of erosion may be mentioned erosion-scoured stream channels, gullies, and the disappearance of topsoils (wholly or in part). Further evidences of damaging soil erosion, even on comparatively level areas, are dead and half-dead shrubs standing, as it were, on root stilts with their crowns 4, 6, and 8 inches above the present ground level. On 28 percent of the watershed the erosion is moderately severe and severe, on 52 percent the lands are moderately eroded, on about 17 percent they are slightly eroded, and on the remaining 3 percent the erosion is purely geologic (map 8). The soil materials washed away as erosion products are carried down and deposited below on the plain, and some are carried onto the agricultural lands during floods as damaging silt.

160. The terms "moderately severe erosion" and "severe erosion" imply that on some areas from 50 to 75 percent of the topsoil has been removed by water or wind, or both, while on other areas the topsoil is all gone, including some of the subsoil. Moderate erosion implies the removal of 25 to 50 percent of the topsoil, and slight erosion



EROSION (STATUS AND ACTIVITY)

QUEEN CREEK WATERSHED

LEGEND

EROSION STATUS

12,13	SLIGHT SHEET EROSION, FEW OR NO GULLIES SLIGHT WIND EROSION
11,15	SLIGHT AND MODERATE SHEET EROSION, LOCAL GULLIES MODERATE WIND EROSION
4,5,9	MODERATE SHEET EROSION, FEW GULLIES SLIGHT OR NO WIND EROSION
10,14	MODERATE SHEET EROSION, FEW GULLIES MODERATE WIND EROSION
1,8	MODERATELY SEVERE SHEET EROSION, FEW GULLIES SLIGHT OR NO WIND EROSION
2,3	MODERATELY SEVERE SHEET EROSION, NUMEROUS GULLIES NO WIND EROSION
7	SEVERE SHEET EROSION GULLIES ARE COMMON SLIGHT WIND EROSION
6	GEOLOGICAL EROSION

EROSION ACTIVITY

☐	VERY LOW WATER EROSION NO WIND EROSION
▨	LOW WATER EROSION LOW WIND EROSION
▨	LOW WATER EROSION HIGH WIND EROSION
▨	MODERATE WATER EROSION LOW WIND EROSION
▨	MODERATE WATER EROSION MODERATE WIND EROSION
▦	HIGH WATER EROSION LOW WIND EROSION
▩	HIGH WATER EROSION MODERATE WIND EROSION

U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
74TH CONGRESS

MAP 8

SOURCE OF DATA FIELD SURVEY
COMPILED E. A. NIESCHMIDT
APPROVED ARTHUR FIFE DATE 10-11-38

BASE DRAFTED BY E. D. MARINE
CARTOGRAPHIC SECTION - SOIL CONSERVATION SERVICE
REGION EIGHT - ALBUQUERQUE, NEW MEXICO

R-1259

Table 7.—Soils of Queen Creek Watershed and Their Erodibility

Soils and percentage of watershed	Origin of soil-forming materials	Thickness, color, texture			Vegetation (present status)	Position	Infiltration rate 1/	Dispersion ratio 1/	Erodibility
		Soils	Topsoils	Subsoils					
Desert (60 percent)	Dacite Schists Granites Mixed volcanics Limestone	Deep	Very light brown Loam Clay loam Gravelly sandy loam	Very light brown Light reddish brown Clay loam Loam Fine sandy loam Local caliche	Desert shrubs	Alluvial plain Colluvial slopes Fans	Low to high	Medium to high	Medium to high
Reddish Brown (Semidesert) (9.3 percent)	Dacite Schists Granites Mixed volcanics	Shallow	Light reddish brown to light brown Gravelly loam	Reddish brown Grayish Loam Cemented caliche	Semidesert shrubs	Fans Terraces Colluvial slopes	Medium	Low to high	Low
Light Chocolate Brown and Brown (Subhumid areas) (22.3 percent)	Dacite Schists Quartzite Granites	Shallow to medium	Brown Light brown Reddish brown Gravelly loam Loam	Light chocolate Light brown Brown Gravelly and stony clay loam Loam	Semidesert shrubs, chaparral,2/ and grasses	Mountains with small plateaus	Medium to high	Low	Do.
Skeleton soils and rough stony areas (5.4 percent)	Dacite Granites Limestone Schists Basalt	Thin and negligible			Semidesert shrubs and grasses	Mountains	Low	—	Very low

---

1/ Based on field judgment.

2/ Chaparral is a mixed growth of various kinds of shrubs (including scrub live oaks, manzanitas, desert ceanothus, and mountain-mahogany) occurring on areas immediately above the semidesert zone.

implies varying degrees of topsoil erosion by the combined action of wind and water, removal up to 25 percent. By geologic erosion is meant the normal wearing away of exposed rocks and the removal of soil-forming materials, or residues from rock weathering, in areas that have never supported sufficient vegetation to make possible soil development. A brief summary of the status of erosion on the watershed is given in the following tabulation:

Erosional status Degree	Areas by number 2/	Percentage of watershed Percent
Severe	7	9
Moderately severe	1,2,3,8	10
Moderate	4,6,9,10,11,14,15	52
Slight	12,13	17
Geologic	6	3

161. Erosional status refers to erosion that has already occurred on the watershed. The erosion now in progress is referred to in this report as erosional activity. The status and activity are both shown on map 8.

162. Additional data pertaining to the relation between the various soils (by broad groups), on the one hand, and land use and erosion, on the other, are summarized in table 8. In this table the soil groups are arranged in order from Desert of the low country to the Light Chocolate Brown and Brown soils of the high subhumid areas, followed by "rough mountain lands" and "skeleton soils."

2/ For areas and erosion, see map 8.

Table 8.—Erosion on Queen Creek Watershed (Contd. on next page)

Soils and area [1]	Relief	Land use	Run-off	Erosional status							Silt production	Remarks
				Removal		Presence of gullies	Deposition		Erosional activity			
				Sheet erosion	Wind erosion		Water	Wind	Water	Wind		
Medium deep Desert soils with local hard caliche 8	Slight	Range	Medium	50-75[2] percent removed	0-25 percent removed	Few	High	Low	High	Med.	Medium	Partly geologic erosion
Deep Desert soils 10	---do---	--do--	Low	25-50[2] percent removed	25-50 percent removed	---do---	-do-	Med.	-do-	---do-	----do----	Do.
Deep Desert soils 14	---do---	--do--	--do---	---do---	------do-----	Very few	-do-	---do-	Med.	--do-	Low	Do.
Deep Desert soils 15	---do---	--do--	--do---	0-25 percent removed	25-50[3] percent removed	---do---	Med.	--do-	Low	High	----do----	Do.
Deep Desert soils 11	---do---	--do--	--do---	---do---	------do-----	---do---	High	--do-	-do-	---do-	----do----	Do.
Deep Desert soils 12	---do---	Irrigation	--do---	0-25[2] percent removed	0-25 percent removed	---do---	Med.	Low	-do--	Low	----do----	Practically stabilized
Deep Desert soils 13	---do---	--do--	Low	---do---	------do-----	---do---	Low	--do-	-do-	---do-	----do----	Do.
Shallow Reddish Brown (semidesert) soils with hard caliche 7	Moderate	Range	High	75-100[2] percent removed	0-25 percent removed	Few to common	Med.	None	High	--do-	Medium	Partly geologic erosion

[1] For location of areas, see map 3.
[2] Includes wind erosion.
[3] Includes sheet erosion.

Table 8.– Erosion on Queen Creek Watershed (Contd. from previous page)

Soils and area 1/	Relief	Land use	Run-off	Erosional status: Removal: Sheet erosion	Erosional status: Removal: Wind erosion	Erosional status: Presence of gullies	Erosional status: Deposition: Water	Erosional status: Deposition: Wind	Erosional activity: Water	Erosional activity: Wind	Silt production	Remarks
Shallow Light Chocolate Brown soils with hard caliche 1	Strong	Range	High	50-75 percent removed	None	Few	None	None	High	Low	Medium	---
Medium deep Brown soils with claypan 2	---do---	--do--	--do---	--do--	--do----	Rather common	-do-	-do-	-do-	-do-	High	---
Medium deep Brown soils with claypan 3	Slight	--do--	Medium	--do--	--do----	---do---	High in places	--do-	Med.	--do-	Medium	Already treated with structures; livestock is excluded
Medium deep Light Chocolate Brown soils with caliche in some places 5	Moderate	--do--	High	25-50 percent removed	---do----	Few	Low	--do-	High	--do-	----do----	---
Rough mountainous lands 6	Strong	Game and range	--do---	---	---	---	---	---	Very low	---	Low	Predominantly geologic erosion
Skeleton soils 4	---do---	Range	--do---	25-50 percent removed	None	Few	None	None	Med.	Low	----do----	Partly geologic erosion
Skeleton soils 9	---do---	--do--	--do---	25-50 2/ percent removed	0-25 percent removed	---do---	-do-	-do-	-do-	-do-	Low	Do.

1/ For location of areas, see map 3.

2/ Includes wind erosion.

Land Types

163. The lands of Queen Creek watershed may be differentiated into 15 types (map 2), which may be grouped into 6 classes, as follows:

- Level lands with irrigated crops:
    - Level irrigated lands of deep sandy desert soils.
    - Level irrigated lands of deep heavier-textured desert soils.
- Mountain plateau with chaparral (brush):
    - Mountain plateau of medium deep brown soils.
- High mountainous lands with semidesert shrubs:
    - Mountainous lands of medium deep brown soils.
    - Mountainous lands of shallow brown soils.
    - High rough mountainous areas.
    - Precipitous rocky areas.
- Low mountainous lands with semidesert shrubs:
    - Low mountainous areas.
- Foothills and hill lands with semidesert and desert shrubs:
    - Foothills of light-brown soils and with semidesert shrubs
    - Foothill and hill lands (fans and colluvial slopes) of shallow reddish-brown soils and with semidesert shrubs.
    - Hill lands (fans and colluvial slopes) of deep desert soils and with desert shrubs.
- Level lands with desert vegetation:
    - Nearly level lands of deep sandy desert soils.
    - Nearly level lands of deep heavier-textured desert soils.
    - Nearly level lands of deep desert soils (closed basin).
    - Rather level poorly drained desert lands.

These land types not only include the broad groups of soils (pars. 152 to 157) and vegetation types (par. 140) but also reflect the climates, outstanding soil characteristics, geology, and the physiographic features of this watershed. In this report, land types rather than soil types are considered in relation to range-use adjustments and supplementary remedial measures, discussed under "Plan of Improvement" (pars. 14-60).

Features of Those Land Types that Bear on the Plan of Improvement

164. Of the 15 land types, 4 have important bearing on the plan of improvement, namely, Nos. 11, 8, 10, and 7 (see map 2). Brief descriptions of these four types follow:

165. Land type No. 11, nearly level lands of deep heavier-textured desert soils (fig. 6), comprises a large part of the alluvial plain, about 150,000 acres (235 sq. miles), the largest land-type area in this basin. Elevations range from 1,325 to 2,000 feet above sea level, and the average annual rainfall varies from 10 to 15 inches. The vegetation consists principally of creosotebushes, rabbitbrush, cacti, some annual grasses, and weeds. Drainageways are marked by trees, such as mesquites, ironwoods, and paloverdes (see map 8 and "Area 11;" table 8).

166. Land type No. 8, hill lands of deep desert soils, which total about 6,000 acres (10 sq. miles), occurs in the northern part of the watershed below Goldfield Mountains, on high fans and colluvial slopes at elevations ranging from 1,650 to 2,100 feet above sea level, with average annual rainfall varying from 14 to more than 15 inches. The relief is slight, and the vegetation consists principally of desert shrubs, some annual grasses, and weeds. Drainageways are marked by lines of trees, including paloverdes, ironwoods, and mesquites. The soils of this area are of the desert types, and vary in color from light grayish brown to very light brown. They are gravelly sandy

loams of high permeability, having originated from granitic materials. They contain free lime carbonate, and in places the subsoils contain hard caliche. The original semidesert grasses have been destroyed through overgrazing, and in consequence, erosion has taken, and is taking, a heavy toll (see map 8 and "Area 8," table 8).

167. Land type No. 10, nearly level lands of deep sandy desert soils, which total about 28,000 acres (44 sq. miles), occurs mostly on the lower colluvial slopes of Santan and Goldmine Mountains. These lands are similar to those of type No. 8. The annual rainfall is somewhat less, and the vegetation more desertic, consisting principally of desert shrubs, some annual grasses, and weeds. The erosion status is similar to that of type 8 (see map 8 and "Area 10," table 8).

168. Land type No. 7, foothill and hill lands of shallow reddish-brown soils, constitutes a long narrow northwest-southeast belt across the watershed immediately below the mountains, totaling 50,000 acres (78 sq. miles). The elevation of this belt varies from 1,800 to 2,300 feet; and average annual rainfall, from 13 to 22 inches. This belt includes hilly lands, foothills, high fans, and colluvial slopes. The vegetation, for the most part, consists of semidesert shrubs, some annual grasses, and weeds. The soils of this belt are mostly shallow gravelly loams of low to medium permeability, and with considerable development of cemented caliche in their subsoils. Overgrazing has practically destroyed the natural grass cover, with the result that these hilly lands have lost most of their topsoils, in some places all, including some of the subsoils. Gullies are common. The present rate of run-off is high, and silt production

is medium (see map 8 and "Area 7," table 8). Because of rough relief, presence of caliche, and steep gradients, no minor structural treatment is planned on this land-type area (see also maps 2 and 3).

Stream-Channel Characteristics

169. The outstanding feature of most of the streams is that they first flow on steep mountain gradients before passing onto the alluvial plain below, where at comparatively low gradients some fan out, while others, before fanning out, become a network of channels, evidence of a gradual stream-bed upbuilding. The stream gradients in the canyons of Superstition and Pinal Mountains average about 25 percent, in the foothills below the Pinal Mountains they average about 10 percent, and on the alluvial plain and piedmont slopes they range from about 0.3 to 1.5 percent.

170. In the mountain channels bedrock is exposed in many places, and, generally, there is not much cobble and gravel in them. Jumbled in these channels are boulders as large as 5 feet in diameter, which, by rolling and undercutting, are moved by high flows.

171. In the foothill part of the Pinal Mountain area, the channels contain cobble, gravel, and boulders. Stream-bank cutting contributes only small quantities of erosion debris, as compared with that which is moved down as bed load. As one of the results of the deposition of these erosion products, the alluvial plain is gradually being built up. This process has been going on during late geological time, and is continuing at present.

172. Queen Creek itself should be given special mention. It has its source high up in Pinal Mountains north of Superior, traverses

Oak Flat, follows a general westerly course down a steep V-shaped canyon, then through a "bowl" in the foothill area below Superior. It passes through a box canyon near Picket Post Mountain, then continues through foothills, and finally onto the plain, at the lower end of which, owing to low gradient and bed-load debris, it has built up a low ridge on which it flows, confined by low natural levees. Within these levees is a network of channels which disappear near the agricultural area, where the water tends to move as sheet flow.

OCCUPANCY AND ECONOMY

173. The present flood problems in Queen Creek watershed are closely related to land use by white men. Previous occupancy had been by prehistoric people and Indians. As a part of the southwestern region, this watershed played an important role during a long period of prehistoric culture which was founded mainly on agriculture. Following this ancient culture and continuing thereafter habitation was by farming Pueblo Indians, who, it is believed, were the descendants of the prehistoric people (5, 6).

174. Although the Queen Creek country was visited by Spanish explorers during the early 1500's and late 1600's and 1700's (13, 14) and was penetrated by American trappers between 1824 and 1842, American settlers did not venture into this country until after its occupation by the United States in 1848 (15, 16, 17).

Modern Developments

175. Farming and livestock grazing were begun by the first settlers around Mesa in the 1850's, and mining developed near Superior in the 1870's. Grazing was the only agricultural activity in Queen Creek watershed itself up to 1888, when irrigation began.

176. Grazing reached its peak about 1900, with stocking far above sustained capacity, to the detriment of the ranges. Following a prolonged drought which began in 1900 and lasted for 5 years.

the grazing business suffered a collapse from which it never fully recovered. The ranges suffered severe deterioration, which condition developed within about 50 years after settlement by white people.

Population

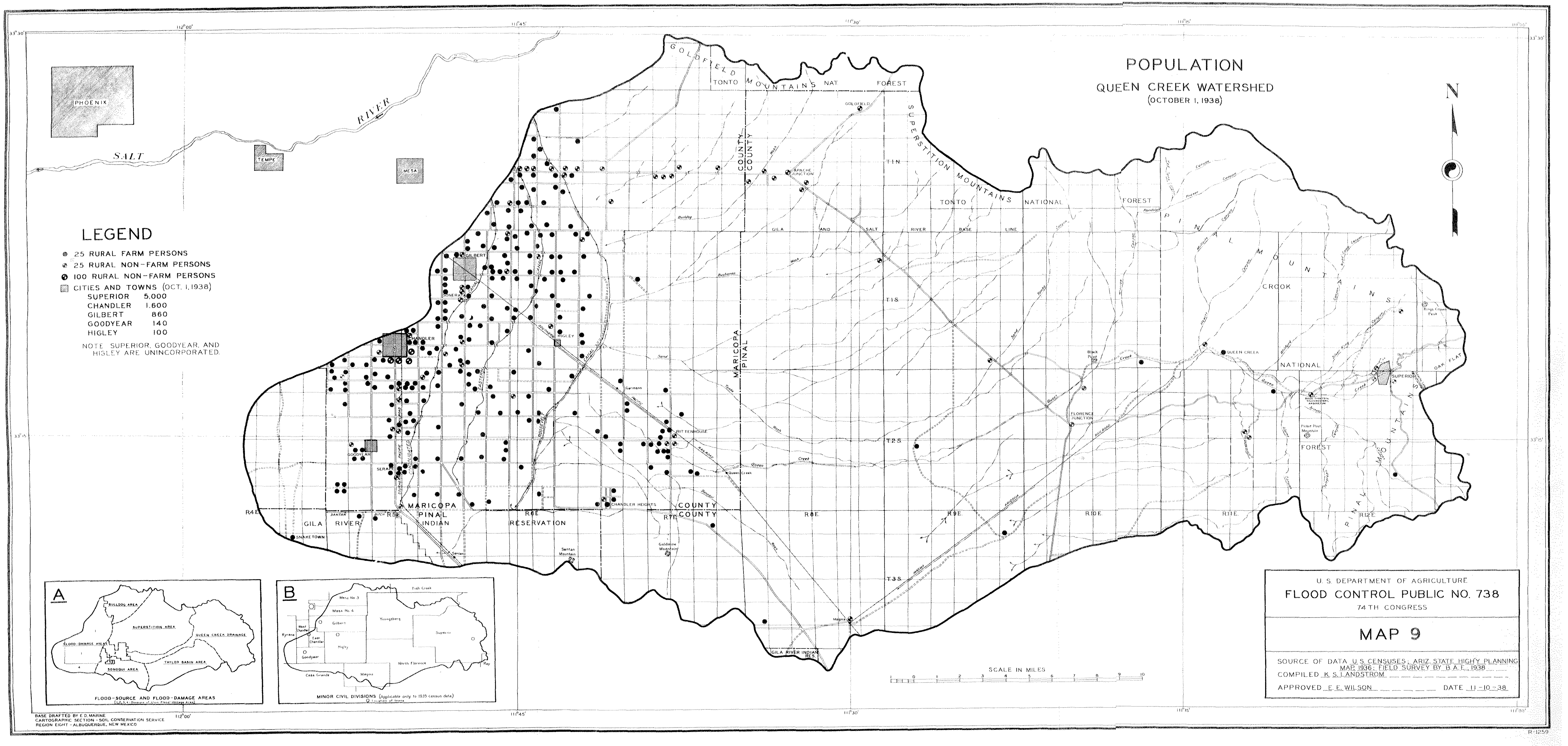
177. The number of people residing in Queen Creek watershed is estimated at 16,000, as of 1938 [3]. Except for those living in Superior, a mining town of 5,000 population in the upper part of the watershed, nearly all the people reside on farms and in small towns in the irrigated, or flood-damage, area, where there are about 10,000 persons (map 9). In the case of a major flood, 10,000 persons would be directly affected. A minor flood would directly affect about 1,000 persons (27, 28, 29).

Population Trend

178. The population in Queen Creek watershed has increased very sharply since about 1880, resulting largely from the development of irrigation and mining. Practically all irrigable lands in this watershed have been developed, hence, barring sharp expansion of mining activities, there seem to be prospects for only a slight increase in population in the next decade or two.

---

[3] The population in the watershed varies considerably throughout the year, because of the movement of migratory agricultural workers into and out of the area. The number of migratory laborers is greatest during summer and fall months (26).



POPULATION

QUEEN CREEK WATERSHED

(OCTOBER 1, 1938)

LEGEND

- ● 25 RURAL FARM PERSONS
- ● 25 RURAL NON-FARM PERSONS
- ● 100 RURAL NON-FARM PERSONS
- ▨ CITIES AND TOWNS (OCT. 1, 1938)

SUPERIOR	5,000
CHANDLER	1,600
GILBERT	860
GOODYEAR	140
HIGLEY	100

NOTE SUPERIOR, GOODYEAR, AND HIGLEY ARE UNINCORPORATED.

U. S. DEPARTMENT OF AGRICULTURE

FLOOD CONTROL PUBLIC NO. 738

74TH CONGRESS

MAP 9

SOURCE OF DATA U.S. CENSUSES; ARIZ. STATE HIGH'Y PLANNING MAP, 1936; FIELD SURVEY BY B.A.E., 1938
COMPILED K. S. LANDSTROM
APPROVED E. E. WILSON DATE 11-10-38

BASE DRAFTED BY E.D. MARINE
CARTOGRAPHIC SECTION - SOIL CONSERVATION SERVICE
REGION EIGHT - ALBUQUERQUE, NEW MEXICO

R-1259

Land Ownership

179. Nearly two-thirds of the lands in Queen Creek watershed are publicly owned. Federal lands make up 38 percent of the watershed; State lands, 26 percent; and private lands, 36 percent (map 4). Federal ownership includes national forests (21 percent of the watershed), Indian lands (6 percent), and other Federal lands (11 percent). Private lands include those owned and held by private individuals under contract of purchase from the State. Increases in State lands may be expected to result if pending State-exchange selections of Federal lands are approved (map 4). The acreages under the different ownerships are shown in table 9.

Table 9.—Land Ownership, Queen Creek Watershed, 1938

Type of ownership	Acreage	
	Acres	Percent
Federal:		
National forests	119,300	21
Indian reservations	31,300	6
Other Federal lands 1/	63,000	11
Total	213,600	38
State:		
State lands	144,800	26
Private:		
Private lands held under deed	172,600	30
Privately held under contract of purchase from the State	32,500	6
Total	205,100	36
Grand total	563,500	100

1/ Includes first-form reclamation withdrawals (except on national forests), stock-drive withdrawals, homestead entries, State-exchange selections, a Farm Security Administration tract, and vacant public lands.

Data derived by planimetering a large-scale land-ownership map (subject to 3-percent error).

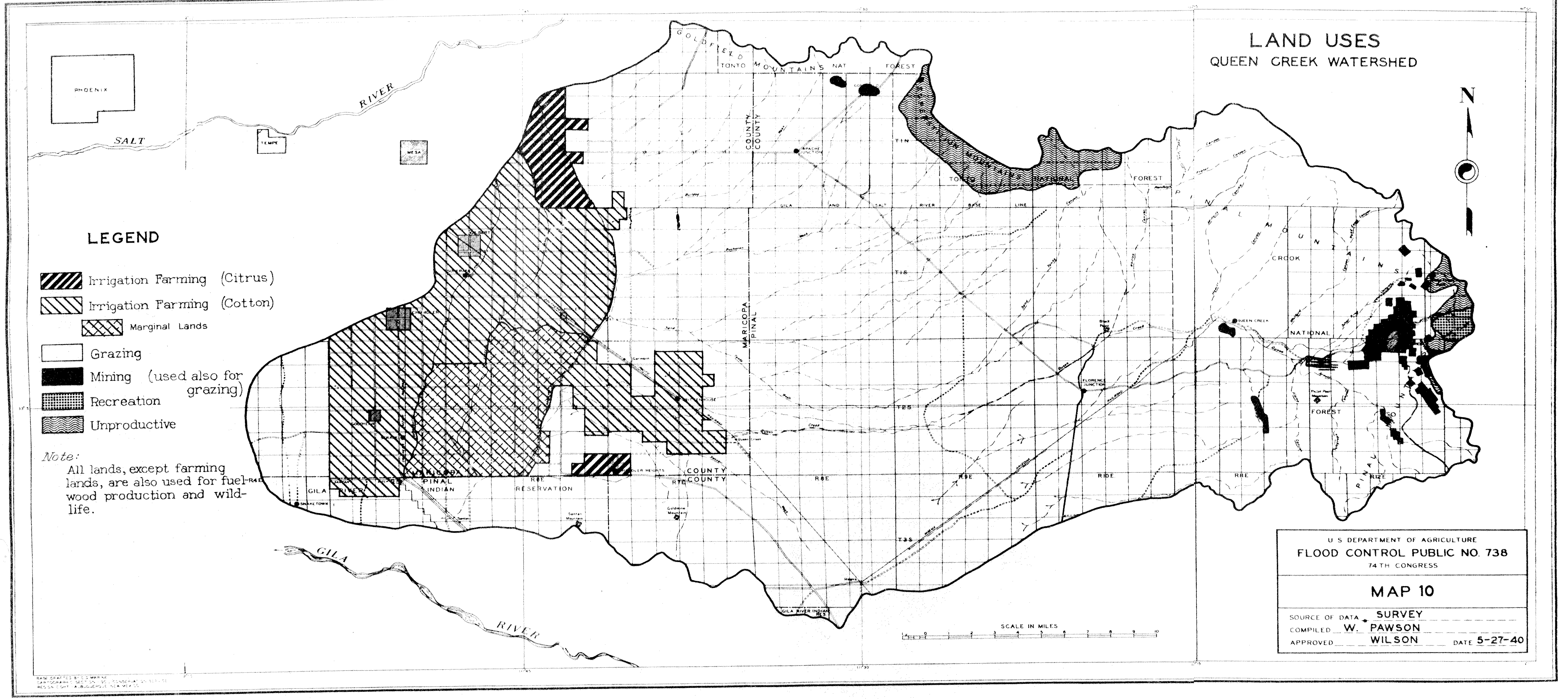
Land Uses

180. The lands in Queen Creek watershed are utilized for various purposes, including farming, grazing, mining, recreation, wildlife, and for the production of fuel wood (map 10). The largest total acreage (about 80 percent of watershed) is used for grazing. However, the use of lands for irrigation farming ranks first, as based on income, despite the fact that such lands comprise only 15 percent of the entire watershed 4/. Mining lands, although comprising less than 1 percent of this basin, support a large proportion of the population. Grazing lands are used also for wildlife and for the production of fuel wood. Certain mountainous lands that are inaccessible to livestock, because of rugged relief, are unproductive, except for wildlife. All the lands east of the agricultural area, in addition to their being used for grazing, have high public values for watershed protection, recreation, and wildlife.

Farming

181. About one-third of the people in this watershed derive their living from irrigation farming. Almost as many more are indirectly dependent upon it for livelihood. Queen Creek watershed, although comprising less than 1 percent of the total area of Arizona, contains about 10 percent of the croplands of that State. The total acreage of croplands in this watershed in 1938 was estimated at 79,500 acres, cultivated by about 500 farmers.

4/ The gross value of crops produced on irrigated land in this watershed is estimated at $4,500,000 per year, as compared with $100,000 worth of livestock and livestock products produced annually from the range lands.



LAND USES

QUEEN CREEK WATERSHED

LEGEND

- ▨ Irrigation Farming (Citrus)
- ▧ Irrigation Farming (Cotton)
- ▦ Marginal Lands
- ☐ Grazing
- ■ Mining (used also for grazing)
- ▩ Recreation
- ▤ Unproductive

Note:
All lands, except farming lands, are also used for fuel-wood production and wild-life.

U S DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
74 TH CONGRESS

MAP 10

SOURCE OF DATA SURVEY
COMPILED W. PAWSON
APPROVED WILSON DATE 5-27-40

Development of Irrigation

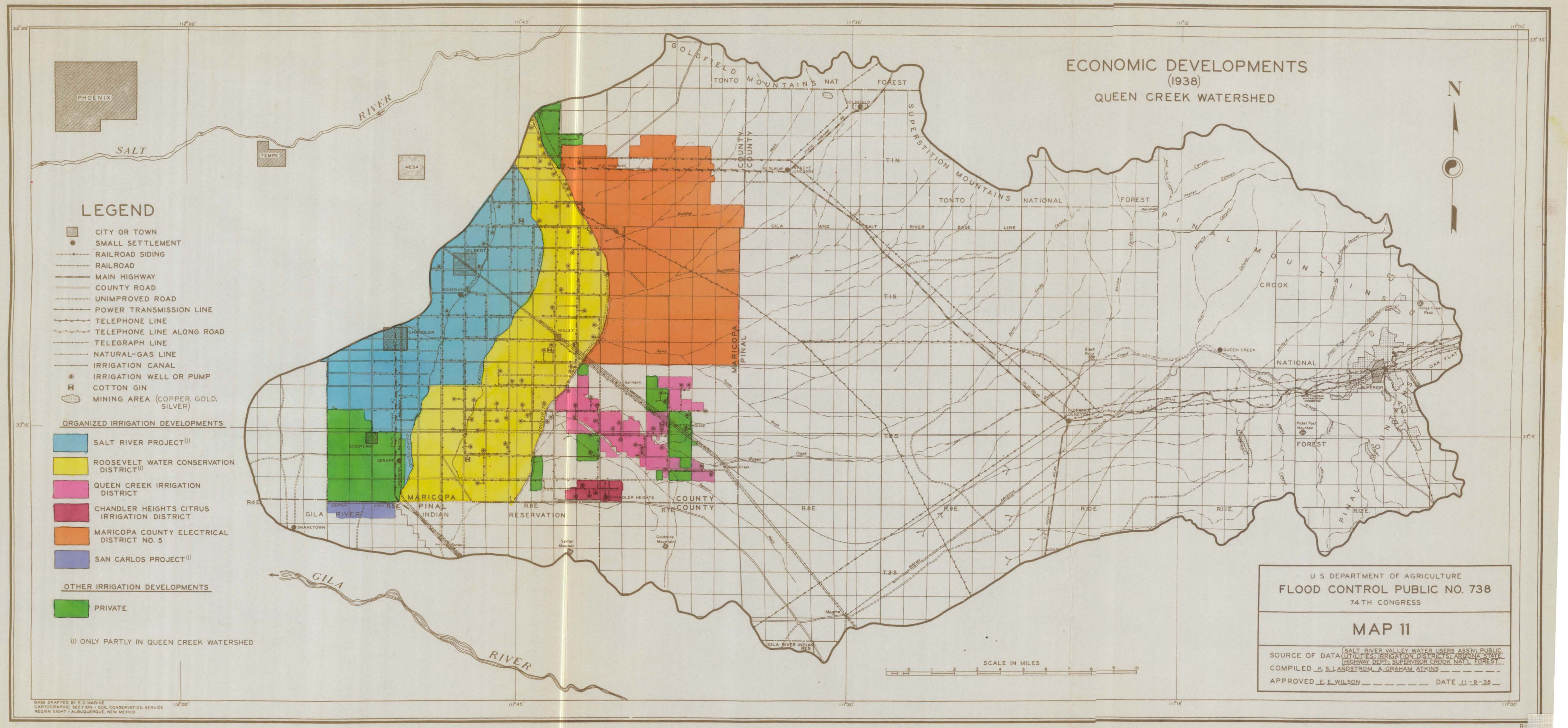
182. Irrigation in Queen Creek basin, which began in 1888, made rapid progress after 1917, with the development of the Roosevelt Water Conservation District, Queen Creek Irrigation District, Chandler Heights Citrus Irrigation District, and the San Carlos Project, and various private pumping developments (map 11). Most of the lands in the Maricopa County Electrical District No. 5, an irrigation district east of the agricultural area, has never been placed under cultivation (18-24).

183. The highways, railroads (25), telephone lines, and other public utilities that serve this area are shown on map 11.

Types of Farming

184. Two principal types of farming are carried on, cotton farming and citrus farming (map 10).

185. <u>Cotton farming</u>. In 1937, in the cotton-farming areas, about 65 percent of the irrigated lands were planted to cotton (fig.3). The acreage of alfalfa, the principal crop grown in rotation with cotton, aggregated about 15 percent. Other crops include small grains (5 pct.), hegari (sorghum, 5 pct.), and truck crops, principally lettuce and cantaloupes (3 pct.). (32-36, incl.) Small grains (wheat or barley) are usually double cropped with hegari. The small grains are planted in December and harvested in May, followed by a planting of hegari, which is harvested in the late fall. Two or more vegetable crops may be grown on the same land each year. There are some specialized dairy and truck farms in the cotton-farming area. Beef cattle and sheep are sometimes fattened on farm-produced feeds and pasturage (fig. 4).



ECONOMIC DEVELOPMENTS
(1938)
QUEEN CREEK WATERSHED

U. S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL PUBLIC NO. 738
74TH CONGRESS

MAP 11

SOURCE OF DATA SALT RIVER VALLEY WATER USERS ASS'N; PUBLIC UTILITIES; IRRIGATION DISTRICTS; ARIZONA STATE HIGHWAY DEPT; SUPERVISOR CROOK NAT'L FOREST
COMPILED K. S. LANDSTROM, A. GRAHAM ATKINS
APPROVED E. E. WILSON DATE 11-9-38

BASE DRAFTED BY E. D. MARINE
CARTOGRAPHIC SECTION - SOIL CONSERVATION SERVICE
REGION EIGHT - ALBUQUERQUE, NEW MEXICO

R-

186. The Salt River Project part of this watershed has a somewhat larger proportionate acreage in feed crops and small grains and less in cotton than does the Roosevelt Water Conservation District and other recently developed areas. More livestock are found in the Salt River Project than elsewhere, and farms are smaller in size, ranging generally from 40 to 80 acres of irrigated land, as compared with the typical farm of 160 irrigated acres in the Roosevelt Water Conservation District and other comparatively new areas.

187. Farming, which is highly commercialized, is dependent on hired labor to a large extent, especially for such operations as cotton picking. Several large-scale farms, ranging in size from 640 to 8,000 acres of irrigated land, comprise about 20 percent of the total acreage of the cotton-farming area.

188. Citrus farming. Citrus farming is predominant in the Chandler Heights Citrus Irrigation District and in an area in the northern part of the agricultural area (map 10). Frost-free conditions prevail in these areas, which allow the growing of citrus. The Chandler Heights citrus-growing area is highly specialized, with farms of from 10 to 20 acres planted entirely to orange, grapefruit, and other citrus trees (fig. 5). In the northern area, citrus growing is not a specialized type of farming, but is commonly an enterprise that is combined with the growing of cotton, alfalfa, and other crops on farms of from 80 to 160 acres in size, which farms, however, produce their major income from citrus growing.

Crop Yields

189. The average yield of short-staple cotton under irrigation is 1 bale, or about 500 pounds of lint per acre. In favorable years, yields of from 1½ to 2 bales per acre have been obtained by some farmers. Five cuttings of alfalfa, averaging 1 ton per acre to a cutting, are commonly obtained in a year, plus fall and winter pasturage. A normal wheat yield is 30 or 35 bushels to the acre.

Influence of Floods on Cropping Systems

190. According to farmers, county agents, and other local persons, floods have had very little, if any, effect on the cropping systems in Queen Creek basin. The areas in which truck crops, for example, are grown seem to be determined principally by the type and fertility of the soils, availability and cost of irrigation water, accessibility to packing and shipping facilities, and personal inclination of farmers. Truck farming is specialized, with approximately 15 large individual and corporate farms which control about 90 percent of the acreage in truck crops in the Salt River Valley.

191. A smaller percentage of the acreage in the Roosevelt Water Conservation District is utilized for the production of sugar-beet seed and truck crops like lettuce and melons than in the Salt River Project. It seems that this is due primarily to factors other than floods. The Queen Creek Irrigation District, situated in a flood-hazard zone, has a larger percentage of its croplands in vegetables than has the Salt River Project as a whole 5/.

5/ Average for years 1937-39; Queen Creek Irrigation District, 18 percent; Salt River Project, 12 percent; Roosevelt Water Conservation District, 3 percent.

192. The gross returns per acre are greater for vegetables than for other important competitive crops in this basin. But while returns are greater for these crops, the costs and risks are also greater. Fluctuation in income from this type of cropping is great, and most farmers prefer a cropping program that provides stable annual returns.

193. Present market demands for these crops have been well satisfied, and it seems unlikely that this market will expand in the near future. The market for sugar-beet seed is very limited. Production is under contract. Should there be an increase in demand for vegetables, there is sufficient land of a more suitable type throughout the Salt River Valley Project, so that the acreage of these crops in this valley might be greatly increased in response to more favorable cost-price relationships.

194. In view of these considerations, it is believed that the elimination of flood hazards would likely have little effect on kinds of crops grown. This conclusion is in agreement with the opinion of agricultural experts and farmers who operate in the flood-damage area. Out of more than 50 farmers interviewed, all but one indicated that the elimination of flood damages would likely have no effect upon the crops grown on their farms. Included among these are some of the most experienced growers of truck crops in the watershed. Changes in cropping systems, as in the past, may be expected to be largely in response to other economic considerations.

Value of Irrigated Lands

195. Lands in the cotton-farming area in the Salt River Project part of the watershed are valued at from $150 to $250 per acre. in the

Roosevelt Water Conservation District the values range from $25 to $125 per acre. The differential in land values between the first and the second districts is due principally to the higher cost of irrigation water in the latter district 6/. Citrus lands in production are valued at from $200 to $600 per acre.

196\. The total value of the irrigated farm lands in this watershed is estimated at $11,000,000.

Irrigation Water, Supply

197\. The Salt and Verde Rivers, to the north of this watershed, are the sources of about 60 percent of the water used for irrigation in Queen Creek watershed. Water from these rivers is stored in Roosevelt and Bartlett reservoirs 7/, constructed by the Bureau of Reclamation. About 40 percent of the irrigation water used in this basin is pumped from underground sources. The draft on the ground-water supply during recent years has been greater than the recharge. The result has been a considerable lowering of the water table, particularly in the northern part of the agricultural area (see pars. 272 to 276, "Hydrology").

198\. Comparatively little of the surface water originating on the watershed, with the exception of the flows of Queen Creek and Sonoqui Wash, is utilized for irrigation and other purposes. However, flood flows from Queen Creek and Sonoqui Wash are used to supplement the

---

6/ The average 1931-37 irrigation-water cost (for 3 a.-ft. of water) was $13 per acre in the Roosevelt Water Conservation District, as compared with $3.30 per acre in the Salt River Project.

7/ Roosevelt Reservoir is supplemented by three smaller reservoirs for power-production purposes.

irrigation-water supply in the Queen Creek Irrigation District. In that area, dependence is placed upon pump irrigation for a constant water supply. However, the use of flood flows reduces the quantity of pumped water. Some of the floodwater that originates on the Superstition and Bulldog areas is passed into the Roosevelt Canal and utilized for irrigation. The following vested water rights will have a bearing on the flood-control program of the Department of Agriculture:

Name	Source of flow	Diversion point	Acres Irrigated
J. O. Suver	Sand Tanks Wash	Sec. 18,T.2S.,R. 8E.	180
Germann Ranch	Do.	Secs. 1,2,11,12,T.2S.,R. 7E.	1,500
Leo Ellsworth	Sonoqui Wash	Secs. 26,27,28,T.2S.,R. 7E.	850
J. O. Power	Do.	Secs. 13,T.2S.,R. 6E.	640
Clyde Rouse	Do.	Sec. 14,T.2S.,R. 6E.	260

Irrigation District Bonded Indebtedness

199. The Roosevelt Water Conservation District was heavily bonded in financing the construction of its irrigation and pumping works. Bonds of this district, aggregating $3,860,000, were in default from 1931 to 1937. Since that time practically all the outstanding bonds and warrants of the district have been purchased by the Reconstruction Finance Corporation (at 37½ cents on the dollar). The present bonded indebtedness of this district is therefore about $1,500,000. Interest payments on the bonds held by the Reconstruction Finance Corporation have been met regularly since 1937, and the first payments on the principal will be made July 1, 1940.

Tax Delinquency

200. Delinquency of general property taxes is heavy in the southern part of the Roosevelt Water Conservation District and in the Queen

Creek Irrigation District. Tax delinquency is comparatively light in the Salt River Project and in the northern part of the Roosevelt Water Conservation District.

Marginal Lands

201. There seem to be some marginal lands in the southern part of the Roosevelt Water Conservation District (map 10), as evidenced by lower crop yields, lower land values, higher proportion of tax delinquency, and a larger proportion of idle land than in the northern part of this irrigation district and in other irrigated parts of the watershed.

202. The character of the soils of this marginal-land area and the high cost of irrigation water are the main factors that operate in preventing better yields. Within this area are scattered patches (locally known as "slick" land) that are not suitable for irrigation, because of heavy soil texture and claypan, which hinder the penetration of water(37).

203. Farmers in this marginal-land area reported that under deep plowing, slow irrigation, and crop rotation with alfalfa, crop yields are about the same as in other parts of the district; but with usual methods, much lower yields are obtained than elsewhere in the watershed. Deep plowing and slow irrigation, however, are expensive. Further, because of extensive tenancy in this area, many farm operators are not inclined to grow alfalfa for soil improvement. Should farm prices advance or the cost of irrigation decline, the economic problem in this area might disappear. On the other hand, lower farm prices would undoubtedly intensify the problem and might result in throwing some of this land out of use.

Influence of Floods on Agricultural Credit

204. The Federal Land Bank of Berkeley has established a policy that farm real estate loans in Queen Creek basin shall be confined to the Salt River Project. No loans are being made in the Roosevelt Water Conservation, Queen Creek, and Chandler Heights Irrigation Districts. However, Federal Land Bank officials state that flood hazards are not an important factor in the establishment of this policy. The high cost of irrigation water, the questionable status of underground water supplies, and the newness of the latter three irrigation projects are the primary considerations.

Future Agricultural Developments

205. The amount of water available for irrigation limits the acreage of crops grown in Queen Creek basin. Since water shortage and a lowering water table have already developed under the present crop acreage, no future expansion of crop acreage, on a permanent basis, is anticipated. In fact, the land-use consultants of the Arizona State Planning Board have recommended reduction of irrigated acreage in the Roosevelt Water Conservation District, because of inadequate ground-water supplies (57).

206. A large percentage of the privately owned land immediately to the east of the agricultural area is held speculatively by absentee owners in anticipation of future irrigation developments 8/. From

---

8/ Some of this land lies in Maricopa County Electrical District No. 5, organized in 1930 for the purpose of pump irrigation, but never developed. This nonirrigated land is held in tracts that average about one-quarter section in size.

In Taylor basin area and in the eastern part of the Sonoqui area, a considerable acreage is held by individuals under contract-of-purchase from the State in anticipation of irrigation developments. It was proposed at one time to build a reservoir on Queen Creek to irrigate land in this vicinity; but development did not take place. The right to the reservoir site (Whitlow Ranch dam site) has been forfeited. Irrigation wells are now proposed instead.

a physical point of view, these lands are well adapted to irrigation farming; but with a lowering water table, development of these lands for irrigation would be socially undesirable. However, under private initiative some socially ill-advised development might take place 9/. With insufficient water supply for acreage under present projects, such development would increase water shortage on lands already in use, and in the long run would likely reduce the total gross productivity of the watershed as well as increase capital investment and cost of irrigation. Restriction of development of irrigation on new lands by means of zoning or through the passage of ground-water law seems advisable 10/. A Federal policy denying all requests for loans or grants of money for use in this area would exercise some restrictive influence on unwise agricultural development.

207. In view of the fact that the present irrigated areas, with the exception of the Salt River Project, have been only recently developed and that farms are rather large, as compared with those of many older irrigated areas, some increase in the number of farms and in

---

9/ Depth to water table in the undeveloped area varies from 100 to 400 feet, and is mostly in excess of 175 feet. Beyond the latter limit, pumping costs are considered prohibitive with present farm prices and pumping power rates.

10/ Zoning, whether rural land-use zoning or flood-plain zoning, is not legally possible in Arizona, because of lack of necessary legislation, and would require the passage of an enabling act. A change in the State water code, declaring all ground water subject to appropriation along lines similar to those now used to control appropriation of surface water, should be an effective means for restricting the development of additional pump-irrigated lands where such development would cause the lowering of the water table. A study of ground-water law in Arizona and neighboring States has recently been made by the University of Arizona, and the recommendations made in connection therewith include the above mentioned amendments to the water code (58).

intensity of farming might take place. A gradual shift from highly specialized cotton farming to more alfalfa and livestock, with cotton as the predominant crop, might occur on the more recently developed lands.

Grazing

208. The mountainous and foothill lands in the eastern and northern parts of this watershed are used mostly as yearlong ranges, whereas the nearly level valley lands with desert vegetation are used mainly for seasonal grazing.

Yearlong Ranges

209. The mountainous-foothill areas are used in the production of calves and yearlings. The four larger outfits that use these lands own or lease irrigated farms, or pastures, in the Salt and Gila River Valleys, which furnish feed and pasturage for the fattening period, pasturage for the cattle in case of drought, and forage for supplemental range feeding when needed. Most of the eight smaller outfits that use this yearlong range do not depend on cattle raising as their sole sources of income.

Seasonal Ranges

210. The valley range is grazed seasonally by both sheep and cattle 11/. Sheep are summered in the mountainous country of central Arizona, and are brought down to farm pastures in the Salt River Valley in the fall for lambing and winter feeding. Most sheepmen are renters of farm pastures. The pasturage is usually alfalfa, with some fall-sown barley. During years favorable for forage growth, sheep and

---

11/ About 25 operators, exclusive of Indians, graze livestock on the valley range.

lambs are put on the desert range in early spring (Feb., Mar., or Apr.). Fat spring lambs are usually sold in April (56). Sheepmen report that desert range, when at its best, provides as good forage for fattening lambs as do irrigated pastures.

211. Most of the valley-range lands exhibit wide fluctuations in forage production from year to year, as determined by rainfall and temperature. Since sheepmen cannot depend on grazing this range every spring, they arrange to stay on alfalfa pasture for finishing lambs for early spring delivery when desert conditions are unsatisfactory. Although in exceptionally favorable seasons sheep can be grazed on the desert range for a period of 3 months, the average period for which these range lands are used is probably less than 1 month in a year. This takes into account the fact that in some seasons there is no grazing. The desert forage, when available, has a high value per animal unit for seasonal sheep grazing, since the alternative is to use irrigated farm pastures at a rental cost of from ½ cent to 2 cents per ewe per day ($0.75 to $3.00 per animal unit month).

212. Cattlemen in the valley area, like the sheepmen, can depend only to a limited extent on the desert range, and hence must have in addition either yearlong mountainous range or irrigated pasture, or a combination of both.

Grazing Capacity and Number of Livestock

213. The range lands of this watershed, altogether, are estimated to have a total grazing capacity sufficient to support about 2,000 animal units yearlong (or the equivalent thereof on the seasonal basis). Of this total, 1,250 animal units are for the mountainous-foothill range, which is about 4 animal units per section of land,

and 750 animal units are for the valley range, or about 2 animal units per section, making an average for the whole watershed of 3 animal units per section. The range conditions at the time of this survey indicated considerable stock in excess of grazing capacity. Because of excessive stocking, the vegetation has deteriorated, with consequent loss of grazing values.

Land Tenure and Management

214. The ranges in this watershed include private lands and lands under the control of State and Federal agencies (see map 4). Exclusive of the national-forest areas, practically all range lands, public and private, are leased. While lease contracts of State lands and public domain usually specify that there shall be no waste committed by the lessees, the responsible agencies do not administer these lands with a view to good range management.

215. National forests. In the Crook and Tonto National Forest areas, a permit system is in operation. These forests were established between 1905 and 1909 for watershed protection (31). Grazing permits have been issued to local ranchers covering yearlong use on the Queen Creek watershed. Past use under established preferences, however, has resulted in overuse of the range. Because of this, most of the allowable protective reductions under the limitations of the 5-year policy, ending with 1940, have been made. Additional needed reductions, however, can be administratively effected after 1940, in accordance with range-protection needs.

216. Indian lands. The Gila River Indian Reservation grazing lands in this watershed are not at present under regulated grazing. However, these lands are lightly grazed by Indian-owned stock; and

if grazing should become more intense, the Indian Service would likely place restrictions in effect.

217. Other Federal lands. Most of the public domain in this watershed is leased to the same ranchers who have national-forest grazing permits. No restrictions are made as to numbers of livestock to be grazed. Until a more permanent policy is established, most of the vacant public lands are leased for 1-year terms, subject to renewal for like periods. Lease rates are fixed separately for each lease. On leases approved in 1936 and 1937, the lease rates varied from 3/4 cent to 1½ cents per acre. Lands outside the national-forest boundaries that are subject to reclamation withdrawal have in the past been administered by the Bureau of Reclamation; but until reorganization of the administration of such land under the Taylor Grazing Act is effected, these lands are being grazed free of charge and without control.

218. State lands. State lands are leased to stockmen for periods of 5 years at a rental of 1½ cents per acre, with no restriction as to the numbers of stock to be grazed [12]. Rental rates in the past have been set at 3 cents per acre, and may return to the same level.

219. Private lands. The proportion of range lands in private ownership in the mountainous-foothill range area is negligible. In the valley-range area, the private lands, most all of which are held by nonresidents largely for speculation, are rented by stockmen largely on a

---

[12] There is in progress at present a State-sponsored W.P.A. project designed to classify all State lands under the jurisdiction of the Arizona State Land Department. This classification is to be used as a guide in the management, sale, and rental of these lands. The grazing capacity of State lands will be estimated.

year-to-year basis 13/, or are grazed trespass. There is no limitation on, or control of, livestock numbers on these private lands.

Value of Range Lands

220\. Privately owned lands east of the cultivated area, which are held for speculative purposes, are valued at about $10 per acre. For grazing purposes, the productivity value of these and most other lands in Queen Creek Watershed probably does not exceed $1 per acre.

Tax Delinquency

221\. At present, more than 90 percent of the speculatively held private grazing lands in Maricopa County east of the cultivated area is tax delinquent.

Mining

222\. About one-third of the people in Queen Creek watershed derive their support directly and indirectly from mining. There are about 3,000 acres in mining claims in this watershed, most of which are in the vicinity of Superior in the upper Queen Creek drainage area (map 9). The Magma Copper Company, which operates most of the mines at Superior, has reported that in 1937 the sales of minerals (copper, gold, and silver) amounted to more than $4,000,000 (45). Most of the mining lands are also used for grazing.

13/ The privately owned valley-range lands south of Queen Creek channel are usually leased at from 3 to 10 cents per acre per year. These lands are rented almost exclusively by three or four large ranchers. North of Queen Creek channel, rentals are usually in lump sums, ranging from $15 to $75 per section per year. These lands are mostly rented to smaller operators, some renting as few as 160 acres. Some lands are rented only when forage is available, the rentals in such cases being upwards of 15 cents per sheep month or 50 cents per cattle month. Other lands are turned over to ranchers in exchange for payment of taxes.

Recreation and Wildlife

223. Lands used for recreation include the Boyce Thompson Southwestern Arboretum, a privately endowed foundation, open to the public, and Oak Flat, a picnicking area above Superior, set aside by the Forest Service (map 9). Livestock are excluded from both these areas.

224. The proximity of Queen Creek watershed to the population center of Arizona makes wildlife an important asset. Parts of the national forests that are inaccessible to livestock are excellent habitats for game, particularly quail, mountain sheep, javalinas (wild hogs), and rabbits. The desert range provides sportsmen with Gambel quail and rabbits. The Arizona Game and Fish Commission has established three game refuges wholly or partly within this watershed.

Production of Fuel Wood

225. The cutting of fuel wood (mostly mesquite and ironwood), once extensive, now produces gross returns estimated at not over $5,000 annually. The cutting of fuel wood on a sustained-yield basis is authorized on the national-forest areas. On most other lands there are no effective wood-cutting regulations.

HYDROLOGY

226. The following discussion of hydrology of Queen Creek basin centers mainly on the storms of flood-producing magnitude, which may be classed as (a) short-duration, high-intensity, storms of frequent occurrence (typical of summer rains) and (b) widespread, prolonged storms of low intensity (typical of winter rainstorms). Included in each of these two broad classes are the heavier rains and also great, or unusual, rainstorms.

Storm Records

227. The rain-gaging stations on and near Queen Creek watershed are so scattered and far apart that any isohyetal map of flood-producing storms based on such few and far-between records would have little or no value. There are given, instead, in the following table, the precipitation data recorded at the various stations on the dates of the reported occurrences of floods on this watershed since 1914, the year of the first reported occurrences of damaging floods.

The Heavier Storms

228. There are no satisfactory rainfall-intensity records for stations on and near Queen Creek basin that show during a storm the highest rainfall by minute and hour periods.

The Heavier Summer-Type Rains

229. Typical of the heavier summer thunderstorms may be mentioned the one that occurred at the Parker Creek Branch of the Southwestern

Summary Rainfalls on Dates of Floods 1/
Queen Creek Watershed

Station	Elevation	1914		1915		1925			1925			1925				1926				1926			1926			1927			
		September		August		July			August			September				April				July			September			August			
		15th	16th	26th	27th	1st	2nd	3rd	28th	29th	30th	16th	17th	18th	19th	4th	5th	6th	7th	26th	27th	28th	25th	26th	27th	15th	16th	17th	18th
	Feet	Inches		Inches		Inches			Inches			Inches				Inches				Inches			Inches			Inches			
Pinal Ranch	4,520		2.04	3.43		.56		2.21							1.63		1.00	.95			1.19			1.12	1.06		.90		
Miami	3,603		.80		1.51								.94		.93			1.27				1.15		.98					
Superior	2,990	No record		No record				1.05			1.53			1.20			.73	.94		1.43						1.83			
Arboretum	2,800	No record		No record			.77				1.97			1.38			.75				1.15					.95			1.38
Roosevelt	2,275				1.25								.67		.62			1.14	1.03		.84				.56				
Florence	1,500				.67							1.99		1.40						.85				1.35					
Granite Reef Dam	1,325													1.65				1.72		No record			No record						
Mesa	1,245	No record										.89					.76							.98					
Chandler	1,213											1.00						.63			.50			.94					
Goulds Ranch	1,195	No record												.50			.91							.65					
Phoenix	1,108												.68				1.30			1.21				2.62					

Station	Elevation	1930			1930			1931			1931		1932		1932				1933			1934			1936			1936
		July			August			August			September		July		October				September			August			July			August
		7th	8th	9th	7th	8th	9th	7th	8th	9th	13th	19th	1st	2nd	8th	9th	12th	13th	8th	9th	10th	3rd	4th	5th	23rd	25th	26th	20th
	Feet	Inches			Inches			Inches			Inches		Inches		Inches				Inches			Inches			Inches			Inches
Pinal Ranch	4,520					1.52	.79					.64		1.61		.67		.78		3.10					1.40			
Miami	3,603					.94			1.35			.58		1.60		.92				2.10							1.15	1.40
Superior	2,990		.50		3.06	.50							.94		.50		1.55		2.65							.80		
Arboretum	2,800		.72			1.75			1.15		.58							.65	2.30		1.18							
Roosevelt	2,275		.78			.61										.58				1.66	.64						.53	
Florence	1,500			.65		.75				.61											.99						1.45	
Granite Reef Dam	1,325		1.03			.79										.62						No record						
Mesa	1,245		.83						.72						.55				.92							1.82	1.78	
Chandler	1,213		.75						1.03										1.20			No record			No record			No record
Goulds Ranch	1,195												.53		.60	1.27							1.28					
Phoenix	1,108														1.04	.62			1.33							1.12	1.23	

1/ No rainfall less than .5 inch in 24 hours is listed.
Note: Blank spaces interpreted to mean no rainfall greater than .5 inch was recorded.

Continued——

(Continued)

Winter Rainfall on Dates of Floods 1/
Queen Creek Watershed

Station	Elevation	1914			1915			1915	1915			1916				1916				1916			1917			1919		1919
		December			February			March	December			January				February				March			January			February		February
		17th	18th	19th	11th	19th	20th	2nd	30th	31st	1st	15th	16th	17th	18th	26th	27th	28th	29th	22nd	23rd	24th	19th	20th	21st	1st	2nd	12th
	Feet	Inches			Inches			Inches	Inches			Inches				Inches				Inches			Inches			Inches		Inches
Pinal Ranch	4,520	1.40	2.21	2.30	1.37			.74	.85	.87		2.36	2.25	2.00		2.22	1.26		1.08	.52	.95	1.50		1.84	1.22	1.78		1.60
Miami	3,603				1.08		1.12	.92	.66	.74	.53		1.57	1.18	.80	.54		1.59	.53		.87	.78		1.11	.75	1.35	.85	
Superior	2,990	No record			No record			No record	No record			No record				No record				No record			No record			No record		No record
Arboretum	2,800	No record			No record			No record	No record			No record				No record				No record			No record			No record		No record
Roosevelt	2,275				1.04		.65	.78	.51	1.80		.90	1.64	2.53	1.26		1.10	.80			.93			1.30		1.02	1.28	.93
Florence	1,500		1.38	1.00	.88	.61		1.09		1.85								.54		1.33	.74			.98				No record
Granite Reef Dam	1,325		1.95	.71					.56	1.82			1.06	.67							.51							
Mesa	1,245	No record				.71			.60	1.73		.50	.87	.64										1.05				
Chandler	1,213	No record				.52				2.04		1.75												1.35		.71		
Goulds Ranch	1,195	No record			.70				1.20	1.10													1.25					
Phoenix	1,108		.79	.50	.54	.64			1.54				1.05										.83					

Station	Elevation	1920			1920		1926				1930			1931					1931			1931		1932			1932			1932			
		January			February		March				January			February					November			December		February			February			December			
		3rd	4th	5th	20th	21st	26th	27th	28th	29th	11th	12th	13th	12th	13th	14th	15th	16th	20th	21st	22nd	9th	10th	9th	10th	11th	15th	16th	18th	12th	13th	14th	15th
	Feet	Inches			Inches		Inches				Inches			Inches					Inches			Inches		Inches			Inches			Inches			
Pinal Ranch	4,520	2.00	.71	.60	.58	2.74					.93	1.45	.53		2.50	1.31	.94	.35				3.05				1.50					1.18		
Miami	3,603	1.42			1.37						.80	1.08	.50		2.10	.57	1.15				2.00		2.80		2.10			.50			.72	1.40	1.51
Superior	2,990	No record							1.30		.98			1.83	.78	.57	.74			2.57		2.11		1.30	.75		.74		.61	.52	.95	1.62	
Arboretum	2,800	No record			No record				1.58		1.02	.94		1.91		.65				2.50			2.42	1.30	.30		.90		.56				
Roosevelt	2,275		1.64				.56				.65	1.43			2.20	.86	1.45				2.80		2.45		1.51			.55			1.07	1.20	1.53
Florence	1,500	No record			No record					1.40				.91	.70	.51			.31	.96		.55	.35	.52	.71		.50					.76	.52
Granite Reef Dam	1,325		.98							1.45		.78		1.20		.61			1.08	.54					1.00						.78	.50	.80
Mesa	1,245		1.31						1.62			.60		.67	1.21	.94				1.03		1.00		1.18						.76		.61	
Chandler	1,213		1.45							2.00	.52			.56		.55	.64			.90			1.05							.77		.58	
Goulds Ranch	1,195									1.50	.76			.57	.53	1.15				.72				1.35			.60						
Phoenix	1,108				.55			.91						.74	.82	.92				.56			.88										

1/ No rainfall less than .5 inch in 24 hours is listed.
Note: Blank spaces interpreted to mean no rainfall greater than .5 inch was recorded.

Continued——

Winter Rainfall on Dates of Floods 1/, Queen Creek Watershed (Continued)

Station	Elevation	1933		1935				1936			1936	1937
		January		March				February			February	February
		20th	21st	2nd	3rd	4th	5th	15th	16th	17th	23rd	12th
	Feet	Inches		Inches				Inches			Inches	Inches
Pinal Ranch	4,520				1.84	.97		.73	1.53	1.25		
Miami	3,603		.92		1.42				.72	.58		
Superior	2,990	1.15		1.28	.78			.94	.75			
Arboretum	2,800	1.10				1.73						
Roosevelt	2,275		.93		1.69				.65	.65		
Florence	1,500		1.00		1.11							
Granite Reef Dam	1,325		.95				.72					
Mesa	1,245	.96		.56								
Chandler	1,213	.77		No record				No record			No record	No record
Goulds Ranch	1,195	.80										
Phoenix	1,108	.77		.52								

1/ No rainfall less than .5 inch in 24 hours is listed.

Note: Blank spaces interpreted to mean no rainfall greater than .5 inch was recorded.

Forest and Range Experiment Station, Arizona, 35 miles north of the east point of Queen Creek watershed, on September 10, 1933, and another that occurred at Tucson, Arizona, on July 31, 1935. Data pertaining to the intensity of those two storms follow:

Table 10. - Maximum Rainfalls in Minute Periods [1]

Parker Creek (elev. 5,200 ft.)[2]

5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	55 min.	60 min.	80 min.	100 min.	120 min.
In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
0.54	0.95	1.26	1.48	1.80	2.11	2.32	2.57	2.74	2.83	2.90	2.98	3.16	3.23	3.25
Tucson (elev. 2,423 ft.)[3]														
0.45	0.85	1.25	1.44	1.68	1.83	1.88	1.94	2.00	2.02	2.03	2.04			

---

[1] The rainfall given for each period is not cumulative. For example, the fall of 2.98 inches in 60 minutes in the Parker Creek rain is the maximum fall in any 60-minute period during that storm. It happens, however, that after the first 20 minutes of the Parker Creek storm the figures given (min. and fall) for each period occurred consecutively, that is, the maximum fall in 40 minutes occurred in the first 40 minutes of that storm.
[2] Maximum storm in a 6-year intensity record.
[3] Maximum storm in a 7-year intensity record.
Compiled from unpublished records of the Southwestern Forest and Range Experiment Station and of the University of Arizona.

230. The Parker Creek record, taken on a south slope of Sierra Ancha, may be regarded as typical of the high rainfalls at elevations above 2,500 feet in the Pinal Mountains area of Queen Creek watershed; whereas the Tucson record, taken at the University of Arizona, may be regarded as typical of the high rainfalls at elevations below 2,500 feet, and may therefore be representative of the alluvial-plain part of the watershed. The Parker Creek, or high-country, storm lasted 2 hours, during which time 3.25 inches of rain fell. The Tucson, or low-country, storm lasted 1 hour, during which time 2.04 inches of rain fell. Such storms

on Queen Creek watershed result in high surface run-off from comparatively small areas, and cause local flash flows which may contribute to floods.

231. Frequency of the heavier summer rains. Experience in the vicinities of Parker Creek and Tucson indicates that summer rains of such magnitudes as 3.25 inches of fall in 2 hours and 2 inches of fall in 1 hour would probably happen in Queen Creek basin once in about 10 or 20 years. Storms of lesser intensity and of flood-producing magnitude may occur one or more times in a single summer season and not again for several years. According to the testimony submitted at the public hearing before the district engineer, War Department (20), regarding the flood problems on Queen Creek watershed, to information from C. H. W. Smith, chief engineer for the Roosevelt Water Conservation District, and other residents, summer storms have caused 20 floods on this watershed during the 24-year period from 1914 to 1937, inclusive (see under "History of floods," par. 242).

The Heavier Winter Storms

232. During the 24-year period from 1914 to 1937, there occurred 25 winter rainstorms that caused as many floods on Queen Creek watershed, or an average of one a year. The intensities of the heavier storms are assumed to have ranged from 0.15 to 0.50 inch of fall in 1 hour's time, based on the intensity of winter rainstorms at Parker Creek. Winter-type rains of lesser magnitude may last from 2 to 4 days, with from 2 to 4 inches of total rainfall, and may occur several times during a single winter season, whereas

in other years the winter season may be free of such storms. Occasionally, winter rainstorms with a total of about 8 inches of rainfall may occur, lasting about 5 days.

Unusual or Great Storms

233. No storm on record on and near Queen Creek watershed is considered sufficiently large to form the basis for designing major flood-control structures on this watershed. Unusual or great storms, both summer and winter, are taken into consideration.

Unusual Summer Rainstorms

234. Unusual summer-type rainstorms may occur on Queen Creek watershed, whose local concentrated rainfalls may occur between rain-gaging stations, and hence without records. Of the unusual summer rainstorms, there are those of infrequent occurrence that cover large areas, on a given area of which, at different points, there may occur various local intense rainfalls. It is not known that such a storm has ever occurred in this basin. However, known heavy rainstorms that have occurred in similar areas in the Southwest indicate the intensity and magnitude of unusual summer rains on the desert plain of Queen Creek basin, which magnitudes according to the following list, have been as great as 8 inches of rainfall in 45 minutes (local downpour), 6.5 inches in 2 hours, and 4.15 inches in 2 hours.

Station	Date	Magnitude of storm
Albuquerque, N. Mex.	Oct. 9, 1865	5.2 inches in 5 hours
El Paso, Tex.	July 9, 1881	6.5 inches in 2 hours 14/

14/ Communication from R. M. Shaver (Weather Bureau), El Paso, November 5, 1938. Record questioned by other authorities.

Station	Date	Magnitude of storm
Ft. Mojave, Ariz.	Aug. 28, 1898	8.0 inches in 45 minutes [15]
Pinal Ranch, Ariz.	Sept. 26, 1905	3.55 inches in 24 hours
Casa Grande Ruins, Ariz.	Aug. 1, 1906	5.4 inches in 6½ hours [16]
Desert Laboratory, Tucson, Ariz.	July 22, 1910	5.01 inches in 3 hours [17]
Roswell, N. Mex.	Aug. 8, 1916	2.78 inches in 2 hours
Roswell, N. Mex.	Sept. 14, 1923	2.34 inches in 80 minutes
Roswell, N. Mex.	Sept. 16, 1923	2.69 inches in 100 minutes
Superior, Ariz.	Aug. 1917	2.34 inches in 50 minutes [18]
Hermosa, N. Mex.	Aug. 31, 1925	6.35 inches in less than 12 hr.
Parker Creek, Ariz.	Sept. 10, 1933	3.24 inches in 2 hours
Santa Marguerita, Ariz.	Aug. 22, 1935	4.1 inches in 1½ hours [19]
Las Cruces, N. Mex.	Aug. 29, 1935	(4.15 inches in 2 hours (6.49 inches in 9 hours [20]

The Las Cruces storm covered about 125 square miles, with varying intensity. On about 2.5 square miles a total of 8 and more inches of rain fell; on about 7 square miles, a total of 7 and more inches; on about 38 square miles, a total of 6 and more inches; and on about 50 square miles, a total of 5 and more inches of rain fell.

235. The maximum 24-hour summer precipitations recorded each year of record for four stations in and near Queen Creek watershed are plotted in figure 20. These data are for the 4 summer months only, June to September, inclusive. It is generally true that the 1-day summer rainfalls on this watershed actually occur in a few hours. The graph of figure20 shows that the magnitudes of the

---

[15] Probably too high, not measured in standard rain gage.
[16] Weather Bureau communication.
[17] Storm duration estimated from temperature and barometric records.
[18] Mr. Dentzer, Magma Copper Co., Superior, asserted that this amount fell in 50 minutes.
[19] Most of this fell in 2 hours. Communication from Weather Bureau.
[20] Unpublished Rept. on Las Cruces Flood, by H. W. Yeo, S. C. S., Rio Grande District. Rainfall recorded on the New Mexico Agricultural College rain gage.

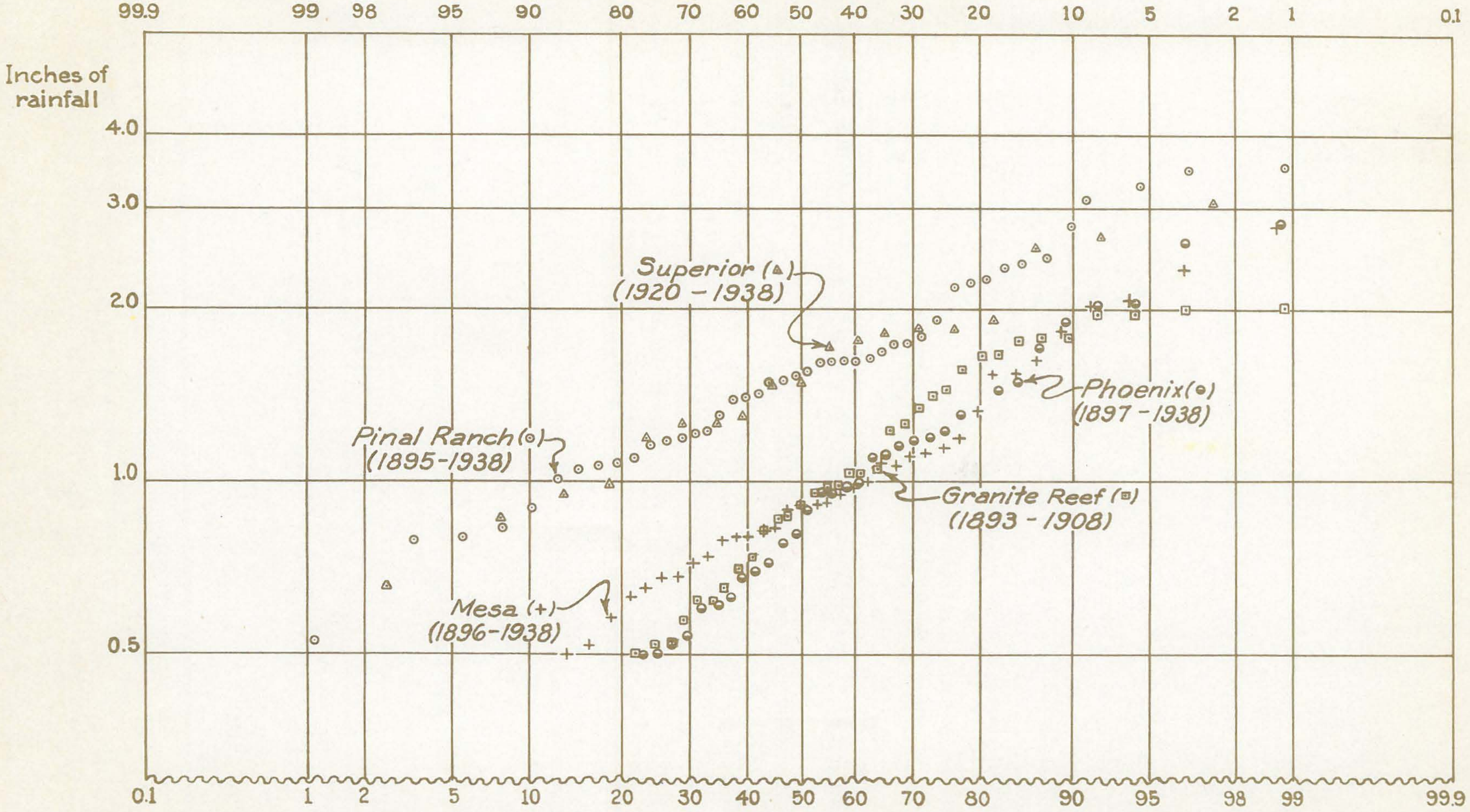


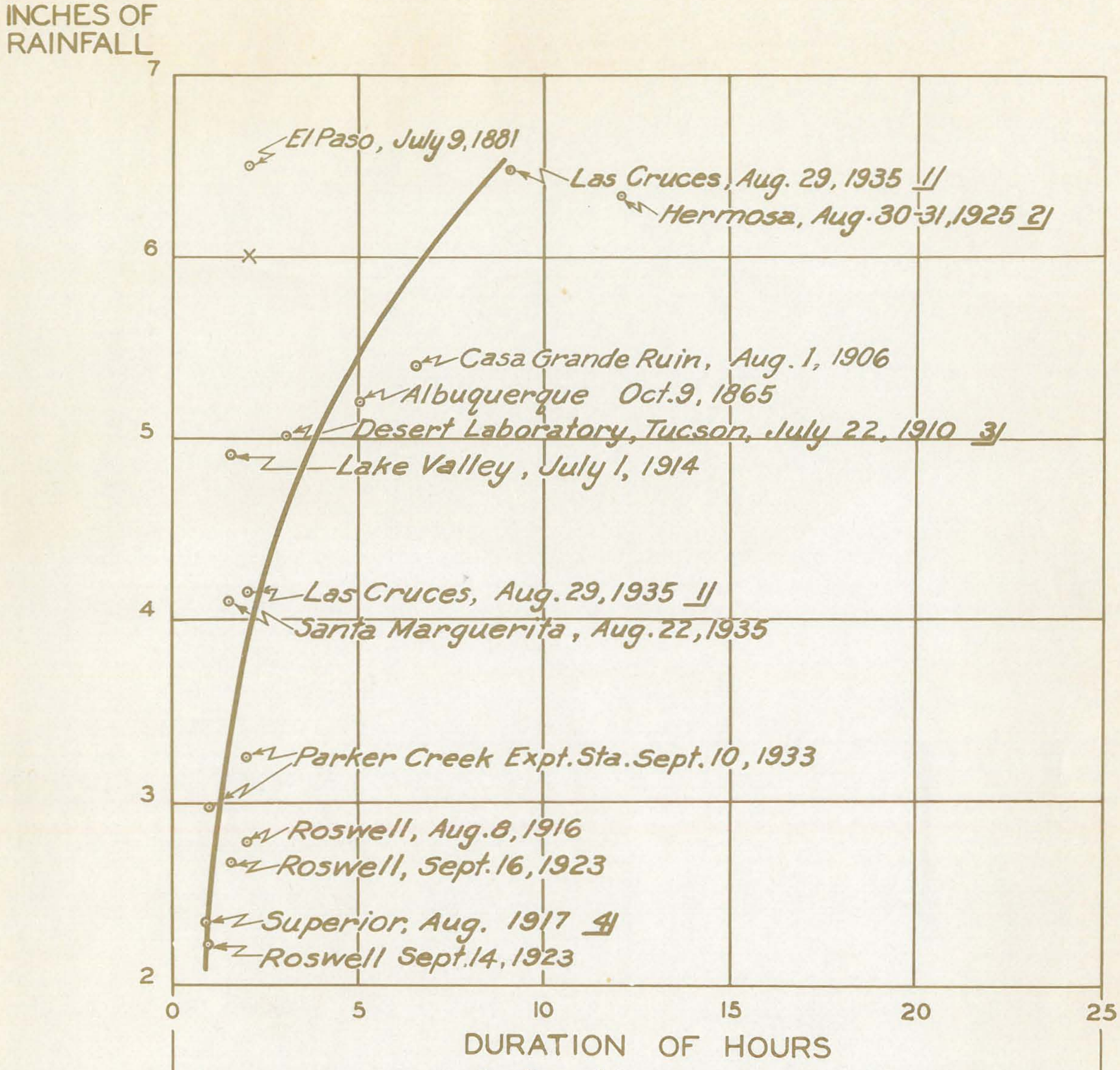
Fig. 20 —Maximum 1-day rainfalls in each summer period of record—June-September, inclusive. For maximum 1-day summer rains of from 1- to 3-year frequency, there is a wide spread in magnitude between rains at low elevations (Mesa, Granite Reef, and Phoenix) and those of high elevations (Pinal Ranch and Superior). For less frequent summer rains (10- to 100-year frequency), those of low elevations are of only slightly less magnitude than those of high elevations. (Hazen method.)

maximum summer rainfall of any particular frequency are nearly the same for Superior (elev. 2,990 ft.) as for Pinal Ranch (elev. 4,520 ft.). The graph also indicates that on this watershed the maximum summer rain of any particular frequency increases generally with elevation up to about 3,000 feet. At greater elevations there is no significant increase. The greater the magnitude of the rain, the more nearly do the maximum rainfalls at low elevations approach those at higher elevations.

236. Magnitude of great summer storm. From the known distribution of the great storm at Las Cruces, N. Mex. (par. 234), one may well assume that a great summer storm on the alluvial-plain part of Queen Creek watershed would cover a larger area at any particular moment than a lesser storm of high intensity like the Ft. Mojave storm. Based on the foregoing facts, a summer-type storm in which 6 and more inches of rain falls in 2 hours on 16 square miles (about 10,000 a.) is used in this report as the basis for designing the dikes on the lower part of the watershed. (See fig. 21.) A storm with such a concentrated rainfall would cover more than 16 square miles, with zones of lesser intensities. The frequency of such a storm is probably less than one occurrence in 100 years.

Unusual Winter Rainstorms

237. The largest winter storm experienced on Queen Creek watershed since 1914, when the first definite records of damaging floods were reported, occurred January 15-20, 1916. This storm period was about 5 days. In 72 consecutive hours (3 days), the rain-gaging station at Mesa (elev. 1,245 ft.) recorded a total rainfall of 1.8 inches; at Granite Reef Dam (elev. 1,325 ft.), a few



Ft. Mojave, Ariz. 8.0" in 45 minutes, Aug. 28, 1898. "Believed reliable though not measured in standard gage." Pickels, "Drainage and Flood Control Engineering."

1/ Unpublished feport H. W. Yeo, SCS Rio Grande District "Las Cruces Flood, 1935".

2/ Less than 12 hours. U. S. Weather Bureau.

3/ Duration estimated from temperature records.

4/ Personal communication from E. G. Dentzer, Magma Copper Company.

Fig. 21-Unusual summer rains in the Southwest. The curve approximates the magnitude duration of great summer rainfalls in the Southwest. Note that a storm with magnitude at 6 inches of rainfall in 2 hours (x) exceeds the curve. Such a storm may be expected less frequently than the storms represented by the curve.

miles north of the watershed's northwest boundary (map 10), a total fall of 2.2 inches was recorded; and at Pinal Ranch (elev. 4,520 ft.), a total fall of 6.7 inches. Owing to the fact that the rainfall varied generally with elevation, the average fall on upper Queen Creek drainage area (about 182 sq. miles above Black Point narrows) must have been less than at Pinal Ranch. The average fall on this high area is interpolated to have between 5.5 and 6.5 inches in 72 hours.

238. The hydrology on which the proposed major dam on upper Queen Creek is designed by the Army engineers, including a great winter storm and also a great summer storm on upper Queen Creek drainage area, is discussed in "Hydrology of Queen Creek Area, Arizona," enclosure 4, War Department Survey Report, Flood Control, Queen Creek, Arizona, March 1, 1940.

Normal Stream Flows

239. All stream flows in Queen Creek watershed are ephemeral during the summer months. The upper part of a few of the largest ones had continuous low winter flows up to the time when the town of Superior was established, about 1880. In fact, Queen Creek, the principal stream, was perennial down nearly to the foot of Pinal Mountains until about 1910; but now its continuous winter flow — from 15 to 30 second-feet — sinks into the stream bed just below Superior. During summer its entire channel is dry, except during storms. In winter this stream is usually clear and free from suspended materials, but is muddy during high winter and all summer flows. Although the channel of lower Queen Creek, on the

alluvial plain, is dry most of the time, water has flowed down this drainageway as far as the Roosevelt Canal as many as 10 times a year (par. 249). The waters that Queen Creek contributes to damaging floods are of the heavier flows which result from high rainfalls on the upper part of the watershed.

240. Other drainages on Queen Creek watershed -- those that head in the Superstition, Goldfield, Santan and Goldmine Mountains -- have ephemeral flows during both the summer and winter months. The quantity of water discharged during a flow and the distance that the water flows before sinking into the channel beds are determined largely by storm intensity and duration. The flows in these drainages from the lesser rains do not reach the flood-damage areas. In general, the flows in these drainageways from heavy rains are characterized by sudden rises in previously dry channels, with momentary high peaks. The flows may carry and move heavy loads of erosion products, especially on the upper part of the plain and on the hilly and foothill areas. Even after heavy storms these ephemeral streams usually dry up quickly. Only a few of the drainage channels on the Superstition and Goldfield Mountain areas extend to the Roosevelt Canal.

Channel Capacities and Gradients

241. On the mountainous parts of this watershed, except in a few small basins, even the high flows stay within the channels, moving with high velocities down steep gradients to the alluvial plain.

242. Upper Queen Creek capacity. An estimate of 10,000 second-feet has been recorded in upper Queen Creek channel at Whitlow Ranch

dam site, about 3 miles above Black Point narrows. Except a few small areas, the channels of the upper Queen Creek drainage areas are considered adequate to carry the discharges from the great storms.

243. Lower Queen Creek. The channels of lower Queen Creek for about 11 miles below Black Point narrows are sufficiently large to accommodate discharges from upper Queen Creek of about 18,000 acre-feet, with a peak of about 24,000 second-feet.

244. Immediately below Black Point narrows the gradient of the well-defined Queen Creek channel averages about 33 feet to the mile. Farther down, where the channel divides into a network, the gradient gradually decreases to about 22 feet per mile, as one approaches the railway bridge. Immediately below this bridge, for several miles, the channel gradients average about 16 feet to the mile, and the capacity of the larger channels is about 5,000 second-feet. Farther down the flood flows have often exceeded the total channel capacity, and in case of major floods, inundated between 3,000 and 4,000 acres. At or near the Roosevelt Canal there are no well-defined channels, and flows of 200 and more second-feet spread out over the land and cause breaks in the canal embankment. Some of the flood waters pass down onto the Gila River Indian Reservation, spreading out in the Snaketown district, but without any reported damages.

245. Superstition drainage channels. During the heavy July 1926 storm, the larger drainage channels on various parts of the Superstition and Goldfield Mountain areas, at points along and below the Mesa-Superior highway, carried measured flows of from 600 to 900 second-

feet (21), down rather uniform gradients which average about 60 feet to the mile. Only a few of the drainageways on these two desert areas extend to the Roosevelt Canal, the others fan out, and the waters discharged therefrom spread out in sheet flows.

Stream Discharges

246. During the 5 years of records by the U. S. Geological Survey, 1916 to 1920, inclusive (55), the maximum total monthly discharge of upper Queen Creek at Whitlow Ranch dam site (map 5) was estimated at 14,700 acre-feet (Jan. 1916). During this 5-year period of record, seven monthly flows of 2,000 and more acre-feet were recorded — two in 1916, three in 1917, one in 1919, and one in 1920. Three of these high flows were during summer and four during winter. Thus, the maximum total monthly flow of January 1916 was about five times the ordinary total monthly high flows. The discharges from Queen Creek drainage area, past and expected, are discussed fully in the report of the Army engineers.

247. Discharges from Superstition drainages. The flows of from 600 to 900 second-feet in the larger drainage channels on the Superstition and Goldfield Mountain areas, referred to in paragraph 245, gave an estimated total peak discharge of between 1,600 and 1,700 second-feet at the Roosevelt Canal. According to rough estimates of water-masters of the Roosevelt Water Conservation District, the total discharges at various points and along Roosevelt Canal from the Superstition area since October 1, 1931, have varied from 7 to 2,100 acre-feet. The largest discharges have resulted from summer-type storms.

Floods and Flood-Contributing Flows

248. Early historical records pertaining to the Southwest indicate that flood flows occurred in Queen Creek basin even when it had its original or natural vegetation. However, those flood flows did not occur with the flashy character of those of recent years (7, 8, 9, 48-53).

History of Floods

249. Floods in Queen Creek basin have not occurred with any regularity 21/. Records of the stream flows in the Gila watershed indicate the probability of high flows in the Queen Creek basin in 1891 and also 1905. According to the history of the reported floods since 1914, as many as four and five floods may occur in a single year. Summer floods have occurred as often as three times a year, likewise winter floods. Following is a table of 20 summer and 25 winter floods in Queen Creek basin since 1914, based on reported occurrences, together with the best available information as to probable sources of the flood-contributing flows, flood-flow discharges, areas inundated, and the nature of damages. The dates in this list have been drawn from several uncorrelated sources each of which is incomplete, and what constitutes a flood in several of these sources has been defined arbitrarily. Hence this list is subject to a wide error, and should not be considered a complete or uniform tabulation of all

---

21/ A flood in Queen Creek basin (since 1925-26) is considered as a concentration of water behind the Roosevelt Canal. Before 1926 (date of completion of Roosevelt Canal) flood may be defined as a flow of water onto the irrigated farming area.

floods. Inasmuch as the field survey of agricultural flood damages covered the period 1926-38, the data are more complete for this period than for the preceding period. According to this account, the summer floods of September 1925, July 1926, August 1931, September 1933, and July 1936 must have been outstanding. The greatest of the winter floods, so far as flow of water onto the agricultural area is concerned, was that of January 1916. It is to be noted that of the 20 summer floods, 8 occurred in the month of August, 5 in July, and 5 in September. Of the 25 winter floods, 11 occurred in February, and 5 in January. Ten of the summer floods were caused by the combined discharges from Queen Creek and the Superstition Mountain areas; six were caused by discharges from Queen Creek alone, and only 2 from Superstition area alone. The waters of 23 of the winter floods were contributed by Queen Creek alone, and only 2 by the Superstition Mountains area.

Table II - Reported Occurrences of Floods in Queen Creek Basin 1/
(Twenty-four years—Sept. 1914 to Dec. 1938)

Summer floods (Apr. to Oct., incl.)

Designation number	Date 2/	Source 3/	Source of data 4/	Notes 5/
1	Sept. 15-16 1914	Q	a	Washed out Arizona-Eastern Railway bridge near Queen Creek settlement.
2	Aug. (26), 1915	Q	b	"Floods" at Whitlow Ranch dam site reported by U. S. G. S.
3	Aug. 1917	Q	b	Discharge of 2,720 acre-feet at Whitlow Ranch dam site.
4	July 2-3, 1925	Q, S	c, d	Flow lasting 24 hours reported at Boyce Thompson Arboretum. Severe damage to newly constructed R. W. C. D. laterals.

Continued--

5	Aug. 30, 1925	Q	c	Large flow reported at Boyce Thompson Arboretum.
6	Sept. 18-19, 1925	Q, S	c,d,c	Maximum flows reported at Boyce Thompson Arboretum. Roads impassable. Severe damage to crops north of S. P. Railway southeast of Gilbert.
7	April (6), 1926	Q, S	f	Agricultural damages reported southeast of Gilbert. (Note: Roosevelt Canal completed in 1926.)
8	July 27, 1926	Q, S	d, f	Heavy flow of streams in Superstition area. Agricultural damage reported in R. W. C. D. southwest of Higley.
9	Sept. (26), 1926	Q, S	d, f	Agricultural damage reported southeast of Gilbert and southwest of Higley.
10	Aug. 16, 1927	Q	c, f	Very high flow reported at Boyce Thompson Arobretum on Aug. 15. Agricultural damage reported east of Gilbert and southeast of Chandler.
11	July 8, 1930	S	d, f	Canal and agricultural damage reported near Gilbert.
12	Aug. 8, 1930	Q, S	c,d,f	Large flow reported at Boyce Thompson Arboretum on Aug. 7-8. Canals damaged. Agricultural damage reported east and southeast of Gilbert near Higley and southeast of Chandler.
13	Aug. 8, 1931	Q, S	d,f,g,h,i	Peak flow of 6,000 second-feet in Queen Creek at Rittenhouse bridge. Roosevelt Canal broken in 127 places (east bank only) from Higley south. Agricultural damage in R. W. C. D. and in Queen Creek Irrigation District.
14	Sept. 1931	Sq	d	Two floods at Chandler Heights.
15	July (2), 1932	S	f	Agricultural damage reported northeast and southeast of Gilbert.

Continued—

16	Oct. 13, 1932	Q	i, j	Peak of 530 second-feet at Rittenhouse bridge. Discharge of 250 acre-feet from Queen Creek at Roosevelt Canal.
17	Sept. 8-11, 1933	Q, S	d,f,i, j	Discharge of 2,100 acre-feet from Superstition area and 2,250 acre-feet from Queen Creek at Roosevelt Canal. Peak of 4,500 second-feet in Queen Creek at Rittenhouse bridge. Severe canal, road, and agricultural damages. Gilbert flooded.
18	Aug. 4, 1934	Sq	d, f	A 2-inch rainfall in 40 minutes at Chandler Heights (unofficial record). Agricultural damages at Chandler Heights and extreme southern end of R. W. C. D.
19	July 24-25, 1936	Q, S	d,f,i, j	Discharge of 2,000 acre-feet from Superstition area and 500 acre-feet from Queen Creek at Roosevelt Canal. Peak of 2,000 second-feet in Queen Creek at Rittenhouse bridge. Severe crop, road, and canal damages.
20	Aug. 20-21, 1936	Q, S	f,i,j	Discharge of 300 acre-feet from Queen Creek at Roosevelt Canal. Peak of 700 second-feet in Queen Creek at Rittenhouse bridge. Agricultural damage east and northeast of Gilbert and south of Chandler along Consolidated Canal.

Winter floods (Nov. to May, incl.)

1	Dec. 18-19, 1914	Q	k	Crops of dry farmers east of Higley inundated. Train service delayed in Mesa-Winkleman branch of Southern Pacific Company. South part of Chandler flooded.
2	Feb. 1915	Q	b	"Floods" at Whitlow Ranch dam site.

Continued—

3	Mar. 1915	Q	b	"Floods" at Whitlow Ranch dam site.
4	Dec. 31, 1915	S	1	Consolidated and Eastern Canals out of banks. Water over railway tracks at Gilbert.
5	Jan. 15-20, 1916	Q	b,m,n	Discharge of 14,700 acre-feet at Whitlow Ranch dam site. Higley area flooded. State highway south of Higley impassable. Water broke into Consolidated Canal. South part of Chandler flooded. (Note: Roosevelt Canal not yet built, completed in 1926.)
6	Feb. (29), 1916	Q	b	Discharge of 2,700 acre-feet at Whitlow Ranch dam site.
7	Mar. (24), 1916	Q	b	Discharge of 2,460 acre-feet at Whitlow Ranch dam site.
8	Jan. (20), 1917	Q	b	Discharge of 2,470 acre-feet at Whitlow Ranch dam site.
9	Feb. (1), 1919	Q	b	Discharge of 2,880 acre-feet at Whitlow Ranch dam site.
10	Feb. (8), 1919	Q	b	Discharge of 2,860 acre-feet at Whitlow Ranch dam site.
11	Jan. (3-5), 1920	Q	b	Discharge of 2,050 acre-feet at Whitlow Ranch dam site.
12	Feb. (21), 1920	Q	b	Discharge of 2,380 acre-feet at Whitlow Ranch dam site.
13	Mar. 28, 1926	Q	c	"Full" flow reported in Queen Creek at Boyce Thompson Arboretum. (Note: Roosevelt Canal completed 1926.)
14	Jan. 11, 1930	Q	c	"Full" flow reported in Queen Creek at Boyce Thompson Arboretum.
15	Feb. 13-16, 1931	Q	o,p	A 4-day general storm over Arizona. Queen Creek reported to have run swiftly, but property near Higley was not damaged.

Continued—

16	Nov. 22, 1931	Q	i,j,q	Queen Creek reported "above normal". Discharge of 750 acre-feet from Queen Creek at Roosevelt Canal; peak of 3,000 second-feet at Rittenhouse bridge.
17	Dec. 10, 1931	Q	i,j	Discharge of 1,000 acre-feet from Queen Creek at Roosevelt Canal. Peak of 1,500 second-feet at Rittenhouse bridge.
18	Feb. 10, 1932	Q	i,j	Discharge of 800 acre-feet from Queen Creek at Roosevelt Canal. Peak of 1,600 second-feet at Rittenhouse bridge.
19	Feb. 16, 1932	Q	j	Discharge of 260 acre-feet from Queen Creek at Roosevelt Canal.
20	Dec. 15, 1932	Q	i,j	Discharge of 400 acre-feet from Queen Creek at Roosevelt Canal. Peak of 700 second-feet at Rittenhouse bridge.
21	Jan. 21, 1933	S	j	Discharge of 150 acre-feet from Superstition area at Roosevelt Canal.
22	Mar. 3-4, 1935	Q	i	Peak of 2,000 second-feet at Rittenhouse bridge.
23	Feb. 15-17, 1936	Q	i,j	Discharge of 2,600 acre-feet from Queen Creek at Roosevelt Canal. Peak of 500 second-feet at Rittenhouse bridge.
24	Feb. 24-25, 1936	Q	i,j	Discharge of 2,000 acre-feet from Queen Creek at Roosevelt Canal. Peak of 800 second-feet at Rittenhouse bridge.
25	Feb. 12, 1937	Q	r	Roads impassable between Higley and Rittenhouse.

1/ Other floods may have occurred, of which there are no available records.

2/ Days of months in parentheses are interpolated from rainfall records; no confirmation of date otherwise available.

3/ Sources of flows, determined by available evidences:

S, Flow from Superstition and/or Bulldog flood-source areas.

Q, Flow from Queen Creek flood-source area, with or without augmentation from Sonoqui flood-source area.

Sq, Flow from Sonoqui flood-source area.

4/ Key to sources of data:

- a, Mesa Daily Tribune, Mesa, Ariz., September 17, 1914.
- b, The months of discharges of 2,000 acre-feet and over at Whitlow Ranch dam site, between October 1915 and September 1920, and the reports of "floods" in Queen Creek in February, March, and August 1915 (not gaged) are taken from U. S. Geological Survey (55).
- c, Notes on stream flow of Queen Creek and Silver King Wash taken at Boyce Thompson Arboretum (unofficial), 1925-38.
- d, Maricopa County Flood Control Committee; report presented at public hearing, Mesa, Ariz., October 6, 1937.
- e, Lacy et al. vs. Phoenix and Eastern Railroad Co. et al., Maricopa County, No. 23156, 1937.
- f, Day (or month) in which farm property was damaged by floods in the period 1926-38 are from field survey of agricultural damages. (Reports by one farmer only and references to whole years not considered.)
- g, Chandler Arizonian, Chandler, Ariz., August 13, 1931.
- h, Map of canal damage from August 8, 1931, flood, C. H. W. Smith, Supt., R. W. C. D.
- i, Estimated peak discharges of Queen Creek at Rittenhouse highway bridge (R. W. C. D. between Aug. 1931 and Aug. 1936) disregarding flows of less than 500 second-feet.
- j, Estimated total run-off of Queen Creek and Superstition drainages at Roosevelt Canal (R. W. C. D. between Oct. 1931 and Aug. 1936); flows of less than 150 acre-feet from Superstition drainages and 200 acre-feet from Queen Creek disregarded.
- k, Mesa Daily Tribune, Mesa, Ariz., December 19-22, 1914.
- l, Chandler Arizonian, Chandler, Ariz., December 31, 1915.
- m, Chandler Arizonian, Chandler, Ariz., January 21, 1916.
- n, Mesa Daily Tribune, Mesa, Ariz., January 19-21, 1916.
- o, Mesa Journal Tribune, Mesa, Ariz., February 12, 1931.
- p, Arizona Republic, Phoenix, Ariz., February 16, 1931.
- q, Arizona Republic, Phoenix, Ariz., November 22, 1931.
- r, Chandler Arizonian, Chandler, Ariz., February 12, 1937.

5/ Discharge measured at Whitlow Ranch dam site is for the whole month indicated. Discharges estimated at Roosevelt Canal, notes on flows at Boyce Thompson Arboretum, and peak flows at Rittenhouse bridge are for the day or days indicated, unless otherwise stated.

Causes of Floods

250. Floods commonly of flashy nature in Queen Creek basin result from heavy precipitations on the watershed— of storms of high intensity for short periods (typical of summer-type rainstorms) and of rains of moderate intensities but which may last for several days (typ-

ical of winter-type rains). The precipitations of these storms fall on extensive areas of eroded lands with deteriorated vegetation, hence readily escape as surface run-off. Moreover, there are no adequate outlet channels in the lower part of this watershed to take care of the flood-flow discharges, hence the concentration of flood-flow waters and the frequent breaks in the canal embankment.

251. When this watershed had its natural vegetation, the normal flood flows were dissipated on the alluvial plain without widespread erosion. Now, as the result of overgrazing, together with the effects of roads, trails, cow paths, and highway and railway culverts, there are some active erosion channels extending almost entirely across the plain, and many more are in process of similar extension, all facilitating the accumulation of flood waters. Rainfall records (par. 227) do not indicate the minimum rainfall that, under present conditions, would cause a flood, because rainfall stations are too few and scattered to give a complete picture of the storms, and information relative to flood intensities is inadequate.

Flood-Source Areas

252. Flows contributing to floods have come largely from the Queen Creek, Superstition, and Bulldog areas (map 2). It is impossible to determine to what degree the Sonoqui area contributes to floods. Taylor basin area probably contributes to floods only during unusual storms.

Flood Discharges

253. The only flood-contributing flow in Queen Creek channel for which official run-off data are available is that of January 15-20, 1916.

This storm is described in paragraph 237. During 5 days of highest flow (Jan. 16 to 20, incl.), there was a total run-off of 8,400 acre-feet, or less than one-tenth acre-foot per acre.

254. Flow of flood-producing magnitude. What the minimum magnitude of a flow discharge from upper Queen Creek drainage must be to contribute to a flood at the agricultural area is indicated by a summer flow in 1938, caused by a local storm. On August 8 of that year, there occurred a flow in upper Queen Creek channel whose maximum rate of discharge at the highway bridge about 1½ miles northwest of Florence Junction (map 11) was estimated at 3,600 cubic feet per second. All except about 200 second-feet of the total flow, which lasted about 4 hours, was dissipated in the lower channel. The water that reached the Roosevelt Canal (about 200 sec.-ft.) caused one slight break in the embankment of that canal. Accordingly, it may be assumed that the Queen Creek channel below Black Point narrows and the agricultural area, when dry, will absorb a 4-hour flow whose peak is between 2,000 and 4,000 second-feet, and whose total volume is less than 1,000 acre-feet. From these observations, it may be concluded that before a summer flow in upper Queen Creek channel can become flood contributing, it must attain a peak equal to, or exceeding, 3,000 second-feet at the highway bridge about 1½ miles northwest of Florence Junction. As regards the winter performance of Queen Creek, a flow whose peak is somewhat less than 3,000 second-feet at the highway bridge would likely be flood contributing, if the flow lasts longer than 4 hours.

Flood Discharges, Superstition Area

255. During heavy rains, the various separate drainages in the Superstition area deliver flows of high magnitudes. Sometimes these drainages

produce tremendous run-offs from small areas. In a similar country on the north side of Salt River, not far from the northwestern boundary of Queen Creek watershed, a cloudburst produced a flow with a measured peak of 3,000 second-feet from a 2-square-mile area (21). In the latter part of July 1926, immediately after a heavy rain on the Superstition areas, engineers of the Salt River Project determined the peak flows at points on a survey line (for a proposed flood ditch) east of the Roosevelt Canal. The distance between this survey line and the canal varied from about 1 mile at its north end to about 9 miles at its south end. The peak flows in the washes and channels from this July storm along this survey line ranged from 11 to 635 second-feet (21).

256. Estimated flood discharges since 1931. According to rough estimates of flood discharges from Superstition area since 1931, made by watermasters of the Roosevelt Water Conservation District, the July 1926 discharge at the Roosevelt Canal was probably less than those from the Superstition area during September 1933 and July 1936, when total discharges at the Roosevelt Canal were estimated at 2,100 and 2,000 acre-feet, with peaks of not less than 2,000 and 3,000 second-feet respectively. (See also pars. 259 and 268.)

257. Flood discharge from great summer storm. It is assumed that the greatest flood-flow discharge from the Superstition area during a great summer storm, to be handled by the proposed Superstition Dike, would result if the concentrated-rainfall part of the storm (6 and more inches rainfall in 2 hrs. on 16 sq. miles) struck at a point immediately east of this dike. It is estimated that on this assumption and under present uncontrolled conditions there would be about a

66-percent run-off (see under "Infiltration," par. 270), thus giving a total discharge of 3,400 acre-feet at the dike, with a peak of about 16,000 second-feet. With minor structural treatment and range-use adjustments, this peak is expected to be reduced to 6,000 second-feet.

Flood Discharges From North Bulldog and Santan Areas

258. It is estimated that, without watershed treatment the North Bulldog and Santan areas would each contribute peak flows of 12,000 cubic feet per second from a 100-year summer storm, and with remedial measures, 6,000 cubic feet per second.

Simultaneous Flood Flows

259. According to residents of lower Queen Creek basin, the largest floods, but not necessarily the most damaging, are caused by discharges that come about the same time from different flood-source areas--expecially from Queen Creek, Superstition, and Bulldog areas--resulting from more or less widespread storms. Potent factors in relation to flood damages, in addition to volume and duration of flow, are peak flow and season. Some damage in the southern part of the Roosevelt Water Conservation District may result when discharges from Queen Creek, at the Roosevelt Canal, exceed about 200 second-feet, which is about the capacity of the flood gates and flood ditch to the east of this canal (par. 254). At points north of the railway to the Mesa-Superior highway, damages result from discharges (at the Roosevelt Canal) that equal and exceed 200 second-feet for about 3 hours 22/; at some points, less. In table 12 are significant data pertaining to floods, compiled from unpublished records of the Roosevelt Water Conservation District:

22/ A discharge of 200 second-feet for 3 hours is equivalent to about 50 acre-feet.

Table 12. - Flood Data, Queen Creek Watershed

Date 1/	From Superstition and Bulldog areas	From Queen Creek 2/		Damage
	Acre-feet	Acre-feet	Second-feet	Degree
1931 Aug. 8	No data	No data	6,000	Severe
Oct. 1	7	--	--	None
Nov. 12	19	--	--	None
Nov. 21	50	375)	3,000	Slight
Nov. 22	--	375)		
Dec. 10	50	1,000	1,500	Slight
1932 Feb. 10	10	800	1,600	Slight
Feb. 16	--	260	400	Slight
Feb. 19	--	50	No data	None
July 1	15	--	--	None
July 2	--	90	270	Slight
Aug. 25	40	10	No data	Slight
Oct. 8	25	--	--	None
Oct. 13	--	250	530	Slight
Oct. 22	50	--	--	None
Dec. 15	85	400	700	Slight
1933 Jan. 21	150	--	--	None
Jan. 31	100	--	--	None
Sept. 8	1,000	150)	4,500	Severe
Sept. 9	1,000	1,500)		
Sept. 10	100	400)		
Sept. 11	--	200)		
1934 June 24	50	--	--	Slight
1935 Mar. 3	--	250)	2,000	Slight
Mar. 4	--	425)		
1936 Feb. 15	--	600)	500	Considerable
Feb. 16	--	1,000)		
Feb. 17	--	1,000)		
Feb. 24	--	1,500)	800	Not much additional to that of Feb. 15-17, not yet repaired.
Feb. 25	--	500)		
July 24	500	--)	2,000	Severe
July 25	1,500	500)		
Aug. 20	150	100)	700	Slight
Aug. 21	--	200)		

Continued—

(Continued)

Table 12. - Flood Data, Queen Creek Watershed

Date 1/	From Superstition and Bulldog areas	From Queen Creek 2/		Damage
	Acre-feet	Acre-feet	Second-feet	Degree
1937 Feb. 17	No data	--	--	
Feb. 28	No data	--	--	
Mar. 16	No data	--	--	

1/ Observations began October 1, 1931.
2/ Estimates of maximum flows at Rittenhouse highway bridge, made by Supt. Smith, Roosevelt Water Conservation District.
A dash indicates no run-off on that date.

Movement of Bed Loads

260. In the high mountainous parts of this watershed, during flows, considerable quantities of erosion materials are carried down to lower areas. Some channels have beds of sand, gravel, and boulders. In many stream channels in the mountainous area, bedrock is exposed, indicating that the capacity to transport materials is greater than the load. On areas at intermediate elevation, the channels contain considerable sand and gravel, indicating heavy bed loads. The alluvial plain is the recipient of most of these bed-load and suspended materials. The distance that bed loads are moved during a storm and the place where erosion products are deposited are determined by quantity of water and rate of channel discharge.

Existing Improvements Affecting Stream Flows

261. There are no major flood-control structures in this watershed. However, some small erosion-control structures have been built by C.C.C. labor on the Soil Conservation Service demonstration area and on Oak Flat, above Superior.

262. Demonstration area. On the Soil Conservation Service demonstration area, about 2,000 acres, in the aggregate, have been intensively

treated and about 27,000 acres, extensively treated, in 1936 and 1937. The nature of this work is of the regular Soil Conservation Service activities, but the work was done as a special project outside the Gila District. Although the lowering of peaks of flood-contributing flows and the retardation of flood flows may be incidental benefits, the work is not regarded as permanent, and no provision is made for continuance or maintenance after the expiration of the 5-year co-operative agreement. It is anticipated that what has been done on this demonstration area will materially reduce peak flows in the drainage areas concerned.

263. Oak Flat. On Oak Flat, the Forest Service has done run-off retardation, erosion-control, and revegetation work on about 1,000 acres, completed in 1934. This area is now fenced against livestock, and has been withdrawn for recreational purposes. Twelve small detention dams were built, each of 1-acre-foot capacity; also structures for retarding and spreading surface waters. These works have checked both surface run-off and silt movement, and definite improvement in the ground cover is in progress.

264. Highway and railway bridges. The capacity of the Mesa-Superior highway bridge 1½ miles northwest of Florence Junction is estimated at 20,000 cubic feet per second.

265. The total capacity of the Southern Pacific Railway bridges between Queen Creek station and Rittenhouse, near the Queen Creek Irrigation District, is estimated at more than 6,000 second-feet.

266. The Rittenhouse highway bridge over lower Queen Creek channel (map 11) has a capacity that is considered adequate for unusual flows. According to Superintendent Smith, of the Roosevelt Water Conservation

District, rough gagings at this bridge indicate that during the heavy floods of August 8, 1931, and September 8-11, 1933, peak flows at this point reached 6,000 and 4,500 second-feet, respectively (par. 259).

267. Dams above Superior. Three dams above Superior constructed by the Arizona Edison Co., now filled with silt, have but little effect, if any, on stream and flood flows.

268. Canals, laterals, and dikes. It is considered impracticable to count on the use of the irrigation canals and laterals for dissipation of summer flood waters, because the flash summer floods come too quickly to allow preparation to receive such flows. Moreover, these floods may occur at night. In 1930-31, considerable work was done on the east side of Roosevelt Canal in connecting borrow pits and cutting through low ridges to create a canal-embankment channel, in order to facilitate the escape of flood waters southward. Its maximum capacity, according to Superintendent Smith (R.W.C.D.), is estimated at about 400 second-feet. However, "it was***known that this [embankment-canal] would not constitute flood control."

269. A dike about 2½ miles long, with a capacity of about 500 second-feet, has been built (1937) in the east end of the North Boundary area of the San Carlos Project (Gila River Ind. Res.), also a short dike east of the Southern Pacific Railway below Santan station (1935) with capacity of 300 second-feet, for protection against flood flows that originate on Queen Creek watershed (see map 11).

Infiltration

270. In relation to remedial measures proposed by the Department of Agriculture for flood and erosion control in Queen Creek basin, the

principal question regarding infiltration, that is, the entering of rain water into soils, concerns the run-off yields that may be expected from flood-producing storms, especially of the probable great or 100-year summer storms on which the designs of the dike-channel structures are based. When the deteriorated condition of the ground cover and the character of the soils of Queen Creek basin are taken into account, it is estimated that the run-off yield of such a storm, without remedial measures, would be, on the average, 66 percent of the total rainfall (par. 257).

271. This estimate of run-off yield is based on field infiltration studies in the Southwest on soils similar to those of the Queen Creek basin 23/. On the basis of these studies, which were made under conditions of infiltrometer rainfall of 3 inches per hour, it is estimated that, on the average for Queen Creek basin, the infiltration rate under rainfall excess is 0.35 surface inches of rain water per hour.

Ground Water

272. The ground-water table in Queen Creek watershed slopes downward from the mountains westward. In the mountainous area it is presumably closer to the surface than in the valley-fill deposits. Near the base of the mountains the depth to the water table varies from 500 to 600 feet. The depth decreases generally from the mountains southwestward toward the agricultural area, where it varies from

---

23/ Beutner, E. L., and Gaebe, Ralph R., Progress Report of Infiltration Studies on a Number of Southern Arizona Soils, Unpublished. Soil Conservation Service and Ariz. Agr. Expt. Sta., Sept. 1939.

75 to 150 feet.

Ground Water in Salt River Valley

273. It is believed by those concerned with the water resources in the region of Queen Creek watershed that increases and decreases in pumping from underground sources in adjacent agricultural areas of Salt River Valley directly affect the underground water for a few miles into Queen Creek basin.

Ground Water in the Salt River Project Part of Basin

274. In the west-end part of Queen Creek basin (the Salt River Project part, map 11), the underground water supply is probably large. Here the Salt River Valley Water Users' Association usually pumps about 19,000 acre-feet annually from underground sources. In a year of low surface supplies, the quantity may be greater. Some of this pumped water is that which had percolated to the underground reservoir during irrigation, and hence is used again. Just what percentage of the total irrigation water applied finds its way to ground water is not known. In seven wells in the Salt River Project part of the watershed, the pump lifts, as of 1938, ranged from 37 to 137 feet, fluctuating annually (table 13). In general, the lifts north of Chandler are greater than in the wells southwest of Chandler, where they have remained rather uniform. In the northern part of this area the general trends indicate that the lifts are increasing, especially since 1932.

Ground Water in the Roosevelt Water Conservation District

275. The total quantity of underground water pumped by the Roosevelt Water Conservation District during 1937 was 51,110 acre-feet, which was

Table 13. - Changes in Pump Lifts and in Water Table, Queen Creek Basin

Location of wells	PUMP LIFTS												
	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938
SALT RIVER PROJECT PART 1/	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
Northern Part													
Sec. 7, T.1S., R.6E.	--	--	--	--	78	84	--	82	89	90	90	150	90
Sec. 6, T.1S., R.6E.	--	--	--	87	94	98	--	96	--	98	98	95	103
Sec.32, T.1N., R.6E.	--	--	--	--	122	--	--	78	86	87	102	99	103
Sec.33, T.1N., R.6E.	--	--	--	--	94	--	--	62	115	123	123	132	137
Sec.32, T.1S., R.6E.	--	--	--	--	82	105	--	101	--	100	100	94	104
Southwest of Chandler													
Sec. 36, T.1S.,R.4E.	--	--	--	--	--	36	--	35	40	33	--	--	37
Sec. 7, T.2S.,R.5E.	--	41	--	58	--	--	--	--	--	42	--	--	40
DEPTH TO GROUND-WATER TABLE													
ROOSEVELT WATER CONSERVATION DISTRICT 2/													
Along Roosevelt Canal due east of Mesa													
NE1/4 sec. 9, T.1N.,R.6E.	--	--	--	--	147	154	--	--	158	159	164	167	--
NE1/4 sec.26, T.1N.,R.6E.	--	--	--	136	144	150	--	--	159	153	158	165	163
East of Gilbert and Higley													
NE1/4 sec. 11, T.1S.,R.6E.	--	--	--	112	108	--	--	--	--	--	121	125	125
Vicinity of Higley													
SE1/4 sec. 25, T.1S.,R.6E.	--	--	--	--	90	91	--	--	--	87	89	89	92
NW1/4 sec. 34, T.1S.,R.6E.	65	--	--	--	72	--	--	72	72	--	72	72	72
Southern Part													
NE1/4 sec. 16, T.2S.,R.6E.	94	--	--	--	95	--	--	--	--	--	92	93	93
SW1/4 sec. 20, T.2S.,R.6E.	--	--	--	--	71	--	--	--	79	85	65	60	67

1/ The day of year these records were taken is different for each reading.

2/ Seven examples selected from 53 wells of this district. The day of year these records were taken is different for each reading.

nearly as much as that obtained from the surface flows of the Salt and Verde Rivers. The lowering of the water table in wells along the Roosevelt Canal due east of Mesa indicates that the quantity pumped in this part of the watershed is greater than the increment added to the underground supply (table 13). The water table in two wells has lowered 20 and 27 feet, respectively, in 7 and 9 years. Farther south, east of Gilbert and Higley, the water table has lowered less than in the area to the north. In the vicinity of Higley the water table has remained about the same, although some wells show a slight lowering. The maintenance of the ground-water level in this particular area, in spite of pumping, is probably due to the infiltration of water from lower Queen Creek channel during flows and to seepage in irrigation. In the southern part of this irrigation district the water table has risen slightly or has remained nearly stable.

Ground Water East of Roosevelt Canal

276. In the general area east of Roosevelt Canal, the depth to ground water increases toward the mountains (map 11). At the foot of the mountains it varies from 500 to 600 feet. Along the Roosevelt Canal, due east of Mesa and Gilbert, the depth is about 150 feet, and it decreases to the south. The depth to the ground-water level in the Queen Creek Irrigation District varies from 100 to 130 feet. In contrast, the depth near Goodyear, to the west, varies from 50 to 75 feet.

Ground Water in Relation to Flood Flows

277. Although there are no definite data to show whether flood flows and

floods in Queen Creek basin add to the underground supplies, it is conceded that "the water from Queen Creek feeds the underground water" (20). It is not possible to give even an estimate of how much water Queen Creek contributes annually to the underground waters of Queen Creek basin.

FLOOD DAMAGES

Description of Floodwater Flows

278. Most of the stream courses fan out before reaching the agricultural area. Floodwaters from these drainages accumulate at the Roosevelt Canal, sometimes to a depth of several feet, and break into and over it, or flow southward along its east bank. Breaks commonly occur at the points of intersection of the washes with the canal.

279. After overtopping the canal embankment, the floodwaters continue to flow in a general westerly direction in the irrigation laterals and along the highways and roads, and fan out as sheet flows over the level croplands (fig. 11). The flows range from swiftly flowing sheets a few inches deep of a few-hours' duration on the steeper slopes to sluggish flows of from 2 to 3 feet deep which may stand for several days on the flatter areas and against such obstructions as canal and railroad embankments. When the water, in its westward movement, reaches the Eastern Canal, it is again deflected southward and is dammed up until it breaks into and across this canal, to again fan out over the croplands. During recent years, floods in the Queen Creek watershed have covered as many as 67,000 acres of highly developed irrigated lands.

280. The waters from the Superstition and Bulldog areas have been reported as far west as the western boundary of the watershed. Floodwaters from Queen Creek channel have been reported as far north as the line indicated in figure 11 24/ and those from Sonoqui Wash and from the

---

24/ It is possible that in the case of a great storm, the floodwaters from Queen Creek might extend somewhat farther north.

Superstition and Bulldog areas mingle with those of Queen Creek, and move in a southwesterly direction toward Gila River. The general belief is that large flows have overtopped the natural levee on the north bank of Gila River and have overflowed into the river.

Description of Flood Damages

281. Flash summer floods that strike the developed irrigated areas, break irrigation canals, inundate and wash out crops, damage other farm properties, wash out highways, flood towns, and do other damage (figs. 8, 9, 10, 12, 13). The greatest amount of damage is caused to farm properties, highways, and irrigation works. During recent years, no damage has been caused by winter floods from drainages other than Queen Creek.

Farm Flood Damages

282. The principal damage to farm properties in Queen Creek basin concerns growing crops, particularly cotton and alfalfa. The wetting of the lower cotton bolls usually causes them to rot, thus lowering the yield. Instances also occur in which the quality and price of cotton are lowered because of mildewed or silty bolls. In some instances, whole fields of young cotton have been completely washed out. Where this occurs in the early spring, the fields have to be replanted, involving additional planting costs and also reduced yields as the result of the shortened growing season. Alfalfa (ready to cut or already cut) is destroyed when floods strike. If not completely destroyed, the quality of hay may be lowered by wetting and silt deposition. Silt deposited on the crowns of alfalfa, particularly on young plants, causes the plants to rot, thus

thinning the stand and often necessitating replanting. The spreading of weeds in cotton and alfalfa fields was reported to have entailed extra weeding costs and to have lowered the quality of the hay. Some farmers reported that stands of alfalfa and cotton were "scalded out" by floodwaters that remained on the fields for several days under a hot sun. Other crops are damaged by floods. Losses in crop yields also result indirectly from insufficient irrigation following the breaking of irrigation canals, laterals, furrows, and borders, or the sealing of soils with fine silt.

283. Farm lands, including citrus orchards, are damaged by gullying and scouring, by deposition of silt, and by destruction of irrigation ditches and borders, thus entailing heavy relevelling, rebordering, and reditching costs. In a few instances, the productivity of farm lands was reported to have been decreased by gullying. Farm improvements, including residences and other buildings, fences, and wells, are damaged to some extent. Adobe houses, which are rather common, are particularly damaged by wetting, which causes the lower part of the walls to "melt" and the houses to settle and crack.

284. Other losses to farm property include damage to stored crops (particularly stored alfalfa hay), drowning of chickens, turkeys, and hogs, and damage to machinery, equipment, furnishings, personal belongings, and the like.

285. <u>Highways.</u> Indirect damage results from inability to use roads (especially dirt roads) for a time after a flood.

286. <u>Irrigation works.</u> Damage to irrigation works have resulted from the washing out of canal embankments and the breaking of concrete canal lining. Indirect losses have resulted from irrigation water

lost by seepage, or otherwise, and from reduced power sales.

287. Public utilities. A slight amount of damage has been done to railroad property. No other rural public-utility property has been damaged during recent years.

288. Urban properties. Damage to urban properties in the town of Gilbert has been caused by flood flows from drainages other than Queen Creek. Losses consist of damage to business buildings and merchants' stocks; indirect damage from loss of business; damage to residences, furnishings and belongings; and damage to streets and utilities.

289. Rural non-farm property. Rural non-farm properties, such as rural residences, service stations, and tourist camps, have experienced light damage.

Measurable Flood Damages

290. Total measurable flood damages, direct and indirect, in the whole Queen Creek watershed are expected, on the annual-equivalent basis, to average $200,700 annually, if no remedial measures are undertaken. The United States Army engineers have estimated that damage amounting to $41,700 annually would be caused by Queen Creek drainage if no remedial measures are put into effect to control that stream (59). It is estimated by the Department of Agriculture that the equivalent of $159,000 damage annually would be caused by the other drainages in the watershed.

291. It is estimated by the Army engineers that the proposed Whitlow Ranch Dam on upper Queen Creek would prevent $36,600 annually of the average expected damage of $41,700 from Queen Creek (59). Damages from Queen Creek permitted under the Army plan (because the flows

of the Whitlow Canyon branch would be uncontrolled) amount to $5,100 per year (59). Thus, exclusive of the damages that would be prevented by the plan of the War Department, the remaining flood damages in this watershed would total an estimated $164,100 per year ($5,100 from Queen Creek and $159,000 from other drainages).

292. Inasmuch as the Army engineers have prepared estimates of damages from Queen Creek, the following discussion deals only with estimates of flood damages from drainages other than Queen Creek.

Damages Based on Past Floods 25/

293. The 13 years between 1926 and 1938 were selected as representing recent past damages, mainly because the development of the Roosevelt Water Conservation District in 1925 shifted the principal damage area eastward. During this 13-year period, tangible flood damages, direct and indirect, from drainages other than Queen Creek are estimated to have averaged $73,000 annually, distributed as follows:

Property	Flood damages	Proportion of flood damages
	Dollars	Percent
Farm property:		
Crops	29,200	40
Lands	7,500	10
Improvements	1,900	3
Other 26/	1,900	3
Subtotal	40,500	56
Irrigation works	11,000	15
Highways	19,500	27
Public utilities	300	27/
Urban property	1,500	2
Rural non-farm property	200	27/
Total	73,000	100

25/ Because of the lack of flood-flow records, and because of the flat relief and the lack of through channels in the flood-damage area, no reliable flood stage damage relationships can be established for drainages other than Queen Creek. Hence, dependence is placed on estimation of past flood damages.

26/ Includes mainly stored crops, livestock, machinery, house furnishings, and personal belongings, in the order named.

27/ Less than 0.5 percent.

Flood Damages to Farm Properties

294. Farmers have suffered the most losses of any group of persons in the watershed 28/. The heaviest losses, mostly to crops, include reduced yields which have resulted indirectly from lack of sufficient water following severe breaking of irrigation canals 29/.

295. Damage estimates based on sample field survey. The estimate of $40,500 average annual damage to farm property, occurring during the period 1926-38, was arrived at from a sample field survey 30/. A total of 117 farmers, or about one-fourth of all those in the flood-damage area, were interviewed. The samples represent farms on almost every section of land in the flood-damage area. The difficulty of finding farm operators who had resided in the area longer than a few years prevented the use of a uniform system of sampling. An effort was therefore made to contact farmers who had been in the area for a considerable number of years, and at the same time, also, to obtain a good geographical distribution of the samples. To minimize the subjective factors in estimating flood damages, the field data, so far as possible, were obtained in terms of physical quantities as, for

---

28/ Farmers bear the losses to irrigation works, amounting to 15 percent of the total flood damages in the watershed, as well as the damages to farm properties which amount to 56 percent of all flood damages.

29/ It is estimated that about 10 percent of the flood damage to farm crops during the period 1926-38 consists of the indirect losses from reduced yields. It does not seem that there has been any appreciable indirect damage of other types to farm property. No significant loss has resulted from the inability to market crops, because the principal crops produced are non-perishable.

30/ In the Chandler Heights area, a protective dike was built by the Maricopa Board of Supervisors in 1931, offering partial flood protection. The sampling period for this area was, therefore, taken as the years 1931-38, inclusive.

example, reductions in crop yields resulting from specific floods, as shown on the following questionnaire and referred to in the instructions for its use. In order to arrive at the monetary damage sustained on the sample farms, the quantitative physical data were evaluated at normal prices 31/, allowance being made for harvesting costs when crops were destroyed before harvest.

296. Intensity-of-damage areas. The relative intensity of damage on each sample farm was determined through the use of the following class intervals of average annual damage per acre:

Low damage	Less than $0.25 per acre
Medium damage	From $0.25 to $1.25 per acre
High damage	More than $1.25 per acre

297. A map was then prepared showing generalized intensity-of-damage areas (see map 2) 32/. The total farm flood damage within each intensity-of-damage area was determined by multiplying the average annual damage per acre on all sample farms within that area 33/ by the total

---

31/ The following "normal prices", used by the Federal Land Bank of Berkeley as the basis of its loan policy in Salt River Valley were used in estimating the damages to crops: short-staple cotton, 12¢ per lb.; long-staple cotton, 24¢ per lb.; alfalfa hay, $10 per ton baled; hegari, $1.25 per cwt.; wheat, 90¢ per bu.; barley, 50¢ per bu.

32/ These areas are highly generalized. Even the high-damage area contains some farms located on sand ridges which reported no flood damage. Similarly, there are farms in the medium and low intensity-of-damage areas which reported high damage per acre. The boundaries of the intensity-of-damage areas are determined mainly by physical features—irrigation canals, the railroad, and topographic features generally.

33/ The average annual damage per acre within each intensity-of-damage area was weighted according to the acreage farmed by each operator in the sample. All sample farms within each intensity-of-damage area, including those that reported no damage, were included in arriving at the average annual damage per acre for each intensity-of-damage area. The average annual damage per acre on each sample farm is the average for the period of residence of the individual operator since 1926.

FARM FLOOD-DAMAGE SCHEDULE

No. ________

Name __________ Yrs. res. ______ T. ____ R. ____ Sect. ______
Address __________ Canal ______ Flood date ______ 19 __ Stream ______

CROP LOSSES

Crop	Acres	Yield			Price			Loss	
		Normal	Actual	Loss	Normal	Actual	Loss	Per Acre	Total
1.					$	$	$	$	$
Variable Expenses- - - - -									
Type of damage								Net Loss:	$
2.									
Variable Expenses - - - -									
Type of damage -								Net Loss:	$
3.									
Variable Expenses - - - -									
Type of damage -								Net Loss:	$
4.									
Variable items of expense - - -									
Type of damage -								Net Loss:	$
Acres damaged -								Total crop losses . . .	$

Not damaged:
________ : ______ :
________ : ______ :
________ : ______ :
Total irr. acres : ______ :

Land Value, Acre $ ______
Without floods $ ______

Livestock numbers:
Dairy cattle ______
Beef cattle ______
Sheep ______
Hogs ______
Chickens ______
Horses ______

CAPITAL LOSSES

Livestock:
No. ____ Kind ______ @ ______ $ ______
No. ____ Kind ______ @ ______ $ ______
Stored crops and supplies:
Amt. ______ Kind ______ @ ______ $ ______
Amt. ______ Kind ______ @ ______ $ ______
Relevelling, reditching, etc $ ______
Improvements and structures $ ______
Machinery and equipment $ ______
Furnishings and belongings $ ______
Other (____________) $ ______
Total losses from this flood $ ______

Were crops substituted for destroyed crops? ________. Do you raise different crops and livestock than if there were no floods? ________. (Explain on separate sheet).

State effect of floods on productivity of land; use of flood flows for irrigation:

Instructions for Use of Farm Flood Damage Schedule

General

Use separate sheet for each flood occurrence.

Crop losses

Show name of crop on first line. Show yield data if yield was affected; show price data if quality was affected. Opposite "Variable expenses" show on a per acre basis (1) additional expenses caused by the flood (replanting, extra cultivation, etc., but not relevelling or reditching), and (2) ordinary expenses obviated by the damage (cultivating, harvesting, irrigating, etc.). Use actual amounts paid or estimates as stated by the farmer, including own labor, labor of family, use of farm equipment, etc., as well as hired work. Do not extend amounts into "Loss" column in the field. State type of damage on last line of section (inundation, washing, silting, lack of water following canal break, etc.).

Land value

Secure statement of present value per acre of land subject to flood hazard. Get farmer's estimate of value of this land if hazard is removed. This information to be used as a check on the estimates of flood damages.

Livestock numbers

Fill in numbers of livestock kept on farm. This is used for determining type of farming.

Capital losses

Show number, unit, kind, and unit value of livestock and stored crops and supplies as estimated by farmer. Where loss in quality is involved, indicate loss in price. Show nature of other types of damage.

Questions

First question: If another crop was substituted after destruction, show on separate sheet gross receipts therefrom and special expenses incurred. Determine net returns from substitute crop and subtract this from loss on original crop.

Second question: If answer is yes, show details of influence of floods on cropping system on separate schedule. Show farmer's estimate of effect of this on income by setting up gross returns and variable expenses for crops which would be grown as compared with same for crops grown because of floods. Show difference in net returns.

present irrigated acreage within the area 34/. The farm flood damages to crops, lands, improvements, and to other farm property were similarly calculated.

298. Total farm damage. The total flood damage to farm properties in the entire Queen Creek watershed during the period 1926-38 was found to average $46,300 annually. Of this total, $40,500 is estimated to have been caused by flood flows from drainage areas other than Queen Creek 35/. It is of interest to note that more than half of the

---

34/ The present irrigated acreage (as of 1938) was taken as being indicative of the future acreage likely to be cultivated. No future expansion of crop acreage, on a permanent basis, is anticipated (see par. 205). Gross irrigated acreage was used, because in the samples the acreage figures were expressed in rounded numbers not corrected for land in roads, canals, ditches, farmsteads, fences, etc. Although some increase in number of farms may take place by subdivision and some change in cropping systems might take place as a result of factors other than flood control (see par. 207), it is not believed that such changes would have any material effect on future flood damages.

35/ The area south of the line marking the northernmost limit of Queen Creek floods (fig. 11) is flooded not only by waters of Queen Creek but also by waters from Sonoqui Wash, Santan, and Superstition-Bulldog areas, intermingling with those of Queen Creek. Waters from the Superstition-Bulldog area can pass southward into the area flooded by Queen Creek, inasmuch as the total estimated capacity of culverts under the Southern Pacific railroad from Gilbert to the Roosevelt Canal near Higley (11,600 c.f.s.) is sufficient to take care of the probable maximum flow from the Superstition-Bulldog area. Based on statements by farmers, on estimated sizes of floods from various areas, and on the capacities of railroad culverts, it is estimated that in the area flooded by Queen Creek (including Queen Creek Irrigation District) 55 percent of the damages were caused by Queen Creek and 45 percent by drainages other than Queen Creek. Of the estimated average annual damage of $40,500 to farm property from drainages other than Queen Creek an estimated $35,500 occurred on farms situated in the Chandler Heights Citrus Irrigation District and in the area north of the line marking the northernmost limit of Queen Creek floods, which areas were flooded solely by Santan and by Superstition-Bulldog waters, respectively. In the area flooded by the intermingled waters of Queen Creek and other drainages, $5,000 damage is estimated to be due to drainages other than Queen Creek. This involves no overlapping of damage claims between those of the War Department and the Department of Agriculture in the area flooded by Queen Creek, inasmuch as the Army engineers dealt only with expected flows from Queen Creek.

total farm flood damages occurred on farms situated in the "high-damage area", a triangular area of land east of Gilbert and north of Higley, embracing about 14 sections of farm land (see map 2). This small area receives the brunt of the damage caused by the flood waters from the large Superstition flood-source area. The average annual damage to farm properties within this high-damage area is estimated at $2.73 per acre, as compared with $0.71 and $0.21 per acre, respectively, for cotton farming lands in the medium and low damage areas north of the line demarcating the northernmost limit of Queen Creek floods (map 2).

Damage to Highways

299. Flood damage to highways, the second most important type of flood damage in this watershed, principally concerns Maricopa County highways within the agricultural area. Such damage was estimated by the county engineer at about $22,450 per year for the 10-year period prior to 1937, comprised of the following items (20):

Cost item	Average annual damage for 10-year period
Additional maintenance 36/	$9,450
Reconstruction	5,500
Uncompleted reconstruction 37/	7,500
Total	$22,450

300. During flooding, and sometimes for days thereafter, some roads, particularly dirt roads, are impassable, or if passable, are in

---

36/ This is 50 percent of all maintenance costs on Maricopa County roads in the watershed.
37/ This is the estimated cost of reconstructing roads which the county has not had funds nor equipment to repair.

bad condition. The usual grocery, mail, and other delivery services are not available then. Extra trips to town are often necessitated, and must be made over poor roads. Bad roads, following the floods experienced in recent years, have caused damage estimated to equal not less than 10 percent of the direct damage to highways. The total damages to Maricopa County highways in the watershed, based on recent past floods, are therefore estimated at about $25,000 per year, including direct and indirect damages.

301. The most severe damage to Maricopa County roads occurs in the "high-damage area" just east of Gilbert, in which farm properties are also most severely damaged (map 2). The intensity of damage to roads in various parts of the populated area is reported to be about the same as the intensity of damage to farm properties.

302. Direct and indirect damages to Maricopa County roads caused by drainages other than Queen Creek are therefore estimated to have averaged about $19,500 annually. The real cost of flood damage to roads results largely from lessened expenditures available for the regular road program, and consists therefore of poorer and fewer roads than would otherwise exist. In Arizona, the principal source of revenue for county roads is a proportionate share of the State-collected gasoline tax. Additional taxes are not levied to repair roads damaged by floods.

303. Pinal County highways. Past damage to Pinal County roads from drainages other than Queen Creek has been nominal.

304. State highways. The office of the State highway engineer has reported that, owing to highway relocation, improvements in drainage, and enlargement of structures, very little flood damage to State highways

has been experienced.

Damage to Irrigation Works

305. Past flood damages to irrigation works in Queen Creek basin are estimated to have averaged $13,250 annually, during the period 1930-38, of which about $11,000 per year was due to floods from drainages other than Queen Creek. These estimates include both direct and indirect damages. Direct damage to irrigation works consists primarily of the cost of repairing canals. Direct damage is also caused by floods washing out irrigation district power lines. Indirect damage consists mainly of additional seepage losses in canals, the lining of which had been broken by floods, and the loss of power revenue resulting from the washing out of power lines and the discontinuance of pumping while canals are broken 38/. Three irrigation projects in the watershed have suffered damage from floods: Roosevelt Water Conservation District, Salt River Project, and Chandler Heights Citrus Irrigation District.

306. Roosevelt Water Conservation District. Average annual past flood damages, direct and indirect, to the Roosevelt Water Conservation District from all drainages within the watershed are estimated as follows, from data obtained from district officials:

Direct damage:	
Canal repairs	$3,800
Indirect damage:	
Seepage losses and other losses of irrigation water	$2,650
Total	$6,450

38/ Indirect flood damage due to reduced crop yields from lack of irrigation water following the breaking of irrigation canals is included as crop damage (par. 294).

307. The average annual direct flood damage to irrigation works in the Roosevelt Water Conservation District, based on the sums expended for canal repairs during the period 1930-38, is estimated at $3,800 per year 39/.

308. The seepage loss that results from breaks in the canal lining is an item of indirect damage. Breaks in the canal embankments must be repaired to allow distribution of irrigation water, but breaks in the concrete canal linings need not be. The engineers of the Roosevelt Water Conservation District do not consider repairs to the canal lining to be economically justifiable, in view of the flood menace. The superintendent of this district estimated that, as of 1938, 175,000 square feet, or 5 percent of the concrete lining of the Roosevelt Canal, has been washed out by floods. A study of canal seepage in the Salt River Project indicates that the average loss per square foot of wetted area in unlined canals and laterals is 0.34 cubic feet in 24 hours, as compared with a loss of 0.04 cubic feet in lined canals and laterals (39). It is believed that the rate of

---

39/ Total of flood repairs for 1930-38, inclusive, was $34,128. The records of the district do not report flood-repair work separately from ordinary repair work prior to 1930. It should be noted that this amount does not include the following items: (a) repairs at a cost of about $100,000 following the 1925 flood, when the newly constructed canals (then unlined) and laterals of this district were severely damaged (21) (the severity of this damage was due largely to the newness of the structures and to the lack of protective vegetation, and hence is not considered representative of damages since 1925); (b) cost of flood-protection works (reported as $39,221.20 for the period 1925-29, inclusive); and (c) initial investments in the now abandoned Queen Creek extension system (reported as $8,791.89) constructed with the view to conserving the flood flows of that drainage, but abandoned, owing to silting and changing of channel and destruction of floodgates.

seepage from the Roosevelt Canal, which is located on the edge of the desert, is about twice as great as this figure, or about 0.64 (0.68 - 0.04) cubic feet in 24 hours. Assuming that the canal averages 75 percent full during the year, it is estimated that as of 1938 the annual seepage loss due to the breaking of the lining was 700 acre-feet. At $3.45 per acre-foot (weighted average charge, 1934-37), this would amount to a total loss in revenue of $2,400 per year.

309. *Other water losses.* Each time a serious flood occurs, the Roosevelt Water Conservation District, in order to accommodate floodwaters in the Roosevelt Canal, shuts down its main pumping plant at the head of the Roosevelt Canal, and this water, which comes from Roosevelt and Verde Reservoirs, is dumped into the dry channel of Salt River and is lost. It is estimated that about 100 acre-feet of water is lost each time this occurs; and tabulations of flood frequencies indicate that during the years 1926-38 the pumping plant was probably shut down 12 times, entailing thereby a total loss of 1,200 acre-feet of water, or an average of 92 acre-feet per year. At $2.45 per acre-foot ($3.45 less $1.00, which represents the approximate saving by not pumping the water up 55 feet into the Roosevelt Canal at the main pumping plant), this is equivalent to a loss of about $250 per year. This loss, together with the estimated loss of $2,400 per year due to seepage in canals, makes a total indirect damage to the Roosevelt Water Conservation District of $2,650 per year from water losses.

310. *Salt River Project.* Annual past flood damages, direct and indirect, to Salt River Project canals from all drainages within the watershed

are estimated to be as follows:

Direct damage:	
Canal repairs, including relining - - -	$2,850
Power-line damage - - - - - - - - - - - -	250
Subtotal - - - - - - - - - - - - - -	$3,100
Indirect damage:	
Seepage losses - - - - - - - - - - - - -	200
Loss of power revenue - - - - - - - - -	3,000
Subtotal - - - - - - - - - - - - - -	$3,200
Total - - - - - - - - - - - - - - - - -	$6,300

311. Damage to canals in the Salt River Project has been practically confined to the Eastern Canal, the length of which in the flood-damage area is less than half of the length of the main canals that are subject to damage in the Roosevelt Water Conservation District. As stated in paragraph 307, the cost of repairing the canals in the Roosevelt Water Conservation District averaged $3,800 per year. One-half of this, or $1,900, is estimated as the average annual cost of repairs to the canals of the Salt River Project, exclusive of relining 40/. Unlike the canals of the Roosevelt Water Conservation District, those of the Salt River Project have been relined to seal the breaks caused by floods. This work was done in 1938 at a cost of $7,700 41/. Inasmuch as this work covered relining of canal breaks that had occurred from floods during the preceding 8-year

---

40/ The records of the Salt River Valley Water Users' Association do not list separately the costs of repairing irrigation works damaged by floods. Although the assistant chief engineer of the association estimates that the cost of immediate repairs to the Eastern Canal following the July 1936 flood, one of the worst floods in years, was about $7,000 (21), no reliable basis exists by which the damages for only the one flood year can be interpreted in terms of average annual damage over a period of years.

41/ The relining of breaks in the canals of the Salt River Project was carried out by the Roosevelt Water Conservation District, under terms of the co-operative water-conservation agreement between those two districts.

period, the average cost for relining canals is estimated at $950 per year. The total cost of repairing canals, including relining, is estimated at $2,850 per year.

312. Direct damage to power lines of the Salt River Project has resulted from the washing out of poles, repairs to which, according to information supplied by the power division of the association, is about $250 per year.

313. Loss of water by seepage occurred in the years before the canals of the Salt River Project were relined in 1938, but such damage could be expected to occur again in the future during the time that would elapse before repair of canal linings would again be feasible. It is estimated that an average of 170 acre-feet of water was lost annually from broken canal linings during the 8-year period,1930-37. At $1 per acre-foot, which is the rate charged in the Salt River Project for all water delivered in excess of 2 acre-feet per acre, the average annual loss in revenue from this cause is approximately $200 per year.

314. Loss of power revenue from flood damage to power lines of the Salt River Project and discontinuance of pumping while the canals were being repaired is reported to have amounted to an average of $3,000 per year (21).

315. Chandler Heights Citrus Irrigation District. Estimated damages to irrigation works in the Chandler Heights Citrus District, caused only by floodwaters from Santan Mountain, have averaged $500 per year.

Damage to Urban Properties

316. The town of Gilbert is the only urban community in Queen Creek

watershed damaged by floods from drainages other than Queen Creek. The most damaging flood to urban properties in this town was that of September 8, 1933, which caused damages estimated at $17,250, as follows:

Types of damage	Amount of damage
Business property:	
Direct damage	$ 6,100
Indirect damage	1,300
Subtotal	$ 7,400
Residential property	$ 8,500
Streets	1,000
Water system	350
Total	$17,250

317. The above estimates are based on a practically complete count of damage to business property, a sampling procedure for damage to residential property, and estimates of town officials of damages to streets and water system. The damage from the only other flood reported, that of September 1925, is believed by local residents to have been about one-fourth as great as the September 1933 flood. The total damage is placed at about $21,500 for 14 years, or an average of about $1,500 per year.

Damage to Rural Non-Farm Properties

318. Rural non-farm properties, such as rural residences, service stations, and tourist camps, particularly in the Superstition-Bulldog flood-damage area, are subject to frequent but light damage, probably not averaging in excess of $200 per year.

Damage to Public Utilities

319. The only public-utility property reported to have been damaged by recent floods is property of the Southern Pacific Railroad. The

superintendent of this railroad reported that in recent years the main line (through Chandler) has had practically no damage, although there have been floodwaters near Serape at times. Damage has occurred on the Mesa-Magma branch line, particularly near Higley, causing interrupted service and delayed freight movements. Drainages other than Queen Creek are estimated to have caused damages to this branch of the Southern Pacific Railroad averaging not more than $300 annually.

320. Other public utilities. The Central Arizona Light and Power Co., which serves the Gilbert-Chandler area with electrical energy and natural gas, has reported that its records show no damage in this area from floods. Officials of the Mountain States Telephone and Telegraph Co. have reported that damage to their properties on the watershed has been insignificant, likewise loss of revenue due to interruptions in service. No damage to the gas lines of the El Paso Natural Gas Co. and to other public utilities on the watershed has been reported.

Summary, Damages from Past Floods

321. Floods occurring during recent years from drainages other than Queen Creek are estimated to have caused direct and indirect total damages averaging $73,000 per year, distributed as follows:

Properties	Damage
Farm properties - - - -	$40,500
Highways - - - - - - - - -	19,500
Irrigation works - - - -	11,000
Urban properties - - - -	1,500
Other properties - - - -	500
Total - - - - - - - -	$73,000

Flood Damages Adjusted to Storm Expectancy

322. Inasmuch as the rainfall records show that the period 1926-1938,

taken as representative of past flood damages, was one of subnormal rainfall, the annual damages of $73,000 cannot be regarded as representative of future annual damages. Adjustment to storm expectancy is therefore necessary.

Method Used

323. Owing to the lack of flood-flow data in Queen Creek basin, the relationship between the rainfalls of the comparatively short 13-year period (1926-38) and a 42-year period (1897-1938) affords the only basis on which to make such an adjustment. The following analysis was made of records of rainfalls over 0.5 inch per day at Phoenix, Mesa, and Granite Reef, Arizona; The amount of precipitation available for run-off from each storm was estimated by deducting the probable infiltration from the rainfall (see pars. 270, 271). Average intensity patterns for different amounts of rainfall were determined from intensity records at Albuquerque, Santa Fe, and Roswell (all in New Mexico, yet applicable to Queen Creek basin). The infiltration rate for summer rains, under condition of rainfall excess, was assumed to be 0.35 inch of rainfall per hour. The average amount of precipitation available for run-off (precipitation minus infiltration) for the 13-year period, 1926-1938, was compared with that for the 42-year period, 1897-1938, and relative relationship determined 42/.

42/ The results of this study are subject to errors, for the following four reasons:
1. A storm producing run-off may be so limited in area as to fail to be recorded at the rain-gage locations.
2. The rainfall recorded may be indicative of that which occurs at the gage and not over the watershed.
3. The rainfall recorded may be that on the edge of the storm and not that which actually produced the run-off.
4. The assumed intensity patterns may not represent actual conditions.

Continued--

324. Adjustment for summer floods. Little difference was found to exist in the long and short periods as to the run-off yield from light summer rains (0.5 to 1.0 inch of rainfall per day). The difference lies in the fact that very heavy summer rains have not occurred so frequently in the short period of record as in the long period. The greatest summer flood during the 13-year period between 1926-1938 occurred in July 1936. According to estimates from rainfall records, a flood that occurred in the summer of 1911 would have caused at least three times as much damage as the 1936 flood 43/.

325. The averages of summer precipitation available for run-off during the 13-year period, as compared with the 42-year period, were found to be as follows:

Rainfall station	Average for 13-year period, 1926-1938	Average for 42-year period, 1897-1938	Percentage by which long-period average exceeds short-period average
	Inches	Inches	Percent
Phoenix	0.87	1.03	18
Mesa	.99	1.27	13
Granite Reef	.81	1.49	84
Average	.89	1.26	42

42/ A preliminary study was first made to determine whether such a method would properly place the years in the order in which damage had occurred during the period 1926-38. It was found that the indices derived did represent the order of magnitude of damage in these years with a fair degree of accuracy.

Computations were not made as to actual run-off, because to have done so would have required introducing so many unknown factors as to make the results of little value.

43/ It seems probable that in this watershed, flood damages at any given season may be correlated most directly with the total quantity of water discharged, that is, the amount of run-off in acre-feet. The amount of precipitation available for run-off being taken as an indication of the magnitude of floods, flood damages are assumed to be proportional to the relative amount of precipitation available for run-off.

326. At each location, the average run-off yield was estimated to be greater during the long period than during the short period. The amount by which the long-period average exceeds the short-period average varies from 13 percent (at Mesa) to 84 percent (at Granite Reef), making an average increase of 42 percent. In order not to give undue weight to the Granite Reef record, however, it was concluded that a conservative increase of 25 percent in the average amount of summer damages sustained during the period 1926-1938 should be used to determine the average damages from summer floods over a long period of years.

327. No damaging winter floods occurred during the period 1926-1938 on drainages other than Queen Creek, and therefore do not figure in the estimate of flood damages for that period (see par. 293). An analysis of rainfall records for the period 1897-1938 indicates that six damaging winter floods probably occurred during the 42-year period, all of them prior to 1926 44/. It was assumed that a winter flood of a given magnitude would cause about 50 percent as much damage as a summer flood of the same magnitude (crops are not susceptible to much damage in the winter time). When this factor is considered an analysis of winter rainfall similar to that made for summer rainfall indicates that, on the basis of their frequency, winter floods from drainages other than Queen Creek could be expected to cause about 10 percent as much damage, in the long run, as was caused by summer floods during the period 1926-1938.

44/ The floods, in order of magnitude, were those of November 1905, January 1897, January 1915, January 1916, December 1914, and March 1905.

328. Summary, adjustment to storm expectancy. It is concluded that, had summer and winter precipitation in the years 1926-38 been normal, flood damages would have been 35 percent greater than they were, and would have amounted to an estimated average of $98,000 per year, instead of $73,000, under conditions of subnormal rainfall.

Flood Damages Adjusted to Increased Erosion

329. The estimated average annual flood damages of $98,000, adjusted to storm expectancy, based on rainfall records for the 42-year period 1897-1938, does not take into account the effects of increased erosion that would result were no remedial measures put into effect. It is believed that in about 25 years, without remedial measures, channel erosion will reach its maximum advanced state, especially on the plain part of the watershed. The consequence would be increased flood damages, owing to the fact that the then well-developed erosion channels extending entirely across the plain to the agricultural area would greatly facilitate the concentration of flood waters at and onto the irrigated area, thus increasing their destructive force. Increased erosion, especially gullying, will also result in more discharge through reduction of infiltration rates, losses of channel storage, and loss of surface detention of water. These conditions call for a further adjustment of the above damage estimate.

Method of Adjustment

330. From a study of rainfall records and flood history covering the period 1926-38, it seems that in order for damaging summer floods to result on drainages other than Queen Creek there must be a minimum of about 1.5 inches of precipitation available for run-off during

the summer season. It is believed that, should erosion reach an advanced state, a damaging summer flood would result if the amount of rainfall available for run-off exceeded about 1.0 inch during the summer season. From rainfall records for the period of recent floods, 1926-38, and the large-flood year of 1911, an estimate was made of the floods that might be expected under badly deteriorated watershed conditions, as compared with present watershed conditions, the size of floods being assumed to be indicated by the amount of summer precipitation available for run-off in excess of the minimum necessary to cause a flood (table 14).

Table 14. - Probable effect of watershed deterioration on floods, as indicated by the estimated summer precipitation available for run-off in amounts in excess of the minimum

Year	Total summer precipitation available for run-off		
	Total amount	Amount in excess of the minimum that would cause a damaging flood	
		Under present watershed conditions	Under advanced state of erosion and watershed deterioration
	Inches	Inches	Inches
1911- - - - - - - - -	5.30	3.80	4.30
1936- - - - - - - - -	2.62	1.12	1.62
1927- - - - - - - - -	2.31	.81	1.31
1931- - - - - - - - -	2.04	.54	1.04
1926- - - - - - - - -	2.03	.53	1.03
1930- - - - - - - - -	1.81	.31	.81
1933- - - - - - - - -	1.59	.09	.59
1928- - - - - - - - -	1.53	.03	.53
1935- - - - - - - - -	1.53	.03	.53
1937- - - - - - - - -	1.32	--	.32
1929- - - - - - - - -	1.20	--	.20
1932- - - - - - - - -	1.14	--	.14
1934- - - - - - - - -	1.03	--	.03
1938- - - - - - - - -	0.83	--	--
Average, with normal rainfall 1/	1.75	.36	.73

1/ Flood-producing summer rains occurring during the period 1926-38 are considered as representative of average expectancy, except for the occurrence of large rains such as that of the year 1911, estimated to occur on a frequency of about once in 40 years. The average expectancy is, therefore, determined by adding to the average for the period 1926-38, one-fortieth part of the amount for the year 1911.

331. As shown by this study, progressive watershed deterioration would cause small floods to become more frequent, and all floods to become larger. It is estimated that with normal precipitation, the average amount of rainfall that would be available for run-off in excess of the minimum amount necessary to cause a damaging flood, would be increased from 0.36 inch to 0.73 inch, or slightly more than doubled, as the result of increased erosion and watershed deterioration (table 14).

332. Increased flood damages from erosion. The increase in future flood damages due to increased erosion alone is assumed to be 90 percent, as a conservative estimate. On this basis, flood damages from drainages other than Queen Creek might be expected to increase from an average of from $98,000 annually to an average of $186,000 annually in 25 years, and would remain at that level thereafter. On the annual-equivalent basis, this would be equal to an all-time average, including the 25 years and all future time, of $159,000 annually 45/.

Non-measurable Flood Damages

333. In addition to the measurable flood damages there are important intangible damages and also other damages not measurable. The damages of the non-measurable class include illness and loss of life resulting directly or indirectly from floods; worry and discomfort; interruption of transportation and communication; and the general loss to the community and Nation from a decrease in the purchasing power of the residents of this area.

45/ All future flood damages, discounted at 3 percent annually, would have a present value of $5,320,000.

Illness and Loss of Life

334. No loss of life is known to have resulted directly from past floods in this watershed, but very large floods might cause some loss of human lives. More serious, perhaps, is the illness and loss of life resulting from frequent typhoid-fever epidemics following floods. Local physicians have reported that uncovered or unprotected wells, together with water from open irrigation ditches, become contaminated with coli or typhoid bacteria, following floods. Eight cases of typhoid fever, one of which proved fatal, were reported as having occurred about 1933. In Gilbert it is the practice to inoculate about 300 young children and students and migratory cotton pickers against typhoid fever each year. To protect against disease following floods all drinking water is boiled by most residents.

Worry and Discomfort

335. Inasmuch as summer floods in Queen Creek basin are sudden and they may occur any time without warning, the residents of the flood-damage areas, who cannot avoid the floods, live in constant fear of them. Mental suffering attends this fear of floods; and discomfort is caused by the floods and by the dirty, muddy conditions which follow.

Interruption of Transportation and Communication

336. Local farming communities are frequently isolated for days at a time by floods which render roads impassable. Major floods would interrupt travel on transcontinental highways and railroads, and disrupt power, telephone, and telegraph services.

General Indirect Losses to Community and Nation

337. Floods decrease the purchasing power of the local people in the

flood-damage area, and this results in smaller purchases of the products and services of industry and commerce, thus depressing local business. This affects to some degree the prosperity of the whole Nation.

EROSION LOSSES AND BENEFITS FROM CONSERVATION OF RANGE RESOURCES

338. The range lands of Queen Creek watershed have suffered serious loss in grazing values as a result of overgrazing. It is estimated that this loss represents 65 percent of the original grazing capacity. The period of most rapid depletion probably occurred about the beginning of the present century, since which time the rate of depletion has been less pronounced. The grazing value of these lands is now so low that another 25 years of overgrazing and deterioration of the vegetation would likely make the use of these lands for grazing purposes uneconomical. On the other hand, with proper regulation and use now the grazing values of these range lands could probably be retained, and gradual improvement expected. Because of the desert conditions and the general soil losses through erosion, it is likely that improvement in grazing values will be slow. Conservation benefits take the form, not of an increase in present income, but rather of the perpetuation of the income from grazing use.

339. The land income produced by the 300,000 acres of range lands in the areas where grazing will be continued, but regulated (see map 3), is estimated at $9,000 per year, based on an average annual rent of 3 cents per acre per year. At 3 percent discount, the present worth of this income for an infinite period of time is $300,000, compared with a present value of $157,000 for 25 years' income. Thus, the benefits from conservation of range resources amount to an increase

in the capital value of the grazing lands of $143,000. Such increase in the capital value of the lands is equal to that of the total value of an area of land that produces a permanent income of $4,300 annually 46/.

46/ It is assumed that the land owners would continue to receive the same rent for their lands as at present and that the reduction in rent entailed by reduced grazing (par. 67) would be borne by public agencies as a cost chargeable to flood control. If the decrease in land income entailed by the drastic reduction in stock numbers were to be borne by the land owners, the effect would be to depress the capital value of the grazing land, not increase it. The loss in present land rent of $6,500 per year resulting from controlled grazing (par. 67), more than offsets the annual equivalent gain of $4,300, due to prolonging land income.

ARIZONA LAWS AND COURT DECISIONS RELATING TO A FLOOD- AND EROSION-CONTROL PROGRAM

340. Pertinent to a flood- and erosion-control program are certain State laws and court decisions that might either obstruct or facilitate such a program, such as legislation enabling the formation of flood-control districts, laws applying limitations on bonded indebtedness and taxes, and regulations governing the leasing of State lands.

Flood-Control District Enabling Legislation

341. The Arizona law provides for the organization of flood-control districts (ch. 81, art. 6). Such districts may be organized "whenever five or more holders of title or evidence of title to improved lands which are subject to overflow or washing, or menaced or threatened by the normal flow or flood or overflow waters of any natural watercourse, stream, canyon or wash, whether perennial, intermittent or flood, and capable of being protected or relieved . . . by the same general system of works, desire to provide protection of such lands." " . . . The works constructed . . . shall be such works as are suitable, proper, and convenient for the protection of the lands of said district from the overflow, washing, or menace to which said district is subject" (sec. 3607). Such districts shall include within their boundaries "all land subject to overflow and washing" (ch. 81, art. 6, sec. 3606).

Powers of the District

342. The flood-control districts, provided for by Arizona law, may issue bonds, levy taxes, initiate condemnation proceedings, own land and

other property necessary for the construction, use, maintenance, repair, and improvements of any works required; they may co-operate with and receive donations from the State or other political subdivisions or from private sources and "perform all such acts as may be necessary to fully carry out the purposes of this article" (art. 5, secs. 3528, 3540, 3541, 3556, 3530; art. 6, sec. 3607).

343. Power to enter into contracts with Federal Government. Flood-control and other districts, agencies or political subdivisions presently existing, or which may be organized in the future, may enter into contracts with the Federal Government for obtaining loans, grants, or advances of money to be used for the acquisition of properties or for their extension, improvement or repair, and for the refunding of existing indebtedness (Rev. Code Sup. 1936, ch. 81, art. 8, secs. 3607r and 3607s). Such contracts may contain the provisions that the properties of the district "be held in trust irrevocably during the terms of such contract," and that the properties shall be maintained either by the Federal Government, by the district ". . . or by any public or private agency designated" (sec. 3607u). The act further empowers the district "to do any and all acts and things, considered necessary or advisable by the Federal Government and the district in connection with or additionally to secure such loans or grants of money . . . ." (sec. 3607v). The powers granted the district are to be liberally construed (sec. 3607z4).

344. Tax assessments. Flood-control district tax assessments may, if the petitioners so elect, be levied on the basis of benefits received (art. 6, sec. 3601), the levies to be determined by an ap-

praisal of the land in units of not less than 40 acres in size (sec. 3600). Two appraisers (appointed by the board of directors) and the engineer for the district determine for each parcel of land the amount of benefit that such parcel will receive by the construction, and apportion the assessment. The maximum assessment in any part of a district cannot be greater than five times the lowest (art. 5, sec. 3602). District tax assessments are collected by the regular county officials (art. 5, sec. 3557), but may be paid separately from State or county taxes (art. 5, sec. 3558).

County Flood-Control Legislation

345. Whenever floodwaters injure or threaten to injure a road or public property or menace human life, the county supervisors " . . . may build dikes, levees or other structures or aid in the construction of such works to control such floodwaters . . . and for such purpose may appropriate and use in any one year out of the general fund an amount not to exceed 15 cents on each $100 of taxable property in the county . . ." (code sec. 820) 47/.

Soil Conservation District Enabling Legislation

346. Arizona has no enabling legislation permitting the organization of soil conservation districts. However, voluntary co-operative soil conservation agreements may be entered into.

State Co-operative Grazing District Enabling Legislation

347. Arizona has no special legislation permitting the organization of co-operative grazing districts.

47/ Based on the assessed valuation of $104,766,107 for Maricopa County property in 1938, a levy of 15 cents on each $100 of taxable property would yield $157,000 of taxes annually.

Zoning Enabling Legislation

348. Arizona has no legislation that permits either flood-plain or rural land-use zoning.

Regulations Governing the Lease and Sale of State Lands

349. The land commissioner, under the direction of the State land department, has "charge and control of all lands owned by the State, except such as are under the specific use and control of State institutions, and of the timber, stone, gravel and other products thereof" (ch. 71, art. 1, sec. 2951). State lands may be sold or leased in the manner and on the conditions and with the limitations prescribed in certain Federal land grants 48/, in the Arizona State Constitution, and as may be further prescribed by law (Ariz. Const. art. 10, sec. 9).

Lease of State Lands

350. All State lands are subject to lease for periods not longer than 20 years (ch. 71, art. 3, sec. 2964). Under the terms of section 28 of the Enabling Act of June 20, 1910, the State is prohibited from leasing lands granted to it by the United States for periods longer than 5 years, except by public auction, when the maximum length of lease may be 20 years. Range-land leases are usually made for 5-year periods. The minimum annual rental that may be charged is 1 cent per

---

48/ Congress in the enabling act of June 20, 1910 (36 stat. 569-75) granted lands to the State of Arizona in trust to be disposed of as provided by the grant. The natural products of the lands are subject to the same trust as the land itself. Grass is a product of the land, and overgrazing amounting to waste is a disposition contrary to the provisions of the grant and therefore a breach of trust.

acre for grazing lands and 5 cents per acre for agricultural lands (sup. 1936, sec. 2967). There is no limitation on the number of acres that may be leased by any one person (Ariz. Const. art. 10, sec. 11).

351. Lease renewal. The Arizona laws give a lessee "a preferred right of renewal" for a term not longer than 5 years at a reappraised rental (sec. 2972). The same section provides that if the commissioner "deemed the continued leasing of the said land not to be for the best interest of the State, the lease shall not be renewed." This "preferred right of renewal" has been construed as not giving the lessee an enforceable interest in the property 49/, but as only giving a "better" or "superior" right, and implies a hearing and investigation to determine the quality of that right and the exercise of discretion and judgment on the part of the commissioner 50/. Where two or more applicants apply to lease the same land, section 2965 gives the person residing on his homestead entry "a preference right to lease such contiguous State lands as is necessary for his personal use." This "right," according to dicta in a recent decision 51/, "may be either a legal right or an equitable one." The courts have not been called upon directly to define this right, but have been called upon only to determine the superior equity. The Arizona State Land Commissioner may, in his discretion, refuse to execute grazing-land leases, even though the applicant may be the first and only applicant, and has made

---

49/ Boice v. Campbell, 30 Ariz. 424, 248 Pac. 34.
50/ Campbell v. Muleshoe Cattle Co. (1923), 24 Ariz. 620, 629, 212 Pac. 381.
51/ Davis v. Campbell, (1922), 24 Ariz. 77, 83, 206 Pac. 1078.

application in the prescribed form. The highest bidder is not entitled as a matter of right to the lease of the land 52/.

352. Lease terms. The terms of the leases are usually determined by the State land department. Leases "shall contain covenants that the lessee will not permit any loss, nor cause any waste in, or upon, the land and will not cut or waste . . . any timber . . . without the written consent of the commissioner, except for fuel for domestic uses, or for necessary improvements . . ." (code sec. 3968). A lessee violating any conditions of a lease may have his rights thereunder forfeited (sup. sec. 2970), but before any action is brought for its cancellation the lessee shall be given a public hearing (code sec. 2971).

Sale of State Lands

353. All State lands, except lands used for State institutions, timber lands, lands containing minerals or oil, or lands adjoining private mineral or oil lands, are subject to appraisement and sale. The State may not sell to any one person more than 640 acres of grazing lands, nor more than 160 acres of tillable lands (code secs. 2978, 2988). No land shall be sold for less than $3 per acre, and no irrigable land shall be sold for less than $25 per acre (Const. art. 10, sec. 5). The Arizona Supreme Court has held that where State lands are sold, the land department "has no authority to sell less than the whole, and until authority is given to sell less, like surface rights or other partial interests, it may not do so" 53/.

52/ Campbell v. Caldwell, (1919), 20 Ariz. 377, 181 Pac. 181.
53/ Campbell et al. v. Flying V. Cattle Co., (1923), 25 Ariz. 577, 586, 220 Pac. 417.

354. Lands that have been struck off to the State for nonpayment of taxes are resold by the county treasurer in the county where the land is located, and are not handled by the Arizona Land Department.

Limitations on Bonded Indebtedness and Taxes

355. The Arizona State Constitution places definite limitations upon the total debt that may be contracted by the State, the counties, cities, and other taxing bodies. Article 9, section 5, limits the aggregate of State indebtedness, whether direct or contingent, except in emergencies, to $350,000. This limitation would prevent the State from lending its credit in assistance of flood control or other projects. However, section 12 permits multiple types of taxation, thereby allowing a wide source of tax revenue. A part of this section reads as follows: "The law-making power shall have authority to provide for the levy and collection of license, franchise, gross revenue, excise, income, collateral, and direct inheritance, legacy and succession taxes, also graduated income taxes . . . production or other specific taxes."

356. Article 9, section 8, of the constitution limits the indebtedness of a county, city, town, school district, or other municipal corporation to 4 percent of its taxable wealth without the assent of the property taxpayers and to 10 percent with their consent. Incorporated cities may be indebted up to 15 percent additional for the building of city-owned water, light, or sewer systems.

357. An irrigation district has been held not a "municipal corporation" within the meaning of constitution article 9, section 8 54/, and

---

54/ Ramirez v. Electrical District No. 4, 37 Ariz. 360, 294, Pac. 614 and Maricopa County Water Conservation District No. 1 v. La Prade, 40 P (2nd) 94.

its limit of indebtedness is, therefore, not limited to a percentage basis of the district's taxable property 55/. Inferentially, a flood-control district's indebtedness would not be limited to a percentage of the district's taxable property, but would be determined by the vote of the real property taxpayers.

358. Limitations on tax-levying power. Definite limitations are placed upon the tax-levying power of certain local taxing bodies. Budget estimates proposed or adopted by a county board of supervisors must not exceed by 10 percent the aggregate of actual expenditures of the previous year, exclusive of the expenditures for school, bond, special-assessment and district levy purposes (code secs. 3079, 3570). Special flood-district assessments may be voted at any time. There are no limitations on State tax levies.

Tax Delinquency and Reversion

359. Property shall be assessed for tax purposes at its full cash value before the first day of May of each year (ch. 75, art. 3, sec. 2074). Taxes are payable in two installments (Code Sup. 1936, ch. 75, art. 1A, sec. 30650). Property on which taxes remain unpaid after the second delinquency date, which is in May of the year following assessment, is that autumn (Oct.) advertised and sold. If there is no bid for any tract offered, such tract is re-offered later until the county treasurer becomes satisfied that no sale can be effected, at which time the tract is struck off to the State (Supp. ch. 75, art. 1A, sec. 3065t). Land struck off to the State may thereafter be purchased by any person who will pay the taxes due thereon, including interest, penalties, and taxes subsequently assessed (sec. 3065 z5). Each year all tax-delinquent lands held by the State in each

---

55/ Ibid.

county are re-offered, by the county treasurer, first at private sale, for taxes due, penalties, and the like; but if no private sale can be made, the tract may then be sold to the highest bidder (sec. 3065 z27).

360\. Real estate sold may be redeemed by the delinquent tax payer within 3 years (sec. 3065 z11). Legal action to foreclose the right to redeem may be brought after 3 years (sec. 3065 z 19). However, a treasurer's deed may be obtained without legal action after the expiration of 5 years (sec. 3065 z23).

361\. Arizona has no legislation that provides for a long-range program of public ownership and administration of tax-reverted lands.

Arizona Resources Board

362\. An Arizona resources board is provided for (ch. 71, art. 9, secs. 3011 to 3013). This board, which shall consist of five members appointed by the Governor, is authorized to ". . . investigate and devise means and plans for the conservation, utilization and control of all waterways, sheds and water resources and of all matters relating thereto," including, among other things, flood control and the prevention of soil waste. The board may recommend regulations to promote and protect the rights and interests of the State and its inhabitants.

Water Rights

363\. Water of all sources, except percolating water, belongs to the public, and is subject to appropriation for beneficial use. Any person, a municipality, the State, or the United States may make application to appropriate any remaining unappropriated water for domestic, municipal, irrigation, stock-watering, water-power or mining uses. Whenever the owner of such appropriated water ceases to use it for 5 successive years it reverts to the public (ch. 81, secs. 3280 to 3284, Revised Ariz. Code, 1928).

Percolating Water

364. "Percolating water oozing through the soil beneath the surface in an undefined and unknown channel" is not subject to appropriation 56/, but is the property of the owner of the land. "Underground waters are presumed to be percolating in nature," and if one asserts that such water is not percolating, he must prove the assertion affirmatively by clear and convincing evidence 57/. However, subterranean streams that flow in natural channels between well-defined banks are subject to appropriation under the same rule as are surface streams 58/.

Riparian Rights, Floodwaters, Etc.

365. The common-law doctrine of riparian rights has been expressly repudiated 59/, and the right to use water is not confined to riparian owners 60/. Floodwaters may be appropriated 61/.

56/ Howard v. Perrin (1906), 200 U. S. 71, 50 L. Ed. 374, 26 Sup. Ct. 195.

57/ Maricopa County Municipal Water Conservation Dist. No 1 v. Southwest Cotton Co., 39 Ariz. 65, 4 P. (2nd) 369.

58/ Howard v. Perrin (1904), 8 Ariz. 347, 76 Pac. 460.

59/ Chandler v. Austin (1895), 4 Ariz. 346, 42 Pac. 483.

60/ Boquillas Land & Cattle Co., v. Curtis (1908), 213, U. S. 339, 53 L. Ed. 822, 29 Sup. Ct. 493, affirming 11 Ariz. 128, 89 Pac. 504.

61/ George v. Gist (1928), Ariz. 93, 263 Pac. 10.

During years of water scarcity, precedence in the use of available water is based on the priority of the original taking of the water (ch. 81, art. 1, sec. 3320, revised code, 1928). The statutes also confer upon a permittee the right of condemnation, under the laws of eminent domain, to acquire rights-of-way for reservoirs, dams, and ditches (sec. 3319). In addition, the code permits the use of natural channels to carry water, even though the natural waters of such channels have been previously appropriated by others (sec. 3323).

Dams

366. It is unlawful to construct, repair, operate or maintain any dam or appurtenant works for impounding or diverting water 15 feet or more in height or of an impounding capacity over 10 acre-feet, except where used exclusively for watering livestock, without the approval of the State engineer (sup. sec. 3607a).

Wildlife

367. House Bill No. 119 passed during the 1939 session of the Arizona Legislature, empowers the State Game and Fish Commissioner to co-operate with the Federal Government for the restoration of wildlife. The commission has "power to acquire, by purchase, lease or gift, lands or other property, or interests therein, as may be necessary . . ." (ch. 51, 1939).

Parks

368. Any county or municipality may lease or purchase or accept as a gift real property, without or within its borders, for use as a park or recreational area (ch. 78, 1939).

AVAILABLE LABOR

370. Available labor on W.P.A. rolls in Queen Creek watershed and vicinity, as of July 1, 1940, is as follows 62/:

	Skilled	Unskilled	Total
Maricopa County:			
Phoenix	1,372	1,565	
Tempe	62	148	
Scottsdale	12	24	
Mesa	158	219	
Gilbert	8	49	
Chandler	13	68	
Subtotal	1,625	2,073	3,698
Pinal County:			
Superior	13	21	
Florence	32	53	
Coolidge	36	72	
Subtotal	81	146	227
Gila County:			
Miami	15	48	
Globe	64	88	
Subtotal	79	136	215
Total	1,785	2,355	4,140

The laborers available on relief rolls are as follows 63/:

Maricopa County	385
Pinal County	30
Gila County	20
	435

62/ Reported by Division of Employment, Work Projects Administration, Phoenix, Ariz.

63/ Reported by State Board of Social Security, Phoenix, Ariz.

ALTERNATIVES IN PLAN OF IMPROVEMENT

371. In addition to the recommended plan, two principal alternatives in the plan were considered. The first alternative involves the placing of complete dependence for flood protection on the minor structural treatment and range-use adjustments. The second alternative would contemplate having only a dike system, without any watershed treatment.

No Dikes

372. The alternative without dikes is similar to the recommended plan, except that only the minor structural treatment and range-use adjustments would be used. Such a plan of improvement would not be so expensive as the proposed plan, but would provide only partial flood protection (table 15).

Effectiveness of Treatment Without Dikes

373. It is estimated that minor structural treatment and range-use adjustments, without dikes, would reduce flood damages, on the average, only about 15 percent at the beginning, but would gradually become more effective as the ground cover improves, reaching a maximum of 55 percent reduction in flood damages after about 25 years of improved vegetation. The effect of progressive watershed deterioration upon flood damages would, of course, be prevented. It is estimated that benefits from the prevention of flood damages without dikes would amount to $102,500 per year, on the annual-equivalent basis. The flood-control benefits from this plan would accrue largely from the prevention of an increase in flood damage by checking watershed deterioration than in the reduction of flood damages from their

Table 15. - Costs and Benefits of Plan Without Dikes, Compared With the Recommended Plan

Remedial measure	Investment costs	Annual costs			Annual benefits			Excess of annual benefits over costs
		Amortization charges for investment costs	Operation and maintenance costs	Total annual costs	Prevention of flood damage	Conservation of range resources	Total annual benefits	
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
Plan without dikes:								
Minor structural treatment	288,800	11,225	1,500	12,725				
Range-use adjustments	94,300	3,675	12,850	16,525				
Total	383,100	14,900	14,350	29,250	102,500	3,400	105,900	76,650
Recommended plan:								
Dikes	304,300	11,850	12,850	24,350				
Minor structural treatment	288,800	11,225	1,500	12,725				
Range-use adjustments	94,300	3,675	12,850	16,525				
Total	687,400	26,750	26,850	53,600	162,000	3,400	165,400	111,800

present level. The flood damages that would be permitted under this plan, even at its best (after 25 years of revegetation), are estimated to average nearly $50,000 per year, and would at the beginning amount to almost $90,000 annually. The smaller floods would be controlled by this manner, but the larger floods would be little affected.

Comparative Advantages, Dikes v. No Dikes

374. The first alternative, which would cost an estimated $29,250 per year, would have slightly higher ratio of benefits to costs than that of the recommended plan. However, the comparative economic advantage of any alternative is to be judged not so much by the ratio of benefits to costs as by the net returns, or excess of benefits over costs. The estimated excess of benefits over costs for the recommended plan are $111,800 per year, as compared with $76,650 per year for a plan without dikes. The recommended plan, in other words, would increase the net income of society by $35,150 more per year than would a plan without dikes.

375. The fact that a plan with dikes would provide immediate and complete flood protection to the residents of the damage areas at an additional cost that is economically justified by a large margin, favors the recommended plan 64/.

376. A variation of first alternative would be to increase the amount of

---

64/ The dikes, when used in conjunction with watershed treatment, are estimated to cost $24,350 annually (table 15). By providing complete flood protection, the dikes would prevent an additional $59,500 per year of flood damage not preventable by minor structural treatment and range-use adjustments (the total flood damages prevented would be increased from $102,500 to $162,000 per year). The dikes, as a part of the recommended plan, are, therefore, economically justified by a margin of 2.4 to 1.0 of benefits over costs.

minor structural treatment. It might be possible to double the acreage of minor structures. It appears, however, that this would increase the flood-control benefits little if any more than enough to offset the increased costs for such structural treatment.

377. Another variation in the plan without dikes would be to exclude livestock grazing on all parts of the watershed, thus giving all possible aid to natural revegetation and its effect in retarding water-flow. Such a plan, however, if it necessitated land purchase in order to obtain legal control of the land, would be very expensive. The investment costs for such a plan would amount to more than $1,000,000. It might also be questionable whether, from a political viewpoint, it would be possible or expedient to exclude livestock grazing from the entire watershed.

Dikes Only

378. The second alternative in the improvement plan would envisage the control of floods by dikes only, without any minor structural treatment or range-use adjustments.

379. The second alternative, with dikes only, would have the advantage of a somewhat lower initial investment cost, but the total annual costs would exceed those of the recommended plan. Although the use of dikes only would probably provide a reasonably high degree of flood protection, there would not be so great an assurance of satisfactory, safe, and permanent operation as the recommended plan, nor would the watershed and grazing values be preserved. The use of dikes only would, however, escape the institutional problems relating to adjustments in the use of range lands, which problems must be coped with

in the recommended plan.

Larger Dikes

380. Larger dikes would be necessary if no minor structures and range-use adjustments were omitted, because these other treatments serve the dual purpose of soil-erosion prevention and water-flow retardation. Without these supplementary remedial measures, the dikes would have to be built of a sufficient size to handle a peak flow of 16,000 second-feet of water instead of a flow of only about 6,000 second-feet (par. 257).

381. A greater silt problem. A more serious problem than that of handling the larger flow of water, however, concerns the deposition of silt in the dike channels. The most serious hazard to the effective functioning of the dikes is the possibility of the formation of silt fans, which, in any storm, might be built up rapidly in front of the dikes, thus possibly causing failure of the dikes. To overcome the menace of silt and to handle the larger peak flow of water, it would be necessary to make the dikes at least 3 feet higher, if a reasonably high degree of flood protection were to be provided without the use of minor structures and range control 65/.

65/ To handle the larger peak flow of water would require adding from 1 to 2 feet to the height of the dikes, depending on location. A much greater flow of water could be handled by the dikes by a relatively small increase in height, because for each unit of increase in height the water spreads over a wider area, thus resulting in an increase in capacity proportionately greater than the increase in height (see dike capacity curves, fig. 15). To overcome the silt menace, it would be necessary to increase the freeboard on the dikes. A uniform increase of 3 feet in the height of the dikes would give a freeboard varying from 3.7 feet for the Santan Dike to 4.8 feet for the Sc section of the Superstition Dike. Silt, which would be removed from the dike channels by maintenance work, would be placed on top of the dikes, gradually building them higher and higher. It is believed this would tend to compensate for the larger peak flow of water that the dikes would have to handle in the future, because of continued watershed deterioration.

382. Higher initial cost. The investment costs for building the large dikes are estimated at $519,300 ($215,000 more than the cost of the dikes in the recommended plan) 66/. Also, the dikes would have to be fenced, the investment cost for which would amount to an estimated $26,600. The total investment cost for the second alternative of dikes only is estimated at $545,900 (table 16).

383. High operation and maintenance costs. The operation and maintenance costs would be very high for a plan with dikes only. The use which is made of the watershed will have an important bearing on the quantity of silt that is likely to be moved into the dike channels, thus increasing their operation and maintenance costs. Without range-use adjustments and minor structural treatment, the cost of dike maintenance would be very high from the start, and would increase markedly as time goes on, because larger and larger quantities of silt would be moved into the dike channels as a result of progressive watershed deterioration (fig. 19) 67/. On the other hand, with range-use adjustments and minor structural treatment, the silt brought into the dike channels would gradually decrease. Without minor structural treatment and range-use adjustments, the cost of operation and maintenance of the dikes is estimated to average $38,100 per year (on an annual-equivalent basis) whereas, with these

---

66/ Adding 3 feet to the height of the dike would almost double the amount of earthwork, would necessitate very greatly enlarged railroad and highway bridges, and would increase the cost for rights-of-way and easements considerably.

67/ It is estimated that, after 25 years, when the watershed had completely deteriorated, there would be brought into the dike channels an average of more than 250 acre-feet (400,000 cu. yd.) of silt annually, 80 percent of which would have to be removed.

Table 16. - Costs and Benefits of a Plan Having Dikes Only, Compared With the Recommended Plan

Remedial measure	Investment costs	Annual costs			Annual benefits			Excess of annual benefits over costs
		Amortization charges for investment costs	Operation and maintenance costs	Total annual costs	Prevention of flood damage	Conservation of range resources	Total annual benefits	
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
Dikes only:								
Dikes	519,300	20,200	38,100	58,300				
Fencing of dikes	26,600	1,025	2,150	3,175				
Total	545,900	21,225	40,250	61,475	162,000	---	162,000	100,525
Recommended plan:								
Dikes	304,300	11,850	12,500	24,350				
Minor structural treatment and range-use adjustments	383,100	14,900	14,350	29,250				
Total	687,400	26,750	26,850	53,600	162,000	3,400	165,400	111,800

measures, it is estimated to average $12,500 per year (table 16). Total operation and maintenance costs for a plan with dikes only, including maintenance of the dike fences, are estimated at $40,250 per year, as compared with $26,850 per year for the recommended plan.

384. Annual costs higher. The total annual costs, including amortization charges for the investment costs as well as operation and maintenance costs, are estimated at $61,475 per year for the alternative plan with dikes only, as against $53,600 for the recommended plan (table 16).

Advantages of Recommended Plan

385. The recommended plan has a net advantage of $11,275 per year over the alternative plan with dikes only, in terms of the net returns, or excess of benefits over costs (table 16). The minor structural treatment and range-use adjustments are therefore fully justified as a part of the recommended plan, because they would reduce the costs of the dikes, increase their safety, and conserve the grazing and watershed values 68/.

386. Safety factor. A plan of improvement that would include minor structural treatment and range-use adjustments would not only be the most economical, but it would also be the most certain of satisfactory operation. Because of the silt hazard, it is unlikely that dikes only would have so great a degree of safety and assurance of satisfactory operation, even were very large dikes con-

---

68/ Considering the conservation benefits, as well as the annual savings in the cost of the dike system, the ratio of measurable benefits which would be derived from the use of minor structures and range-use adjustments, to that of the cost of these measures, is estimated at 1.4 to 1.0.

structed, as would the recommended plan which includes treatment of the watershed. In fact, unless the watershed is protected, it is possible that silt might ultimately overwhelm the dike system.

PRIOR PROPOSALS FOR FLOOD CONTROL IN QUEEN CREEK WATERSHED

387. Six plans for flood control on Queen Creek watershed are reported in the Eastern Maricopa County Flood Control Report (21) as having been proposed by various individuals and agencies. These are briefly summarized as follows:

Plan No. 1

388. In June and July 1926, the Salt River Valley Water Users' Association made a preliminary survey of the area, including a determination of the location of a main drainage channel in the Superstition area, following a heavy run-off. A preliminary line was run for an interception channel from a point near the Maricopa County line 4 miles north of Queen Creek northwesterly to Salt River, and a dike-channel directly east of the Roosevelt Canal to carry Queen Creek waters from a point near the Southern Pacific crossing southwesterly to the end of the canal and thence to the Gila River channel. The total cost of construction was estimated at $380,000.

Plan No. 2

389. In the fall of 1932, a survey was made through the co-operation of Maricopa County, Salt River Valley Water Users' Association, and Roosevelt Water Conservation District, with a view to diverting Queen Creek waters almost directly south from a point on Queen Creek about 7 miles north of Magma to the head of Magma Creek (about 2 miles southwest of Magma) which empties into the Gila River,

and also to constructing a channel from a point northwest of Apache Junction, leading in a southerly direction and emptying into Queen Creek above the diversion point of the Magma Creek channel. The total cost of this construction was estimated at $230,000. Application for financing of this project through Civil Works Administration funds was not approved because of the magnitude of the project and its distance from population centers.

Plan No. 3

390. In the fall of 1933, application was made by Maricopa County to the P.W.A. for funds to finance work along lines proposed by the Eastern Maricopa County Flood Control Committee. While this application was pending, the Civil Works Administration approved a project for the survey of the project. This survey was not entirely completed before the C.W.A. went out of existence. The total construction cost under this plan was estimated at $932,800, consisting of the following items:

Apache Trail drainage channel	$ 40,600
Superstition drainage channel	166,800
Queen Creek dam (Whitlow Ranch site)	335,000
New Queen Creek channel	196,000
Santan drainage channel	83,200
Engineering and contingencies	76,200
Rights-of-way	20,000
Legal expense	15,000
Total	$932,800

The application was not approved by the P.W.A. because of questions as to the right of Maricopa County to issue bonds and obtain funds for this purpose.

Plan No. 4

391. Plan No. 4, with many proponents, suggests the control of floods in the Superstition area by water spreading and absorptive methods, as practiced by the Soil Conservation Service, together with a dam at Whitlow Ranch dam site on upper Queen Creek. The cost of construction was estimated at about $250,000 for the treatment of Superstition area, plus $335,000 for the dam, a total of $585,000.

Plan No. 5

392. Forest Service officials and other parties of upper Queen Creek watershed have suggested the construction of smaller dams on Queen Creek in conjunction with the treatment on the Superstition area. A preliminary estimate of the construction cost of this proposal follows:

Soil-erosion control, Superstition area - -	$250,000
Dam near Boyce Thompson Southwestern Arboretum (capacity 1,100 a.-ft.) - - -	75,000
Black Point dam (capacity 6,000 a.-ft.) - -	55,000
Whitford Canyon dam - - - - - - - - - - - - -	50,000
Arnett Canyon dam - - - - - - - - - - - - - -	100,000
Whitlow Canyon dam (dirt-fill) - - - - - - -	40,000
Total - - - - - - - - - - - - - - - - -	$570,000

Plan No. 6

393. Plan No. 6, proposed by Mr. F. N. Holmquist for the Queen Creek Irrigation District, is similar to Plan No. 3, except that openings were proposed in the dikes to allow infiltration. The total cost of construction was estimated at $906,200.

IMPORTANT SOURCES OF FACTUAL INFORMATION

(1) United States Dept. of Agr. Weather Bureau.
1920-38. Monthly Weather Reviews.

(2) __________
1930. Climatological Summary of the United States, Sec. 26, Southern Arizona.

(3) Darton, N. H.
1933. Geological Map of the State of Arizona.

(4) __________
1925. A Resume of Arizona Geology. Bull. 119, Geological Series 3, Univ. of Ariz. College of Mines and Engineering Arizona Bureau of Mines.

(5) Bandalier, Adolph F.
1890. Final Report of Investigations Among the Indians of the Southwestern United States. Papers, Archaeological Institute of America, American Series, v. 3. Cambridge.

(6) Fewkes, J. W.
1898. Archaeological Expedition to America in 1895. Seventeenth Annual Report, Bureau of American Ethnology. Washington, D. C.

(7) Parke, Lt. John G.
1851. Ex. Senate Doc. 91 H. 33rd Congress, 2nd Session, v. 7.

(8) Graham, Lt. Col.
1852. Report. Ex. Senate Doc. 121, 32nd Congress, 1st Session. Repl. Sec. War.

(9) Bartlett, John Russell.
1854 Personal Narrative of Explorations and Incidents, v.2. New York.

(10) Noon, A. H.
1879. Before the Railroad. Chicago Tribune.

(11) Hannum, A. P.
1930. A Quaker Forty-niner. Philadelphia.

(12) Bowman, Isaiah.
1911. Forest Physiography. New York and London

(13) Lockwood, F. C.
1934. With Padre Kino on the Trail. Univ. Ariz. Social Sci. Bull. 5.

(14) Farish, Thos. Edwin.
1925. History of Arizona. Phoenix.

(15) Marshall, Thomas M.
St. Vrain's Expedition to the Gila in 1826. Leland Stanford University.

(16) Thwaites, R. C.
1905. Pattie's Personal Narrative. Cleveland.

(17) Lockwood, F. C.
1936. Spanish-American History. Arizona and its Heritage. Univ. Ariz. General Bull. 3.

(18) Davis, Arthur P.
1897. Irrigation near Phoenix, Arizona. Water supply and Irrigation Paper No. 2, U.S.G.S., Washington.

(19) District Engineer, War Department.
1937. Preliminary Examination Report, Flood Control, Queen Creek, Arizona. Los Angeles, Calif., Dec. 10, 1937.

(20) District Engineer, War Department.
1937. Transcript of Public Hearing on Queen Creek, Arizona. Mesa, Ariz., Oct. 6, 1937.

(21) Maricopa County Board of Supervisors.
1937. Eastern Maricopa County Flood Control Project. Project Report, Presented at Hearing of Departments of War and Agriculture on October 9, 1937.

(22) Salt River Water Users' Association.
1937. Annual Report of the Power, Irrigation, and Operating Dept. July, 1937, Phoenix, Ariz.

(23) Clerk of the Board of Supervisors, Maricopa County.
1930-37. Annual Reports. Phoenix, Ariz.

(24) Smith, G. E. P.
1933. The Financial Rehabilitation of Irrigation and Drainage Districts. Arizona Agr. Expt. Sta. Bull. 144.

(25) United States Dept. Int.
1933. Guidebook of the Western United States (Part F, Southern Pacific Lines). Geol. Sur. Bull. 845, Washington, D. C.

(26) Tetreau, E. D.
1938. Hired labor requirements on Arizona irrigated farms. Univ. of Ariz. Agr. Expt. Sta. Bull. 160.

(27) United States Bureau of the Census.
1930. Fifteenth Census of the United States, Agriculture and Population, Arizona.

(28) ________
1935. United States Census of Agriculture, Arizona.

(29) ________
1920. Fourteenth Census of the United States, Agriculture and Population, Arizona.

(30) Arizona State Highway Department.
1936. Highway Planning Map.

(31) U. S. Forest Service.
1938. Statistics Southwestern Region (Arizona and New Mexico) Unpublished.

(32) Salt River Valley Water Users' Association.
1937-38. Survey Plats of Cropland Use. Annual Report.

(33) Roosevelt Water Conservation District.
1937-38. 1938 Crop Map. Annual Crop Reports.

(34) Agricultural Adjustment Administration.
1938. Crop Survey Plats, Maricopa County.

(35) Boswell Cotton Co.
1938. Crop Map.

(36) Chandler Heights Citrus Irrigation District.
1938. Crop Map.

(37) Harper, W. G. et al.
1926. Soil Survey of the Salt River Valley Area, Arizona. Soil Survey Rept. 32, Ser. 1926. Bureau Chemistry and Soils. 56 pp., illus.

(39) University of Arizona Agr. Expt. Sta.
1927. The Use and Duty of Water in the Salt River Valley. Ariz. Expt. Sta. Bull. 120.

(43) Hazen, A.
1930. Flood Flows. New York.

(45) Poor Publishing Co.
1938. Poor's Manual, Industrial Volume, New York.

(48) Emory, W. H.
1848. Notes of a Military Reconnaissance. New York.

(49) ________
1852. Rept. on the United States and Mexican Boundary Survey, v.1, part 2. Senate Ex. Doc. 108. 34th Congress.

(50) West, Colonel.
1883. The War of the Rebellion. Ser. 1, v.9, ch.21 Washington.

(51) Cooke, P. St. Geo.
1878. Conquest of New Mexico and California. New York.

(52) Huntington, Ellsworth.
1914. The Climatic Factor. Carnegie Inst. of Wash. Pub. No. 192

(53) Browne, J. Ross.
1869. The Apache Country, A Tour Through Arizona and Sonora. New York.

(55) United States Geological Survey.
1916-1920. Water Supply Papers, Surface Water Supply of Colorado River Basin.

(56) Pickrell, K. P. and Stanley, E. B.
1930. An Economic Study of Range Sheep Production in Arizona. Ariz. Expt. Sta. Bull. 134.

(57) Arizona State Planning Board.
1936. 1936 Report, v. 2.

(58) Smith, G. E. P.
1936. Irrigation and the Ground-water Laws in Arizona and Neighboring States. Univ. of Ariz., Coll. of Agr. Tech. Bull. 65.

(59) Kelton, Edwin C., Lt. Col.
1940. Survey Rept. Flood Control, Queen Creek, Arizona. Mar. 1.