

INTRODUCTION

The area of the report includes about 4,500 mi² in Pinal and Maricopa Counties in south-central Arizona. The counties contain about 55 percent of the agricultural land and 60 percent of the population in the State. The area consists of broad valleys that are underlain by permeable alluvial deposits, which are more than 1,200 ft thick (Coolley, 1973a, 1973b; U.S. Bureau of Reclamation, 1977). The valleys are surrounded by low abruptly rising mountains that are composed of crystalline rocks of low permeability.

From 1915 to 1975, more than 109 million acre-ft of ground water was withdrawn from the alluvial deposits (Babcock, 1977). The volume of water withdrawn greatly exceeds the volume of natural recharge, and water levels have been declining since 1923. As a result of the water-level declines, the land surface has subsided, the alluvial deposits have been subjected to stress, and earth fissures have developed. Land subsidence and earth fissures have damaged public and private properties (Schumann and Poland, 1970; McCalley and Gam, 1975). Subsidence and fissures will continue to occur as long as ground water is being mined and water levels continue to decline. As urban development expands, land subsidence and earth fissures will have an increasingly important socioeconomic impact.

WATER-LEVEL DECLINES

Although the water levels in the alluvial deposits have declined throughout south-central Arizona, the greatest declines generally are in the agricultural areas. The long-term water-level declines were obtained by overlaying maps showing the altitude of the water table for 1923 and for spring 1976 in the eastern part of the Salt River Valley (sheet 2) and for 1923 and for spring 1977 in the rest of the area (sheets 1 and 2).

LAND SUBSIDENCE

The land surface in many of the agricultural valleys in Arizona is subsiding as ground-water levels decline (Schumann and Poland, 1970). Lofgren (1968) and Poland (1969) discussed the mechanisms by which ground-water withdrawal causes land subsidence. Land subsidence was first detected through leveling of the 1905 U.S. Geological Survey first-order level lines by the U.S. Coast and Geodetic Survey (now the National Geodetic Survey) in 1934 (Robinson and Peterson, 1962). Later surveys made by the National Geodetic Survey in 1948, 1952, 1960, and 1967 (Elliott, 1969; 1969b), by the Arizona Department of Transportation in 1961 and 1964 (Winikka, 1964), by the U.S. Bureau of Reclamation in 1964, and by the U.S. Geological Survey in 1977 were used to document the subsidence in south-central Arizona. Data from the surveys were used to prepare the map showing subsidence in southern and central Pinal County from 1952 to 1977 (sheet 1). Leveling of the bench marks in eastern Maricopa and northern Pinal Counties has not been done since 1967 (Schumann, 1974).

The data indicate that about 120 mi² in the Eloy and Stanfield areas subsided more than 7 ft from 1952 to 1977. The subsidence that occurred from 1905 to 1977 between Casa Grande and the Picacho Peak Interchange is shown in section A-A'; the amount of subsidence has increased substantially since 1952 and is greatest near Picacho.

Subsidence changes the slope of the land surface, which affects irrigation systems and flood-control projects. The increased gradients of drainage channels cause accelerated erosion and gullying. Subsidence often causes well failures. Friction between the subsiding alluvial fill and the well casing gradually loads the casing and causes failure by compressive rupture (Poland, 1969), or, if there is little or no friction, the well casing protrudes from the land surface. Subsidence reduces the ground-water storage capacity of the alluvial deposits. As the land subsides, pore space in the alluvium is reduced. The reduction in underground storage capacity is estimated to be more than 500,000 acre-ft in the shaded areas shown on sheet 1. As the land in south-central Arizona continues to subside, the effects of the subsidence will be more widespread and increasingly apparent.

EARTH FISSURES

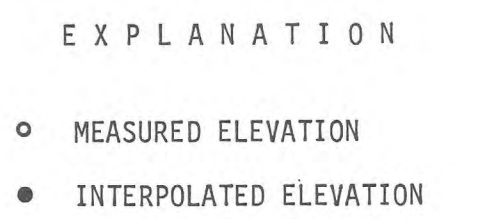
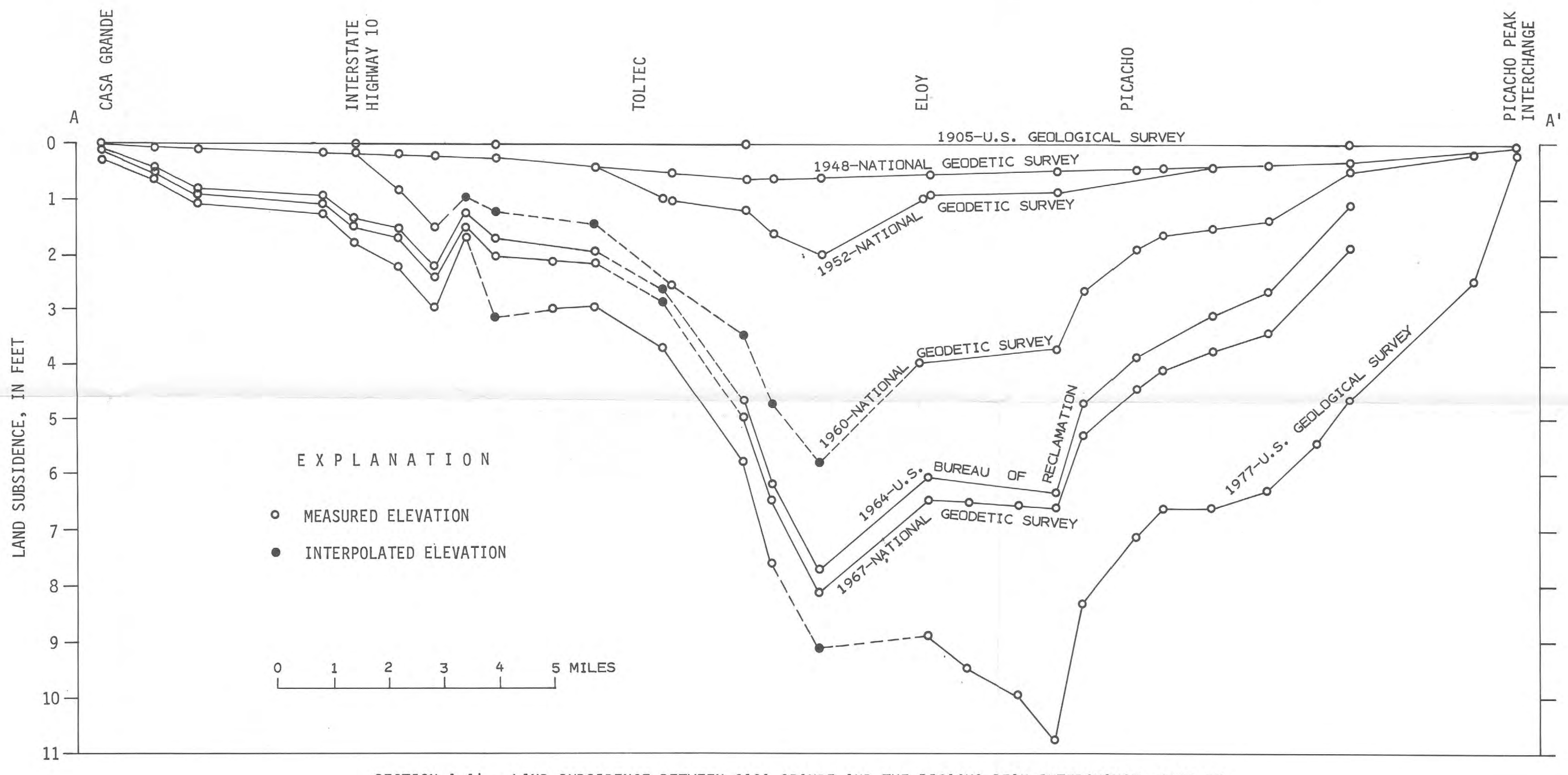
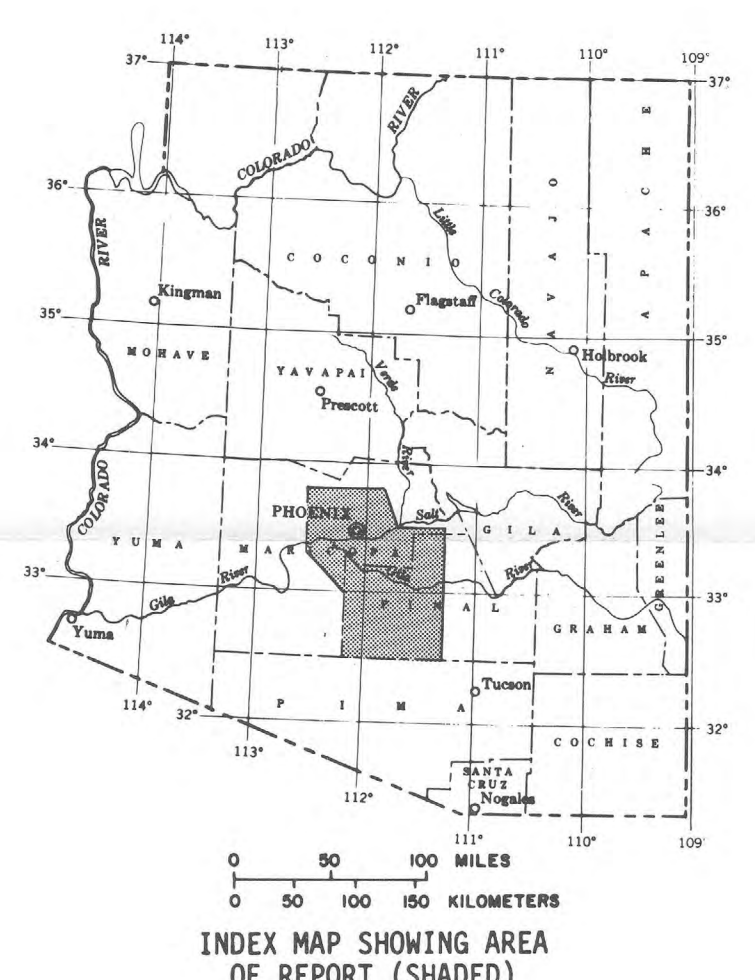
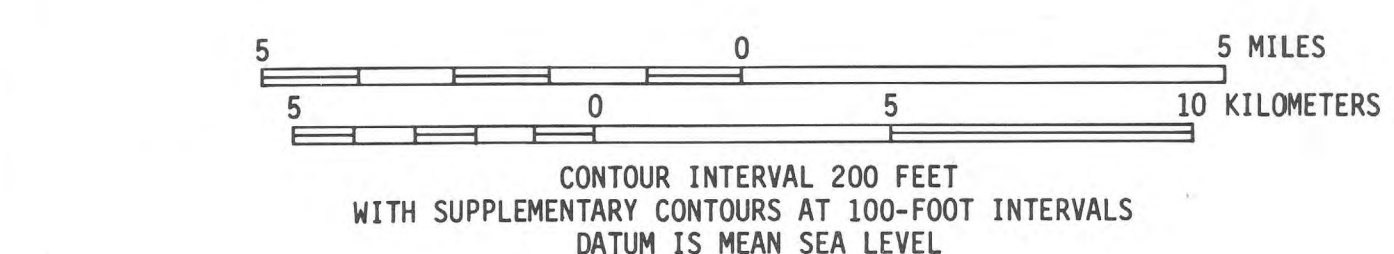
The term "earth fissure" is defined herein as the initial narrow vertical crack in the alluvial deposits. The first surface indication of a fissure may be a hairline crack, a faint linear depression of a few tens of feet long, or a series of holes.

Earth fissures in south-central Arizona have been found only in the alluvial deposits; none have been found in the crystalline rocks. The greatest concentration of earth fissures is near the margins of the basins adjacent to the mountains. The fissures generally surround areas of large water-level decline and land subsidence. A few earth fissures are present in other places in the valleys.

Information on earth fissures that were known prior to 1976 was obtained from published reports and unpublished data in the files of the U.S. Bureau of Reclamation, the Arizona Department of Transportation, and the U.S. Geological Survey. Additional fissures were located on orthophotographs and aerial photographs and by aerial reconnaissance in early 1976 (Winikka and Mold, 1977). Many of the old fissures had lengthened and enlarged, and others were obscured. A few additional fissures were mapped in 1977. The area west of 111°45' was not examined during this study, and, except for a fissure 6 mi southeast of Maricopa, only earth fissures known prior to 1976 are shown.

Most fissures are tensional failures that have no apparent vertical offset, and they may have propagated upward from depth (Holzer and Davis, 1976). A few fissures were observed that have vertical offsets on one side with respect to the other. The most prominent of these is near the Picacho Mountains.

Fissures intercept surface runoff and erode to form gullylike features along the trends of the fissures as water and eroded material travel downward. In this report this secondary erosional enlargement is termed "fissure-gully" and thus is distinguished from the initial cracking of the alluvial material. Where a series of holes is present, an eroded horizontal tunnellike opening (piping) often may be seen near the bottom of the holes trending along the alignment in the subsurface. Eventually, the ground surface collapses, the holes enlarge, and the fissure-gully increases in length and width. Some fissure-gullies form very rapidly, usually following heavy rains (Leonard, 1929), but others develop more slowly. The widening process is enhanced by the development of secondary gullies, which rapidly erode the upslope side of the fissure-gully (Kam, 1965). Fissure-gullies commonly are more than 1,000 ft long and as much as 10 ft wide and 10 ft deep. A 10-ft-deep trench was dug across a fissure-gully near the Picacho Mountains. The fissure-gully was about 4 ft deep and contained sorted and unsorted fill; the fissure below was less than half an inch wide and contained fairly well sorted fine sand. Earth fissures have damaged highways, railroads, utilities, irrigation storage and distribution systems, sewage-disposal facilities, farmland, recreation facilities, and private residences. Most earth fissures have formed in nonurban areas, however, and the economic losses thus far have been small. Potential for damage is high in several expanding urban areas because development is occurring where earth fissures are present. Earth fissures may occur in areas that are now being developed (Cordy and others, 1977).



SECTION A-A'--LAND SUBSIDENCE BETWEEN CASA GRANDE AND THE PICACHO PEAK INTERCHANGE, 1905-77

SOUTHERN AND CENTRAL PINAL COUNTY
MAPS SHOWING WATER-LEVEL DECLINES, LAND SUBSIDENCE, AND EARTH FISSURES
IN SOUTH-CENTRAL ARIZONA

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