LAND SUBSIDENCE IN THE OXNARD PLAIN OF THE SANTA CLARA–CALLEGUAS BASIN, VENTURA COUNTY, CALIFORNIA

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The Oxnard Plain is one of 10 ground-water subbasins within the coastal valleys and plains of the Santa Clara–Calleguas Basin in Ventura County, California (fig. 1). The plain is underlain by a complex aquifer system that has been the primary source for water supplies since the early 1900's. Oil and gas has been produced in the Santa Clara–Calleguas Basin since the 1920's and in the Oxnard Plain since the 1940's. The basin is a part of the tectonically active Transverse Range physiographic province. Ventura County has delineated a probable-subsidence-hazard zone that includes parts of the Piru, Fillmore, Santa Paula, Mound, Montalvo, Oxnard Plain, and Pleasant Valley subbasins (Ventura County Board of Supervisors, 1988). Ground-water withdrawal, oil and gas production, and tectonic movement are three potential causes of subsidence in the Oxnard Plain and adjacent subbasins.

Water-level declines in the upper- and lower-aquifer systems have ranged from about 50 to 100 ft in the Oxnard Plain since the beginning of ground-water development in the early 1900's. Water-levels in the lower-aquifer system at multiple-level observation wells range from 20 ft lower than the upper aquifer system near Port Hueneme along the central coast to about 80 ft lower than the upper aquifer system near the Naval Air Station, Point Mugu, along the southern coast of the Oxnard Plain. Early pumpage data is unavailable for the Oxnard Plain, so the total amount of water withdrawn remains unknown. However, recent pumpage data indicate that during 1979–91 about 822,000 acre-ft of ground water was withdrawn at a relatively constant annual rate, in the Oxnard Plain.

More than 7,900 acre-ft of brines, 8,000 acre-ft of oil, and 72 million ft^3 of natural gas were withdrawn between 1943 and 1991 from oil fields in the Oxnard Plain subbasin (Steven Fields, Operations Engineer, California Department of Conservation, Division of Oil and Gas, written commun., 1992). Pressure declines in the Oxnard oil fields equivalent to more than 1,100 ft of water-level decline have occurred since the onset of oil and gas production. These declines alone could account for potential local subsidence on the order of 1.5 to 2.0 ft.

Tectonic activity in the form of plate convergence and north-south crustal shortening has resulted in an average regional horizontal movement of about 0.007 ft/yr over the past 200,000 years (Yeats, 1983) in the subbasins north of the Oxnard Plain. The vertical movement in the form of uplift north of the Oxnard Plain and as subsidence in the Oxnard Plain is caused by plate convergence and related earthquakes throughout the basin. At the southern edge of the Oxnard Plain (fig. 1A), bench-mark data on bedrock (at BM Z 583) indicate that 0.17 ft of subsidence occurred during 1939–78, at a rate of about 0.004 ft/yr, that could be related to tectonic activity (see Morton abstract for related discussions).

Bench-mark data along a coastal leveling traverse near the southeastern edge of the Oxnard Plain (fig. 1A, B) indicate that as much as 1.6 ft of subsidence occurred during 1939–60 at bench-mark E 584 (0.07 ft/yr) and an additional 1 ft occurred during 1960–78 (0.06 ft/yr). An additional 0.5 ft of subsidence during 1960–92 was measured at bench-mark Z 901 southwest of BM E 584 along the coastal edge of the Oxnard Plain. Farther inland, where water-level and oilfield pressure declines are largest, greater subsidence might be expected.

Indirect evidence for subsidence that is potentially related to ground-water withdrawals includes water-level declines in excess of 100 ft, subsurface collapse of well casings, repeated regrading of irrigated fields for proper drainage, and degraded operation of drainage ditches in agricultural areas. In the Las

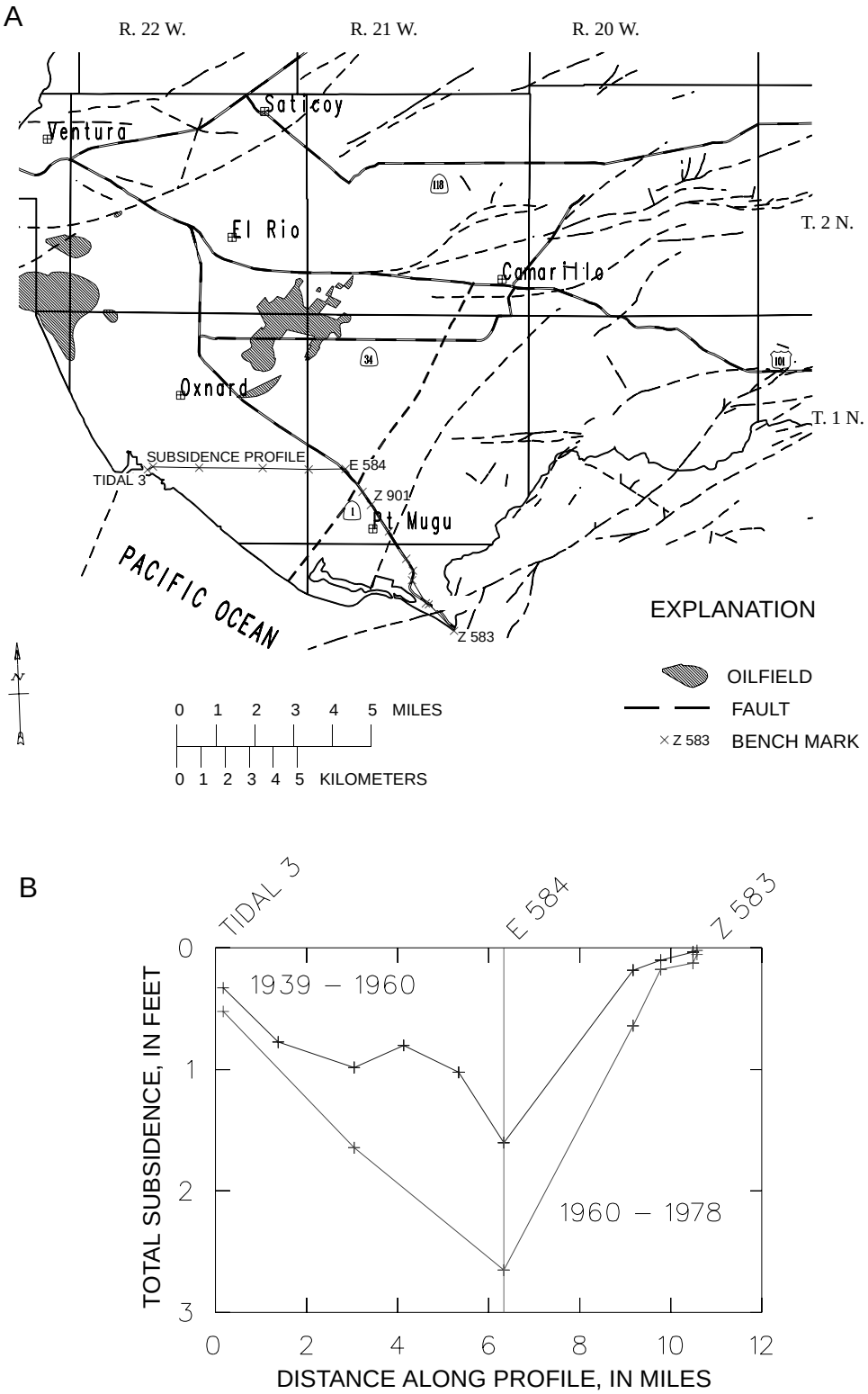

Figure 1. Subsidence in Oxnard Plain and Pleasant Valley, Santa Clara–Calleguas Basin, Ventura County, California. *A*, Geographic features. *B*, Subsidence profile.

Posas and Pleasant Valley subbasins, water-level declines of 50 to 100 ft have occurred in the upper aquifer system and declines of 25 to 300 ft or more have occurred in the lower aquifer system since the early 1900's. On the basis of large water-level declines, the area of probable subsidence may be larger than that previously delineated by Ventura County and may include Las Posas Valley and the remainder of Pleasant Valley. By 1992, total subsidence in the Oxnard Plain could exceed the 2.6 ft measured during 1939–78 along the coastal traverse. Ground-water withdrawal and oil and gas production may be major sources of subsidence in the Oxnard Plain, and tectonic activity probably is a minor source. Delineation of the relative contributions from the three sources and the spatial and temporal distribution of subsidence, would require the installation of extensometers, in combination with accurate bench mark and microgravity monitoring networks.