Introduction

More than 150 historically active faults have been identified (Verbeek and others, 1979) in the Houston, Texas, metropolitan area (fig. 1). Many faults are moving at rates of 0.2 to 0.8 inch per year. Fault movement has caused substantial, costly damage to private and public infrastructure including buildings, roadways, and utilities. In the past, faults have been located using field data and black-and-white aerial photographs. In 2004, the U.S. Geological Survey (USGS), in cooperation with the Harris-Galveston Coastal Susidence District, updated the locations of principal faults using remote sensing technology—specifically light detection and ranging (Lidar). Lidar is a high-precision, laser-based system that enables development of high-resolution topographic maps of land-surface features.

The purpose of this report is to document the locations of principal faults in the Houston metropolitan area. A secondary purpose is to summarize faults documented in previous studies. Using previously mapped fault locations, a Lidar-derived digital elevation model (DEM) was used to enhance the precision of fault locations. The history of fault mapping from previous studies and the use of Lidar for locating faults are briefly described. The faults are shown on a Houston metropolitan area high-resolution map made from the Lidar-derived DEM. Areas on the map with no faults shown are considered insufficiently mapped rather than unfaulted.

This report is a synthesis of known faults in the Houston metropolitan area; no "new" faults were identified for this report. More detailed, site-specific reports are available, notably Verbeek and Clanton (1978) and Verbeek and others (1979), in which the geologic significance of faulting for land-use planning, construction, and engineering is discussed.

Topography in the Houston metropolitan area is predominately flat and low relative to sea level. Land-surface altitude ranges from about sea level upward to about 360 feet. Approximately 25 percent of the Houston metropolitan area lies within the 100-year flood plain (Moser Development Systems, 2002). The subsurface in the Houston metropolitan area consists of lenticular deposits of sand and clay that compose the Gulf Coast aquifer system. This complex system comprises, from the surface downward, the Chicot aquifer, the Evangeline aquifer, the Burkeville confining unit, and the Jasper aquifer (Baker, 1979).

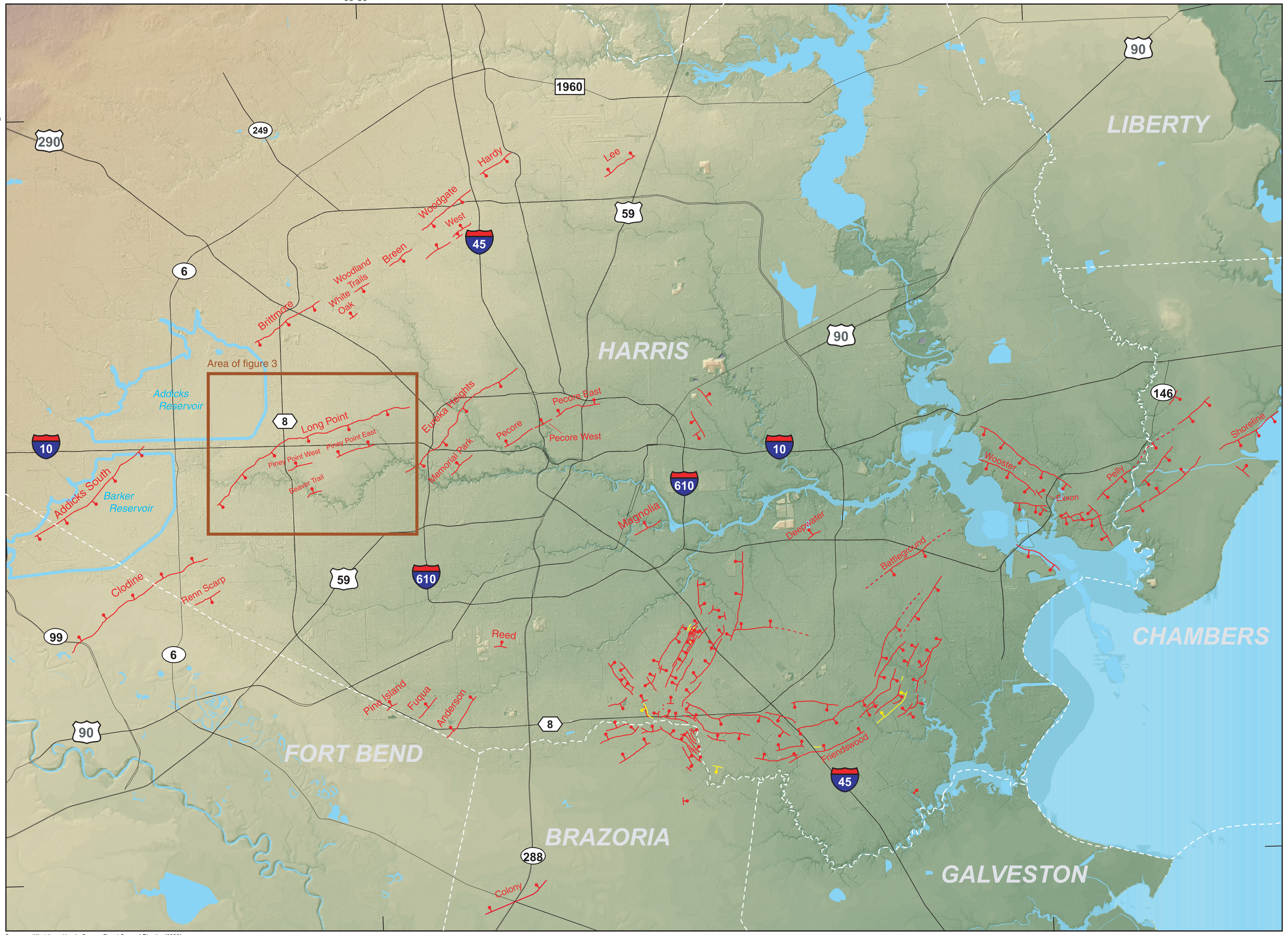
Previous Fault Mapping in the Houston Metropolitan Area

Numerous subsurface faults have been documented beneath the Houston metropolitan area at depths of 3,200 to 13,000 feet (Verbeek and others, 1979). These faults have been delineated through extensive study of geophysical well logs and the results of deep seismic surveys. According to McClelland Engineers (1966) some of these subsurface faults penetrate younger sedimentary deposits at shallower depths (less than about 3,000 feet) and have offset the present land surface and produced recognizable fault scarps (exposed surface of a fault at land surface). On the basis of McClelland Engineers (1966), many of the faults identified at land surface can be traced to appreciable depths. Faults in the Houston metropolitan area are not a surficial phenomenon, but are part of a deep and complex overall geologic structure of the upper Texas Gulf Coast (Verbeek and others, 1979).

A connection between a scarp at land surface and a subsurface fault has been verified for at least 40 faults for which sufficiently detailed information is available for the shallow subsurface. In general, the subsurface faults in the Houston metropolitan area are growth faults. The definitive characteristic of a growth fault is that of increasing displacement with depth. This characteristic generally is considered evidence of a long history of continual fault movement. The continual movement occurs contemporaneously and continuously as sediments are deposited on both sides of the fault scarp, so that the sediment thickness on the downthrown side is thicker than on the upthrown side. For the faults referred to above, there is evidence that the faults are natural geologic features with histories of movement spanning tens of thousands to millions of years. Present-day scarps reflect only the most recent displacements of faults that were active long before the present land surface of the area was formed. Mapped, named faults for this report are documented in the reports listed in table 1. Verbeek and Clanton (1978) provides information on these faults.

Verbeek and others (1979) documented techniques for mapping faults in both urbanized and undeveloped areas of the Houston metropolitan area. In urban areas, vertical offset commonly is the most visible evidence of fault movement. Damage caused by faulting is consistent with the vertical offset of the land surface as deduced from the fault scarp. For example, the land surface is lower on the south side of a fault, observed damage to roads and other structures are consistent with south-side-down movement of the fault (Verbeek and others, 1979). Observations of fault damage in urban areas provide information on the exact location of a fault where structures have been built and show evidence of offset along the fault. The fault scarp connects discrete zones of fault damage and establishes a continuously mappable fault trace.

Verbeek and Clanton (1978) used aerial photographs in undeveloped areas to identify and map faults. Faults commonly are visible on aerial photographs as sharp, gently curvilinear boundaries between two areas that differ in tone on the photo. Tonal contrasts on photographs primarily reflect fault-associated vegetation and soil-moisture contrasts in the field (Verbeek and others, 1979). Identification of faults in undeveloped areas can be difficult to assess because no associated zone of damage serves to document movement and confirm the identity of a mapped feature as a fault. Because topographic features resembling fault scarps were formed by a number of natural processes, Verbeek and others (1979) did not interpret features that could not be verified as fault features. The presence or absence of a fault in an undeveloped area might be confirmed by well-log or seismic data.



Base modified from Harris County Flood Control District (2002)
Harris County digital elevation model
Airborne Lidar Topographic Mapping System, October 2001
State Plane Texas South Central, Datum NAD 83

0 1.5 3 4.5 6 MILES

Figure 2. Principal faults in the Houston metropolitan area as observed from 15-foot bare-earth Lidar-derived digital elevation model (DEM).

EXPLANATION

Relative altitude, above NAVD 88
High
Low

Fault—Documented fault with downthrown side indicated by bar-and-ball symbol (dashed where inferred). Fault name referenced in table 1

Possible fault—Feature that resembles a fault, but evidence is insufficient to establish an origin by faulting (Verbeek and Clanton, 1978). Downthrown side indicated by bar-and-ball symbol

Table 1. Named faults mapped in previous studies.

Fault name (fig. 2)	Source
Addicks South	Verbeek and Clanton (1978)
Anderson	McClelland Engineers (1966)
Battleground	Verbeek and Clanton (1978)
Beaver Trail	McClelland Engineers (1966)
Breen	Heuer (1979)
Brittmore	Heuer (1979)
Clodine	Verbeek and others (1979)
Colony	O'Neill and Van Siclen (1984)
Deepwater	O'Neill and Van Siclen (1984)
Eureka Heights	Verbeek and others (1979)
Exxon	E.R. Verbeek and U.S. Clanton, U.S. Geological Survey [retired], unpub. data (2004)
Friendswood	Verbeek and Clanton (1978)
Fuqua	McClelland Engineers (1966)
Hardy	O'Neill and Van Siclen (1984)
Lee	O'Neill and Van Siclen (1984)
Long Point	Verbeek and others (1979)
Magnolia	O'Neill and Van Siclen (1984)
Memorial Park	Verbeek and others (1979)
Pecore	Heuer (1979)
Pecore East	Verbeek and others (1979)
Pecore West	Verbeek and others (1979)
Pelly	O'Neill and Van Siclen (1984)
Pine Island	McClelland Engineers (1966)
Piney Point East	Verbeek and others (1979)
Piney Point West	Verbeek and others (1979)
Reed	McClelland Engineers (1966)
Renn Scarp	Verbeek and others (1979)
Shoreline	E.R. Verbeek and U.S. Clanton, U.S. Geological Survey [retired], unpub. data (2004)
West	Heuer (1979)
White Oak	Heuer (1979)
Woodgate	McClelland Engineers (1966)
Woodland Trails	McClelland Engineers (1966)
Wooster	E.R. Verbeek and U.S. Clanton, U.S. Geological Survey [retired], unpub. data (2004)

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McClelland Engineers, 1966, Land-surface subsidence and surface faulting (appendix C), *in* Turner, Collie, and Braden, Inc., A comprehensive study of Houston's municipal water system: Report to the City of Houston, 50 p.

Moser Development Systems, 2002, Houston geographic description: accessed November 1, 2004, at http://www.texasbest.com/houston/geograph.html

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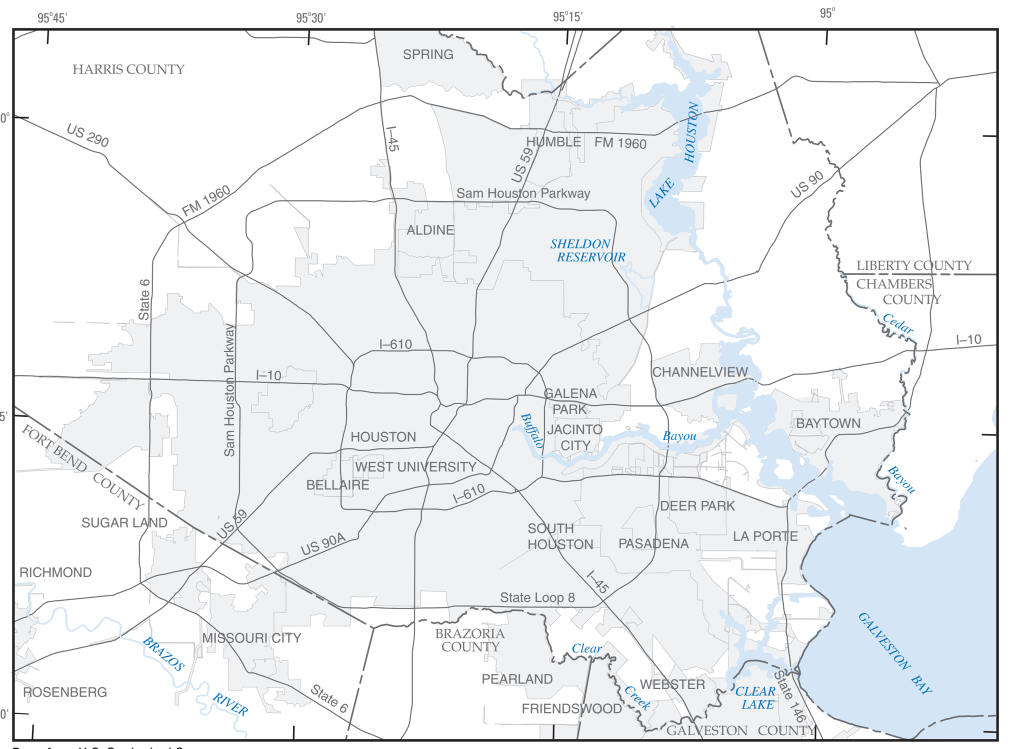


Base from U.S. Geological Survey
Digital data, 1:100,000
Universal Transverse Mercator projection
Zone 15

0 5 10 15 20 MILES

Figure 1. Location of study area. Shaded area is the Houston metropolitan area.

Principal Faults in the Houston Metropolitan Area

A Lidar-derived DEM map with the principal faults expressed at the surface in the Houston metropolitan area superimposed is shown in figure 2. Lidar is a remote-sensing system that uses laser signals to create high-resolution land-surface topography at a high level of measurement accuracy and spatial detail (The University of Texas at Austin Center for Space Research, 2004). In essence, Lidar records the time interval between the generation of a laser pulse from an aircraft and reception at a detector after the pulse is reflected from a point on the ground. With precise knowledge of the aircraft position through a global positioning system, land-surface topography is accurately inferred. The bare-earth Lidar-derived DEM of Harris County (Harris County Flood Control District, 2002) has a vertical accuracy of about 0.5 foot and a horizontal accuracy of about 1.6 feet.

For this report, faults mapped in previous studies were compiled into a digital dataset. To improve fault placement, the previously mapped faults were overlaid on the 15-foot bare-earth Lidar-derived DEM of Harris County and adjusted to be exactly coincident with nearly coincident surface features that clearly indicate faults. Faults are visible in many locations through "hillshading" of the DEM (fig. 3). Hillshading is variation in tone from light to dark to delineate the form of the land surface. Hillshading creates a rectangular grid as a function of the angle of the illumination source with the surface, which results in the appearance of shadowing (J.L. Smith, U.S. Geological Survey, oral commun., 2004). Ridges and valleys are revealed by the hillshaded DEM. Distinct linear or nearly linear ridges in the generally flat Houston metropolitan area indicate faults. For example, the Long Point fault near the intersection of Interstate Highway 10 and Beltway 8 (fig. 3) can be seen on the hillshaded DEM. The Long Point fault and the nearby Eureka Heights fault (fig. 2) are among the longest, and the most destructive, faults that have been traced in the Houston metropolitan area (Van Siclen, 1967).

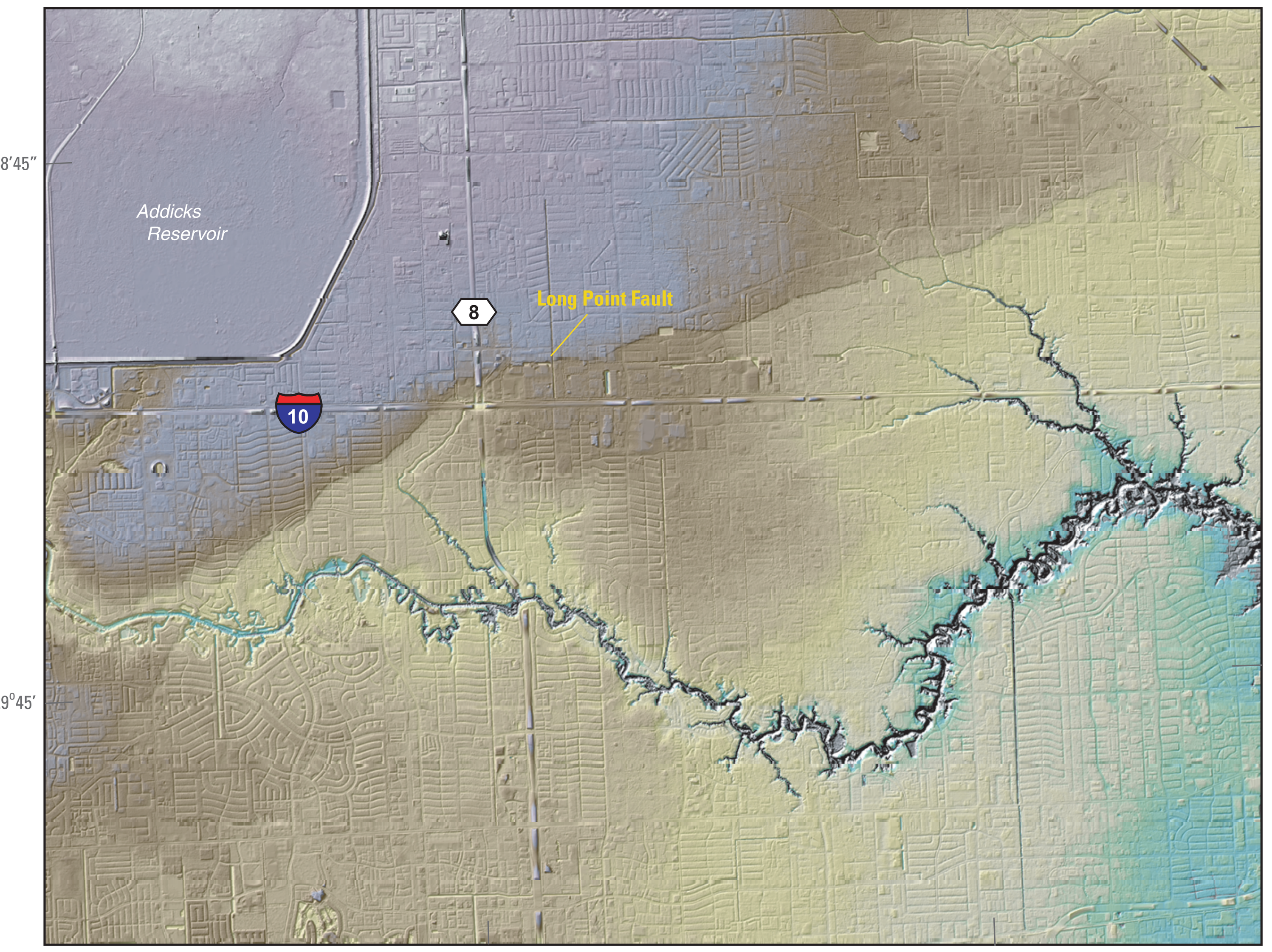
According to Verbeek and others (1979) and verified by the DEM, faults in the southeastern Houston metropolitan area generally are more numerous and more varied in directional trend than faults in northern and western parts of the area (fig. 2). Faults in the southeastern area primarily occur in well-defined groups of high fault density. Faults in northern and western parts of the area tend to occur either individually or in pairs—for example the Long Point-Piney Point and Eureka Heights-Memorial Park fault pairs—with little tendency to cluster in high-density groups. A map of subsurface faults (at depths of about 5,000 to 10,000 feet) prepared by McClelland Engineers (1966) reflects the general pattern of faults mapped at land surface in areas of dense, diversely trending faults in the southeastern Houston metropolitan area.

Summary

This report, prepared by the U.S. Geological Survey in cooperation with the Harris-Galveston Coastal Subsidence District, documents and refines the locations of principal faults mapped in the Houston, Texas, metropolitan area in previous studies. Numerous subsurface faults have been documented beneath the Houston metropolitan area at depths of 3,200 to 13,000 feet. Some of these subsurface faults have affected shallower sediments, offset the present land surface (which has resulted in substantial, costly damage), and produced recognizable fault scarps. Evidence from previous studies indicates that these faults are natural geologic features with histories of movement spanning tens of thousands to millions of years. Present-day scarps reflect only the most recent displacements of faults that were active long before the present land surface of the area was formed.

The precision of previously mapped fault locations was enhanced by overlaying mapped faults on a digital elevation model (DEM) of Harris County derived using light detection and ranging (Lidar). Lidar is a high-precision, laser-based system that enables collection of high-resolution topographic data. Previously mapped faults were adjusted to coincide with surface features that clearly indicate faults, which were made visible by the high-resolution topography depicted on the Lidar-derived DEM.

Results of a previous study, supported by this study, indicate that faults in the southeastern part of the metropolitan area primarily occur in well-defined groups of high fault density. Faults in northern and western parts of the metropolitan area tend to occur either individually or in pairs with little tendency to cluster in high-density groups.



0 0.5 1 1.5 2 MILES

EXPLANATION

Altitude, in feet above NAVD 88

56–57, 57–58, 58–59, 59–60, 60–61, 61–62, 62–63, 63–64, 64–65, 65–66, 66–67, 67–68, 68–69, 69–70, 70–71, 71–72, 72–73, 73–74, 74–75, 75–76, 76–77, 77–78, 78–79, 79–80, 80–81, 81–82, 82–83, 83–84, 84–85, 85–86, 86–87, 87–88, 88–89, 89–90, 90–91, 91–92, 92–93, 93–94, 94–95, 95–96, 96–97, 97–98, 98–99, 99–100

Figure 3. Segment of the hillshaded 15-foot bare-earth Lidar-derived digital elevation model of the area of Harris County showing the Long Point fault.

DATUMS

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88), 2001 adjustment.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

PRINCIPAL FAULTS IN THE HOUSTON, TEXAS, METROPOLITAN AREA

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2005

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