Subsidence: Settling our groundwater debt

The Arizona Geological Survey defines subsidence as “the downward movement or sinking of the earth’s surface caused by removal of underlying support.” In Arizona, subsidence is usually the result of excessive groundwater pumping. As water is pumped from an aquifer, the water occupying the spaces between the rock particles is removed, and the water level drops. Without the water’s buoyancy supporting them, the particles become more tightly packed together; i.e., the particles compact and consolidate. Continued pumping of groundwater without adequate recharge causes sediments to become increasingly compressed and the land to settle or subside.

In other words, subsidence is nature’s way of telling us we are using too much groundwater.

In most cases, subsidence resulting from groundwater pumping occurs at about the same rate over large areas and can be difficult to detect. However, abrupt changes in conditions below the land surface such as changes in the types of sediments or faults below the earth’s surface can cause the rate of subsidence to change abruptly over a short distance. This “differential subsidence” is more likely to cause damage to houses, office buildings, or infrastructure such as water and sewer lines or roads.

A related phenomenon, earth fissures are a visible, and sometimes even spectacular manifestation of land subsidence. Fissures usually are noticed first as land cracks or crevices, a break in the earth’s surface. They can then grow considerably as water erodes the fissured area. Gullies or trenches may be up to 50 feet deep and 10 feet wide, with the fissure extending hundreds of feet below the surface. In the Tucson area fissuring has occurred west of the Tucson Mountains in Avra Valley.

Arizona ranks third in land area affected by subsidence, after California and Texas. More than 3,000 square miles of the state have subsided, with hundreds of fissures occurring since the 1950s. Subsidence in south-central Arizona is a major concern because it contains major agricultural and urban centers, including Phoenix and Tucson.

Bridges, highways, electric power lines, underground pipes, railroads, earthen dams, wastewater treatment facilities and canals are prone to subsidence damage. Sewer lines, laid at precise levels, can have their slopes reduced or even reversed, with serious consequences. Any structure built across the path of a fissure likely will suffer serious damage. The careful and expensive construction procedures applied to protect the Central Arizona Project canal did not prevent a fissure from damaging the canal in Pima County.

The U.S. Geological Survey (USGS) reports that since 1940 groundwater levels in Central Arizona have dropped over 220 feet, with central Tucson subsiding at least one foot since 1950. Meanwhile the rate of subsidence in the area is increasing. Satellite images show that sections of central Tucson are sinking at the rate of just under an inch per year. The area near Speedway and Country Club is considered to be the area of greatest subsidence activity in the Tucson area.

USGS models predict levels of subsidence likely to occur in Tucson wellfields. Assuming that groundwater pumping and natural recharge rates continue at 1986 levels through 2025, and based on other assumptions about the aquifer material being compacted, USGS models indicate that maximum subsidence could range from one to 12 feet in the Central Wellfield by the year 2025. Under the same assumptions, subsidence in the Santa Cruz Wellfield could reach up to four feet by the year 2025. For northern Avra Valley, maximum subsidence potential is estimated to range from one to 15 feet by 2025, assuming that pumping levels and natural recharge rates continue at 1970 levels. If subsidence approaches the maximum level projected for the year 2025 in the Central Wellfield, the risk of differential subsidence and destructive fissures is significant, especially near downtown Tucson.

Subsidence can be halted by ceasing or limiting groundwater withdrawal in an area. Also, under the right conditions, overdraft may be reduced through artificial recharge, thus slowly decreasing the danger of further subsidence. In most cases, subsidence is termed inelastic because the sinking of the groundwater is permanent, and recharge would not reverse the process. In other words, the aquifer’s ability to hold water has been permanently reduced.