Land Subsidence and Cracking Due to Ground-Water Depletion[a]

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ABSTRACT

Subsidence of the land surface due to ground-water overdraft is caused by an increase in the intergranular pressure in unconsolidated aquifers and other underground materials. For unconfined aquifers, this increase is the result of a loss of buoyancy of solid particles in the zone dewatered by the falling water table. For confined aquifers, increases in intergranular pressure are caused by decreases in the upward hydraulic pressure against the bottom of the upper confining layer, due to a drop in piezometric surface. Compression of layers in which the intergranular pressure is increased can be calculated with elastic or logarithmic theory. Sample calculations yield rates of subsidence that agree with those observed, i.e., about 5 to 50 cm (2 to 20 inches) per 10-m (33-ft) drop in ground-water level. Ground-water depletion can also produce surface cracks, particularly above discontinuities in bedrock depth along the periphery or in other parts of subsiding basins. Calculations based on the rotating-slab theory show that the initial surface width of such cracks is about 1 cm (0.5 inch), which agrees with field observations.

INTRODUCTION

Downward movement or subsidence of the land surface is an important environmental consequence of ground-water overdraft. It is caused by compression of underground materials due to declining water tables or piezometric surfaces. In addition, initiation or acceleration of lateral flow of ground water can cause lateral compression of the aquifer and, hence, lateral movement of the land surface, due to an increase in the seepage force or frictional drag exerted by the flowing water on the solid particles. Theoretically, any flow or overdraft of ground water in unconsolidated material should produce some movement of the land surface. This movement normally is quite small, but it can become significant where underground materials are thick and/or compressible and ground-water levels decline appreciably. Recorded subsidences range from a few centimeters (about 1 inch) to almost 10 m (33 ft), as shown in Table 1. Subsidence rates range from about 1 to 50 cm per 10-m drop in ground-water level (0.01 to 0.5 ft per 10-ft drop), depending on thickness and compressibility of the formations. Lateral movement of the land surface of several meters has been reported in conjunction with removal of oil and gas. Nonuniform subsidence, which may result from different rates of ground-water declines or from differences in compressibility of underground formations, can also produce cracks or fissures in the earth's surface.

Land subsidence has increased flood hazards (Venice, Baytown-Houston) and has caused cracking of buildings, misalignment of bridge abutments, damage to roads, railways, storm sewers or other underground pipelines, collapse of well casings, and reversal of gradients of irrigation canals or other conduits. Land subsidence due to ground-water overdraft is essentially irreversible. It can be stopped by halting declines in ground-water levels (combined with ground-water replenishment if necessary to prevent residual compression of clay layers). However, rebound of the land surface normally is insignificant, even if ground-water levels are restored to presubsidence heights.

INTERGRANULAR PRESSURE

The basic cause of subsidence and lateral movement of the land surface is an increase in the intergranular pressure of the underground materials.

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