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CLIMATE SOLUTIONS

How cities are trying to stop their land from sinking

Some cities are putting water back into the ground, a process called managed aquifer recharge, to stabilize land subsidence

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Groundwater has historically been a lifeline in California's Coachella Valley. Water for farming, for your home and community? It came from under your feet, but the extractions didn't go unnoticed. Much like a deflating balloon, the ground began to sink.

From 1995 to 2010, parts of the valley fell by as much 0.6 meters (2 feet), a process called land subsidence. The ground became destabilized, creating large cracks in the earth. Uneven sinking damaged the foundations of buildings and roads. The Coachella Canal started to sag so much that water flow was interrupted.

The scenario seemed all too familiar, especially in populated dry places. Another city pumped too much groundwater and began dropping, struggling with water demands and unstable land. But unlike in other sinking cities, water managers performed a rare feat: They paused the sinking, even partly reversing it in some areas.

Water managers pushed new water conservation approaches, used the Colorado River and recycled water for non-drinking uses (farming, golf courses), and even put water back into the ground. Subsidence rates slowed by 50 to 75 percent in many areas. The northern part of the valley experienced uplift up to 60 millimeters (2.3 inches) during the following years.

“I’ve been working on land subsidence for a long time and we don’t really get too many good-news stories that we get to tell, but Coachella Valley is one of them,” said Michelle Sneed, a hydrologist at the U.S. Geological Survey who has studied subsidence in the region. “The water district there has just been really proactive in water management and land subsidence.”

Across the world, excessive groundwater pumping is one of the main culprits causing cities to lose ground. Some communities that experience only a millimeter or so of sinking may not notice drastic changes, but communities subsiding at higher rates face increased flooding and damage to structures. By 2024, researchers estimate, nearly one-fifth of the world’s population may be living on land that is slowly sinking because of groundwater extractions.

So far, only a small portion of affected places are tackling how to slow or pause land subsidence.

“Unless you have damage from subsidence, then there is the ‘What problem is there to fix?’ kind of thing,” said Sneed. “There hasn’t really been the impetus to [address subsidence] … but more are.”

Putting water back into the ground

Fixing land subsidence doesn’t have a simple solution. Well, unless you just stop pumping groundwater. But most of the time not using groundwater isn’t feasible for communities that need to supply a large number of residents.

Instead, the groundwater can be replenished. This approach is called a managed aquifer recharge, also known as water banking.

To understand how it works, we must first learn how groundwater is stored and extracted. The ground has several layers of various types of sediments. An aquifer, which can appear near the surface or very deep down, is a body of rock or sediment that has a lot of porous space between the grains. These empty spaces are well connected, much like in a kitchen sponge. Aquifers can hold water and also allow it to flow easily through. To extract water, imagine sticking a straw into the aquifer and sucking up water.

A managed recharge system will collect water to put back into the aquifer. The water source can be precipitation, flooding, treated wastewater or rivers. Water can be withdrawn to supply a community, while the added liquid adds volume back into the ground — but only to a certain extent because clay layers compact in the soil.

“If you make this managed aquifer recharge operational when the water is available during, for example, wet-seasonal floods, that water can be treated and injected into the ground to be stored there,” said Manoochehr Shirzaei, who works in remote sensing engineering and environmental security at Virginia Tech. “You reverse the subsidence … and you save the waters for the next year or year after that.”

Several places across the world have employed a managed aquifer recharge system and seen subsidence changes, including in the Coachella Valley, California’s Santa Clara and Santa Ana, Spain’s El Carracillo district, Israel’s Negev desert, South Carolina’s Hilton Head Island, Australia’s city of Perth, and Beijing.

Most places, however, install the system to better supply their groundwater needs. Addressing land subsidence is just a nice bonus.

For instance, in Orange County, more than 2.5 million residents get 85 percent of their water supply from the ground through a recharge system, according to the county water district's chief hydrogeologist, Roy Herndon. As an offshoot, Herndon said, they see minor ups and downs in the land, but they haven't seen subsidence getting worse on a longer scale — that's a good sign.

In Perth, researchers found that a managed aquifer recharge system lifted parts of the land by about 20 mm over 3.5 years.

Water managers are also experimenting with managed aquifer recharge systems around Norfolk, which is experiencing the most land subsidence on the U.S. East Coast. While some of the subsidence is from natural processes, much of the change is due to groundwater extraction, said Jamie Heisig-Mitchell, director of water quality for the Hampton Roads Sanitation District.

In a pilot project, the district set up a recharge system that treated wastewater and recharged the aquifer with 1 million gallons a day. Heisig-Mitchell said the system was originally set up to look for a sustainable supply of groundwater because the Potomac River system was being overused. But the district found that the ground was rising, too.

"You can tell that we're putting water in the ground and that the ground is raising. Very, very, very small amounts, but it is raising," said Heisig-Mitchell. That's only with 1 million gallons of aquifer recharge in a day, she said. In 2026, the district will operate its first full-scale facility, which will recharge 34 million gallons a day.

Manages subsidence, but doesn't fix it

USGS's Sneed said she hasn't seen a managed aquifer recharge system significantly reverse a subsidence trend on its own. In traveling to conferences and studying systems, she said, the most rebound she's heard of was about three inches. That doesn't make a substantial change in places like California's Central Valley, which has subsided several feet over the years. The impact on land subsidence can also be very local.

"The best approach is to stop it from happening in the first place. If it's too late, it's already happening," said Sneed. "You can just move forward and try to alleviate or mitigate it."

Shirzaei, part of the UNESCO Land Subsidence International Initiative, said a goal for managed aquifer systems is to stabilize subsidence rates over longer periods of time, although levels may go up and down between seasons.

But the systems aren't without challenges. From a cost perspective, such a system can be difficult to set up in a place that has fewer resources. Orange County's Herndon said his area has a large tax base to spread the costs over, but funding a big multimillion-dollar recharge project could be challenging for a smaller urban or rural community.

In some places, managed aquifer systems may also be difficult to set up widely. For instance, pilot programs exist in Mexico City, but researchers found that local governments and existing regulations make it difficult to provide more of them in the area.

“Managed aquifer recharge won’t work everywhere,” said Sneed. “It’s kind of a local situation and what alternatives, what mitigation strategies might be appropriate for any particular area.”