In late August, a large hole opened up in the backyard of an Indiana family. The sinkhole was 40 ft wide and swallowed up trees that had been growing in the yard for decades. The event caused obvious problems for the homeowner and the municipalities in which the sinkhole was located. The problem below the surface was harder to see—“piping” within the soil profile, leading to failure of the soil and formation of the sinkhole. Below the backyard, water had moved through fractures in the limestone. The water dissolved the limestone and eroded the fractures until a larger tunnel, or pipe, formed. Over time, the soil above the eroded limestone could no longer be supported. The pipe collapsed, and the sinkhole opened up at the surface as soil fell into the void below.

Piping events are more common than many people think. This soil erosion, happening under our feet and out of view, can be difficult to imagine and even more difficult to study. Soil pipes can even be hard to define, says Glenn Wilson of the USDA Agricultural Research Service in Oxford, MS, but he offers his working definition: “A soil pipe is a large pore that has been eroded internally. It’s been sculptured by water.” Just as river banks are shaped and eroded by the river itself, soil pipes underground are shaped and sculpted by the water that runs through them. Dispersive soils, those that are easily eroded, are ideal for soil pipe formation since water traveling through such soil can detach particles with little effort. The water-sculptured pathways can be initiated and formed through a variety of mechanisms.

Water itself can initiate a soil pipe in some soils. “If there’s a crack in the soil or maybe just a spot where it’s got a little bit less resistance, water will start moving through that pathway,” explains Garey Fox, professor at Oklahoma State University and interim director of the Oklahoma Water Resources Center. “The surrounding water will then follow that earlier water, and a soil pipe can be created just by the action of the water.” In other cases, the initiation of the soil pipe has a little help. As plants die or trees get uprooted, their roots leave openings in the soil. Wildfires can burn up roots leaving holes behind. Animals can also help create soil pipes by burrowing and tunneling in the soil. These voids provide an opening for moving water and create ideal situations for soil pipe formation.

Water-restrictive soil layers can also facilitate soil pipe formation. Soil horizons such as fragipans, clay layers, or bedrock block the vertical movement of water through the soil profile and force it to move laterally. By forcing water in a specific direction, it is more likely that internal erosion will occur and a soil pipe will form. Likewise, restrictive soil layers also restrict the growth of plant roots causing the roots to extend laterally.
Soil pipes cause numerous problems. While they start from very small pores, they can cause large failures of the soil structure and of engineered structures, such as dams. In fact, one study found that 46% of dam failures are caused at least partially by soil piping. While piping in structures has been more widely studied, less is known about how commonly soil pipes cause problems in landscapes. “We think this may be a more prominent process than what people are considering,” Fox says.

Soil Horizons

Locating Pipes Before a Failure Occurs

Understanding more about soil pipes is important to avoid massive soil failures and problems such as gullies and stream bank failure. But researching soil pipes is difficult for an obvious reason—they’re hard to see. Because soil pipes form completely underground, finding them is almost impossible. Surface features such as gullies and failures on river banks can lead us to pipes, but how do we find them before soil failure occurs?

“Pressure is going to fill up behind the plug, and that pressure is going to force the plug to reopen,” Wilson explains. “Filling in the gully was not a solution. Anything that plugs the pipe is just going to cause back pressure on it. [It’s] going to reopen.”

According to one study, 46% of dam failures are caused at least partially by soil piping. Photo courtesy of Wikimedia Commons/Josh deBerge.

Gullies, Landslides, or Stream Bank Failure

Soil pipes in the landscape can grow quite large, with some soil pipes even becoming big enough to crawl through. But even much smaller soil pipes can cause problems. As water erodes soil out of the pipes, the soil above the pipe is no longer supported. The pipe can then collapse, leading to gullies, landslides, or stream bank failure.

Gullies can be caused by soil pipe collapse or by surface erosion. Often times, if caused by a soil pipe collapse, the opening of the pipe can be found at the head of the gully. On agricultural land, farmers will often fill in the gully, blocking the opening of the soil pipe. While the opening is blocked, water will continue to try to run through the pipe, leading to pressure that builds up behind the blockage. That pressure can cause further soil failure by reopening the gully or even causing a landslide.

Researchers do sometimes find hints of soil pipes when the pipes connect to the surface through smaller openings instead of massive soil failures. Sometimes the opening of a soil pipe can be found in a river bank, but these are hard to spot. A surface feature called a flute hole can open up when there are small collapses of an underlying soil pipe. Flute holes connect the pipe to the surface through small openings, and they get their name because they look like the finger openings on a flute.


“Soil pipes can also connect to the surface through biological mechanisms. In one study, Fox and his colleagues found that earthworm burrows can connect the soil surface with underlying soil features, in this case, a subsurface tile system. Tile systems are pipes buried within a field that are used to drain water. They are, in a way, a manufactured soil pipe. In Fox’s experiment, a tile system buried about four feet under a field was receiving pesticides and bacteria from the soil surface. These compounds seemed to be bypassing the filtering abilities of the soil and finding more direct conduits from the surface to the tile system. Fox and his
colleagues came up with an interesting experiment to find those conduits.

“We took a smoke bomb, went to the end of the pipe system, and pushed smoke up under the soil [back through the tile system],” Fox explains. “We could actually see little smoke plumes coming up through the soil surface.”

Beyond hints from these small openings caused by pipe collapse or biological activity, finding soil pipes remains a significant problem for researchers. Some scientists are looking to new technologies, such as acoustics or ground-penetrating radar, to “see” the pipes below the ground. But right now, those technologies aren’t ready to find small pipes or pipes just beginning to develop.

“The techniques that are out there right now are crude,” Wilson says. “It has to be a large pipe close to the surface for them to work. Better techniques are a real need.”

Finding Answers to Key Questions

While scientists work to improve technologies for finding soil pipes, Wilson and Fox are conducting experiments, both in the field and in the lab, to more fully characterize soil pipes and the processes that lead to their formation and eventual collapse.

“We do a lot of experiments in the lab where we can control the conditions,” Fox explains. “There we get an idea of some of the controlling variables. What do we need to look for in the field? The lab is a simplification, but it gives us some guidance about the important mechanisms and processes.”

A better understanding of soil pipes along with the ability to find them easily would allow researchers to answer several questions. The first question is how to include soil pipes in hydrology models of landscapes. Currently, hydrology models focus mainly on the topography of the surface, and subsurface water flow is generally not included.

“A lot of times when we build models to predict hydrology, we have to oversimplify because we don’t know how to represent these complex pathways like soil pipes,” Fox says. “A main focus is eventually to have enough of an understanding of the process that we can incorporate soil pipes into hydrology models,” Wilson adds.

Other questions that researchers hope to answer are how can we predict where soil pipes might form and what do we do about them once they are there? Wilson hopes that answering these questions will allow scientists to “develop a practice to solve the problem, to control soil pipes.”

Beyond the practical goals of research into soil pipes, those studying them hope that more discussion of the topic will generate interest from other scientists. “I talk to people at meetings who say ‘Oh, yeah, that’s probably happening but we don’t ever think about it,’” Fox says. That needs to change if researchers want a better understanding of the many impacts of soil pipes.

Wilson is hoping that soil scientists, specifically, become more interested in piping phenomena. “This is an area that the geomorphologists have worked in and engineers have worked in,” he explains. “But we as soil scientists haven’t. And we need to. This is a soil science process.”

Click on the video above to see Oklahoma State University Extension soil and water specialist Garey Fox talk about how stream bank erosion is contributing sediment build-up in waterways.