Internal Erosion of Soil Pipes: Still More Questions Than Answers

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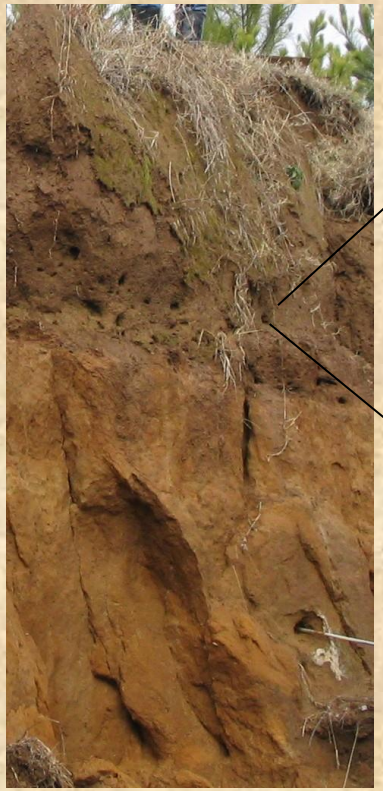
Soil Pipes Are Common Along Streambanks and Gully Banks

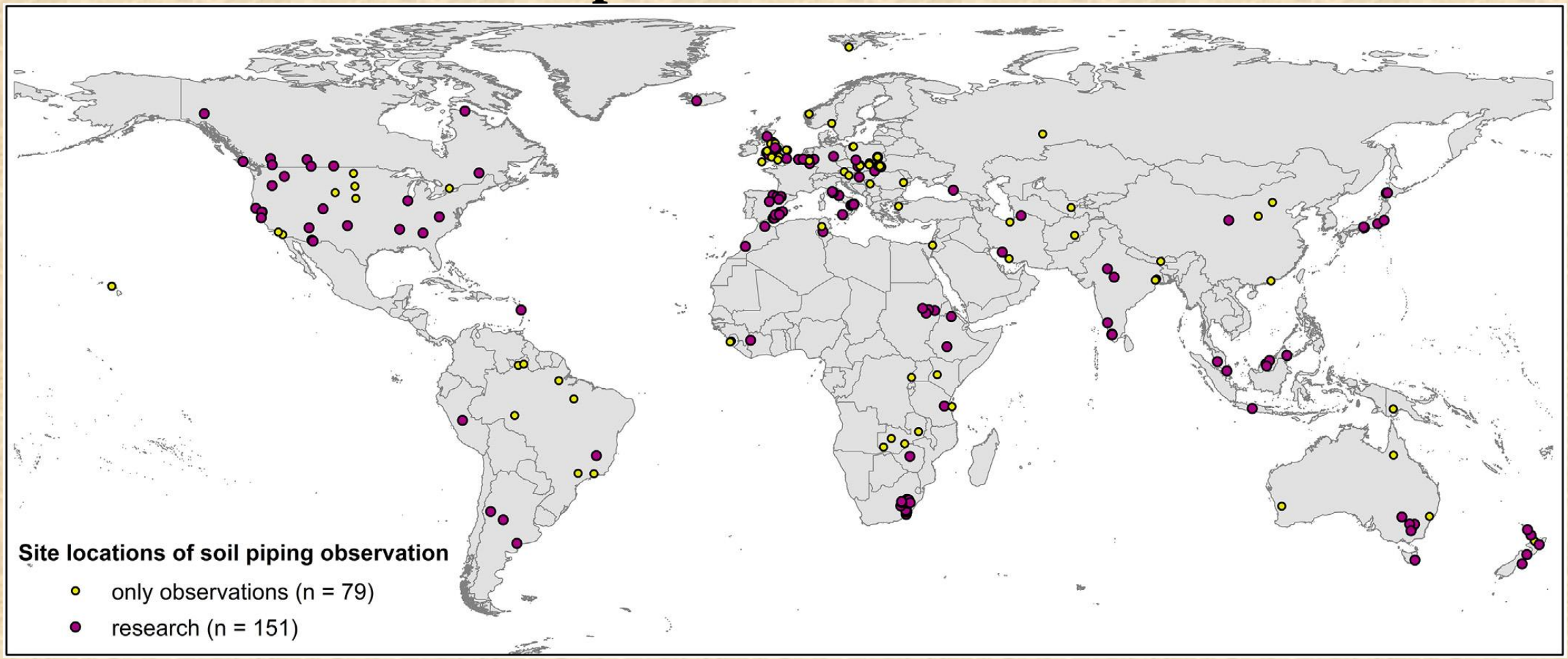
"Natural surface-connected macropores were nearly ubiquitous. Macropores in this region arise by a variety of mechanisms, including soil piping, tree root decay, erosion around hardened structures, macroinvertebrate burrows, and invertebrate burrows."

Menichino et al. 2015



Fox et al. (2007) found 85 macropores/m^2 that were > 5 mm diameter and 709 macropores/m^2 that were 1-5 mm diameter at GCEW in MS.

Soil Pipes Found World-wide



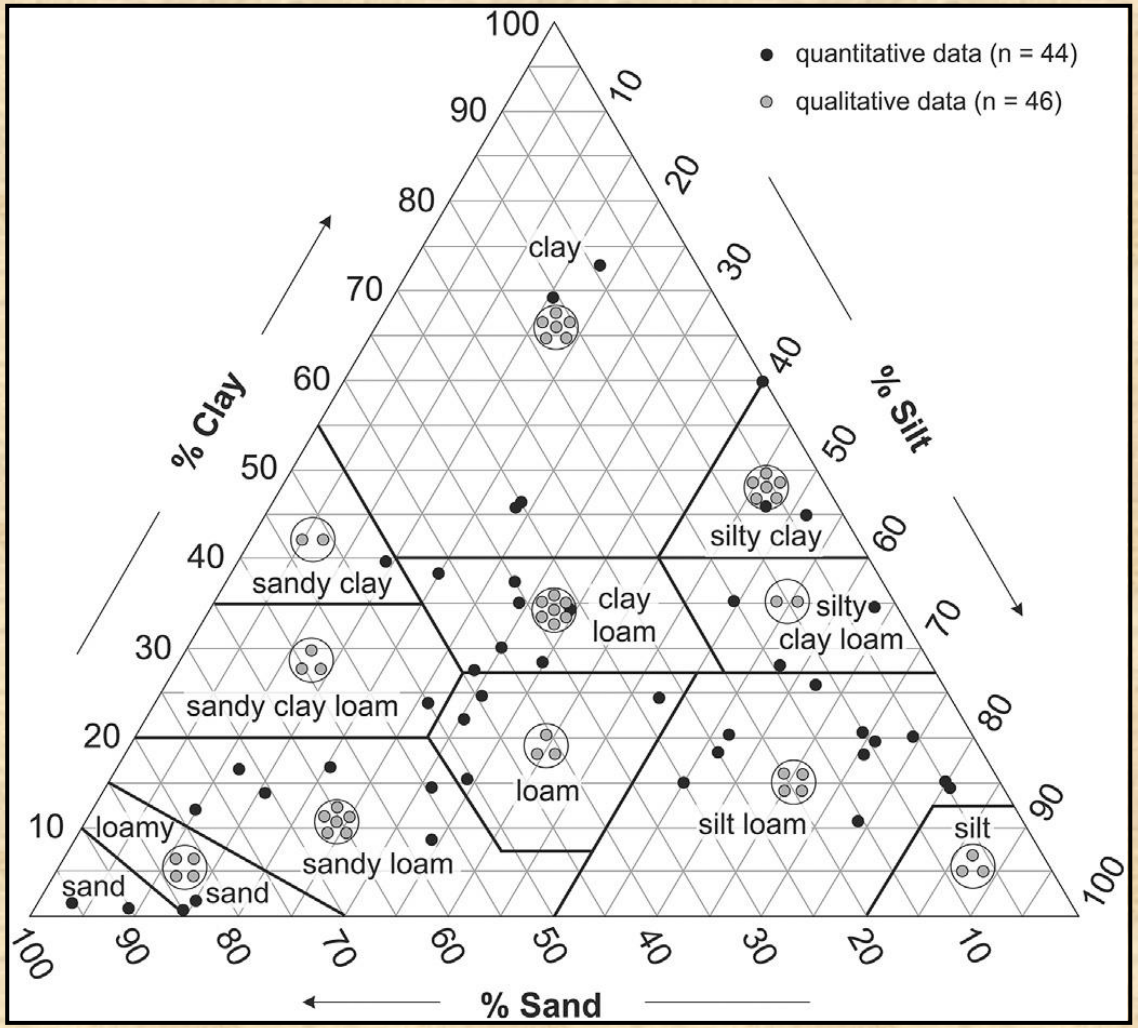
Overview of sites where soil piping has been reported: “only observations” means that soil piping was observed in the field and reported in literature, but without studying this process, whereas “research” means that soil piping studies were conducted at the site. n is the number of sites. Bernatek-Jakiel and Poesen, 2018

Soil Pipes Found in All Soil Textures

“**Soil piping has been reported in almost every soil texture…**
Although soil texture is an important property controlling the susceptibility of soils to piping, it seems to be of lesser importance for identifying sites with piping erosion”

In 22 of the 29 Soil Orders

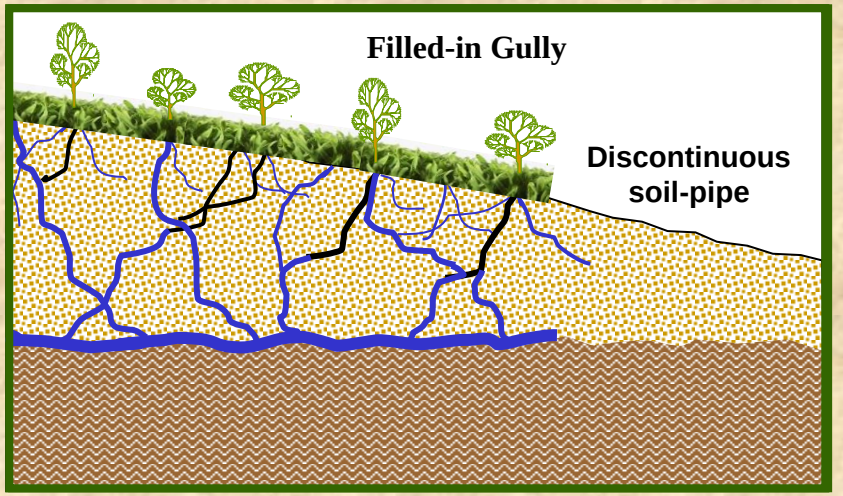
Bernatek-Jakiel and Poesen, 2018



Texture of soils for which piping has been reported in the literature. One dot represents one site where soil piping was reported and soil texture was given. Bernatek-Jakiel and Poesen (2018)

Pipe Formation Processes

A common feature for pipe-erosion is the existence of water-restrictive layers, which Faulkner (2006) termed duplex soils, that focus flow through soil-pipes.



Preferential flow through macropores can be so rapid that the shear forces exceed the frictional strength binding particles and the macropore erodes internally to form a soil-pipe.

Soil pipe erosion continues until the shear strength of the soil is exceeded by the normal forces of the over-burden and the pipe collapses occurs.

Soil Pipe Collapse Features

Flute Holes

Sediment mounds

Discontinuous Gullies

Sinkholes

Continuous Gullies

Soil Pipe Hydrology

It has been “40 years since soil piping was first considered to be a potential factor in the hydrological response of catchments” Jones (2010)

Tremendous body of work on piping phenomena that has focused on:
Soil pipes sizes and distributions in landscapes
Pipe flow rates and role in streamflow
Role of pipes in catchment hydrology

Soil Pipe Knowledge Gaps

The internal erosion processes that formed the soil pipes, e.g. particle detachment and sediment transport, are among the least studied and most poorly understood of the pipeflow processes. Wilson et al., 2018, Bernatek-Jakiel, 2020

Wilson et al., 2018, ESPL

Basic Research on Chemical Controls on Internal Erosion Controls
Bernatek-Jakiel et al. 2020, ESPL

Field measurements of tensile strength (TS) and Relative Erodibility Indicator (REI)

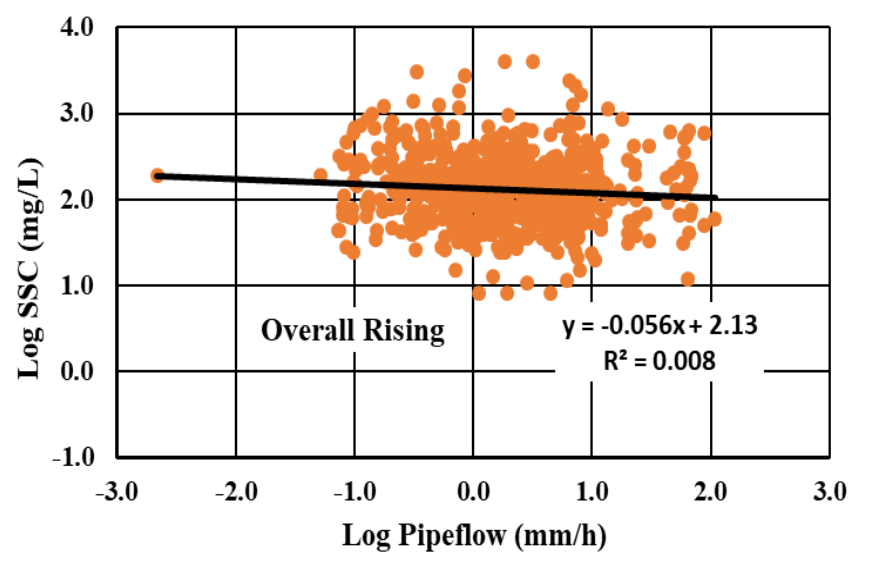
The setup for air slaking experiments

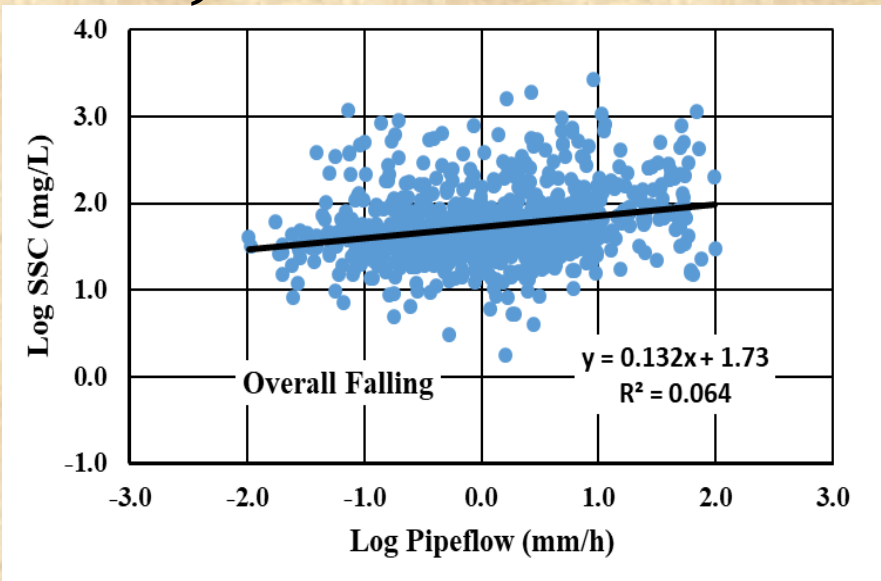
The removal of SOC, and Fe and Al oxides may weaken and disintegrate aggregates in soil pipes.

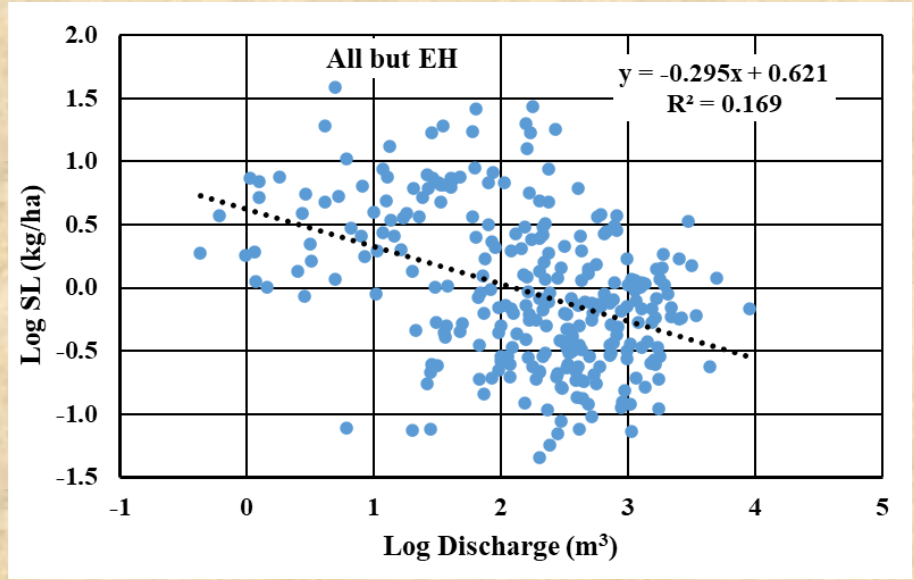
The removal of SOC by oxidation increases as soil pipes increase in size and pipe networks due to higher SOC than non-piped areas.

The removal of Fe and Al oxides is possible under anoxic conditions when decay of vegetation causes a peak in SOC

In Situ measurements of Suspended Sediment Transport and Bedload Transport, Wilson et al. 2020, ESPL

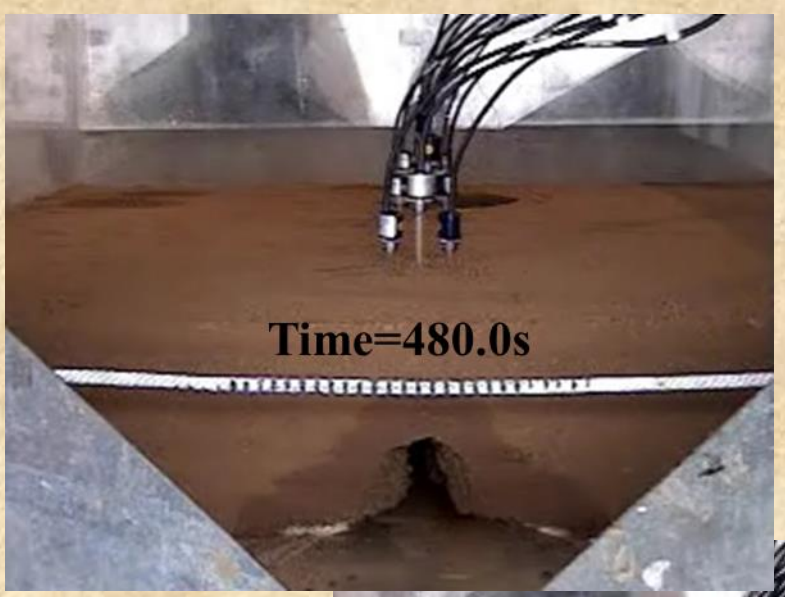




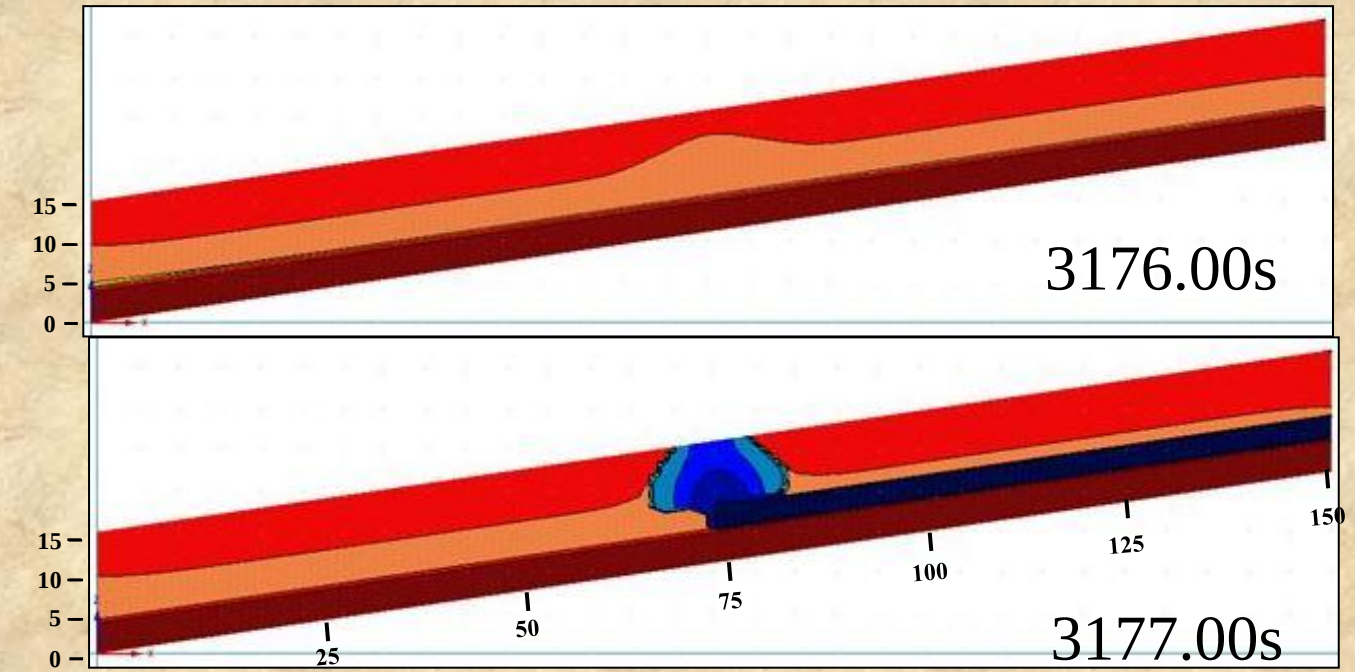


Sediment Transport Limitations:

Sediment detachment exceeding transport capacity results in pipe clogging
Wilson et al. 2011, Hydro. Proc.



Pipe clogging results in pressure buildup and surges in flow rate and sediment concentration.
Midgley et al., 2013 Trans ASABE; Wilson and Fox., 2013, SSSAJ; Nieber et al., 2019 VZJ



Sediment Transport Limitation: Clogging

Bernatek-Jakiel and Poesen, 2018, ESR

Theorized to Cause Pipe Collapse and Hillslope Failure/Landslides

Pressure Surges Results in Artesian Flow, Sediment Mounds

Summary and Recommendations

- Soil pipes are ubiquitous, occurring in almost all soil types and world wide
- Erosion may be taking place below ground without evidence on surface until pipe collapse.
- Wealth of research conducted to date on soil pipe hydrology
- Research on soil pipe formation processes, i.e. sediment detachment and transport is in infancy

More research needed on:

- Soil, and fluid properties controlling internal erosion of soil pipes
- Suspended sediment rating curves and bedload rates
- Sediment transport limitations and implications of clogging