

Knowledge for Successfully Developing your Project in Karst Geology

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Frequently Asked Questions We Hope to Answer Today

- ▶ Where do sinkholes occur?
- ▶ Why do sinkholes occur?
- ▶ How do I fix this?

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Definitions

- ▶ Karst - soluble rock
- ▶ Rock pinnacle - Finger of very hard rock
- ▶ Sinkhole throat - location where water and soil escapes between rock pinnacles

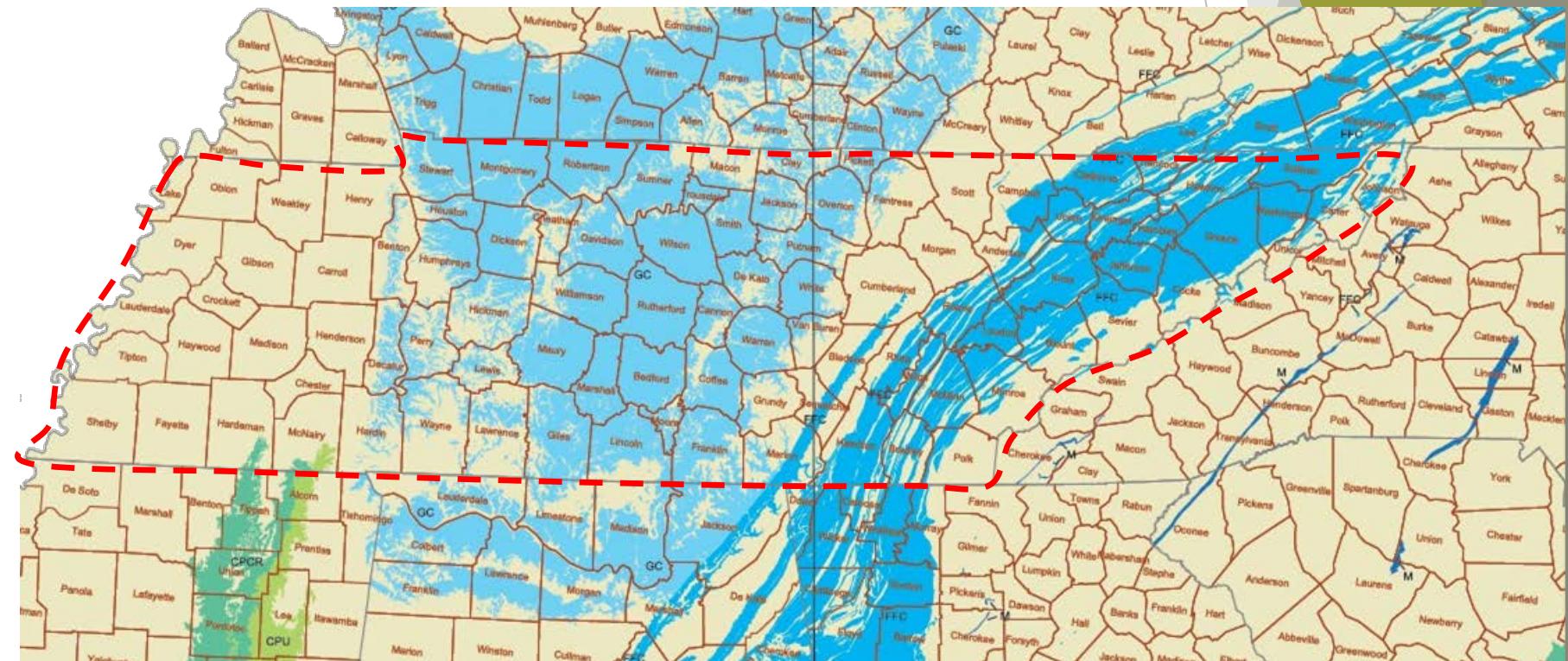
Sinkholes Occur in Karst Geology

- ▶ Sinkholes are closed depressions caused by soil overburden collapse or subsidence due to dissolution of carbonate rock found in Karst terrain.
- ▶ Underlain by carbonate rock (i.e., limestone/dolomite)
 - ▶ Groundwater dissolves soluble material, typically along joints and fissures, leaving insoluble material (clay minerals and silicates) resulting in:
 - Decrease in soil consistency with depth
 - High moisture contents near bedrock
 - Irregular bedrock surface with pinnacles, ledges, boulders, rock outcrops, and closed depressions

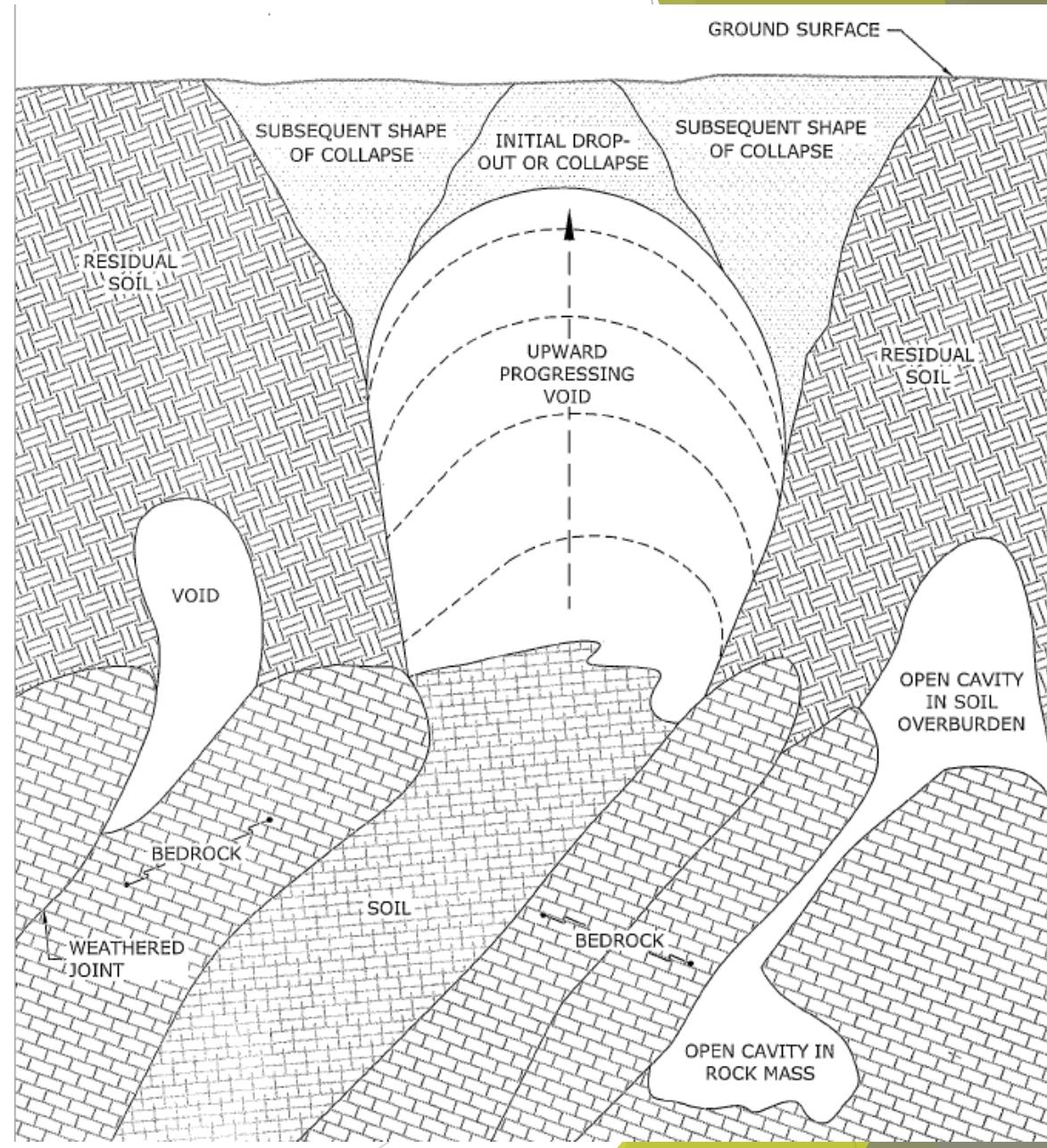


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- Erosion of the overburden soils through the throat, starting near the rock surface, into an existing cavity in the bedrock
- A void is formed in the overburden soil working its way toward the ground surface as the void increases in size
- Eventually the collapse at the surface is caused by:
 - The weight of the overburden exceeds the strength of the soil
 - Construction removal of soil, vibration, or blasting
 - Change in ground water level



Why is this a concern (other than the obvious hole in the ground)?

- ▶ Clearly there is an immediate impact on the safety of the public should a sinkhole open in infrastructure
- ▶ There can be immediate impact to property such as buildings, road, infrastructure
- ▶ Can be an immediate impact to ground water depending on when and where the sinkhole occurs

Remediation of the sinkhole depends on
what the sinkhole impacts

- ▶ Inverted filter

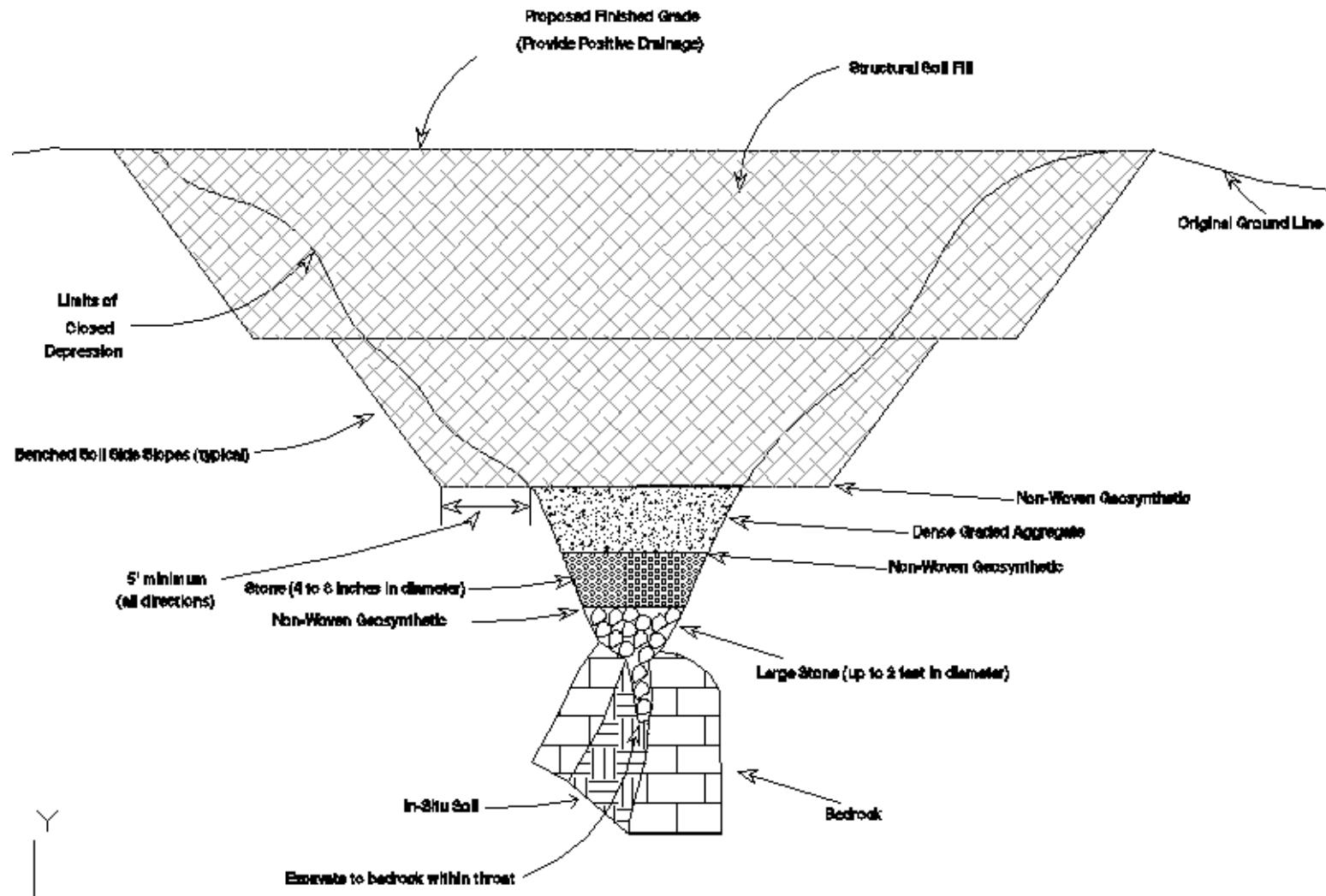
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- ▶ Inverted filter
- ▶ Flowable fill / concrete plug

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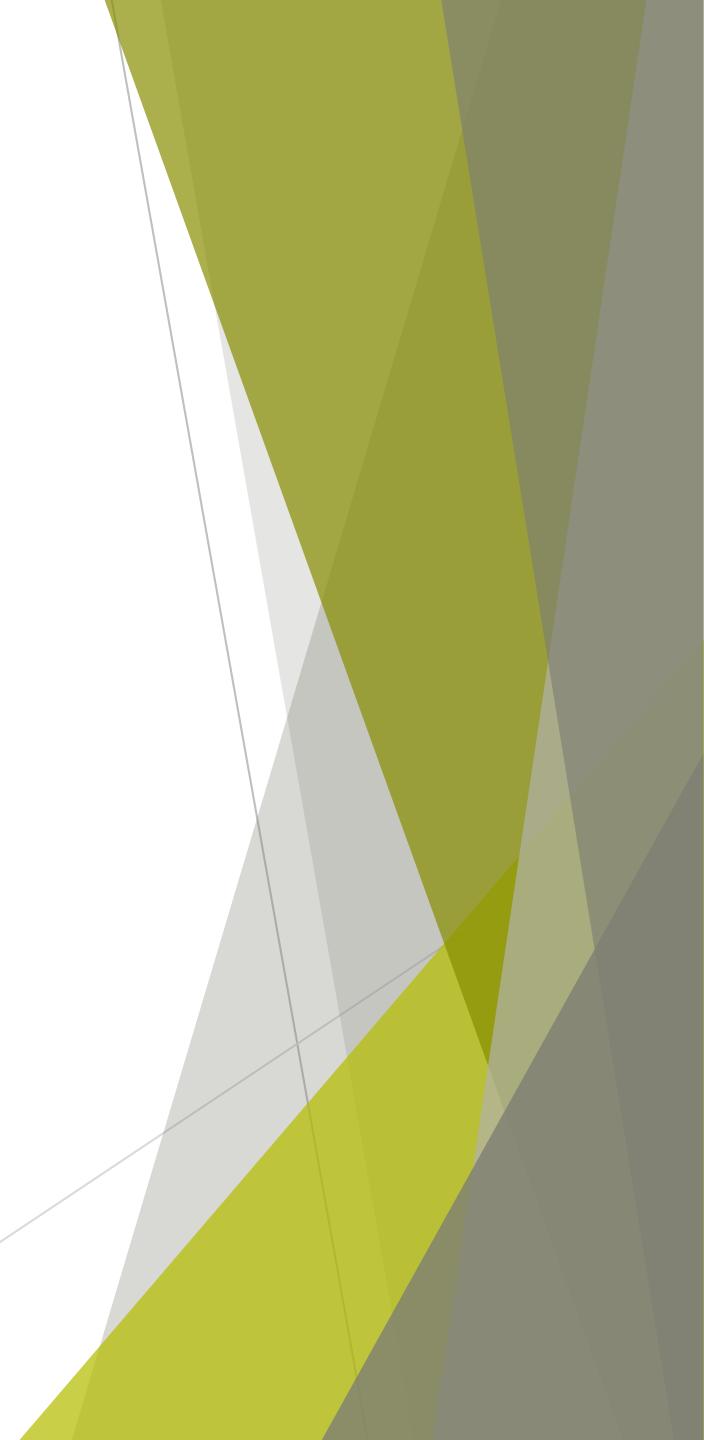
- ▶ Inverted filter
- ▶ Flowable fill / concrete plug
- ▶ Cap and compaction grouting

Inverted Filter









Flowable Fill Plug



Cap and Compaction Grouting

- ▶ Drill to refusal/bedrock
- ▶ Inject larger quantity of grout at rock surface
- ▶ Inject smaller quantity of grout in one foot increments as you withdraw drill casing



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 - ▶ Avoid deep cuts when possible

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- ▶ Risk of sinkholes at drainage outfalls (Class V Injection Well permit required)
- ▶ Regional capacity of the subsurface drainage system can:
 - ▶ be overwhelmed or
 - ▶ be plugged by sediment in runoff
 - ▶ contribute to more sinkholes downstream

Sinkhole Prevention Site Planning

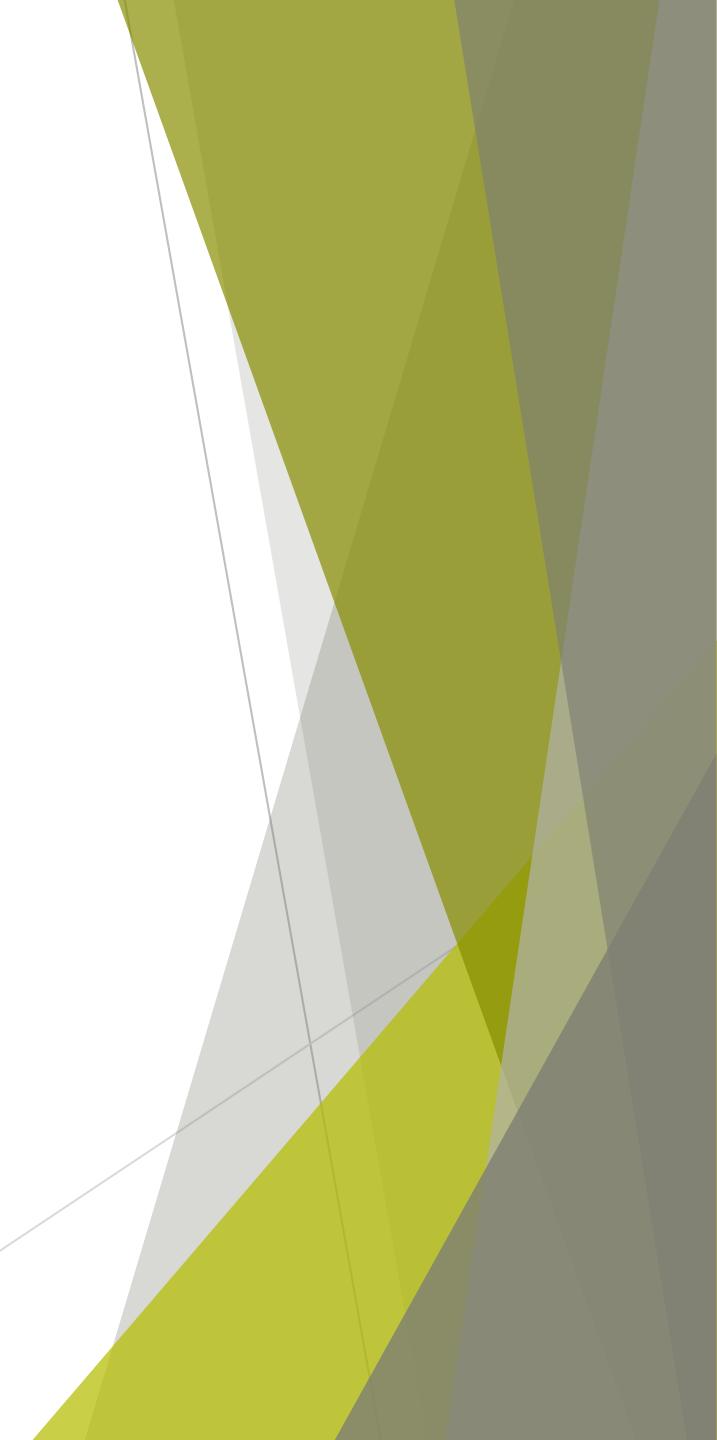
- ▶ Positive site drainage helps to prevent sinkholes
- ▶ Lowering the ground water level can increase chance of sinkholes (typical in Florida)
- ▶ Heavy rainfall and subsequent runoff causes sinkholes in Tennessee
- ▶ Grade selection
 - ▶ Areas of cut have higher risk of sinkhole development due to exposure of the numerous relict fractures in the soil to rainfall and runoff
 - ▶ Areas of modest cohesive fill will have a lower risk because of the impervious layer formed by the remolded soil

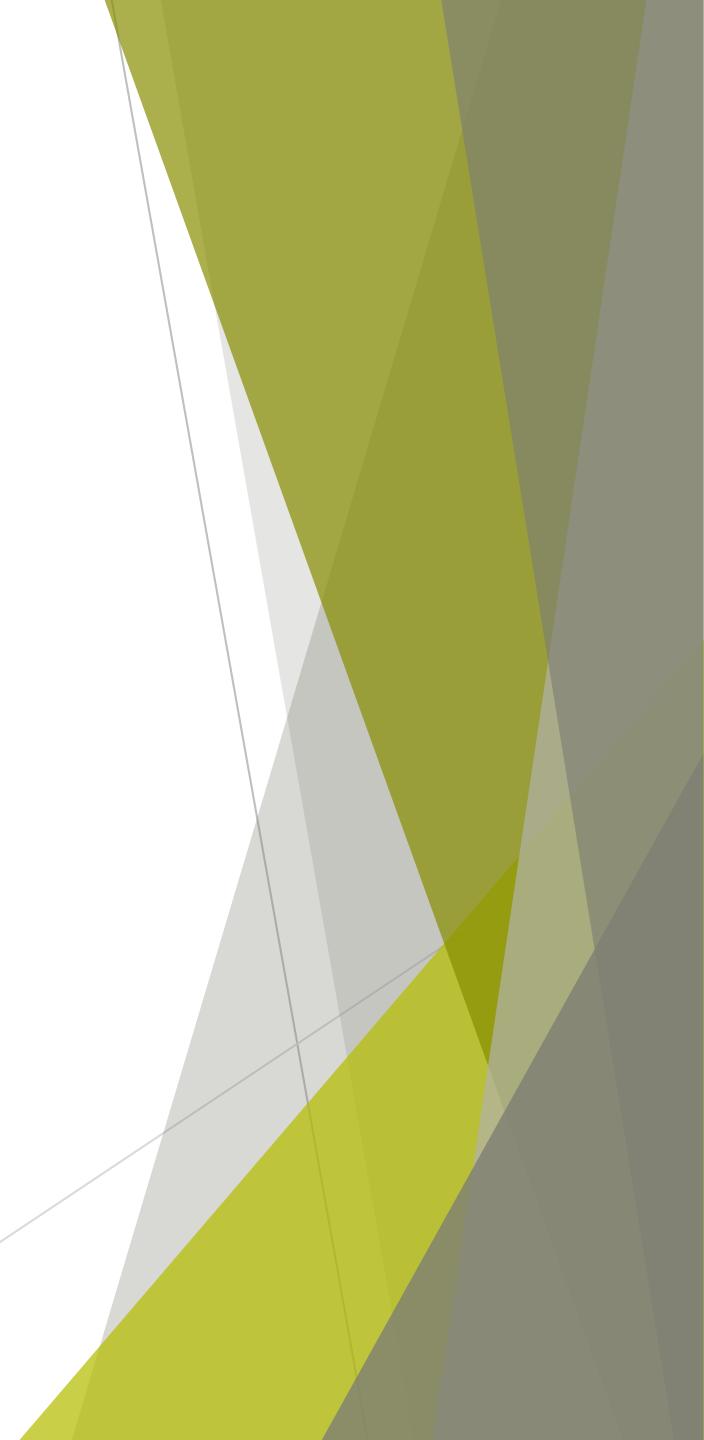
Sinkhole Prevention During Construction

- ▶ Blasting can lead to the collapse/plugging of existing sinkholes
- ▶ Equipment choice - Vibration from large equipment can lead to the collapse of existing sinkholes
- ▶ Remediation of the soil before closed depression occurs by scarifying and re-compact the upper 9 inches of soil exposed in cut sections (blanket of less permeable material)
- ▶ Utility trench backfill
 - ▶ DO use compacted, well-graded material (i.e., dense-graded aggregate), flowable fill, or compacted site soils
 - ▶ DO NOT use open graded stone (i.e., No. 57 stone) unless there is an exit path so water does not pond
 - ▶ Pressure test piping beneath structures prior to service



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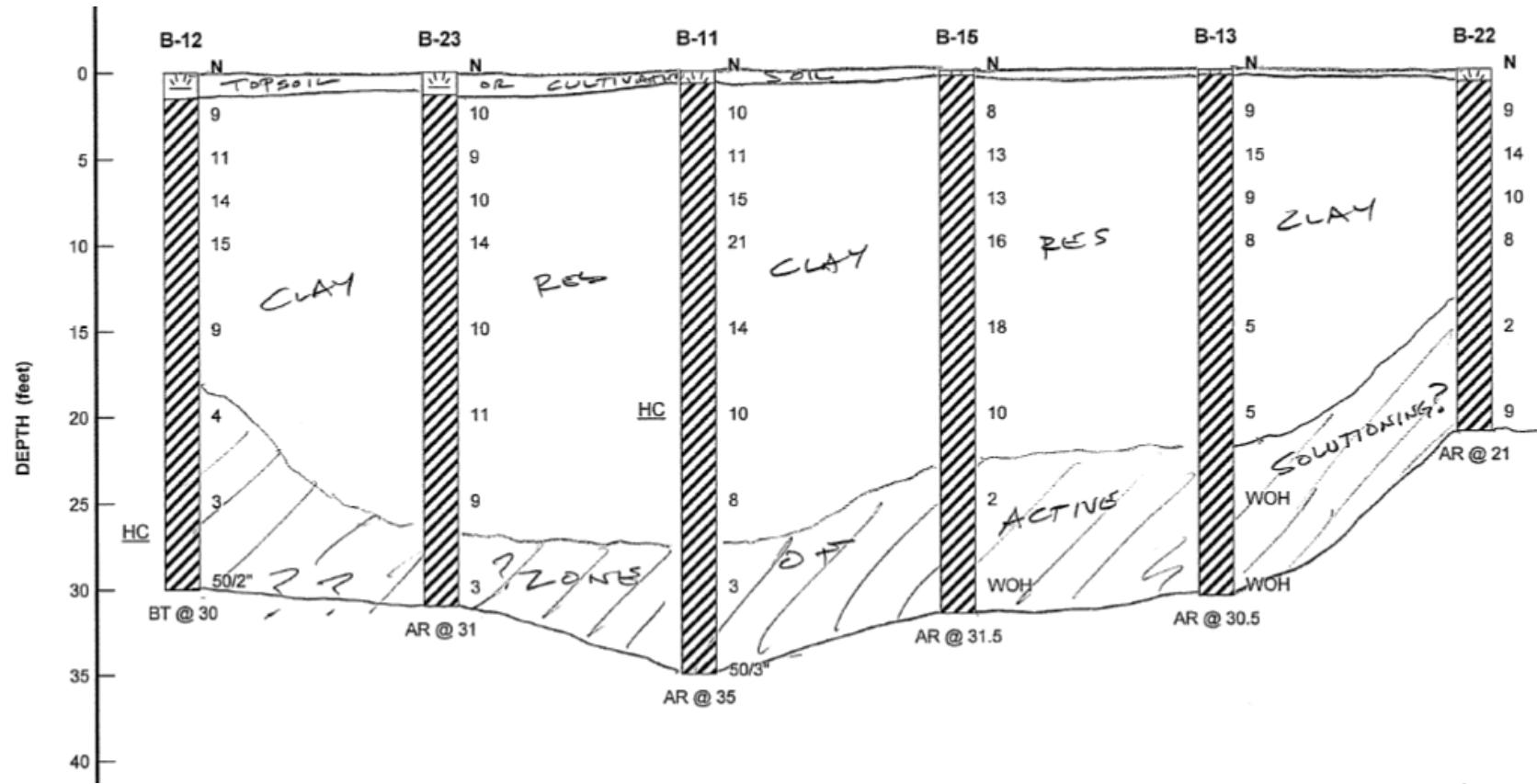




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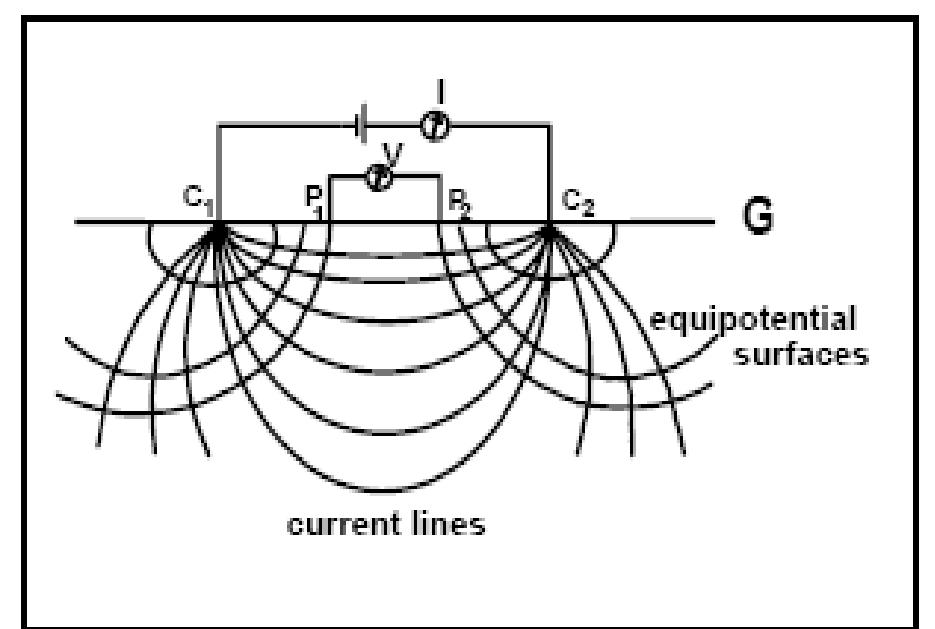
Obtaining data through conventional geotechnical borings



Obtaining data through Geophysical methods

Electrical Resistivity is a measure of how strongly a material opposes the flow of an electric current (DC)

This is done by measuring the potential voltage difference ($\Delta\phi$) between two points; typically with 4 electrodes placed in a line at a given spacing at the ground surface (2 current electrode and 2 potential electrodes; C and P respectively). Apparent resistivity (ρ_a) values of the subsurface are then calculated



Example Output of Electrical Resistivity

