Geotechnical Details Matter

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Geotechnical

- What is geotechnical engineering?
  - Geotechnical engineering, also known as geotechnics, is the branch of civil engineering concerned with the engineering behavior of earth materials. It uses the principles of soil mechanics and rock mechanics to solve its engineering problems. (Wikipedia)

Geotechnical

- Why should I care about geotechnical engineering?
  - Almost everything MDOT builds touches the ground. Because of that, we need to know how best to support our infrastructure so that it performs as intended.

Geotechnical

- What can happen if you ignore Geotech?

- You can have a very bad day.

Let’s start with the basics

It’s just dirt, how hard can it be?

Soil and Rock

- The typical stratigraphy is topsoil over inorganic soil over rock. However, there are areas in Michigan where there is exposed rock at the ground surface.
- Topsoil is the uppermost soil layer that has varying amounts of organic material in it.
- Topsoil has varying depths, depending on the location, but is usually anywhere from a few inches to a foot thick, although it can be thicker.

Soil and Rock

- Below the topsoil is inorganic soil.
- Inorganic soil consists of the following:
  - Gravel
  - Sand
  - Silt
  - Clay

Soil and Rock

- Coarse-Grained Soil
  - Gravel
    - Less than 3 inches but greater than No. 4 sieve.
    - Can be coarse or fine.
  - Sand
    - Less than the No. 4 sieve and retained on the No. 200 sieve.
    - Can be coarse, medium or fine.
- Cobble: A rock fragment with an average dimension of 3 to 12 inches.
- Boulder: A rock fragment with an average dimension of 12 inches or greater.

Soil and Rock

Gravel and Sand

Big Boulder

City of Ouray, CO (May 24, 2019)

Soil and Rock

- Fine Grained Soils
  - Silt
    - Passes the No. 200 sieve.
    - Exhibits low to no plasticity and will crumble when dry.
  - Clay
    - Passes the No. 200 sieve.
    - Exhibits plasticity/cohesion and will not crumble when dry.

Soil and Rock

- Silt
  - This is considered a frost-heave textured material.
  - Remove to 4 to 5 feet below plan grade when north of the north boundary of Township 12 north.
  - Remove to 3.5 to 4 feet below plan grade when south of the north boundary of Township 12 north.
  - May be susceptible to pile driving-induced settlement.

Soil and Rock

- Clay
  - Wide range of strengths.
  - Soft to very soft clay is problematic.
  - Hard clay could be a problem for steel sheet piling.

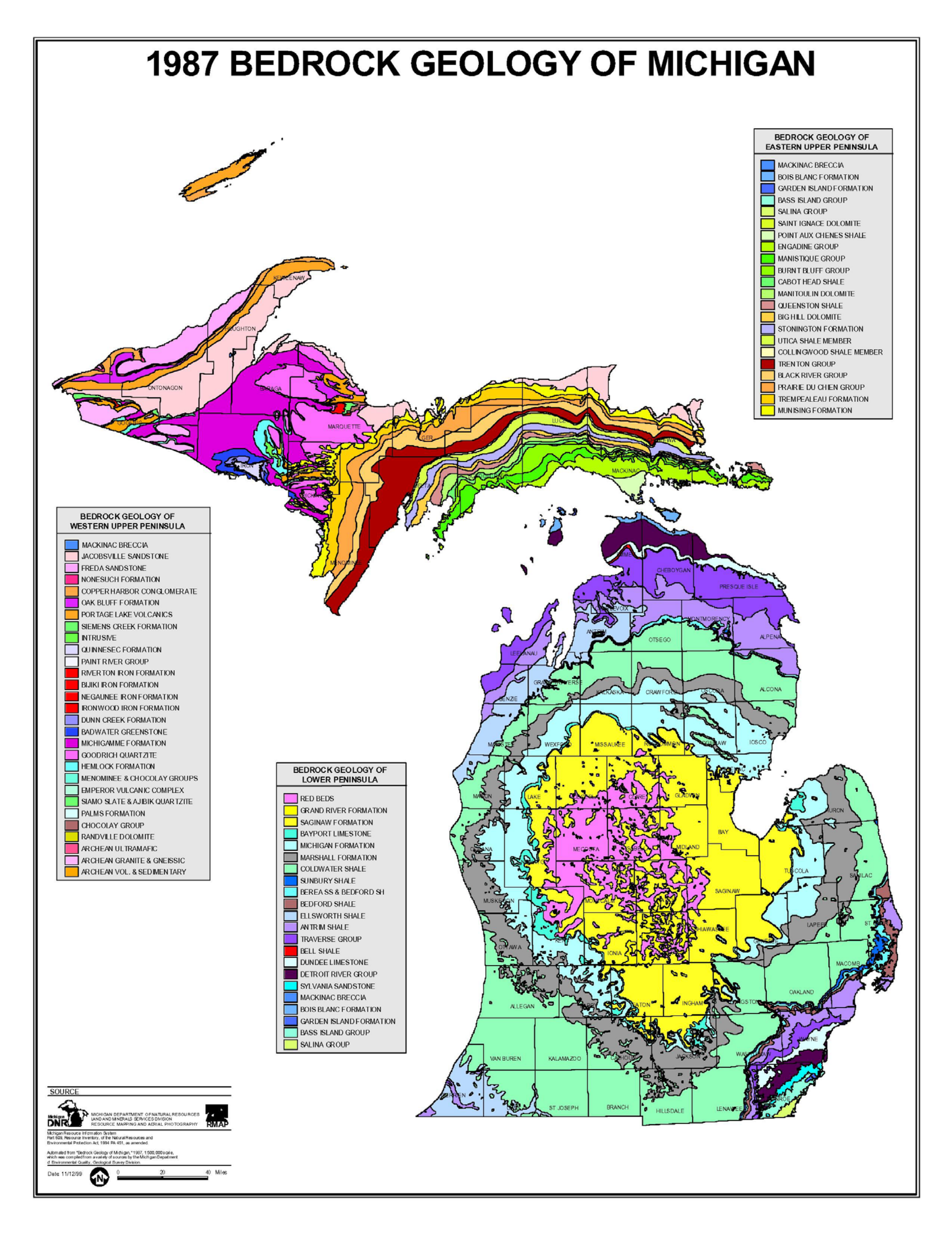
Organic Soils

- Topsoil
- Peat
  - Sedimentary peat, fibrous peat, woody peat, moss peat.
  - Decomposing vegetation.
  - Generally high moisture contents.
  - **Highly compressible.**
- Muck
  - Decomposed vegetation (black ooze).
  - **Highly compressible.**
- Marl
  - Deposit of calcium carbonate precipitate.
  - Typically below peat.
  - **Highly compressible.**

Bedrock

- Below soil.
- Can be at/near surface or extremely deep.
- Most of Michigan is sedimentary rock.
  - Limestone.
  - Sandstone.
  - Shale.
  - Gypsum (a type of soluble rock, found in a few areas of Michigan). This can be problematic if voids are found.
- Western half of Upper Peninsula is Precambrian rock (igneous and metamorphic).

Bedrock

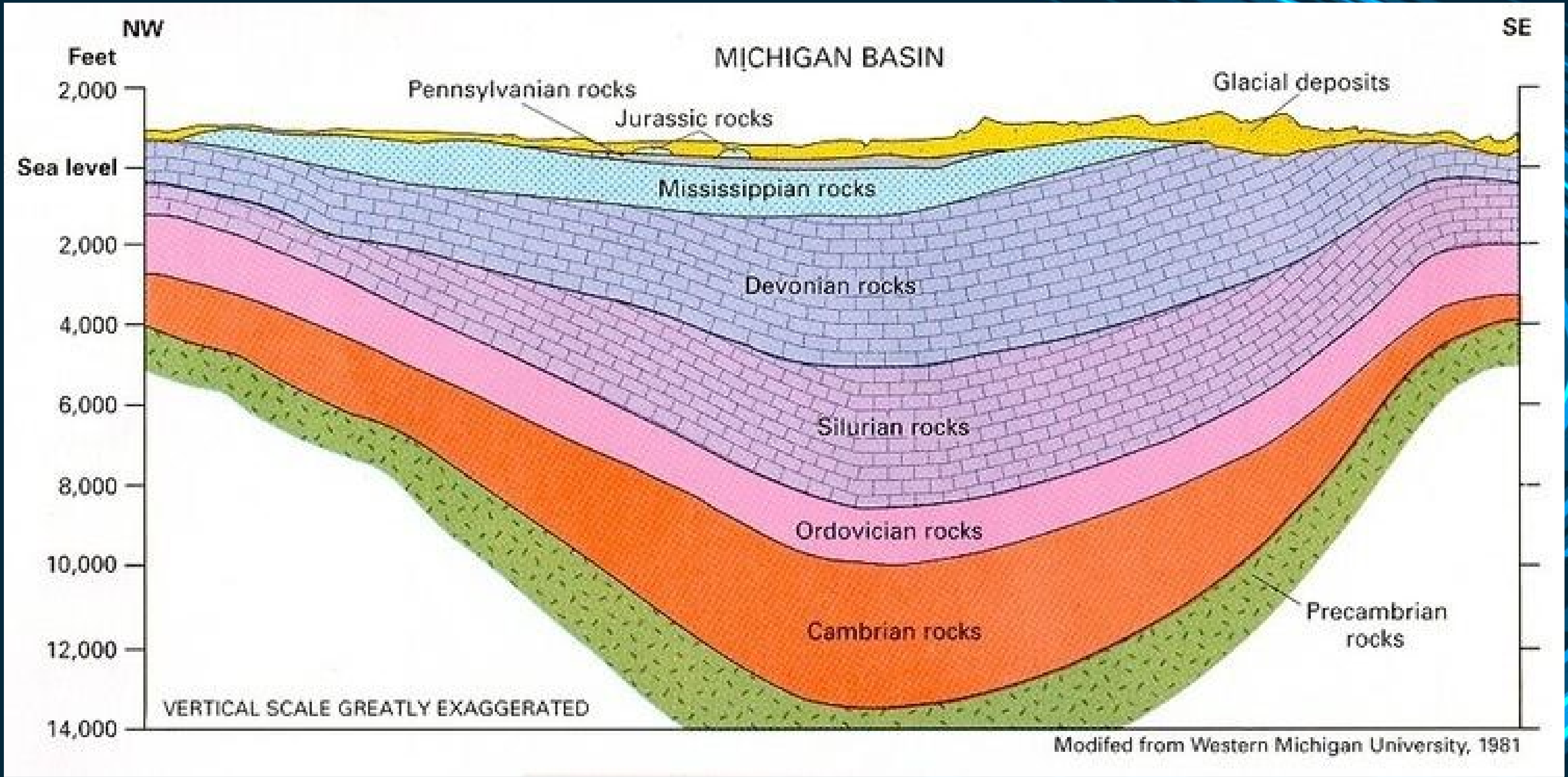


Bedrock Geology of Michigan

Michigan Department of Environment, Great Lakes and Energy Geological Survey Division

Michigan Department of Transportation

Bedrock



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Geotechnical Investigations

- Many projects will need soil borings.
- There is typically a long lead time for getting soil borings.
- Geotechnical consultants are typically two-three months out from when they are authorized to do work.
- This can be longer if an all-terrain vehicle (ATV) is needed for access.

Drilling Equipment

- Truck mounted (CME 75)

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Drilling Equipment

- ATV mounted (CME 850)

Geotechnical Investigations

- Need to review existing plans for what is there and what was done in the past.
- Should pay particularly close attention to old swamps and swamp treatments
  - The original treatment was only for the road that is there. Widening into an old swamp treatment needs special attention.
- Look for areas where there is shallow rock or exposed rock (there's more areas than you think in Michigan).

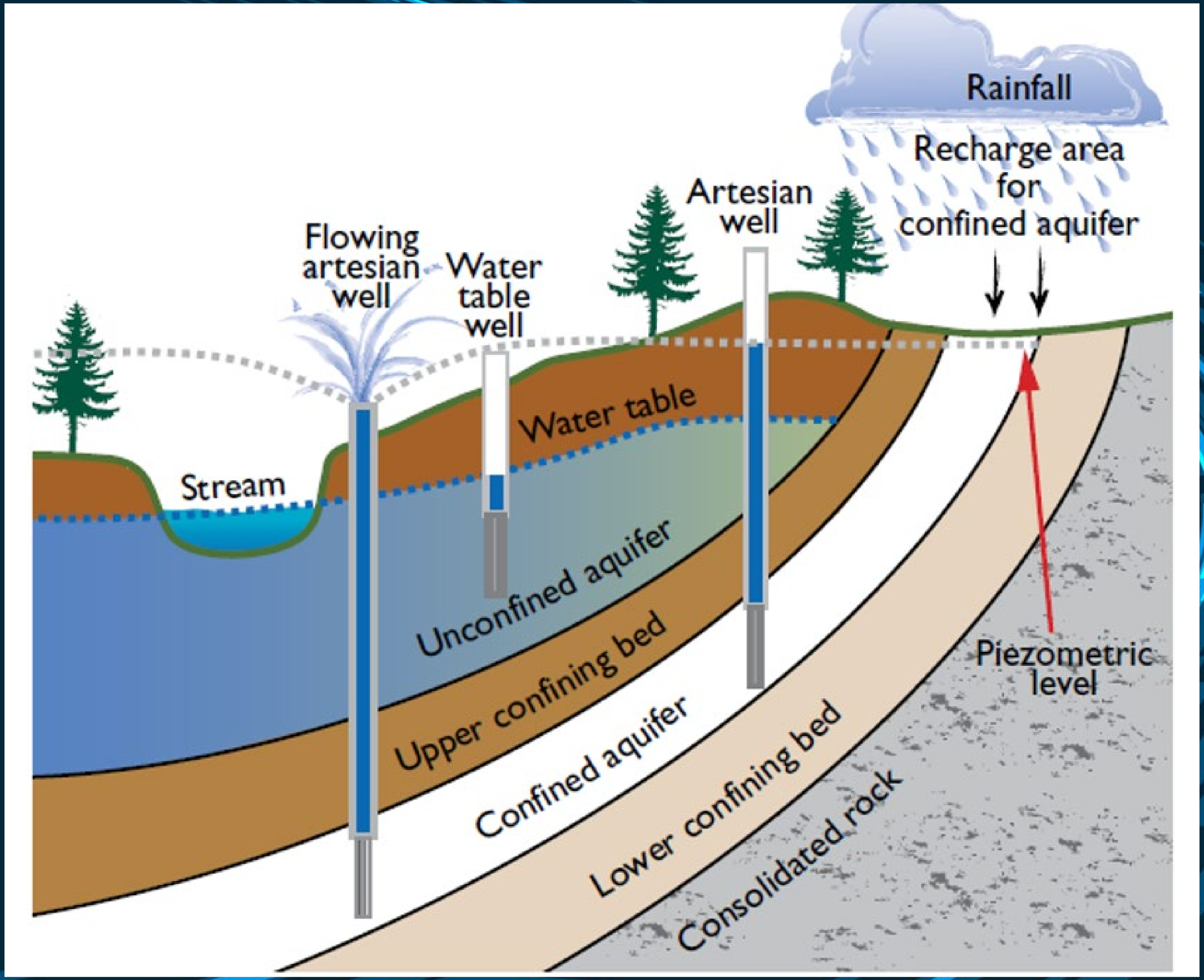
Pop Quiz

Q: Any idea what this is? A: A corduroy road over a swamp (ground improvement)

Groundwater

- This is very important but often overlooked.
- Need to look for perched groundwater.
- Need to look for confined aquifers.
- The drilling method used is important.
  - Hollow stem augers are best.
  - Mud rotary should be avoided until good groundwater information is determined since the drilling mud obscures the groundwater readings.

Groundwater



Picture by Water Science School, 2019

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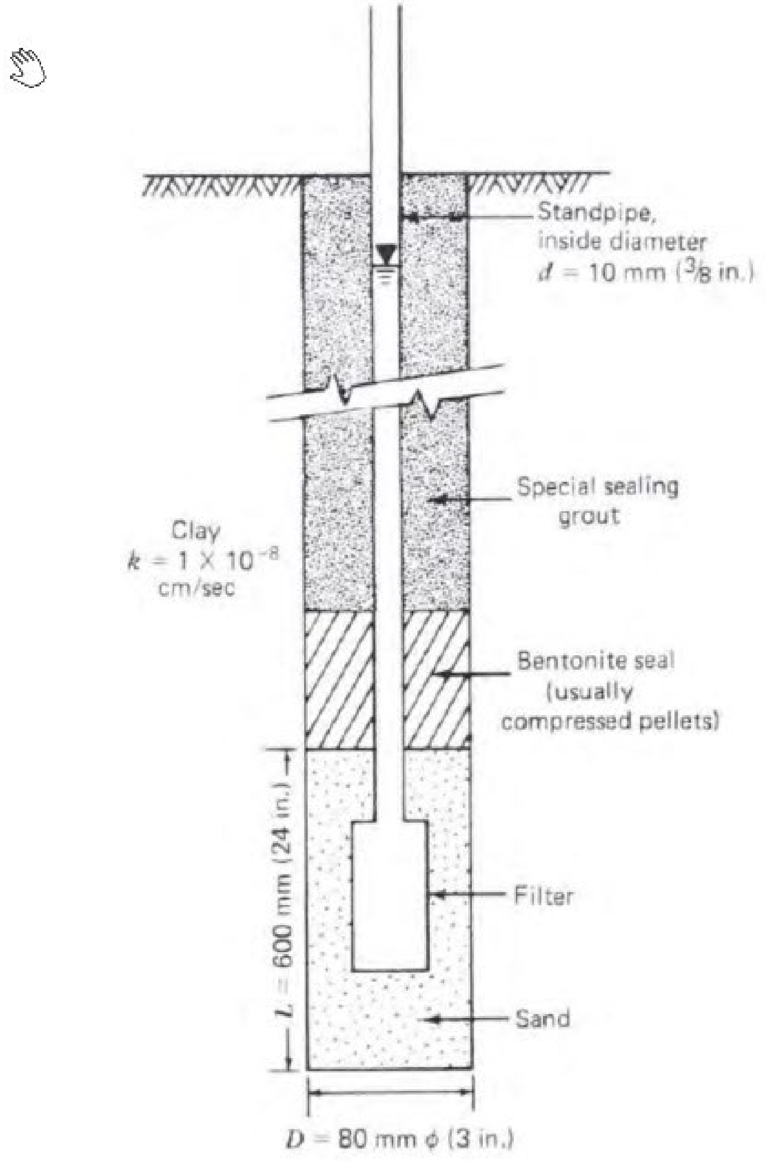
Common Types of Monitoring Wells

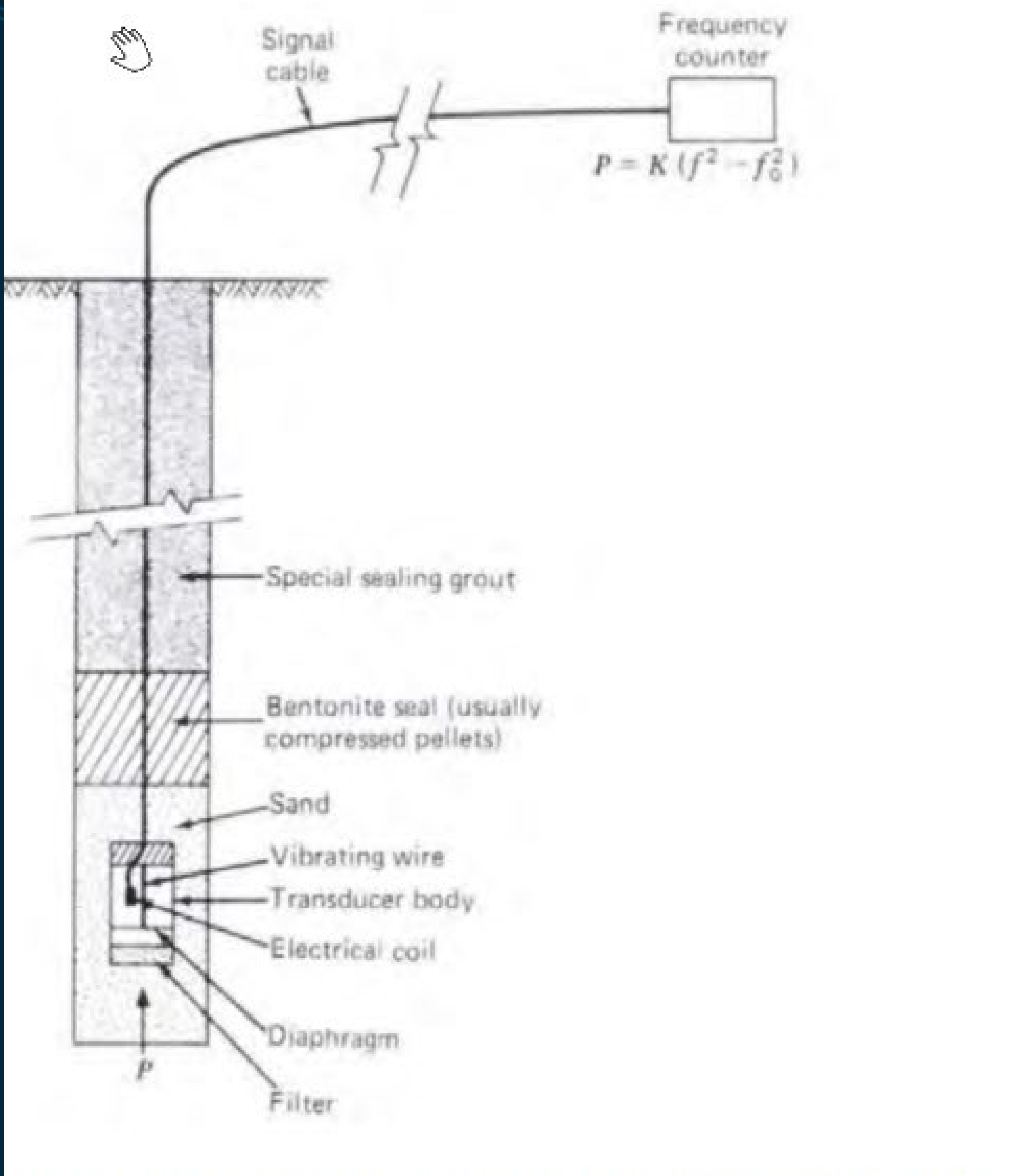
- Open standpipe
- Vibrating wire piezometer

Standpipe Piezometer



Standpipe piezometer installed in a borehole (from Dunnicliff, 1993).

Vibrating Wire Piezometer

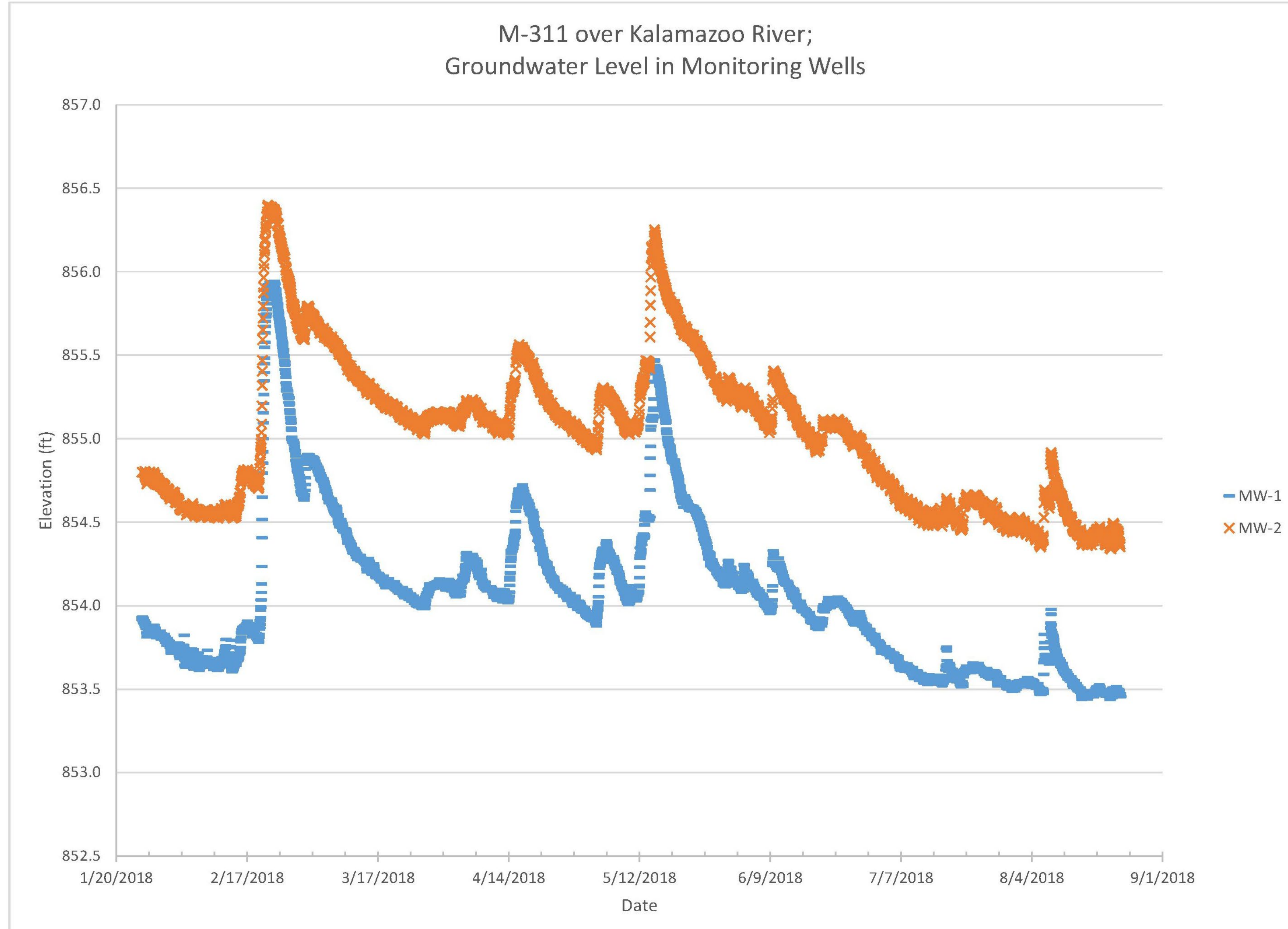


Vibrating wire piezometer (from Dunnicliff, 1993).

Monitoring Well Considerations

- Use appropriate protection, such as either a flush mount with the road or a lockable monument.
- Locate the well in a location that is safe and accessible.
- Consider where the future work is going to be and locate monitoring wells outside of those areas.
- Readings
  - If sporadic monitoring is acceptable then the water levels can be measured with a water level indicator.
  - Continuous monitoring is generally preferred due to potential seasonal fluctuations and/or precipitation events.
  - Consider a datalogger with a modem to upload readings to a cloud-based application.

Monitoring Well Readings



Artesian Considerations

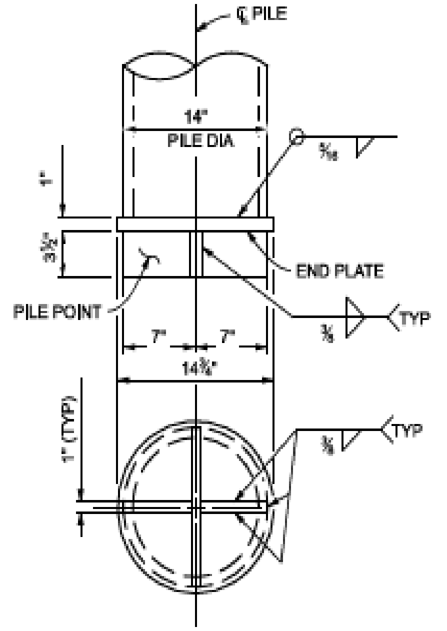
- Avoid artesian groundwater whenever possible.
- Cofferdams
  - Need to have the top of the cofferdam higher than the artesian pressure elevation.
  - Design the tremie seal for the artesian pressure elevation.
  - Make sure the cofferdam is flooded and at a static water elevation before pouring tremie concrete.

Artesian Considerations

- Drilled Shafts
  - Have casing that extends at least 10 feet higher than the artesian groundwater elevation to provide enough water downward pressure.
  - Do not pour concrete when groundwater is flowing into the drilled shaft excavation.
  - Make sure that any voids are completely filled with concrete. Keep track of concrete height during the pour.
- Piles
  - Can use either H-pile or CIP piles, depending on what the bearing layer is.
  - Do not use a standard pile point. It is important to use flush mounted end plates (CIP piles) or to look at driving stresses with H-pile and upsize the section if needed.

Make sure the correct pile point/end plate is being used

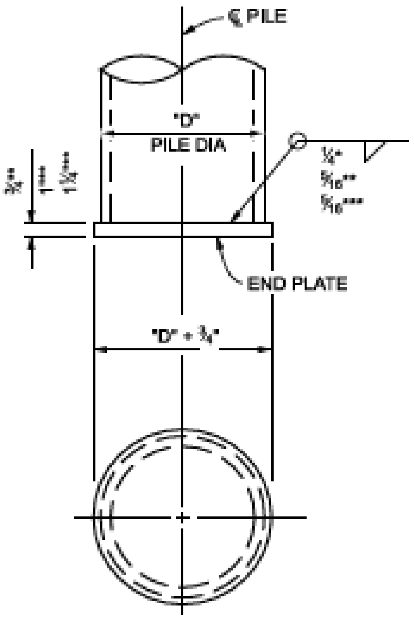
Reinforced CIP pile point extending beyond the diameter of pipe pile. Reinforced plate is used when soils have cobble or are very dense.



CIP PILE POINT DETAILS

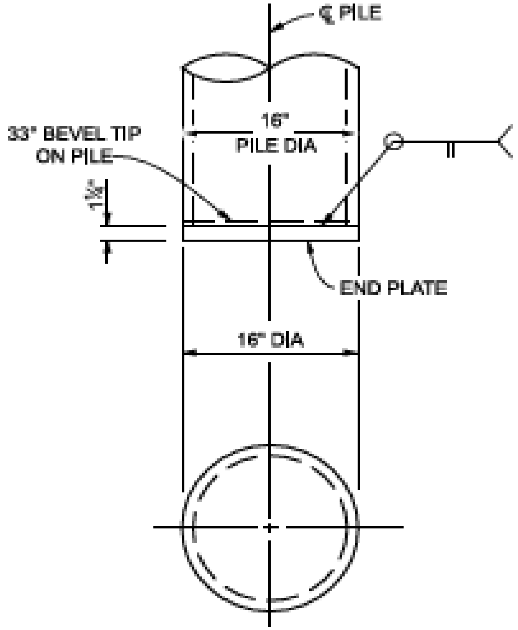
FOR POINT BEARING PILES ONLY. USE WHEN RECOMMENDED BY GEOTECHNICAL SERVICES.

Standard end plate pile point extending beyond diameter of pipe pile. End plate is used in loose or dense.



CIP PILE END PLATE DETAILS

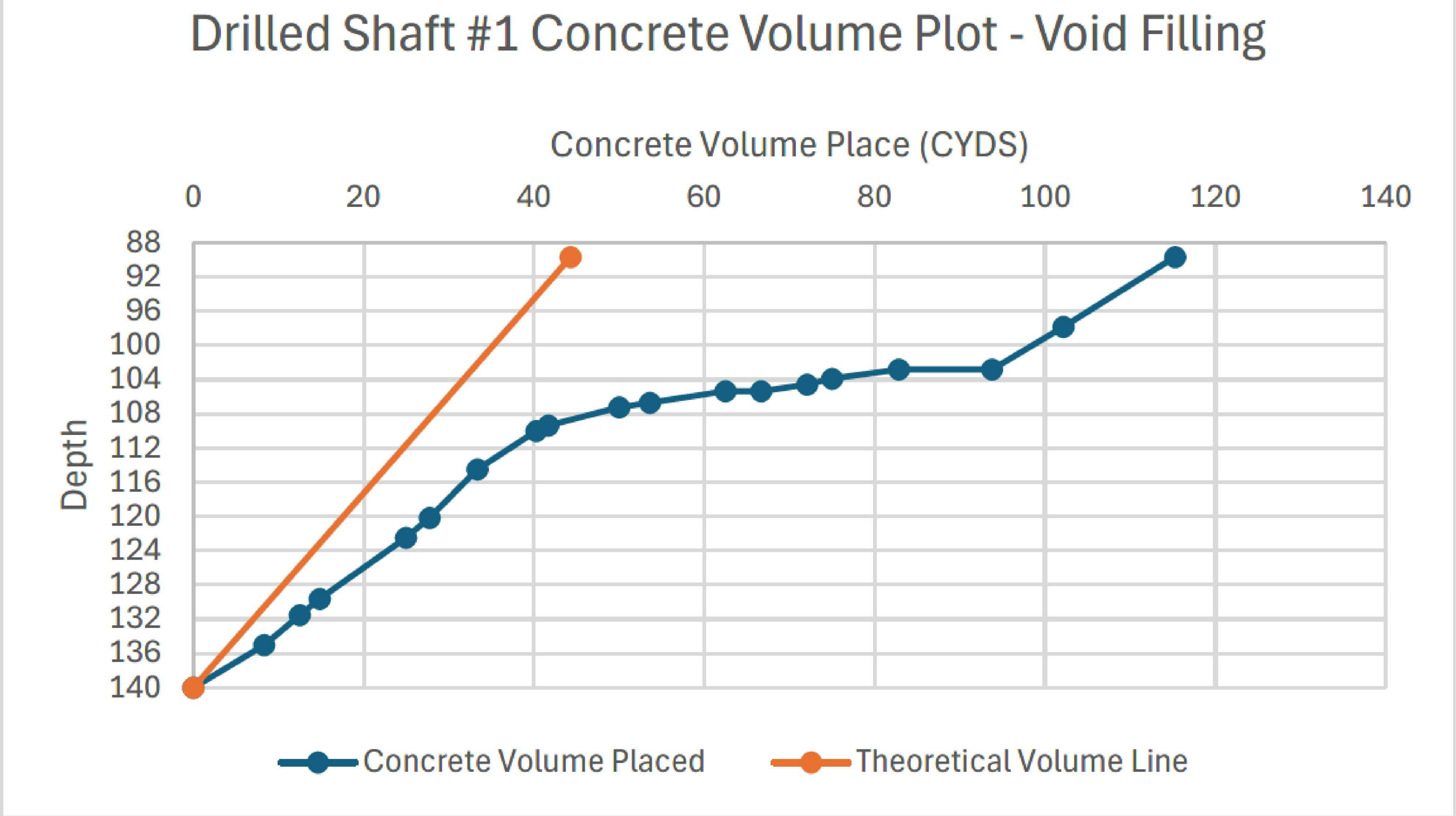
Example of end plate where plate is flush with the diameter of the pipe pile. To be used in an artesian condition.



CIP PILE END PLATE DETAILS

Artesian Considerations

- Need to consider the elevation of the work platform.
- Need to consider where the top of casing is with respect to the artesian groundwater elevation.


Drilled Shaft #1 Concrete Volume Plot - Void Filling
Concrete Volume Place (CYDS)
0
20
40
60
80
100
120
140
Depth
88
92
96
100
104
108
112
116
120
124
128
132
136
140
Concrete Volume Placed
Theoretical Volume Line

Geotechnical Lessons

- Need to look at excavation slope angles.
- Need to look at maintenance of traffic (MOT) early.
- Part-width construction needs to have room to make connections with the proposed work at the stage line.
- Need to look at maintaining flow for bridges/large culverts.
- Hard driving conditions for steel sheet piling.
- Settlement potential from driving steel sheet piling.

Geotechnical Lessons - Excavation Slopes

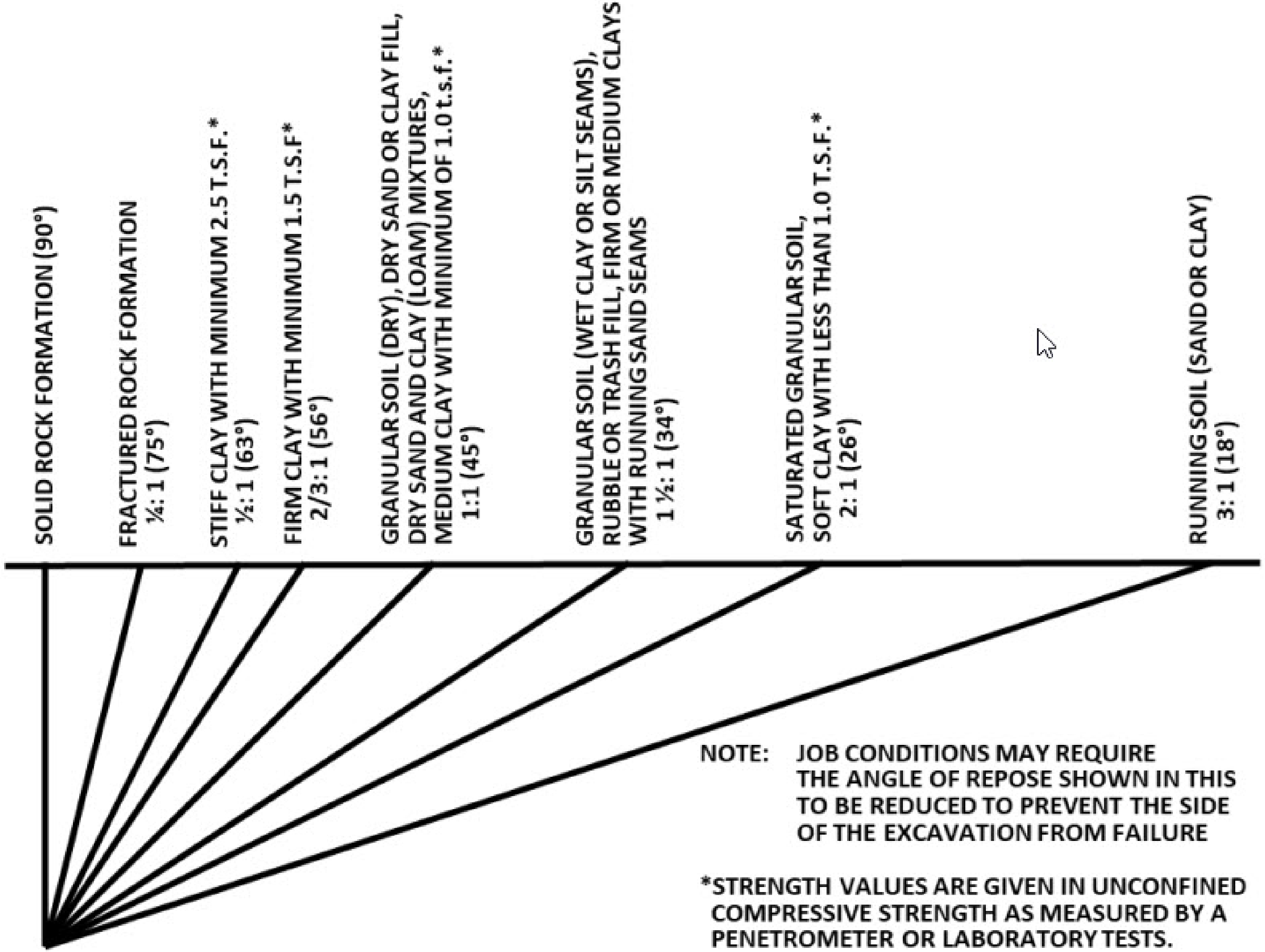
- All slopes need to be done in accordance with MIOSHA Construction Standard, Part 9, Excavation, Trench and Shoring.
- Need to show proper slope angles on the plans.
- This affects excavation limits, excavation and backfill quantities, temporary earth retention limits (steel sheet piling, temporary MSE walls).
- Per MIOSHA, “Excavation-related accidents have a 112 percent higher fatality rate than the overall rate for construction.”

Geotechnical Lessons - Slopes

MIOSHA Construction Standard, Part 9, Excavation, Trench and Shoring, Table 1

TABLE 1

MAXIMUM ALLOWABLE ANGLE OF REPOSE FOR THE SIDE OF AN EXCAVATION IN EXCESS OF 5' DEPTH



NOTE: JOB CONDITIONS MAY REQUIRE THE ANGLE OF REPOSE SHOWN IN THIS TO BE REDUCED TO PREVENT THE SIDE OF THE EXCAVATION FROM FAILURE

*STRENGTH VALUES ARE GIVEN IN UNCONFINED COMPRESSIVE STRENGTH AS MEASURED BY A PENETROMETER OR LABORATORY TESTS.

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Geotechnical Lessons - Excavation Slopes (Good)

Geotechnical Lessons - Excavation Slopes (Bad)

Geotechnical Lessons - Excavation Slopes (Bad)

Geotechnical Lessons - Excavation Slopes (Bad)

Geotechnical Lessons - MOT

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Geotechnical Lessons - Hard Driving

Geotechnical Lessons - Settlement

Steel Sheet Piling

Methods to install steel sheet piling

- Vibratory hammer
- Impact hammer
- Variable moment vibratory hammer (not readily available)

Settlement may occur from installing and/or removing steel sheet piling. Need to evaluate methods of installation as well as if sheet piling should be left in place.

Geotechnical Lessons - Maintaining Flow

Geotechnical Lessons - Maintaining Flow

Geotechnical Lessons - Maintaining Flow

Geotechnical Deliverables

- Soil boring data sheet
  - Needs to have all the factual soil boring information.
  - This is included in the plans (contract documents).
- Geotechnical reports
  - This is the geotechnical engineering recommendations based on the soil information and what the proposed work is.
  - **Make sure geotechnical reports are included in the RID documents.**

Geotechnical Engineering

- Where/when should geotechnical engineers be involved?
- Answer: The entire process.
  - Scoping
  - Base plans
  - Plan Review
  - FPC Review
  - Construction

Geotechnical Lessons

- Don’t use placeholder quantities
  - These are often not revised when final geotechnical recommendations are received.
  - Leads to plan errors, design errors, change orders and construction claims.
- Need to follow the region soils engineer’s recommendations for subgrade undercut quantities.
  - These are often increased during construction.

Geotechnical Lessons

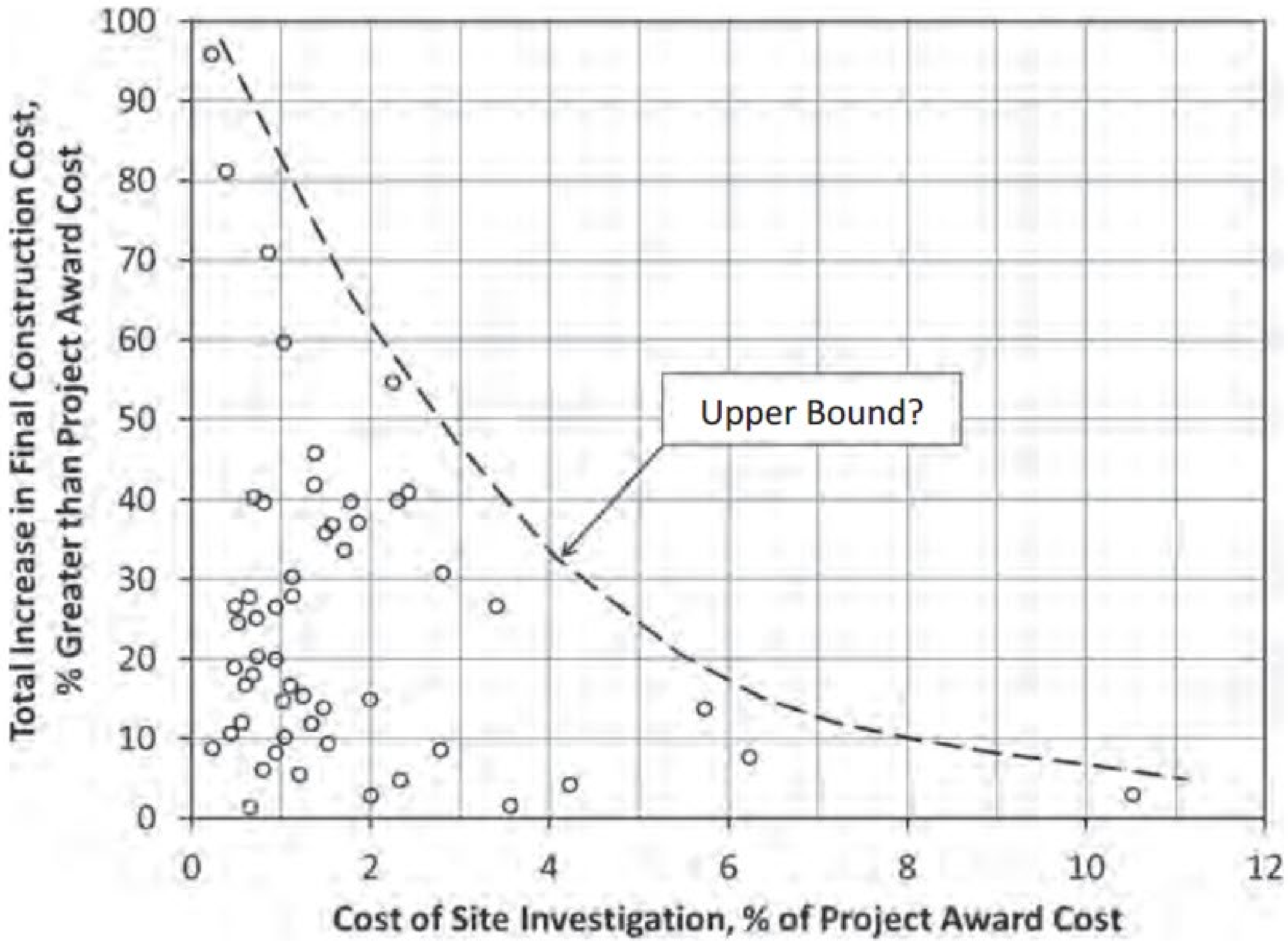

FIGURE 1 Graph of increases in construction cost for infrastructure projects as a function of cost of subsurface investigation (adapted from Clayton 2001 and Mott MacDonald and Soil Mechanics Ltd. 1994).

From NCHRP Synthesis 484

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Geotechnical Lessons

TABLE 9
SUMMARY STATISTICS FOR CLAIMS, CHANGE ORDERS, AND COST OVERRUNS ATTRIBUTED TO SUBSURFACE CONDITIONS

	Total Number			Total Cost		
Statistic	Claims	Change Order	Cost Overruns	Claims	Change Order	Cost Overruns
Number of Responses	4	5	2	4	5	2
Minimum	0	6	3	$0	$1.0*	$0.3*
Maximum	7.8	125	21	$865,000	$10.3*	$1.0*
Average	2	46	12	$240,000	$3.4*	$0.7*
Standard Deviation	3.9	49	13	$419,000	$3.9*	$0.5*

Values are average annual values for data from 2009 to 2013.
*In millions.

From NCHRP Synthesis 484

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Geotechnical Lessons

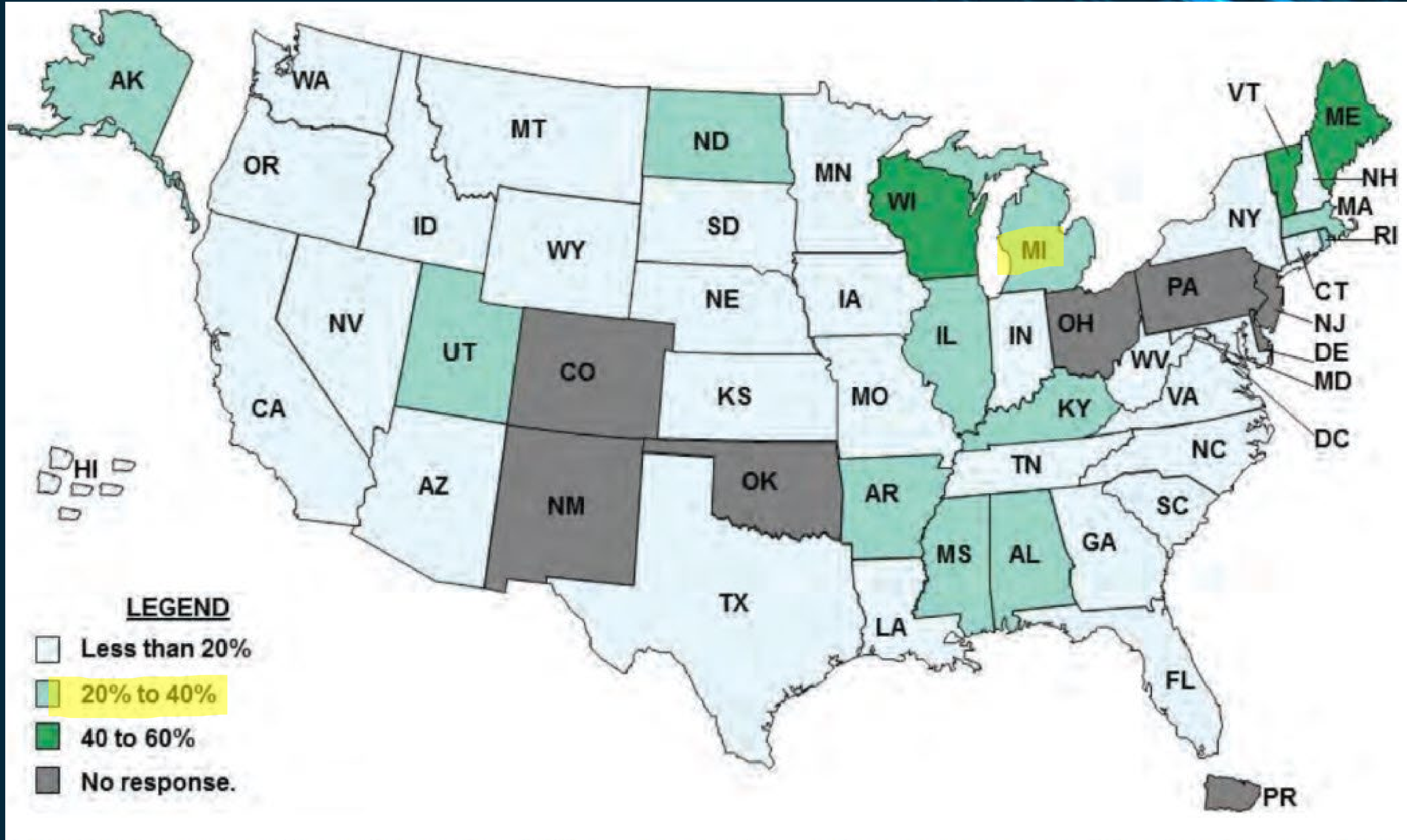

FIGURE 11 Agency *estimate* of proportion of claims, change orders, and cost overruns caused by subsurface conditions.

From NCHRP Synthesis 484

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Questions?

Thank you!!