NORTH AMERICAN SOCIETY FOR TRENCHLESS TECHNOLOGY

UNDERSTANDING GEOLOGIC HISTORY WHEN SELECTING TRENCHLESS METHODS

Session: TM2-T3-03

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NASTT's 2018 No-Dig Show

What does geology tell us?

- What to expect in a trenchless crossing
  - Fundamental understanding of ground behavior
  - How strong is the ground?
  - Need a stable borehole with sufficient strength to prevent inadvertent fluid returns
  - Soil or rock or both? What will be encountered?
  - Select TT approach based on above
- Make link between geology and engineering

Tunnelman's Ground Classification Guide

- "raveling" (slow and fast)
- "squeezing"
- "running"

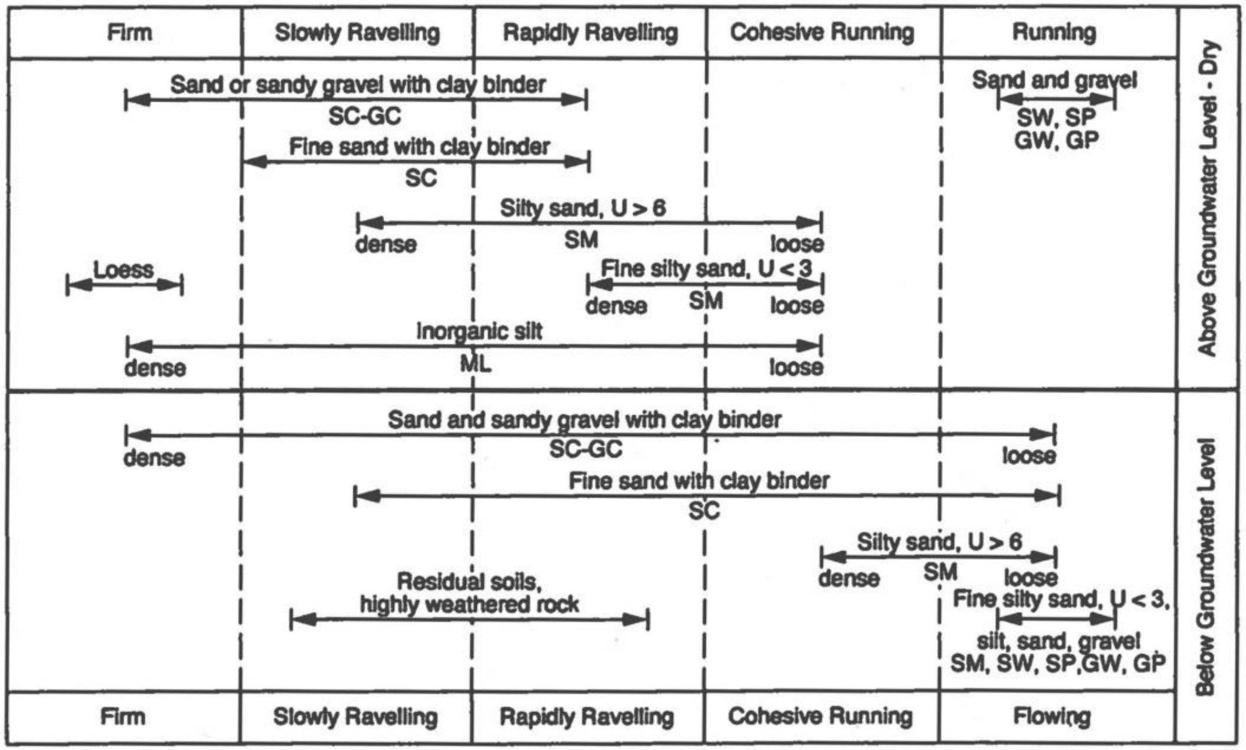
Terms used to describe the ground and emphasize some level of concern.

Tunnel Engineering Handbook (1996)

TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS (after Heuer, 1974)

DESCRIPTION		BEHAVIOR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand, and gravel when not highly overstressed.
Raveling	Slow Raveling Fast Raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table; slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
Squeezing		Ground squeezing or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of raveling at execution surface and squeezing at depth behind surface.
Running	Cohesive Running Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (± 30-35 degrees). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand or weak cementation in any granular soil may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behavior is cohesive-running.
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite clay.

Ground Behavior Trends of Various Soils (Tunnel Engineering Handbook 1996)



NOTES

1. Air loss (in tunnelling under compressed air) and water inflow is governed by the permeability, largely a function of D_{10}.
2. Behavior below groundwater table under suitable air pressure is approximately the same as above groundwater level.
3. Loose is here defined by N < 10 (standard penetration test), dense by N > 30.
4. Descriptive terms of materials according to the Unified Soil Classification.
5. Behavior may be somewhat better than shown above groundwater level, if material is moist and fine or silty.

Trenchless Terms

Trenchless projects can be very close to the land surface. Concerns:

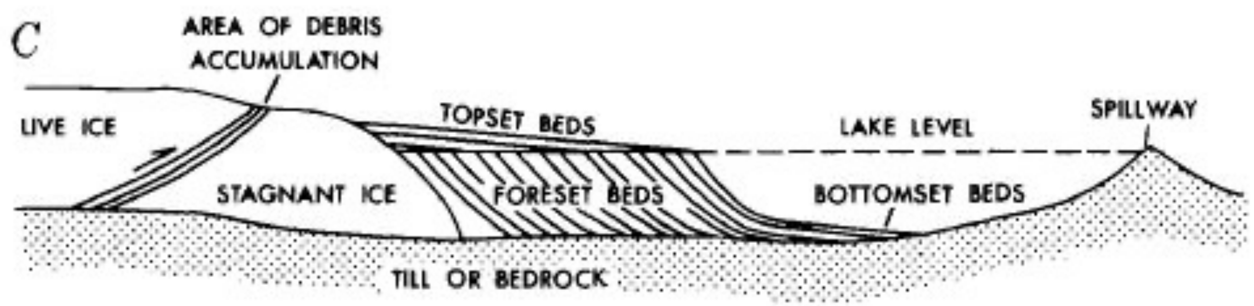
- Weak overburden soils
  - weight-of-hammer (WOH) material, organic material, soft clays, loose silts
- Granular soils with little fines
- Nested cobbles/boulders, obstructions
- Running ground, squeezing/swelling ground that suggest unfavorable ground conditions
- Bedrock (ranges from very hard to decomposed)

Case 1 - Glacial Lakes of New England

- Retreat of the last glacial sheet across New England (estimated from 18,000 to 13,000 years before present)
- Meltwater streams from the decaying glacial ice masses discharged significant volumes of sand and gravel
- Deposits created a temporary debris dam trapping upstream meltwater and forming glacial lake

Case 1 -Glacial Lake Hitchcock

- Granular deposits (glacial lake perimeter topset and foreset beds)
- Fine sediments (silt and clay) as glacial lake bed sediments (bottomsets)
- Lake bed floor, repeating fine sediment layers reflect a seasonal cycle (“varves”) of silt (summer) and clay (winter)
- Mixed-face condition to trenchless construction near lake shoreline
- Anticipate: where is the trenchless crossing in this landscape?



Koteff, 1974

Case 1 – Typical Glacial Lake Delta

Case 1 - Microtunneling in Hartford, CT

- Very soft and deep varved clays with sand interbeds
- Weak overburden led to challenges with MT alignment control
- 48-in. RCP
- Ground improvement at shafts included jet grouting to strengthen soils

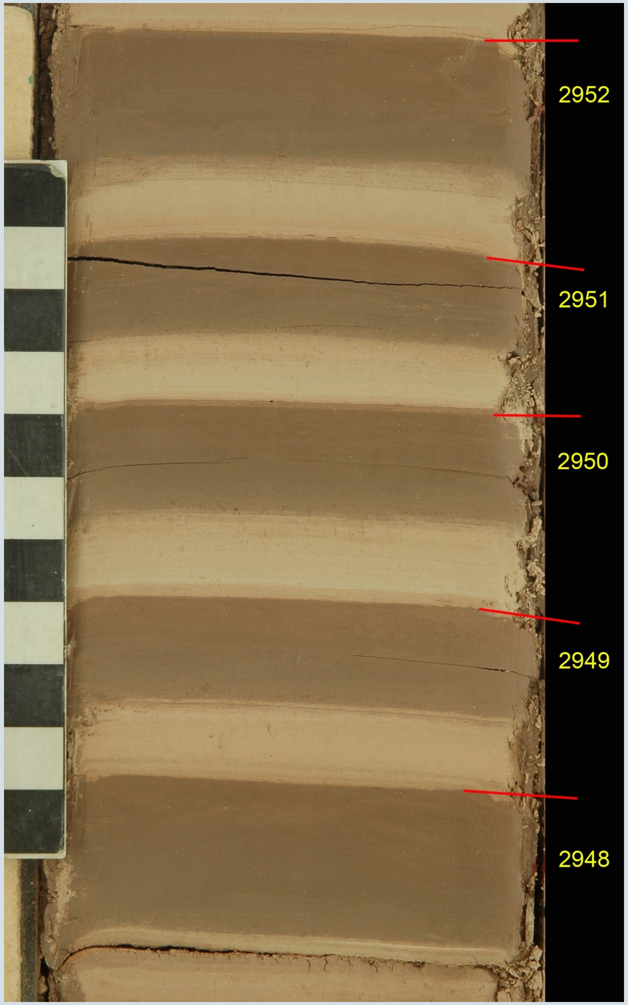
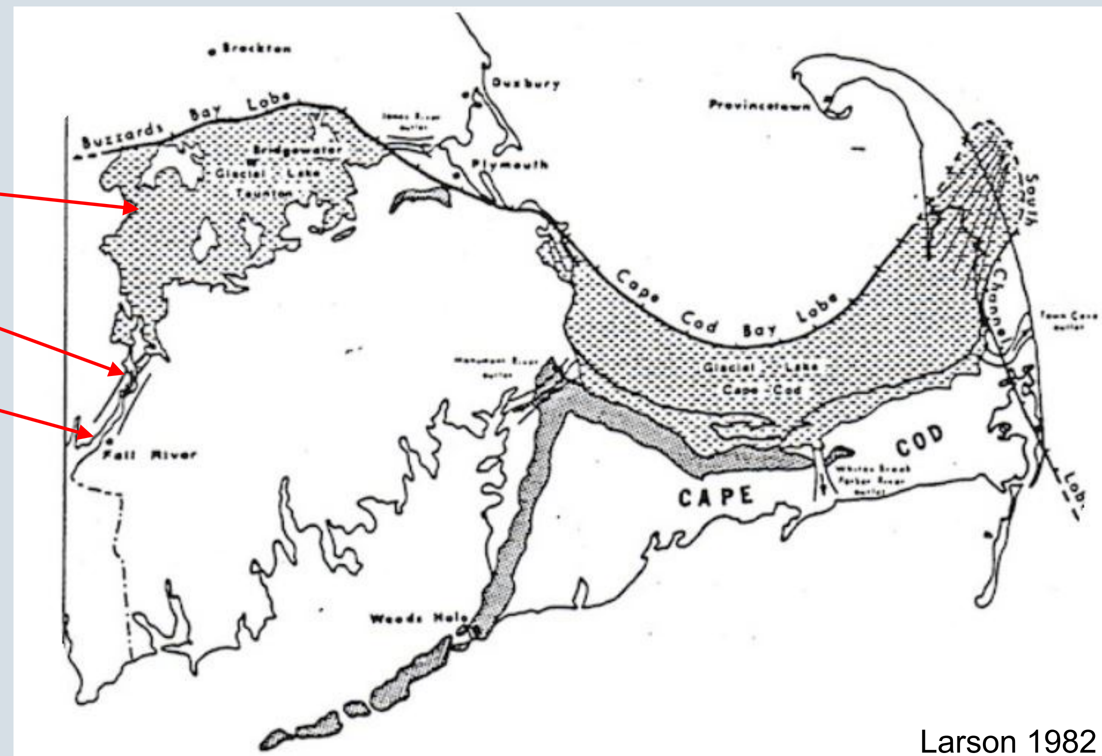


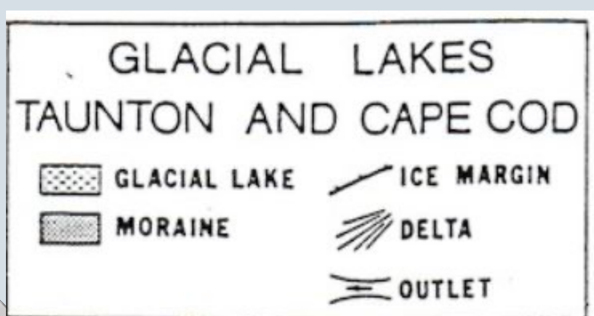
Photo Right: section of subsurface core from Glastonbury, CT, reflecting cyclical varve deposits. Scale bar in cm, time scale calibrated to New England Varve Chronology Project timeline (in varve years).

Case 2 - Taunton River Crossing by HDD

- Overdeepened pre-glacial bedrock valley. Pleistocene sea levels 300 to 700 feet bmsl
- Narragansett Bay was glacial lake with the upstream, dammed Glacial Lake Taunton
- Dam impounding GLT catastrophically breached, rapid discharge of meltwater and sediment down the Taunton River rock valley
- Meltwater carried very coarse debris of gravel, cobbles and boulders in torrents of high-velocity meltwater



Larson 1982



Case 2 - Taunton River Crossing

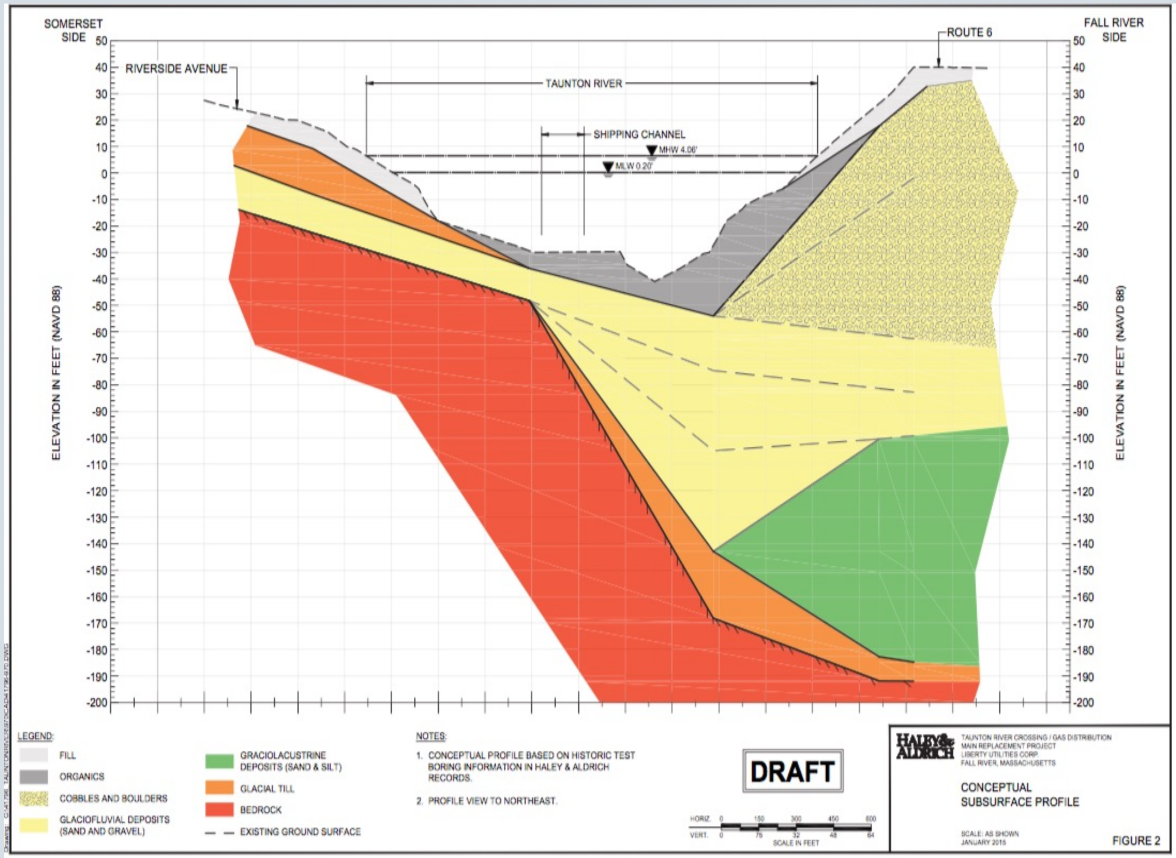
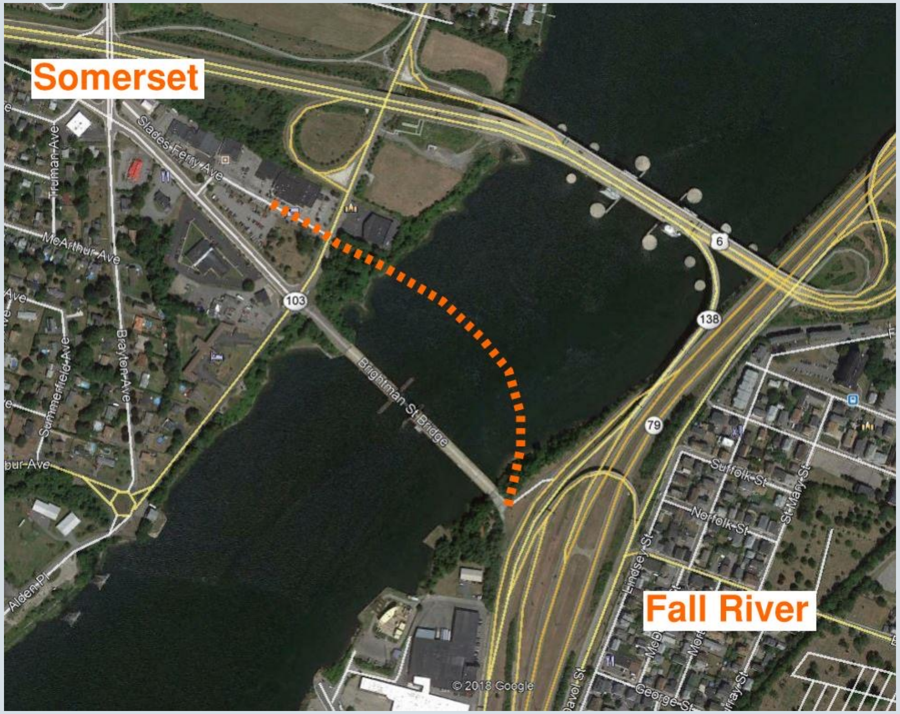


Photo above: Cobbles and boulders encountered during caisson installation, Route 6/Veterans Bridge 2007-2011

Photo Left: Subsurface profile of HDD crossing below Taunton River for new 12-in. gas line

Case 2 – Taunton River Crossing



- 12-in. natural gas pipeline installed successfully in 2016/2017 by HDD
- About 1,950 ft length crossing
- Liberty Utilities reported that borehole had collapsed on Fall River side, due to very coarse granular material
- Enlarged borehole to 36-in. to accommodate 12-in. pipe
- Adopted intersect method
- Two inadvertent fluid returns Fall River side

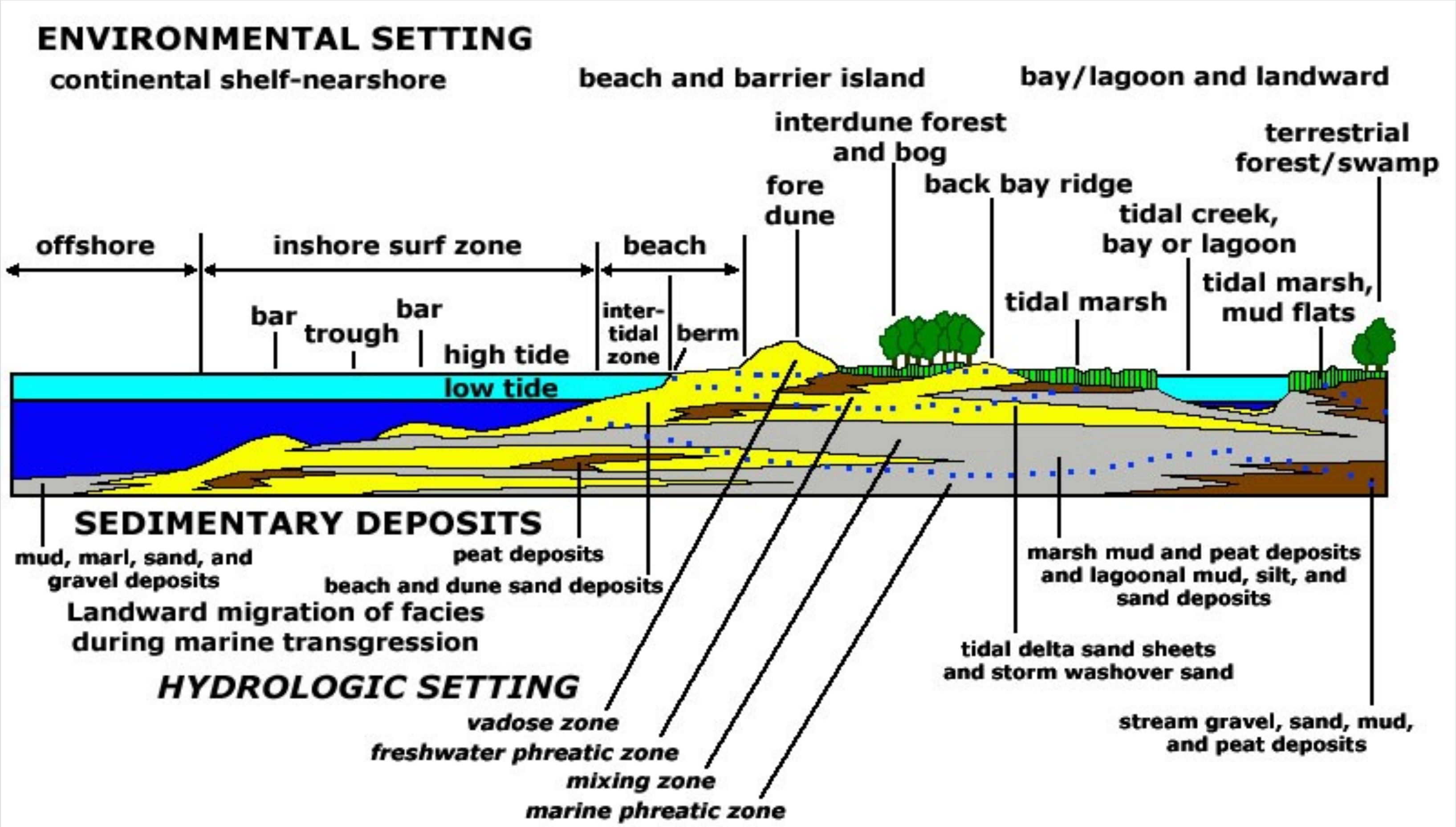
Case 3 – Hamlin Sound/Isle of Palms, SC

- SCG&E 115kV cable under coastal waterway behind barrier islands complex
- Grid reinforcement of overhead lines vulnerable to hurricane damage
- Difficult access in tidal waterways, ecologically-sensitive shellfish/fish breeding grounds, recreational users, Intracoastal Waterway
- 18,000 ft crossing, 8.625-inch OD HPGF pipe, 2 platforms

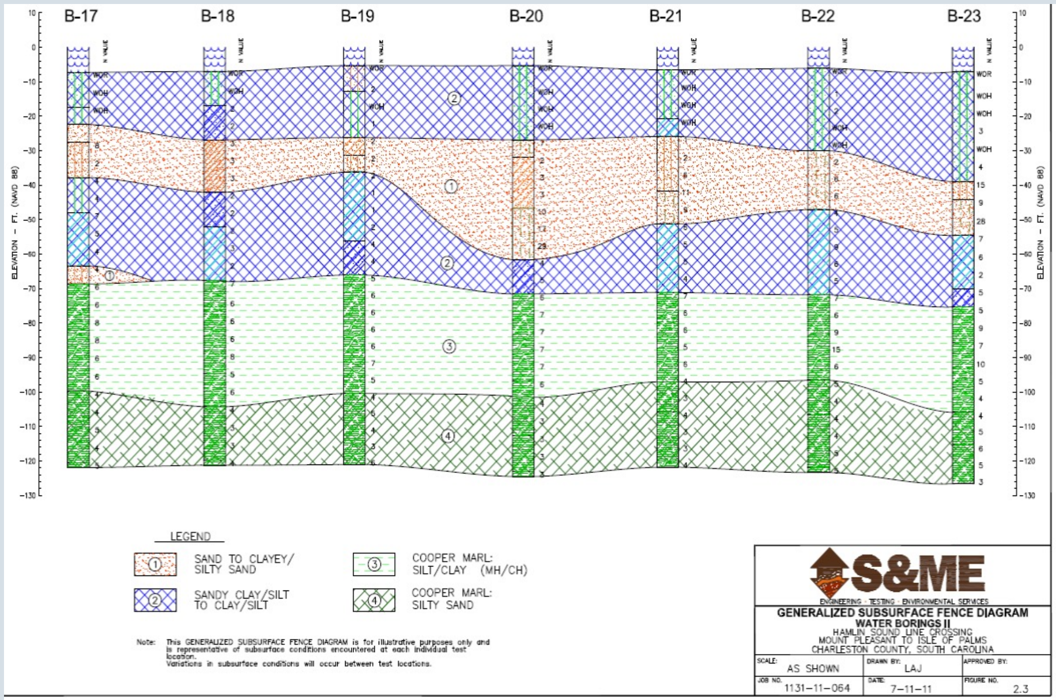
Case 3 – Formation of Barrier Islands

- Coastal Plain Barrier Beaches – needs a supply of sand sufficient to form islands, sea level is rising or generally stable
- Winds and waves move the sand from offshore to onshore
- Submerged sand dunes or barrier island complexes in the sounds, beaches migrate over lagoon deposits, especially during hurricanes

Case 3 - Formation of Barrier Islands



Case 3 – HDD Challenges



- Geotechnical borings indicate a Coastal Plain geology with intermixed layers of clays, silts, peats and sand, overlying Cooper Marl
- High potential for inadvertent fluid returns (frac-outs) due to weight-of-hammer (WOH) organic material, loose sands, brackish sea water and shallow depths below intertidal lagoons

Case 3 – Hamlin Sound HDD Outcomes

- Drills stayed in Cooper Marl when possible (40-100 ft deep)
- 15 to 30 ft of weaker overburden led to challenges with alignment control (steering) in sands
- Restriction on spooled cable length (7,400 ft legs) drove a 3-segment HDD crossing design with two intermediate temporary platforms
- Drill path had to surface in middle of Hamlin Sound with risk of high fluid pressures at end of long drills
- Intercept method with steel conductor casings worked successfully

Above Photo: Mid-sound HDD drill platform with cable splices, pipe connections, overboarding segment lowered into jetted trench in channel, protected with flexible concrete mats.

Publications/References

USGS Publications Warehouse

- https://pubs.er.usgs.gov/

National Geologic Map Database

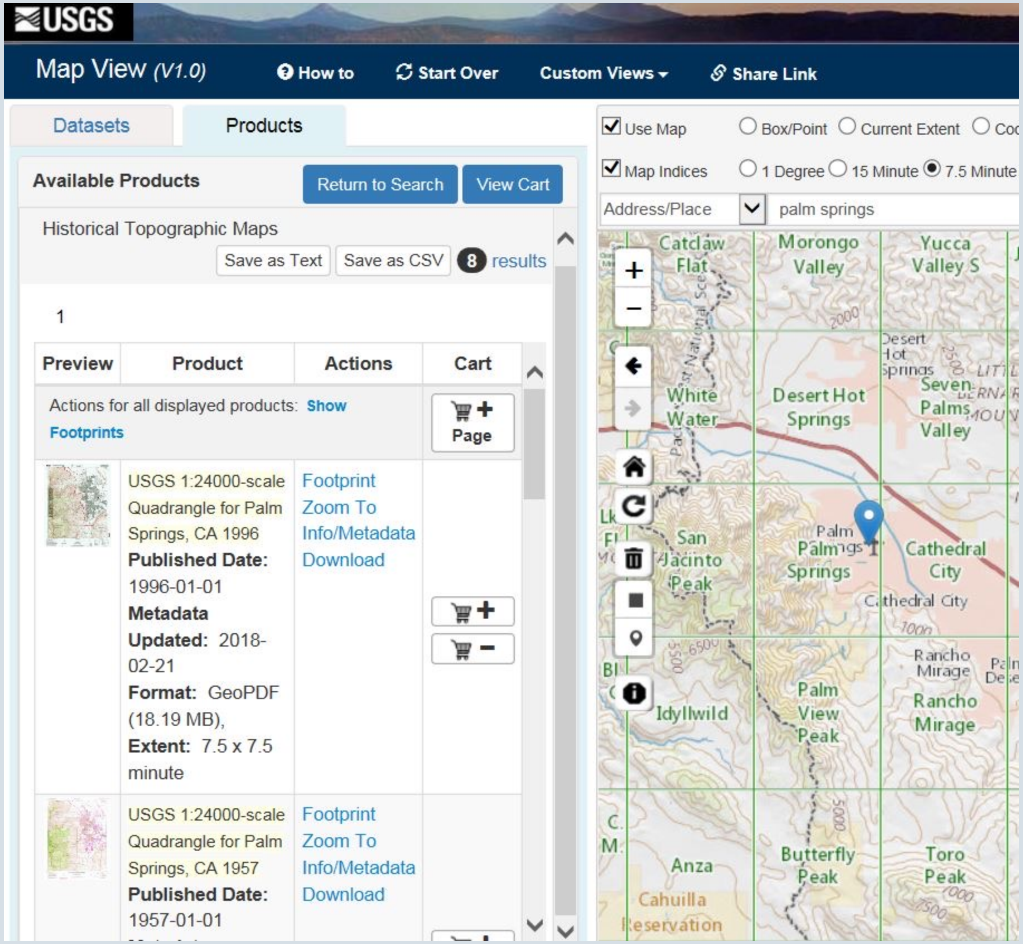
- https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- https://ngmdb.usgs.gov/Geolex/search

Current and Historic Topo Map Locator

- https://viewer.nationalmap.gov/basic

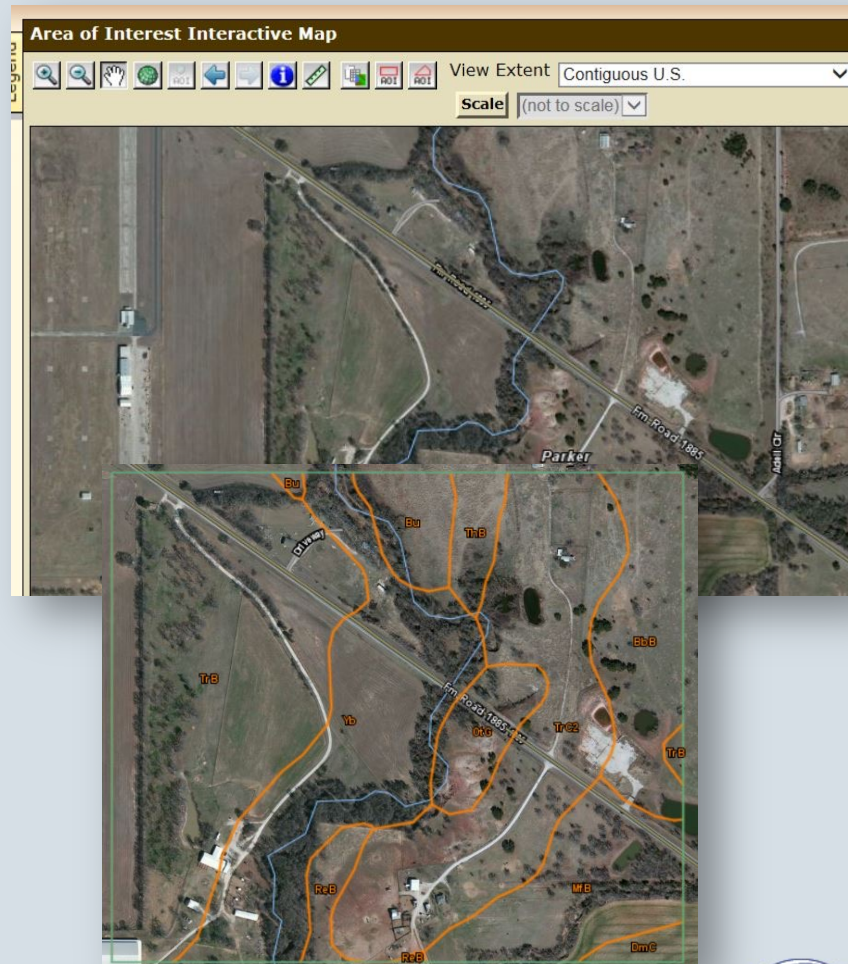
NOAA Bathymetric Charts (old and new):

- www.nauticalchartsonline.com



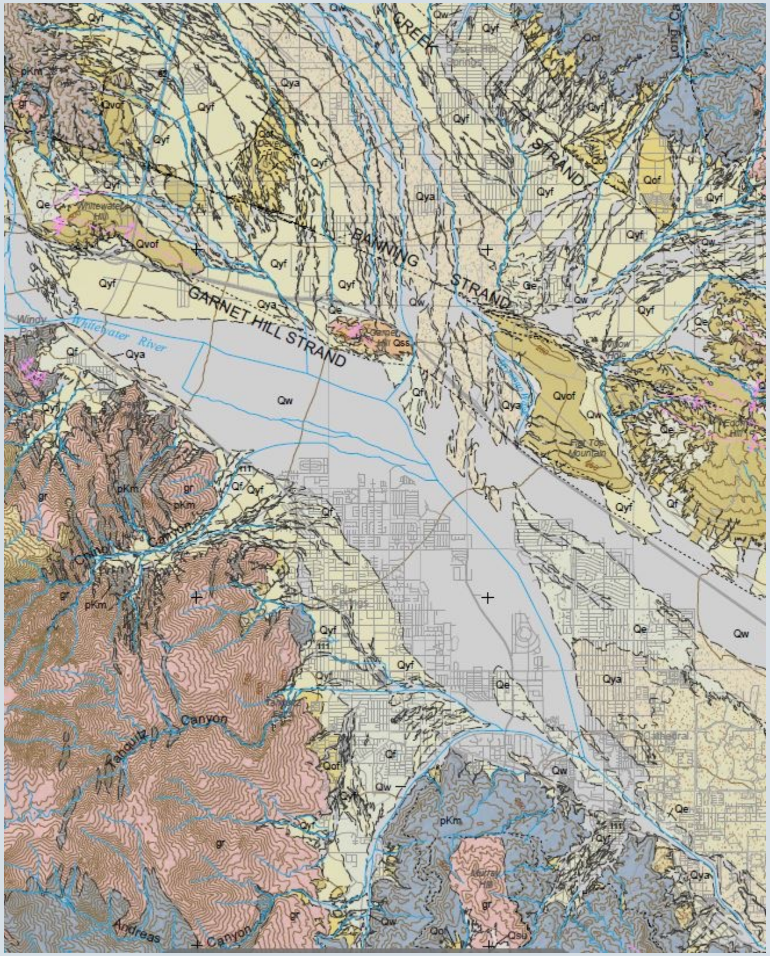
USDA Interactive Web Soil Survey

- Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service
- Mapped by state and county
- Agricultural basis, info on shallow soil. Parent geology and depth to bedrock may be useful
- https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx



State Geological Surveys

- States have different levels of geological surveys and publications available
- Often best source of information
- CGS, CalEPA, Conservation, Dept of Water Resources, mining boards
- Municipal engineering, highway departments (bridges)
- Tip: search by quadrangle name, nearby town, name of geographic feature, or geologic formation



Thank you

- SCG&E
- Geocache.com
- LearnNC.org
- S&ME
- T & D World
- Cornerstone
- Liberty Utilities
- CHA
- USGS
- Power Delivery Consultants
- GeologyCafe.com
- USDA/NRCS
- CGS
- HowStuffWorks.com

HALEY ALDRICH