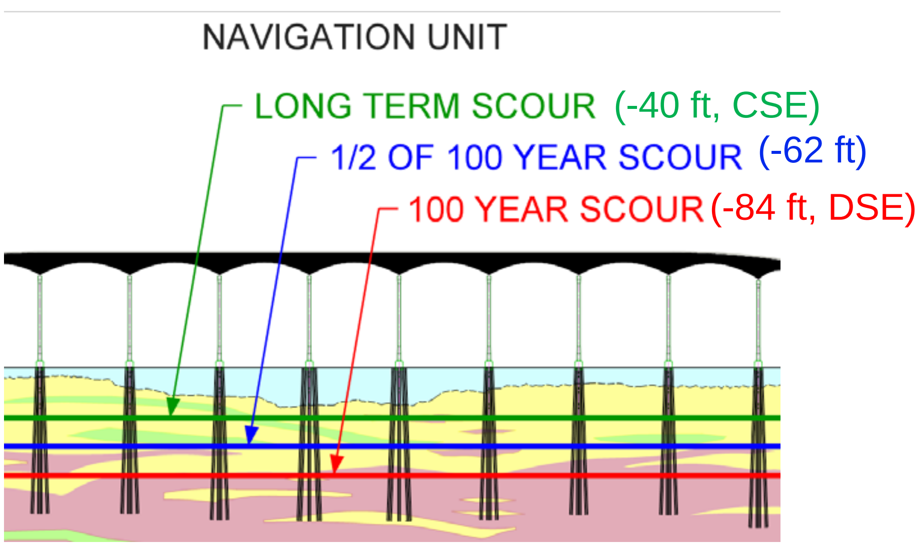
Verify Post-Scour Resistance of Jetted and Driven Pile Foundations

Mike Batten, PE
Beth Howey, LG, PE

April 11, 2017

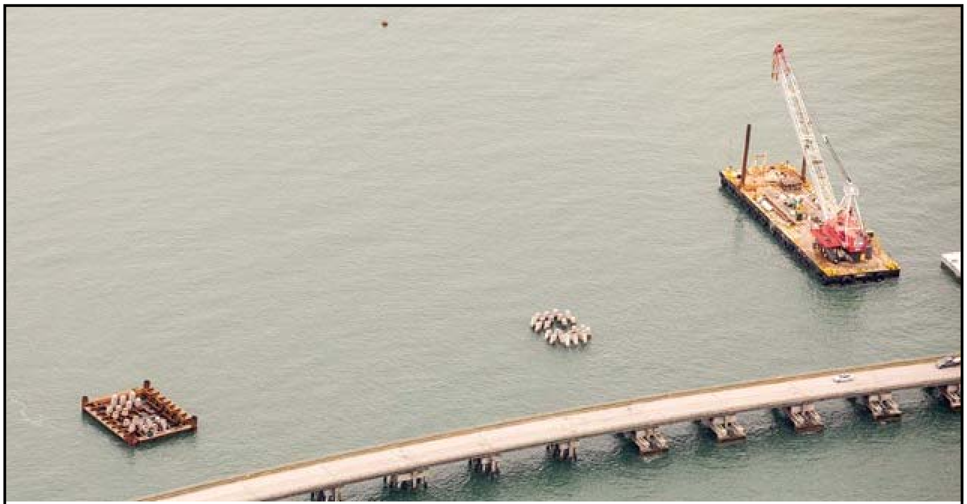
Outer Banks of NC

Existing Bonner Bridge



Subsurface Profile of Navigation Unit

36” Pre-stressed Concrete Piles

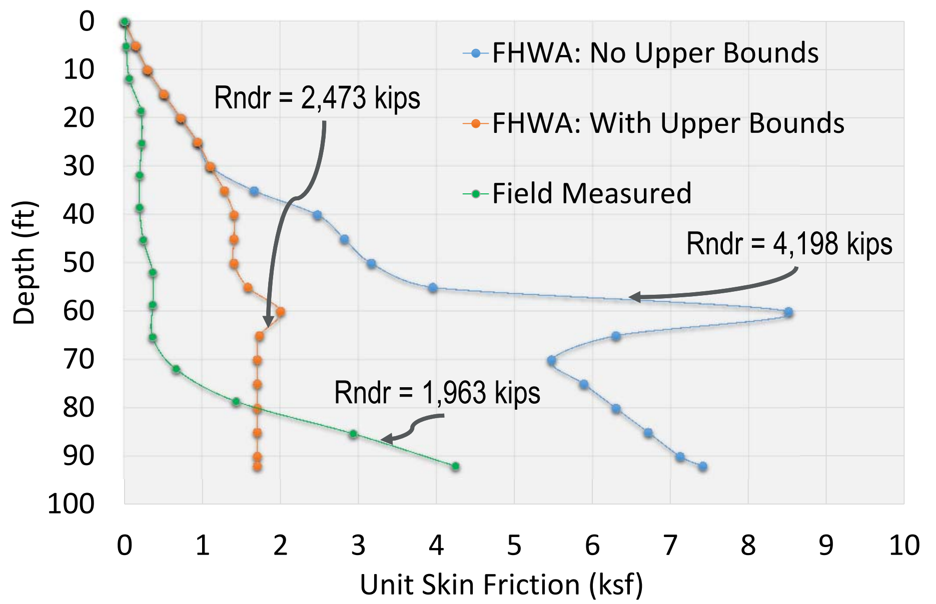


NAVIGATION UNIT PILES

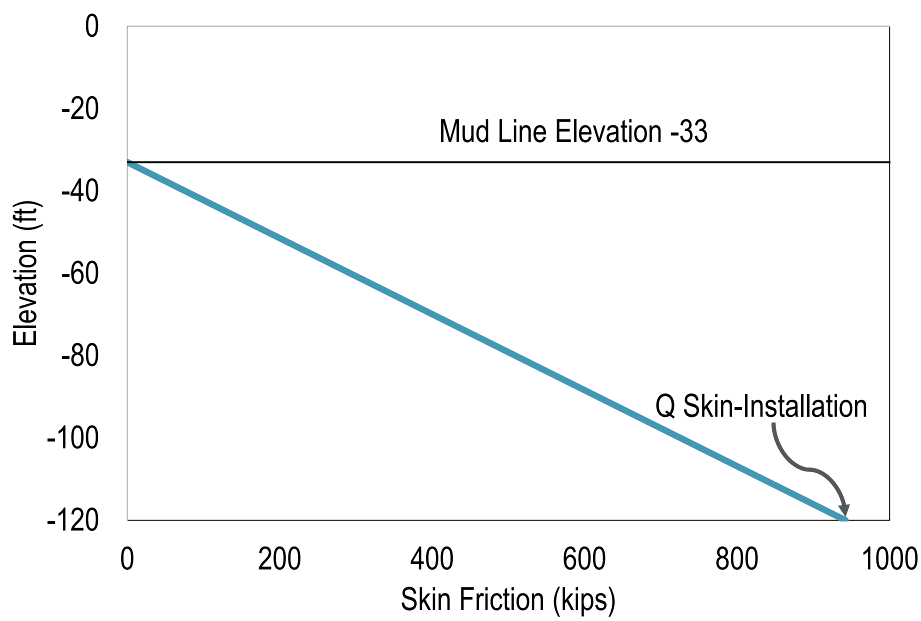
Required Nominal Driving Resistance (R_{ndr})

$$R_{ndr} = \frac{Factored\ Axial\ Load + Factored\ Dead\ Load}{\phi_{resistance}} + \frac{Unfactored\ Scour\ Resistance\ (USR)}{\phi_{scour}}$$

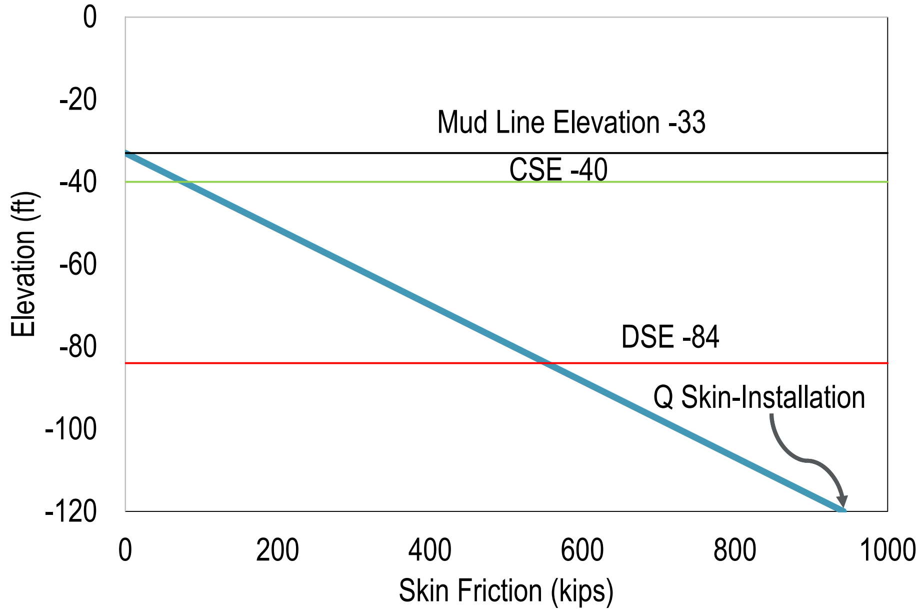
- AASHTO 10.7.3.3 states that scour resistance should not be factored so ϕ_{scour} = 1.0
- $\phi_{resistance}$ should be in accordance with AASHTO or NCDOT policy



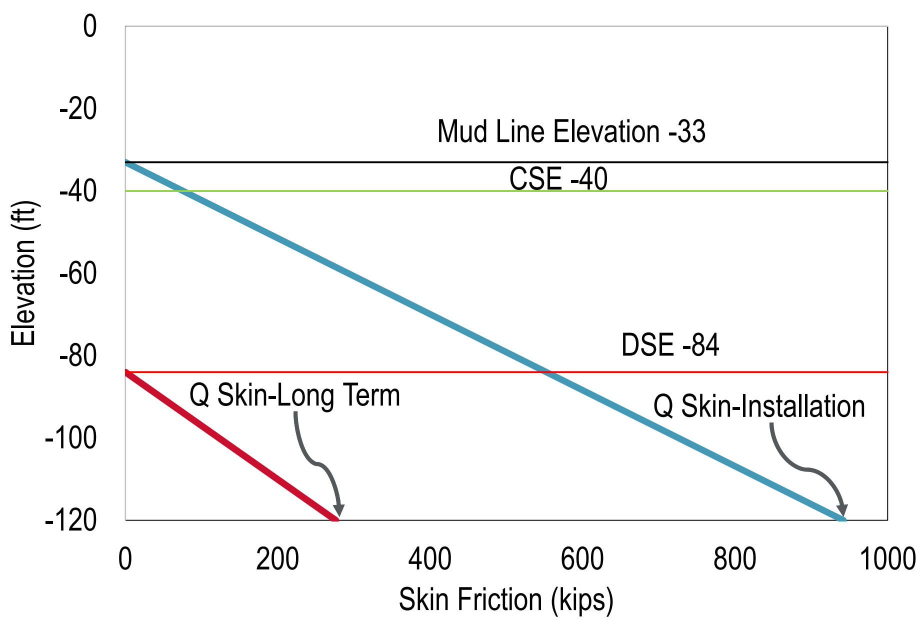
Theoretical and Measured Skin Friction



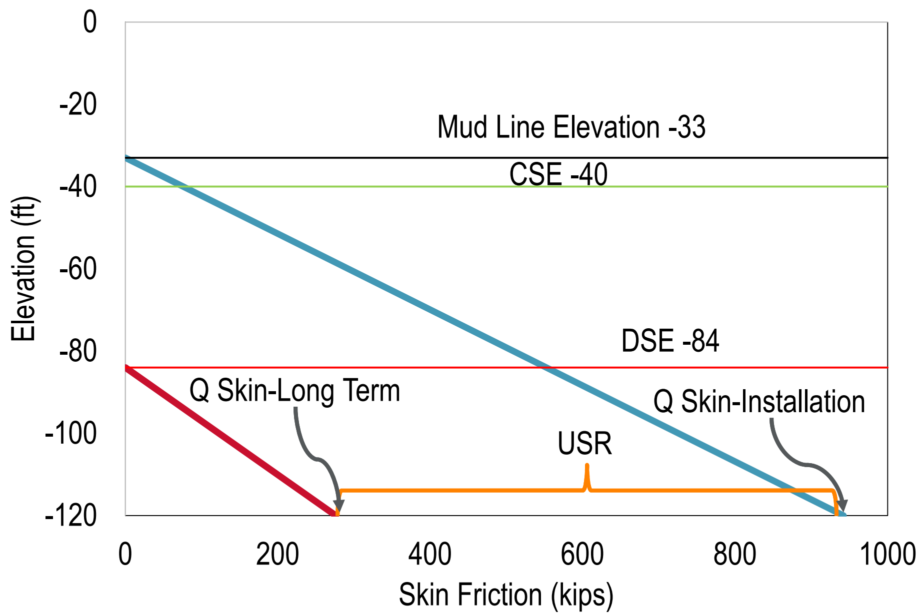
Overview of R_{ndr} Calculation Including Scour



Overview of R_{ndr} Calculation Including Scour



Overview of R_{ndr} Calculation Including Scour



Overview of R_{ndr} Calculation Including Scour

$$f_s = \beta \times \sigma'_v$$

Where:

Fs = Unit skin friction

β = Bjerrum Burland beta coefficient = $K_s \tan\delta$

σ'_v = Average effective stress along the pile shaft

K_s = Earth stress coefficient

δ = Interface friction angle between pile and soil

Effective Stress Method to Determine Beta

Reference NHI Course Nos. 132021 and 132022 Design and Construction of Driven Pile Foundations

Characteristics of Beta

- β is primarily a function of:
  - Relative density of soil
  - Pile soil/interface material
- β increases with densification from driving in pile groups
- β is NOT a function of effective or total stress!

Table 9-6 Approximate Range of Beta Coefficients (Fellenius, 1991)

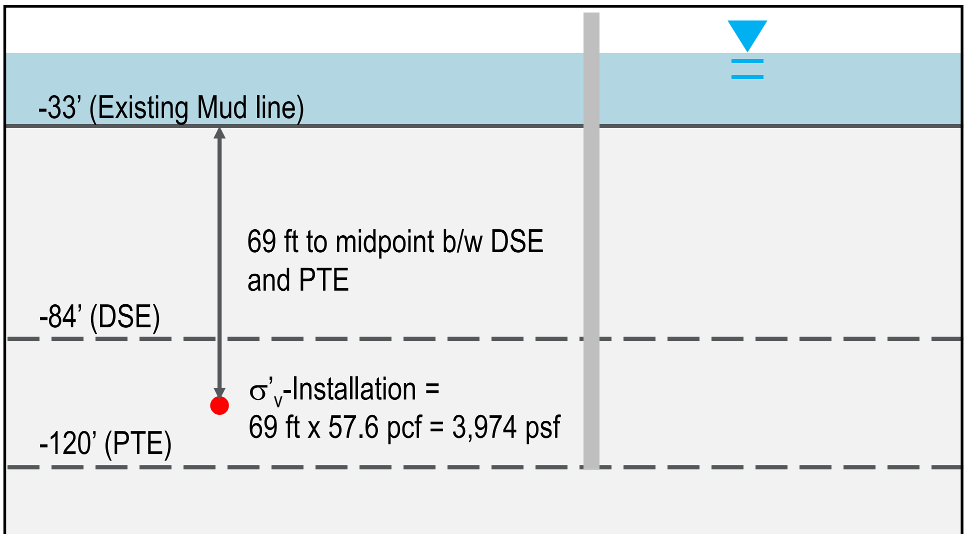
Soil Type	φ’	β
Clay	25 – 30	0.23 – 0.40
Silt	28 – 34	0.27 – 0.50
Sand	32 – 40	0.30 – 0.60
Gravel	35 – 45	0.35 – 0.80

Range of Beta Coefficients

Reference NHI Course Nos. 132021 and 132022 Design and Construction of Driven Pile Foundations

Method to Determine Beta

- Calculate effective overburden stress at the midpoint of installed pile between the Design Scour Elevation (DSE) and the Pile Tip Elevation (PTE) using ground surface at the time of pile installation.
- From CAPWAP data, determine the average measured unit skin friction for this zone.
- $q_s = \beta \times \sigma'_v \rightarrow q_{skin\text{-}installation} = \beta \times \sigma'_{v\text{-}installation}$



Effective Stress at Time of Installation

BENT 22; Pile: P-10 Test: 29-Aug-2016 11:31:
36 IN PSC; Blow: 798 CAPWAP(R) 2006-3
GRL Engineers, Inc. OP: HTW

CAPWAP SUMMARY RESULTS

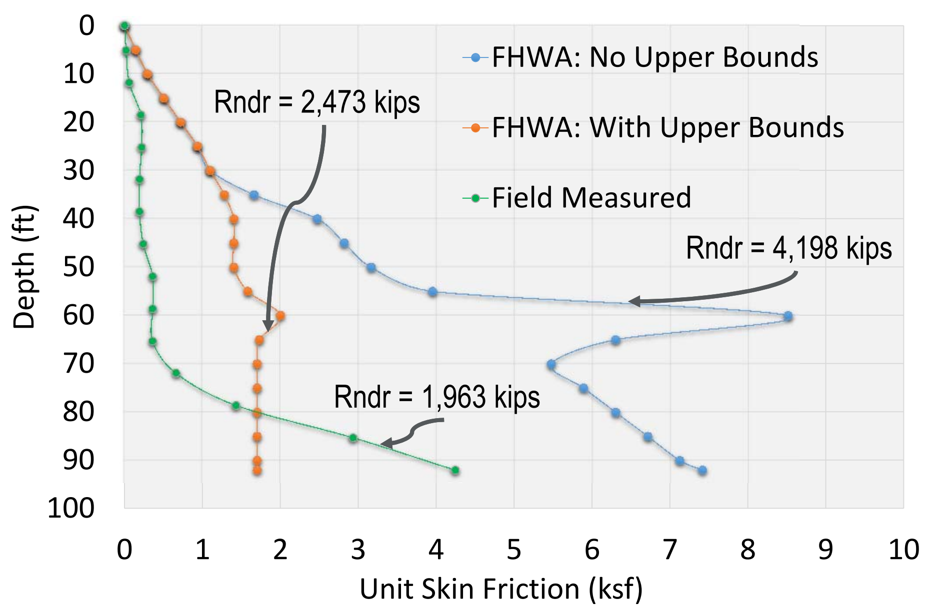
Total CAPWAP Capacity: 2399.9; along Shaft 920.0; at Toe 1479.9 kips

Soil Sgmnt No.	Dist. Below Gages ft	Depth Below Grade ft	Ru kips	Force in Pile kips	Sum of Ru kips	Unit Resist. (Depth) kips/ft	Unit Resist. (Area) ksf	Smith Damping Factor s/ft
				2399.9				
1	40.1	5.1	1.0	2398.9	1.0	0.20	0.02	0.153
2	46.8	11.8	5.0	2393.9	6.0	0.75	0.06	0.153
3	53.5	18.5	17.0	2376.9	23.0	2.54	0.21	0.153
4	60.2	25.2	18.0	2358.9	41.0	2.69	0.22	0.153
5	66.8	31.8	15.0	2343.9	56.0	2.24	0.19	0.153
6	73.5	38.5	15.0	2328.9	71.0	2.24	0.19	0.153
7	80.2	45.2	19.0	2309.9	90.0	2.84	0.24	0.153
~ DSE 8	86.9	51.9	29.0	2280.9	119.0	4.34	0.36	0.153
9	93.6	58.6	29.0	2251.9	148.0	4.34	0.36	0.153
10	100.3	65.3	29.0	2222.9	177.0	4.34	0.36	0.153
11	106.9	71.9	53.0	2169.9	230.0	7.93	0.66	0.153
12	113.6	78.6	115.0	2054.9	345.0	17.20	1.43	0.153
13	120.3	85.3	235.0	1819.9	580.0	35.16	2.93	0.153
14	127.0	92.0	340.0	1479.9	920.0	50.87	4.24	0.153
Avg. Shaft			65.7			10.00	0.83	0.153
Toe			1479.9				164.43	0.106

Use Measured Skin Resistance Below DSE to Calculate Beta

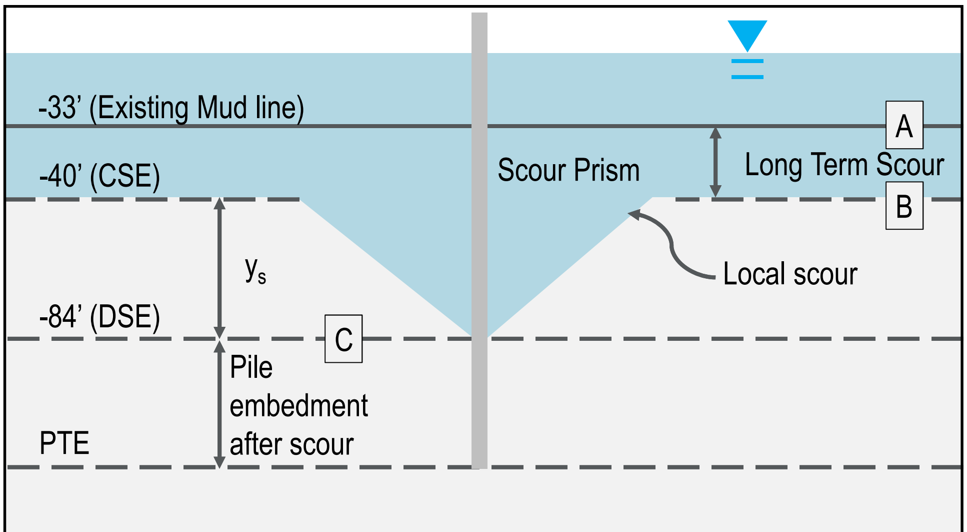
CAPWAP Output

For this Pile, calculated Beta was 0.394



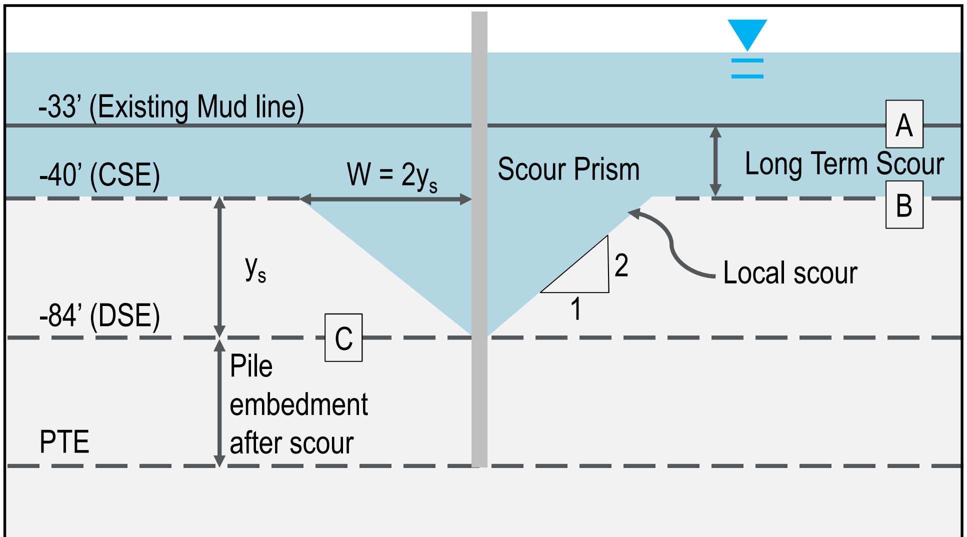
Theoretical and Measured Skin Friction

JETTING 36" SQUARE PILE



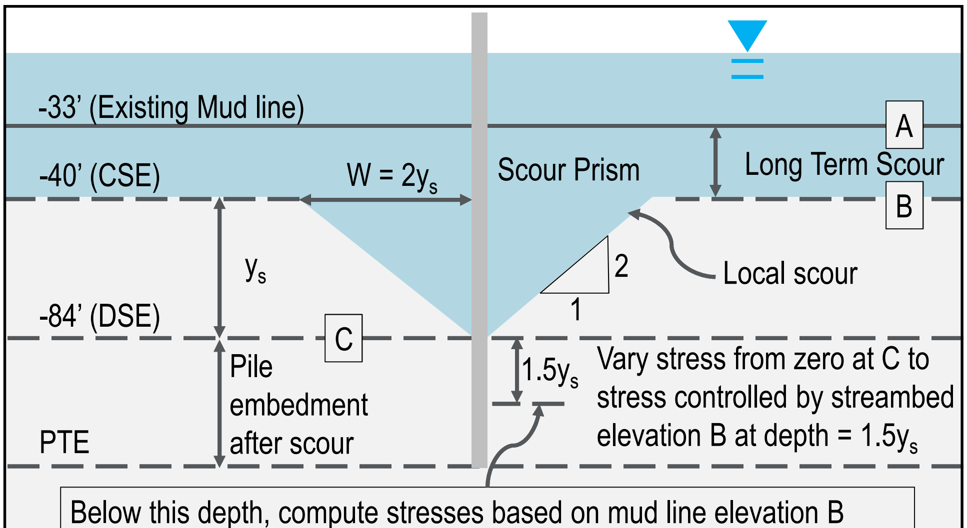
Modeled Long Term Scour using FHWA Drilled Shaft Methodology

Reference NHI Course No. 132014 Drilled Shafts: Construction Procedures and LRFD Design Methods



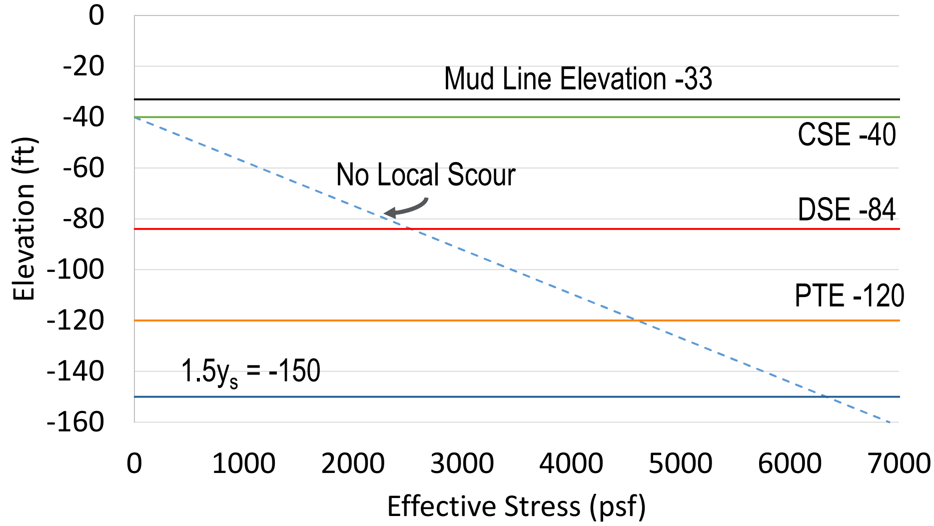
Modeled Long Term Scour using FHWA Drilled Shaft Methodology

Reference NHI Course No. 132014 Drilled Shafts: Construction Procedures and LRFD Design Methods



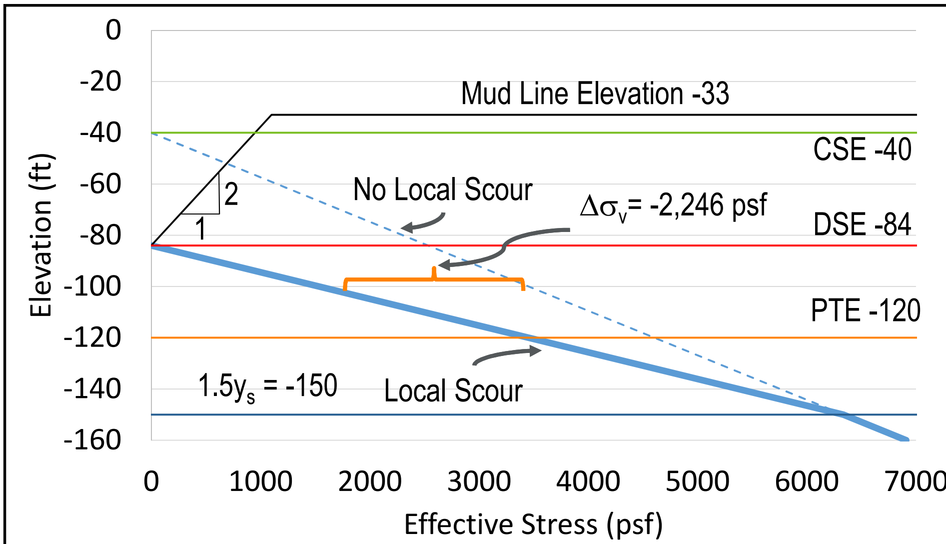
Modeled Long Term Scour using FHWA Drilled Shaft Methodology

Reference NHI Course No. 132014 Drilled Shafts: Construction Procedures and LRFD Design Methods



Modeled Long Term Scour using FHWA Drilled Shaft Methodology

Reference NHI Course No. 132014 Drilled Shafts: Construction Procedures and LRFD Design Methods



Modeled Long Term Scour using FHWA Drilled Shaft Methodology

Reference NHI Course No. 132014 Drilled Shafts: Construction Procedures and LRFD Design Methods

Calculate Long Term Skin Resistance

- Calculate the effective overburden stress after scour with procedure on previous slide with 2:1 scour hole from CSE to DSE.

- Using β calculated during installation, calculate long term skin friction.

- $q_s = \beta \times \sigma'_v \rightarrow q_{skin\text{-}long\ term} = \beta \times \sigma'_{v\text{-}scour}$

- β is CONSTANT – it does not change after the scour event, only effective stress changes.

Calculate Unfactored Scour Resistance

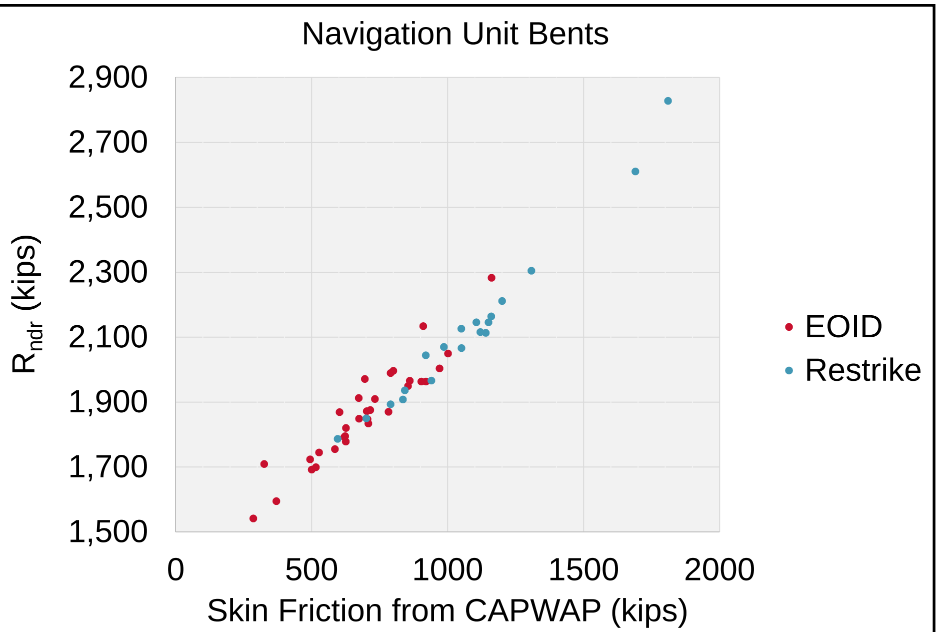
- Unfactored Scour Resistance (USR) is the difference between long term post-scour skin friction and measured skin friction during pile installation.

- $USR = Q_{skin\text{-}installation} - q_{skin\text{-}long\ term} \times A$

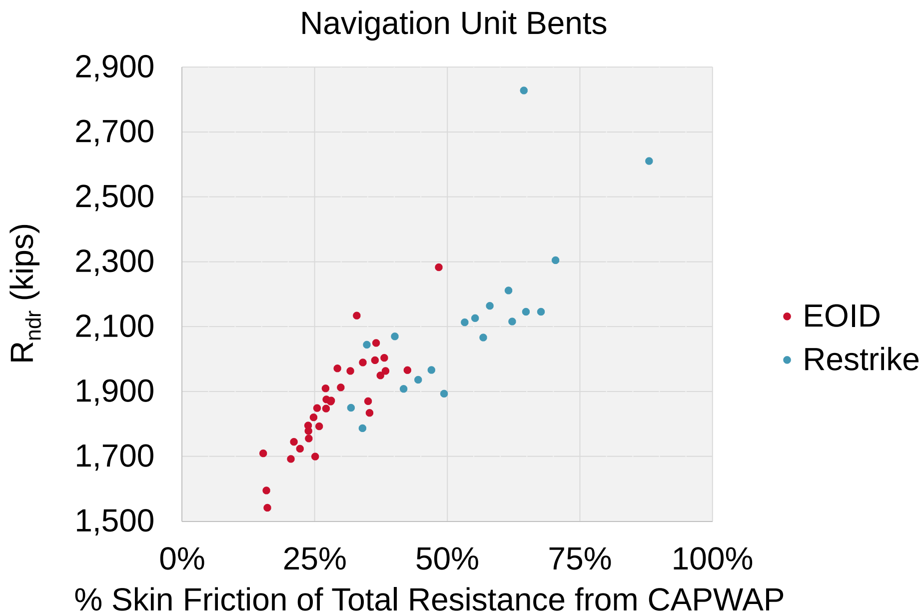
Where:

$q_{skin\text{-}long\ term}$ = Unit skin friction after scour event
A = Surface area of pile between DSE and PTE
$Q_{skin\text{-}installation}$ = Skin friction resistance from CAPWAP

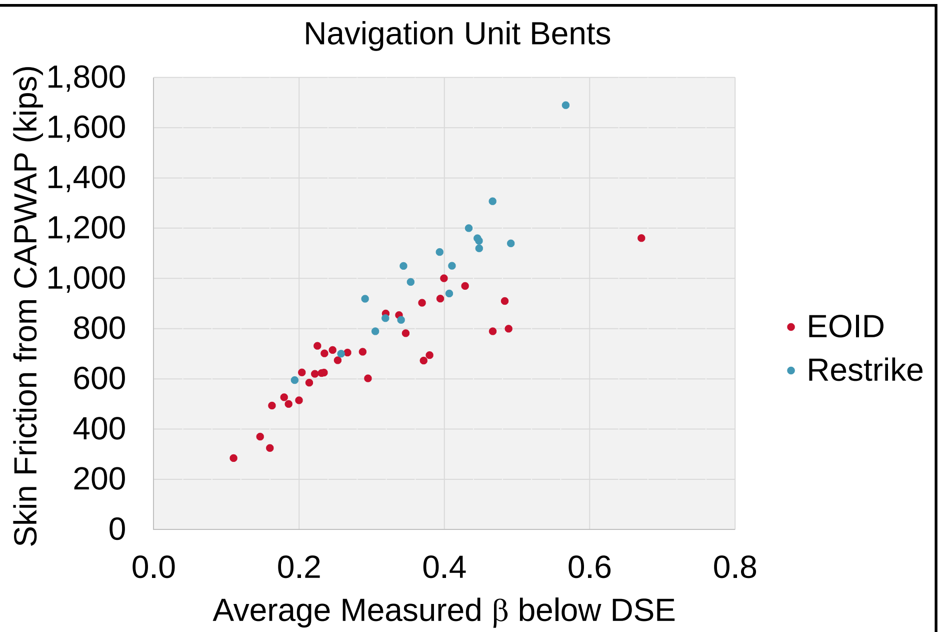
DRIVING 36” SQUARE PILE



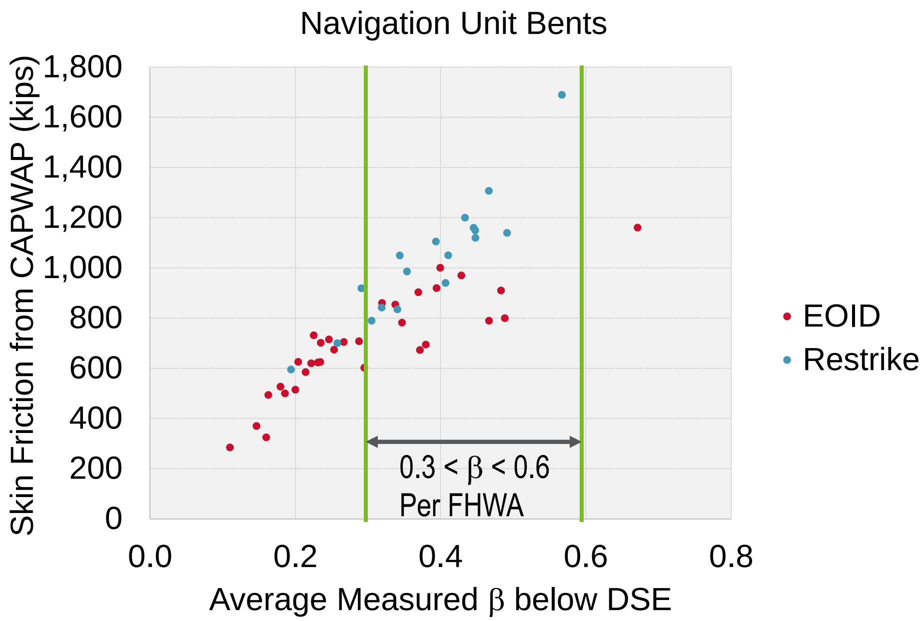
R_{ndr} and Measured Skin Friction



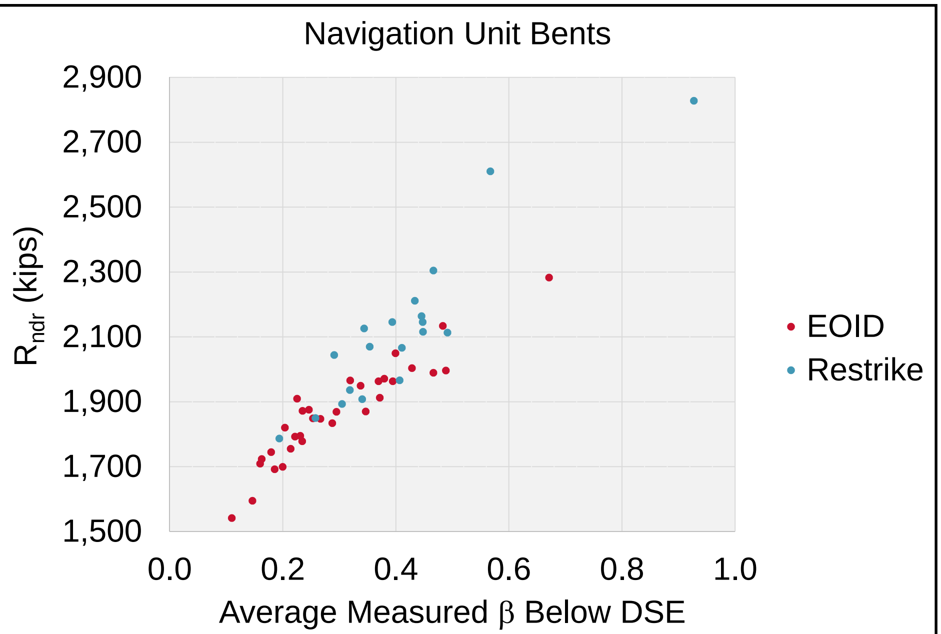
R_{ndr} and Measured % Skin Friction



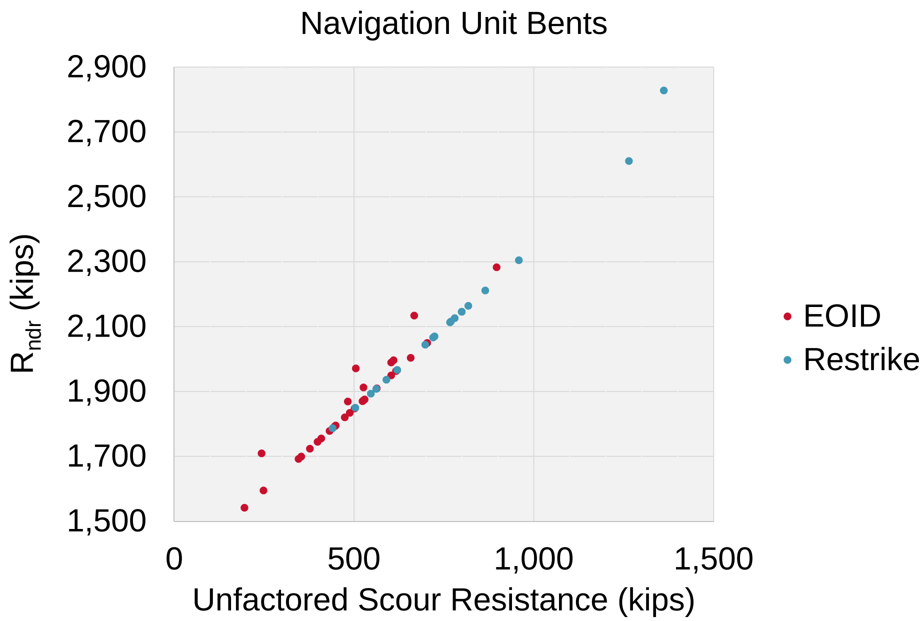
Measured Skin Friction and β



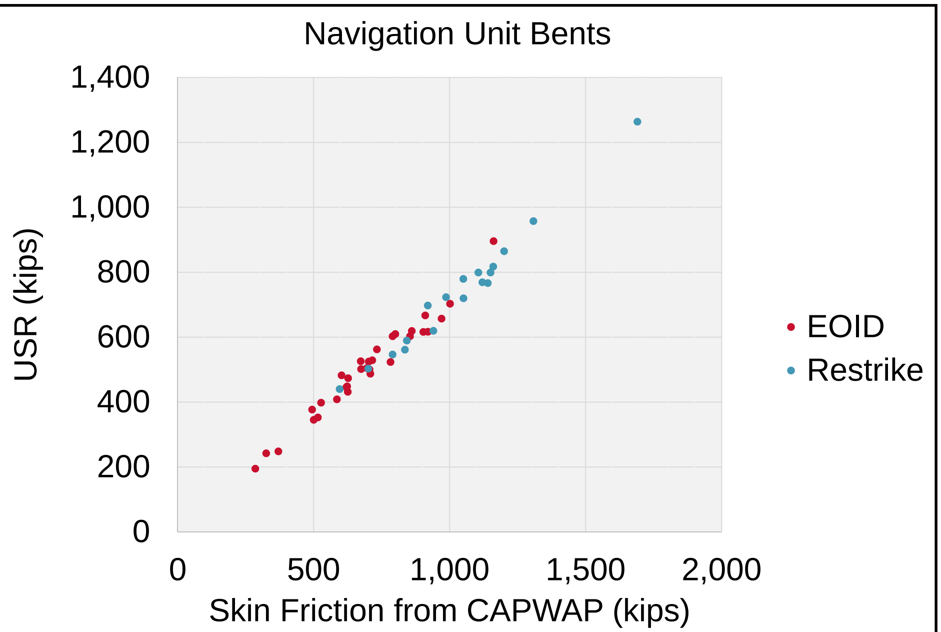
Measured Skin Friction and β



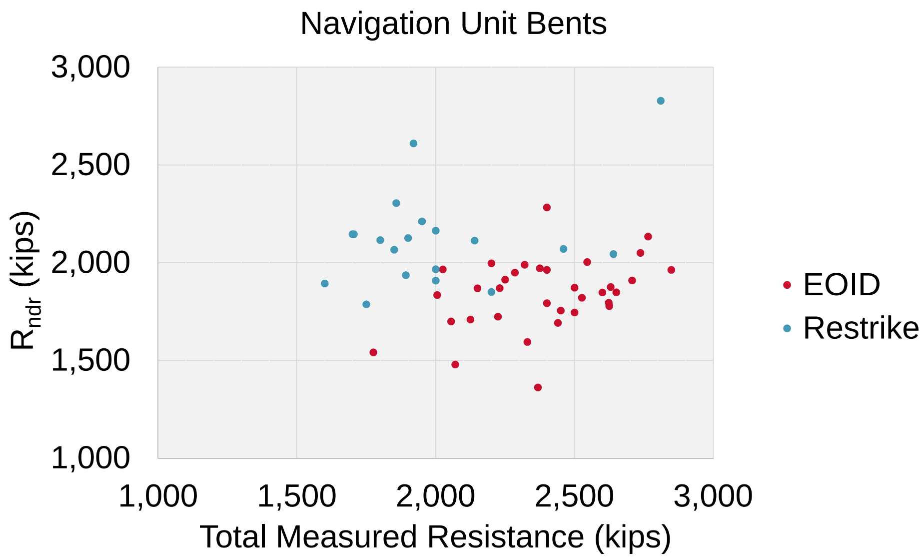
R_{ndr} and β



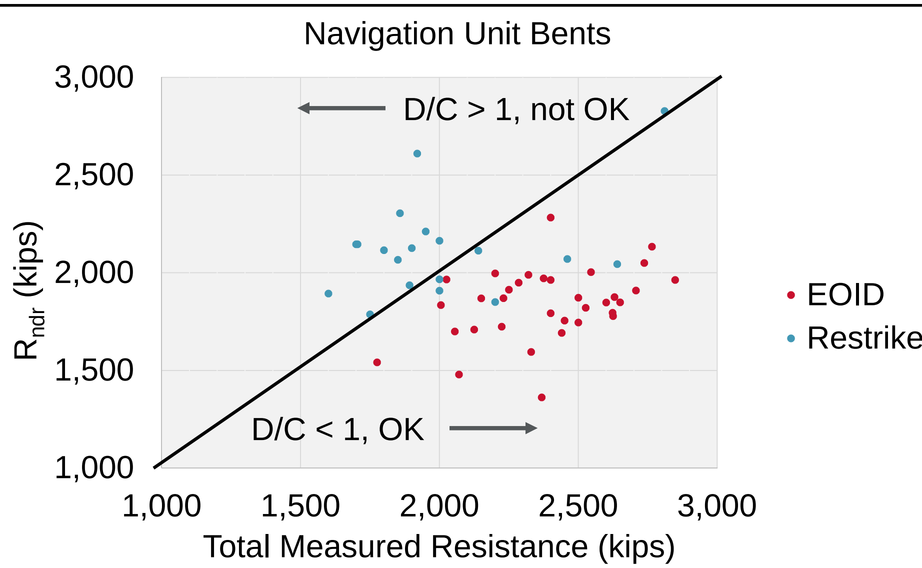
R_{ndr} and USR



USR and Measured Skin Friction



R_{ndr} and Total Measured Resistance



R_{ndr} and Total Measured Resistance


QUESTIONS?
HDR