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***In situ* Ground Investigation Techniques for Soft Soils – new Perth Stadium site**





Plan of talk

- Soft Soil – Swan River Alluvium
- Investigation approach for new Perth Stadium site

- *In situ* CPT testing
 - Methods
 - Results
 - Comparison with other available data

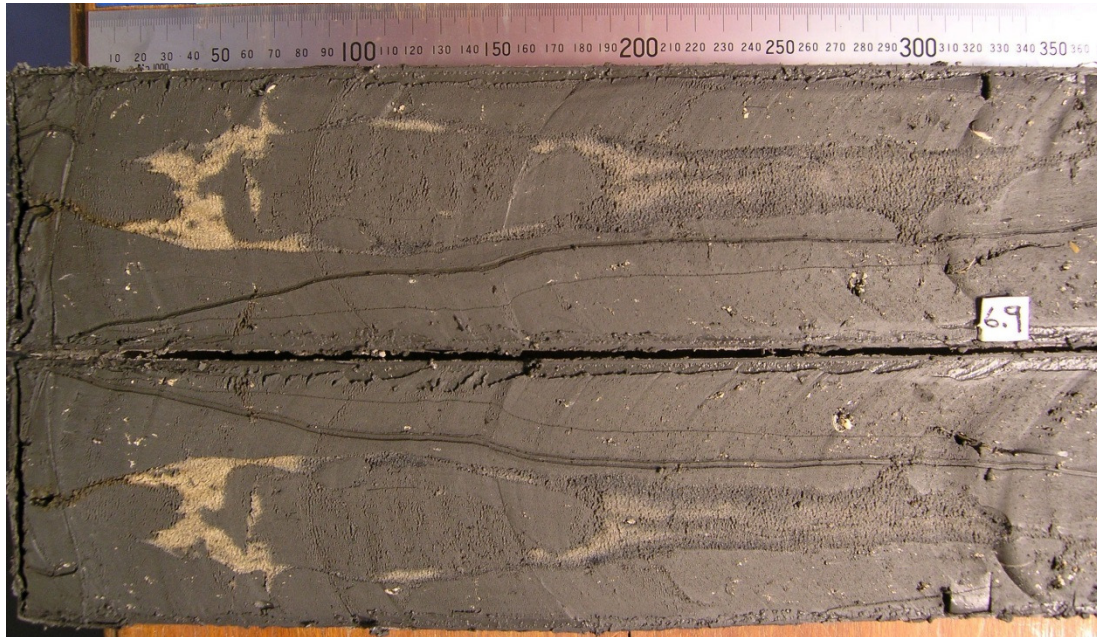
- Use of test results to sub-divide SRA

- Conclusions/Observations



Soft Soil - Swan River Alluvium (SRA)

- Deposited within the current Swan River channel from approximately 30,000 years ago to present day
- Typically a very soft to firm silty clay or clayey silt of high plasticity
- Sand, shells, shell fragments and organics are present as trace elements and as dominant interbeds within a silt or clay matrix





Scope of investigation

General scope

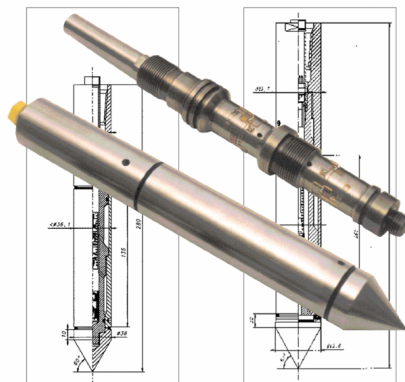
- Extensive review of data from other sites
- Drilling and recovery of undisturbed samples
 - 63 mm diameter push tubes and piston samples
- Laboratory testing
 - Classification Testing
 - Single Stage Consolidated Undrained Triaxial Tests
 - Incremental Load Oedometer Tests
- CPTu probing
- Dissipation testing

- **Detailed Testing Location**
 - **Cluster of tests at one location for comparative purposes**



In situ testing techniques used at location CPT999

- CPT_u – 100 MPa piezocone
- CPT_u – 10 MPa piezocone (higher resolution cone)
- Ball penetrometer
- Flat Plate Dilatometer
- Vane Shear Tests
- Seismic piezocone
- T-bar penetrometer (UWA site)





Comparison of data

Strength

- Standard cone/sensitive cone and ball penetrometer

$$q_t = q_c + (1 - a)u_2$$

$$s_u = \left(\frac{q_t - \sigma_{vo}}{N_{kt}} \right)$$

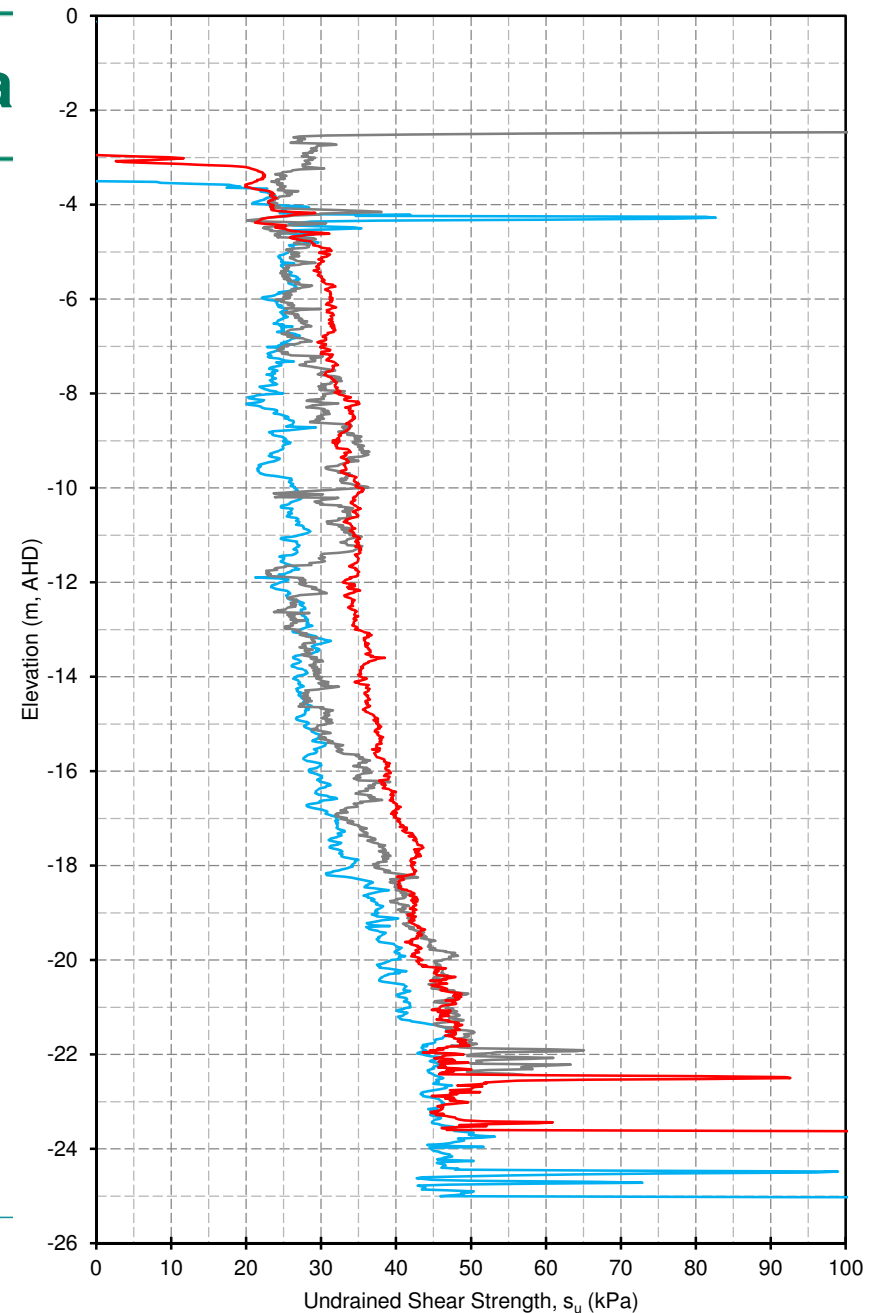
$$q_{net} = q_m - [\sigma_{vo} - u_o(1 - a)] \frac{A_s}{A_p}$$

$$s_u = \frac{q_{net}}{N_{ball}}$$

$$N_{kt} = 12, \quad N_{ball} = 11$$

N_{kt} checked against vane shear tests

N_{ball} after Low et al, 2011



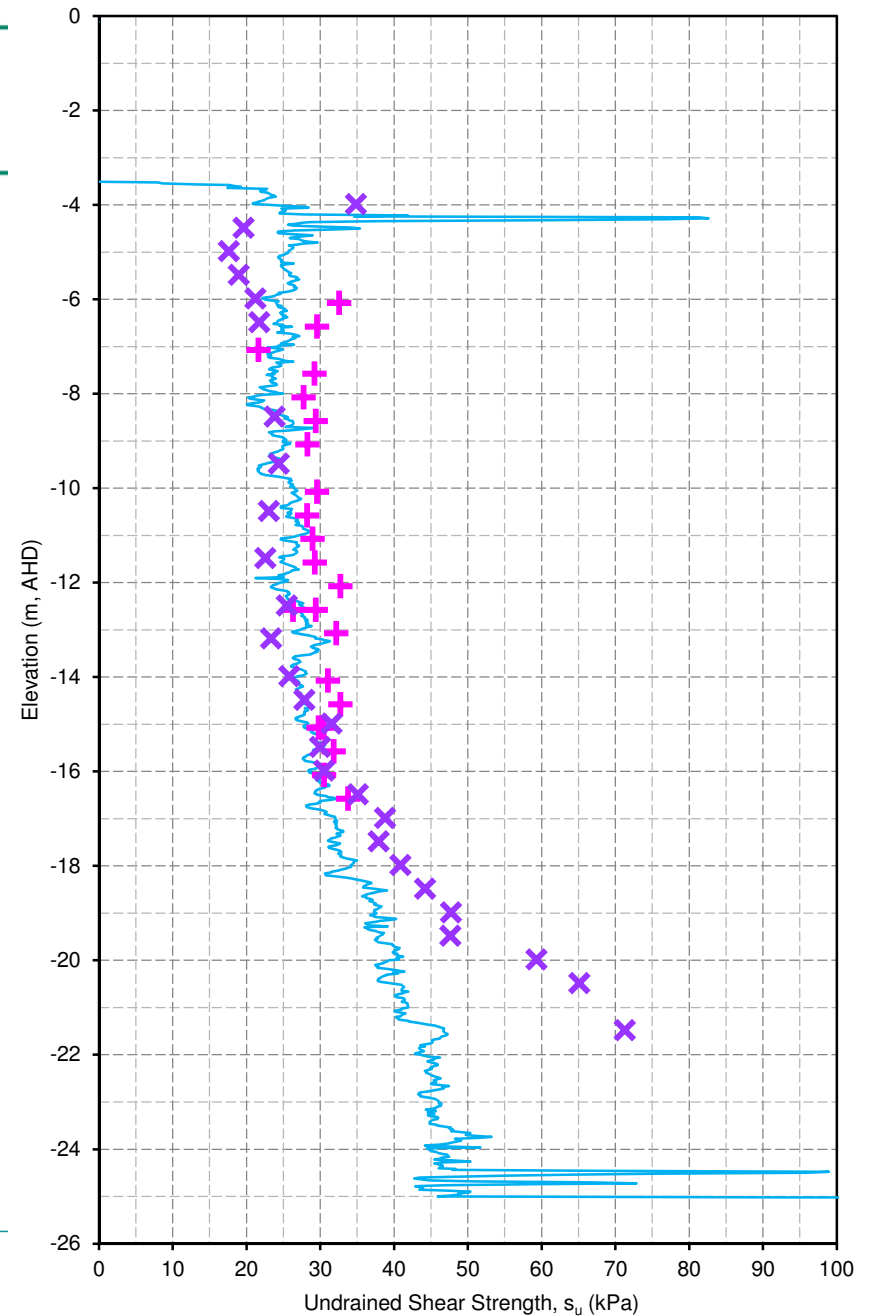
— CPT999-7-CPTsens — CPT152 Z — CPT999-2 -BPT



Comparison of data

Strength

- 10 MPa penetrometer + vane shear test results + DMT strengths
- Good correlation between cone and vane shear
- Sand lenses affecting deeper vane shear test results?

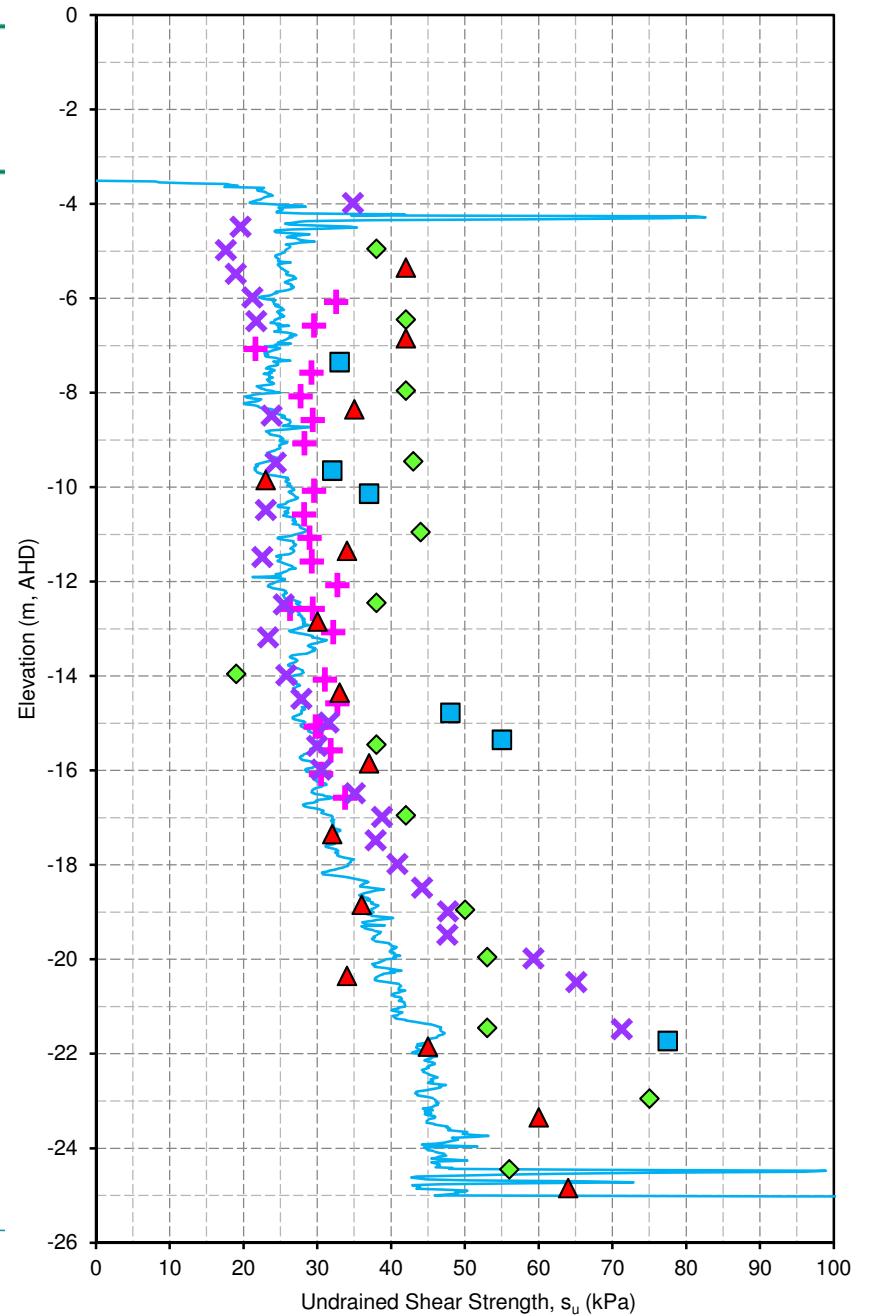




Comparison of data

Strength

- Comparison field and hand vane test results
- Good correlation above 11 m depth.
- nPS Triaxial test results higher (over-estimate of cell pressure?)

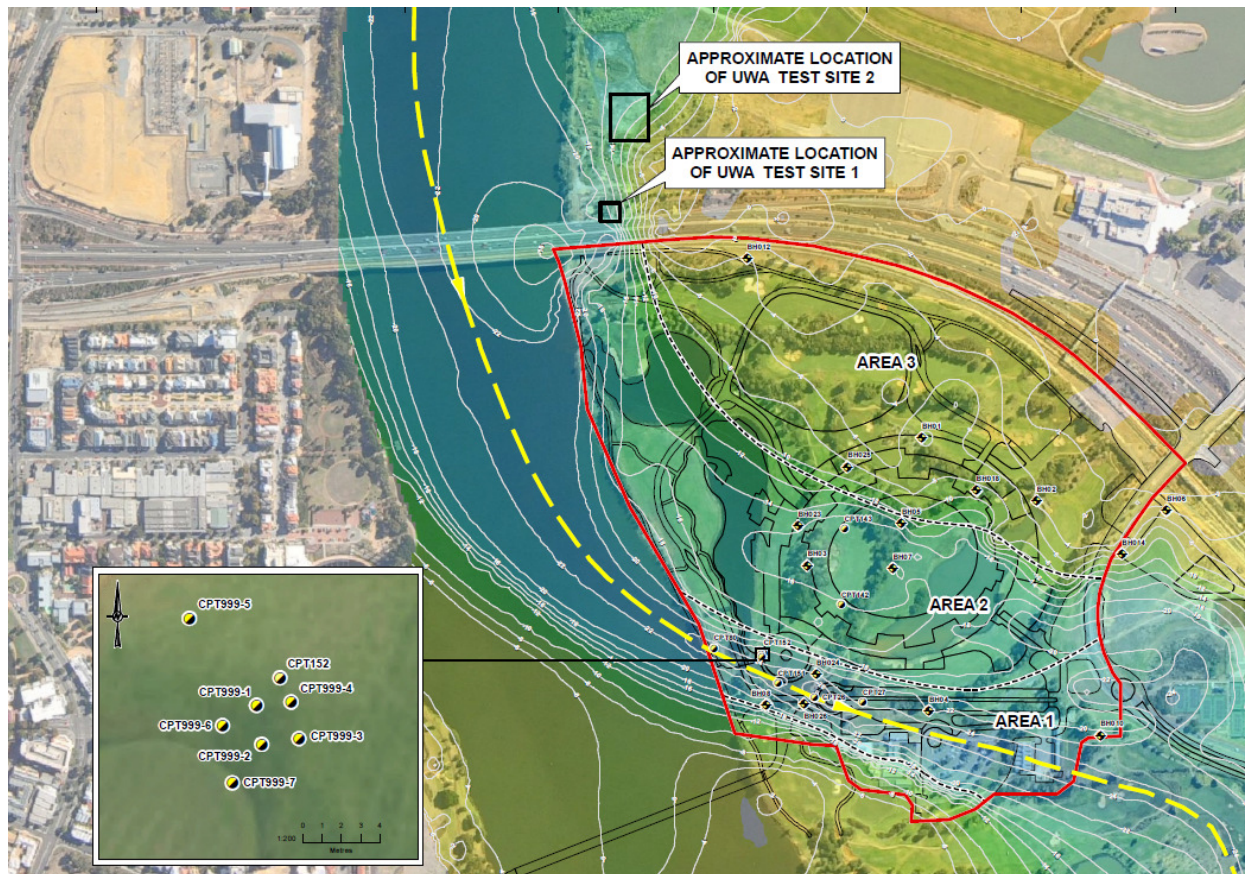


— CPT999-7-CPTsens + CPT999-3-75VST × CPT999-6-50VST
■ nPS - CIU Tests ▲ BH024 - Field Vane ◆ BH026 - Field Vane



Comparison of data

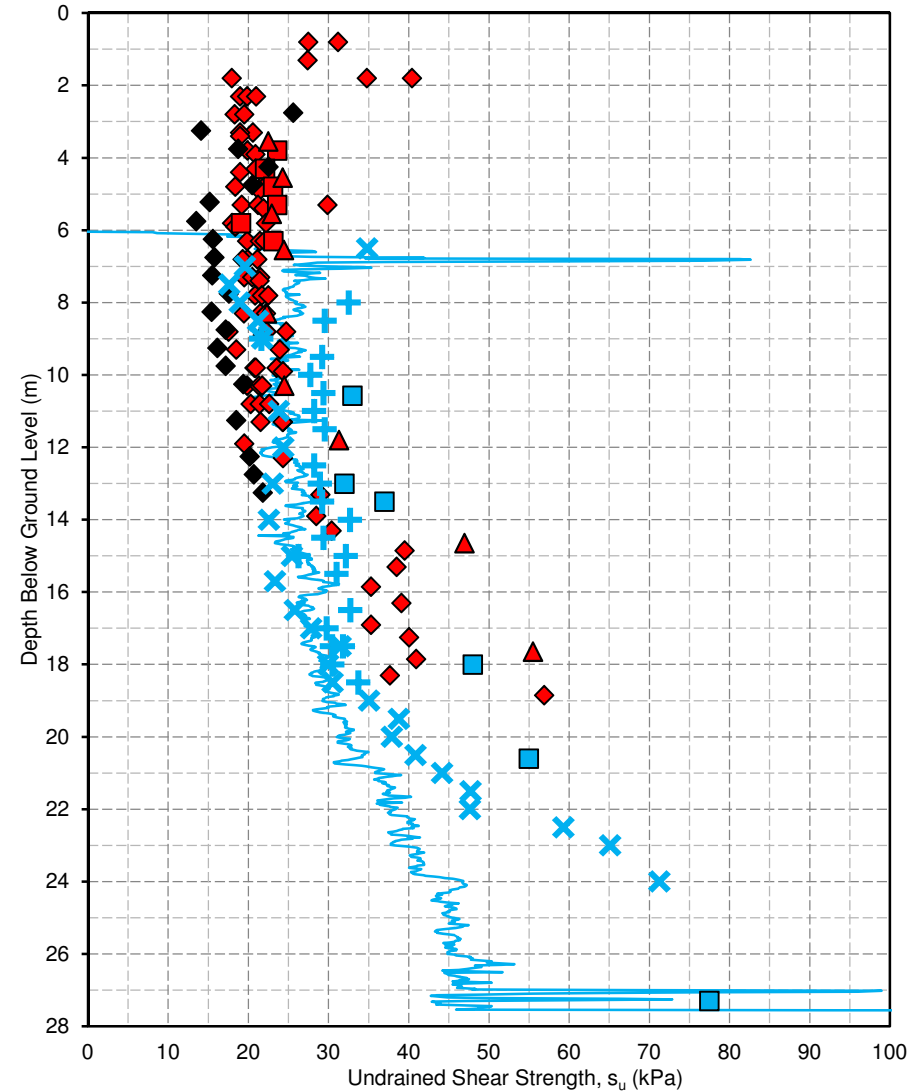
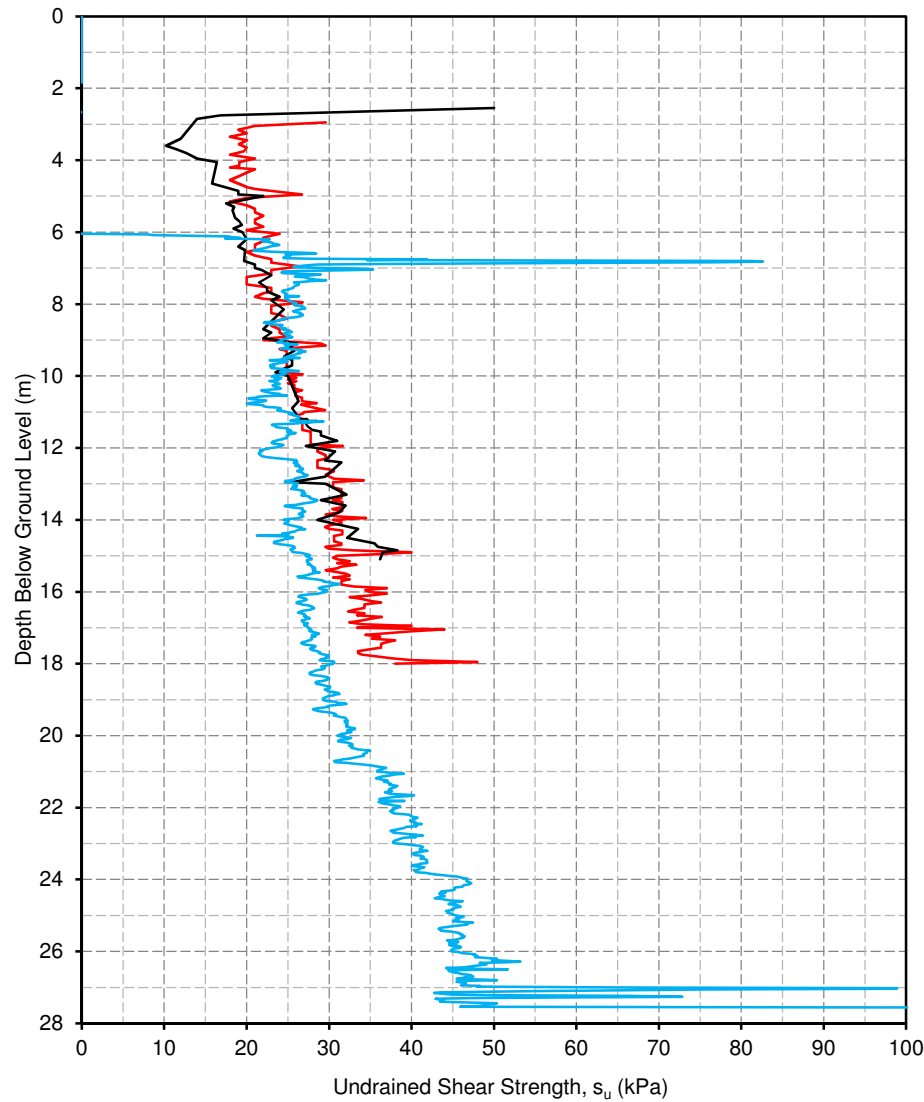
- Comparison with UWA test sites
[1. Stewart and Randolph, 1994 and 2. Low et al, 2011]





Comparison of data

■ Comparison with other data (UWA t-bar and vane shear tests)



— UWA Test Site 1 - T-bar — UWA Test Site 2 - CPT — CPT999-7-CPTsens

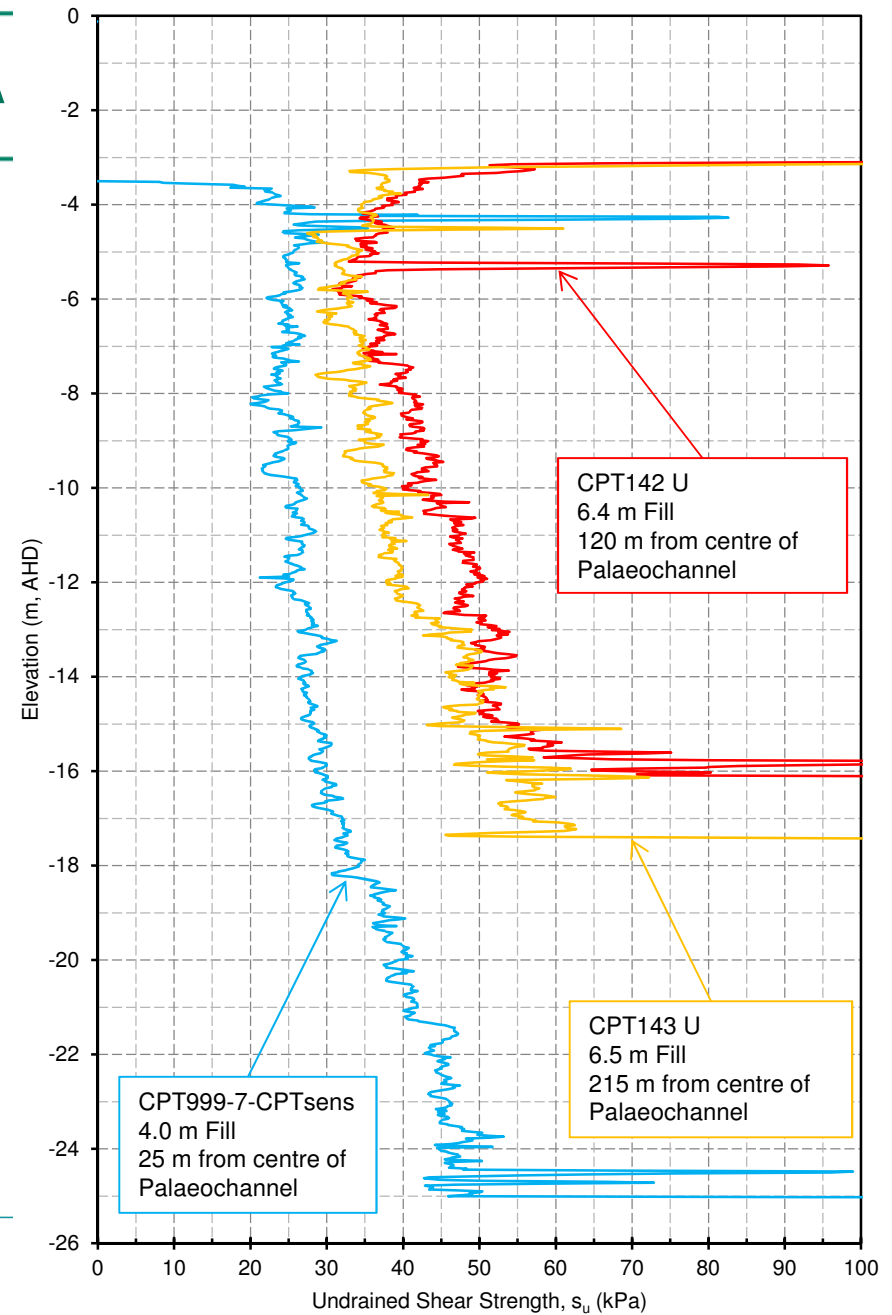
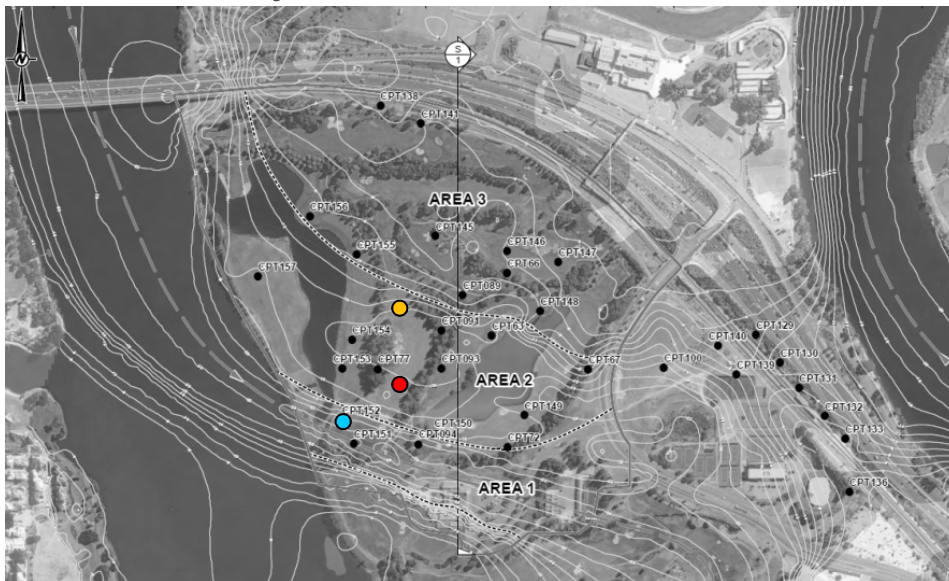
◆ UWA Test Site 1 - Vane Shear ■ UWA Test Site 1 - Triaxial ● CPT999-7-CPTsens
▲ UWA Test Site 1 - SBPM ◆ UWA Test Site 2 - Vane Shear ● CPT999-3-75VST
✦ CPT999-6-50VST ■ nPS - CIU Tests



Characteristics of SRA

Strength

- Comparison with other CPTs further from centre of palaeochannel
- Approx. 2m more overburden currently



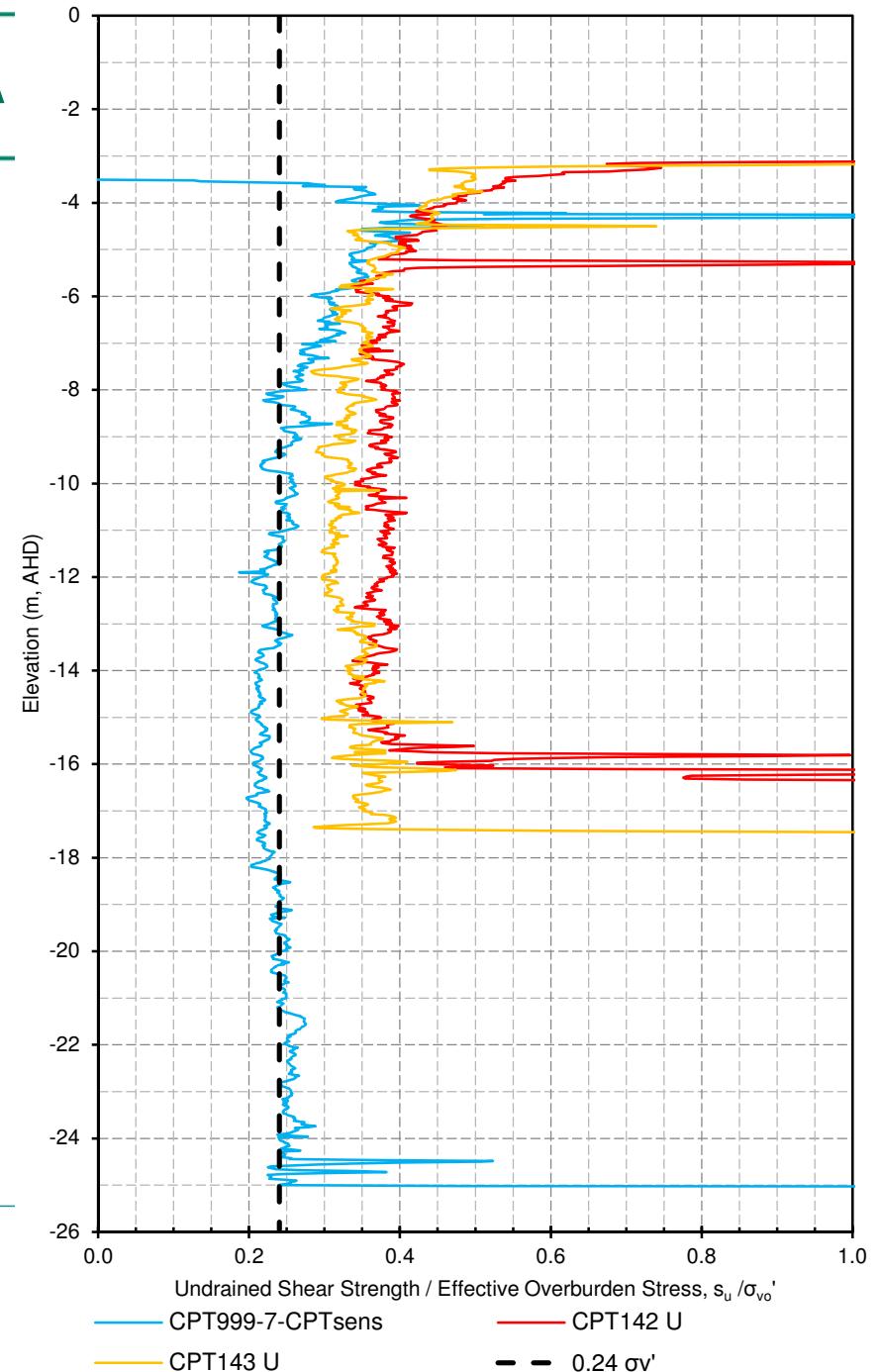
— CPT999-7-CPTsens — CPT142 U — CPT143 U



Characteristics of SRA

Strength/OCR

- Comparison with other CPTs further from centre of palaeochannel
- Approx. 2m more overburden currently
- CPT999 slightly over-consolidated above -8 m AHD
- Other CPTs – generally higher s_u/σ_v' ratio over full depth, ie slightly over-consolidated over full depth

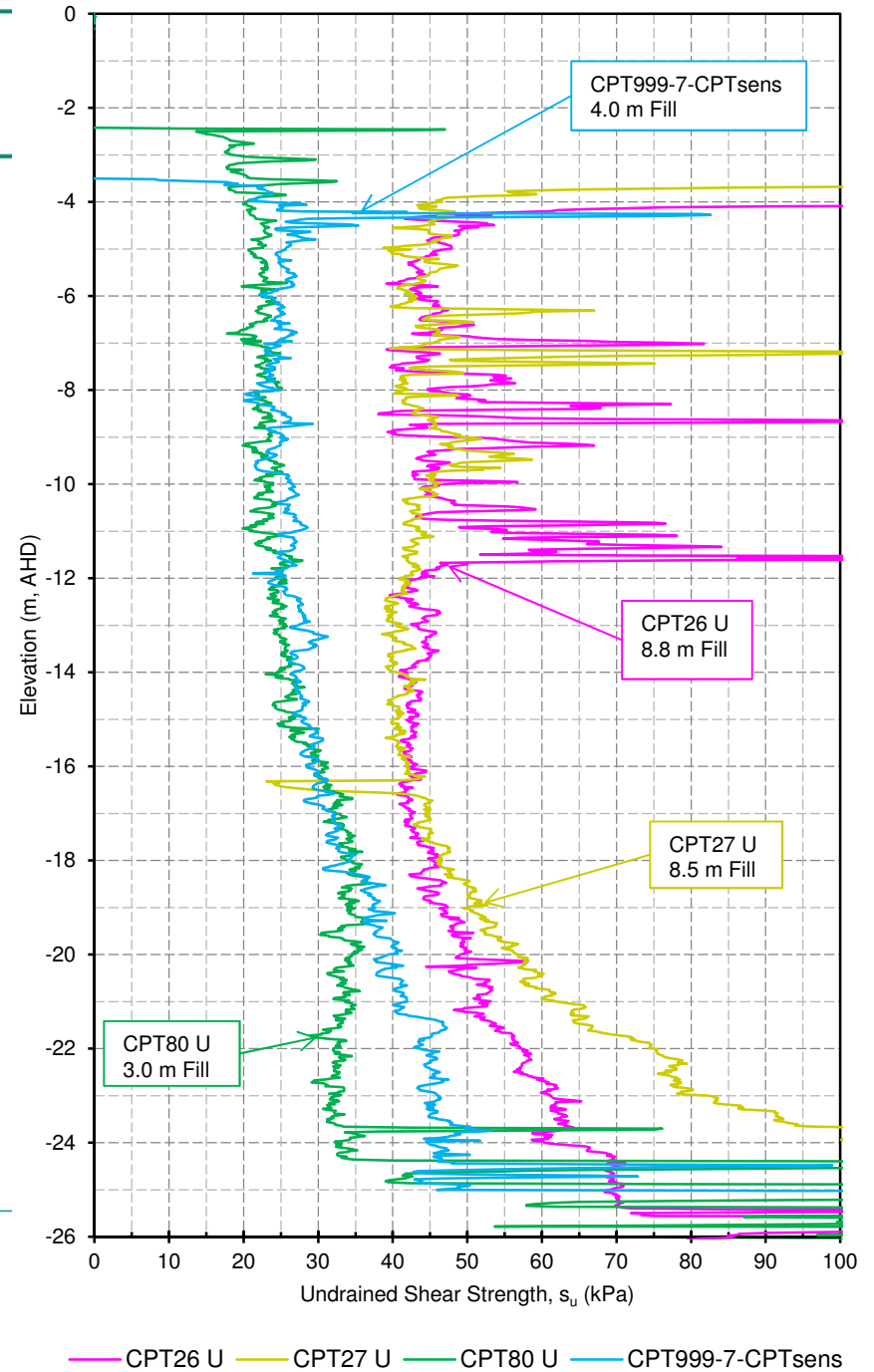
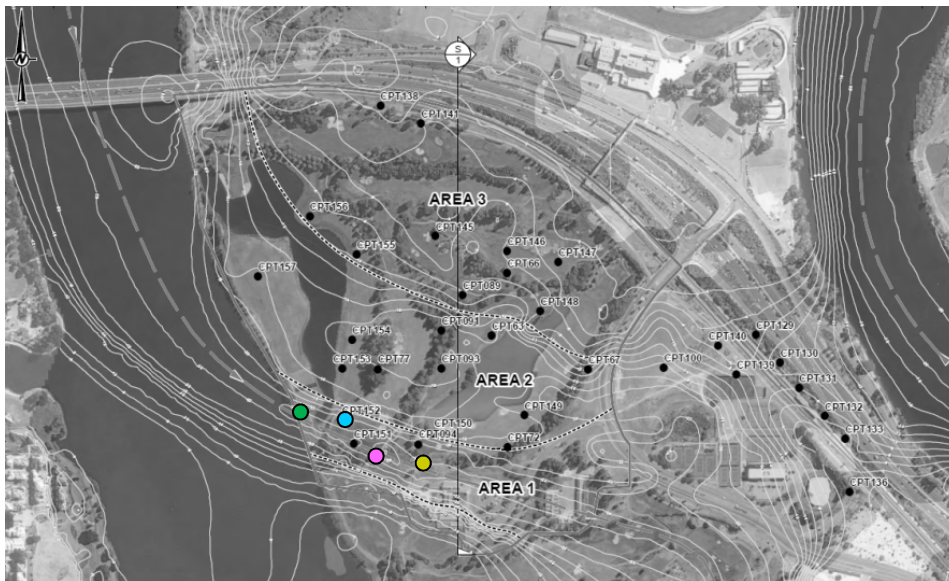




Characteristics of SRA

Strength/OCR

- Comparison with other CPTs along centre of palaeochannel
- Approx. 4m more overburden currently for two of the CPTs

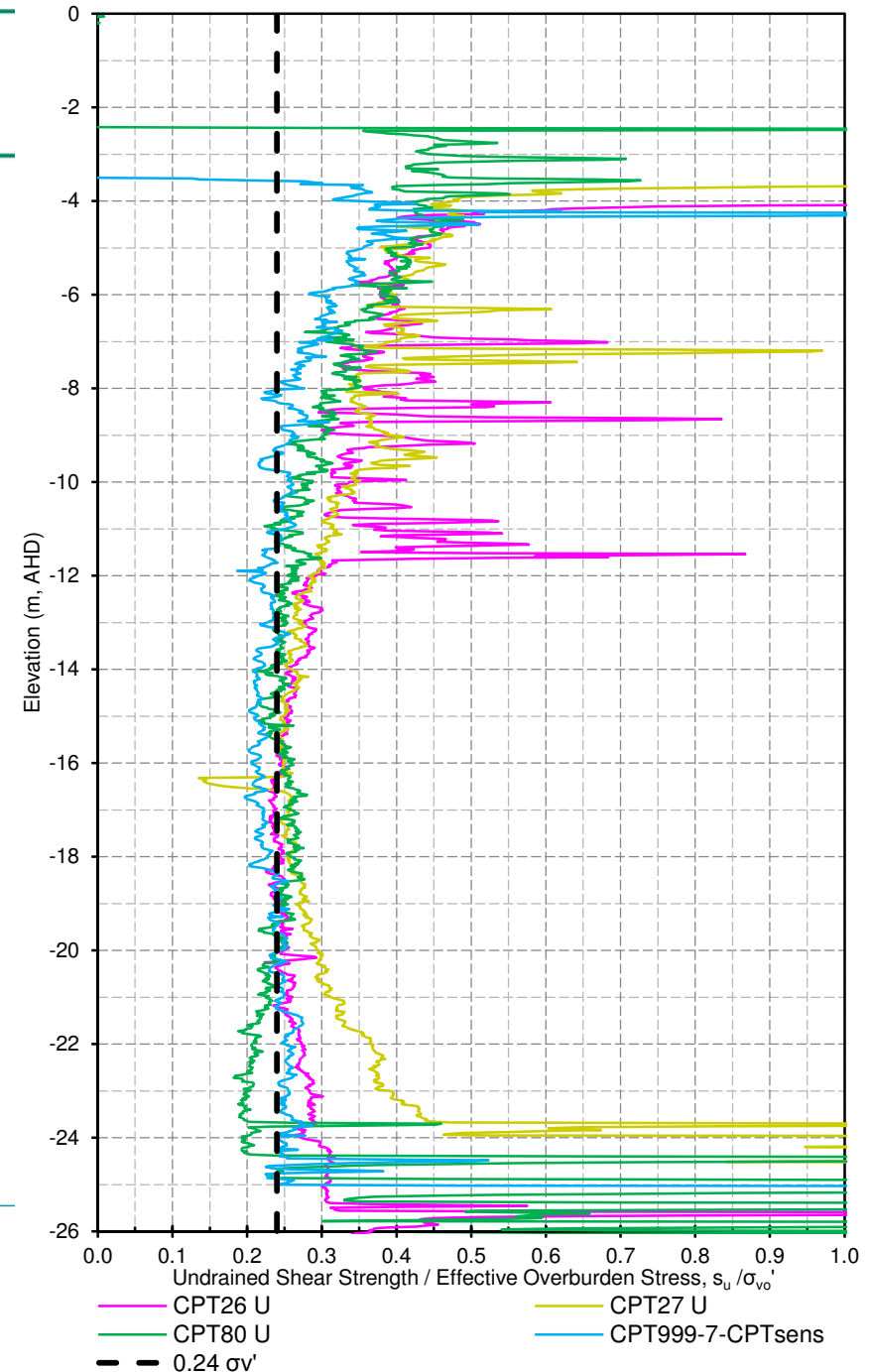




Characteristics of SRA

Strength/OCR

- Comparison with other CPTs further along centre of palaeochannel
- Approx. 4m more overburden currently for two of the CPTs
- Similar profiles
- Slightly over-consolidated over upper layers
- OC section extends slightly deeper for the CPTs with greater overburden (to -12 m AHD)



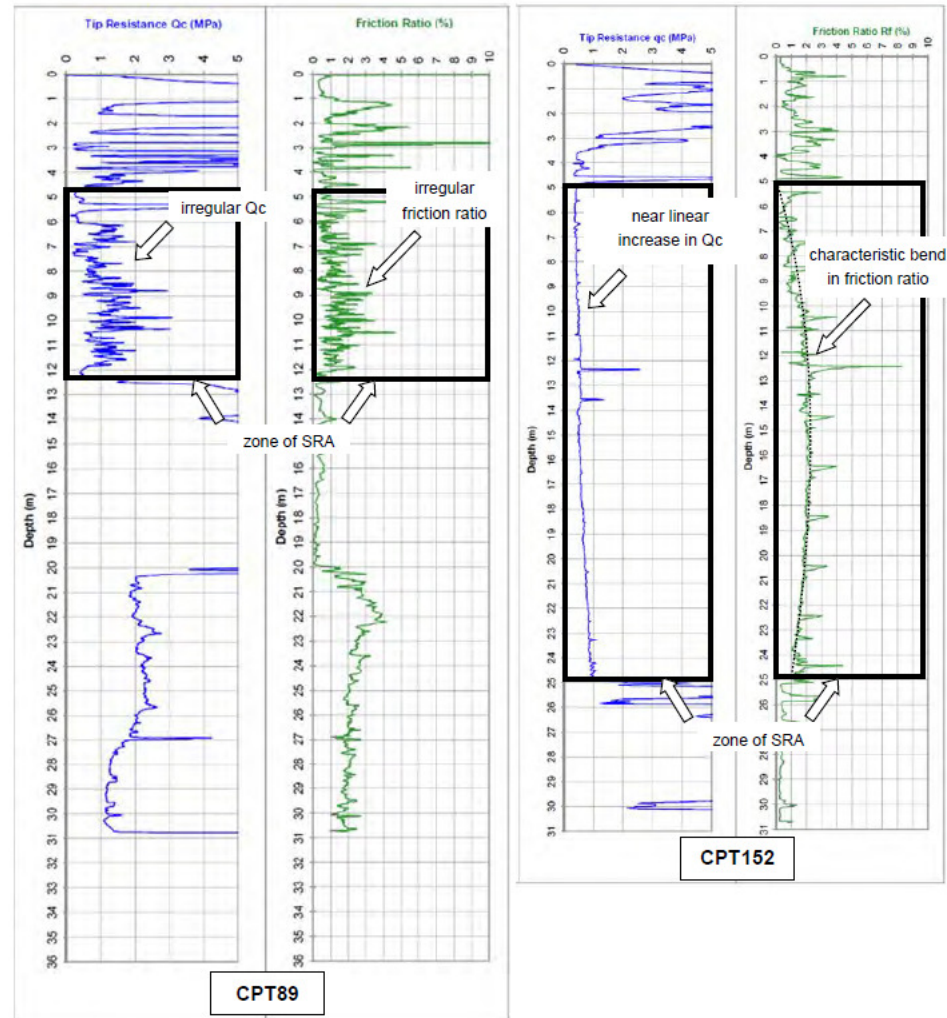


Characteristics of SRA

- Use of the CPT traces to pick out characteristics of SRA to support lab testing etc.

e.g.

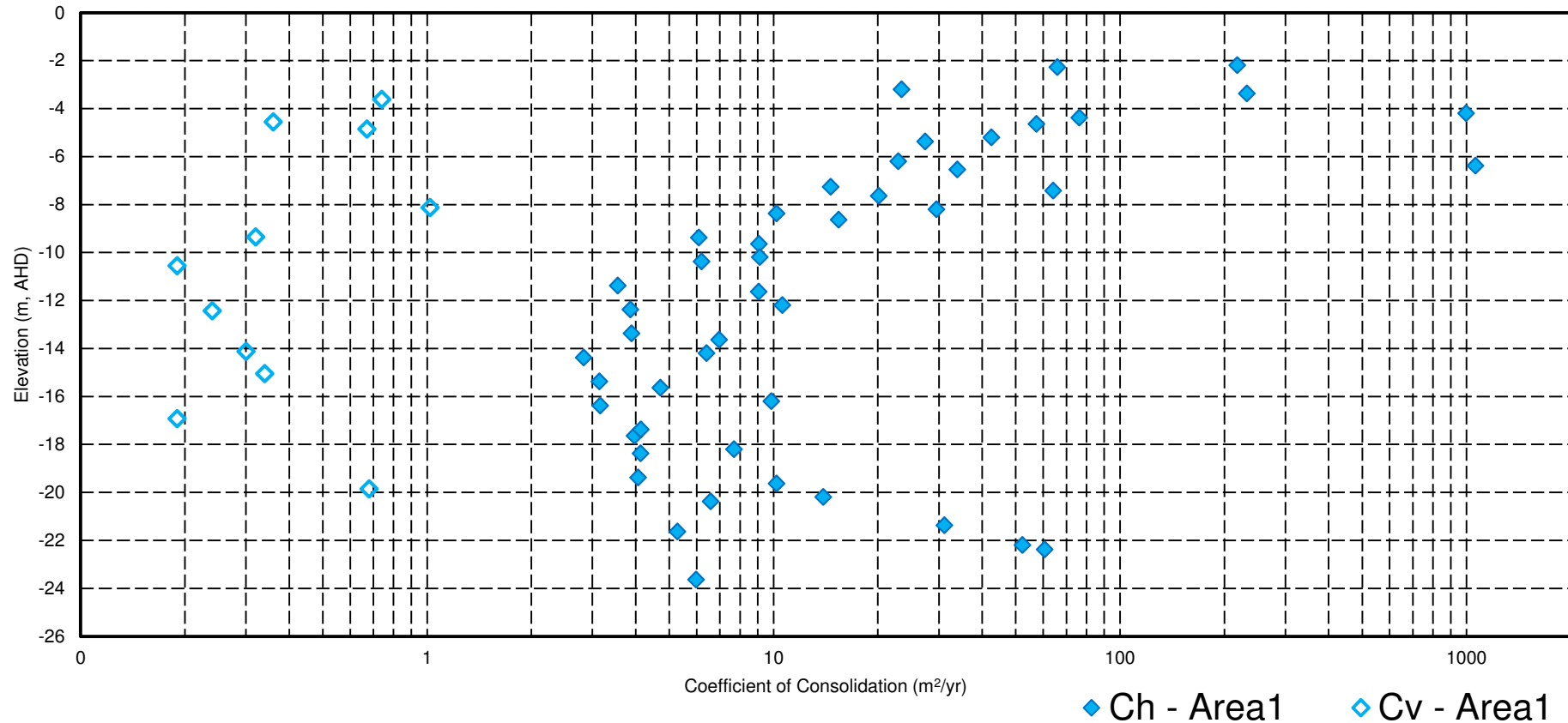
- “fuzzy” plot (more silt/fine sand laminations) – higher ch values?
- “smooth tip resistance and “bend” to friction ratio with sl. coarser materials at top and bottom of layer – supported by PSDs





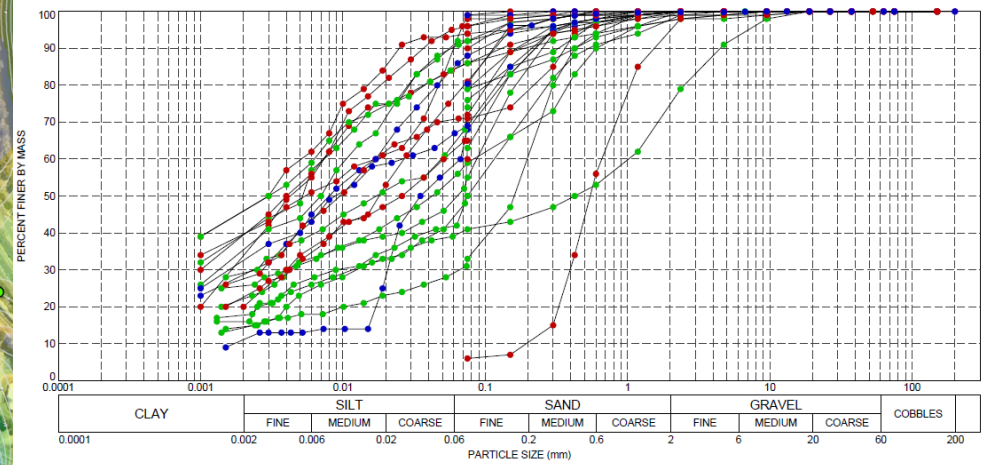
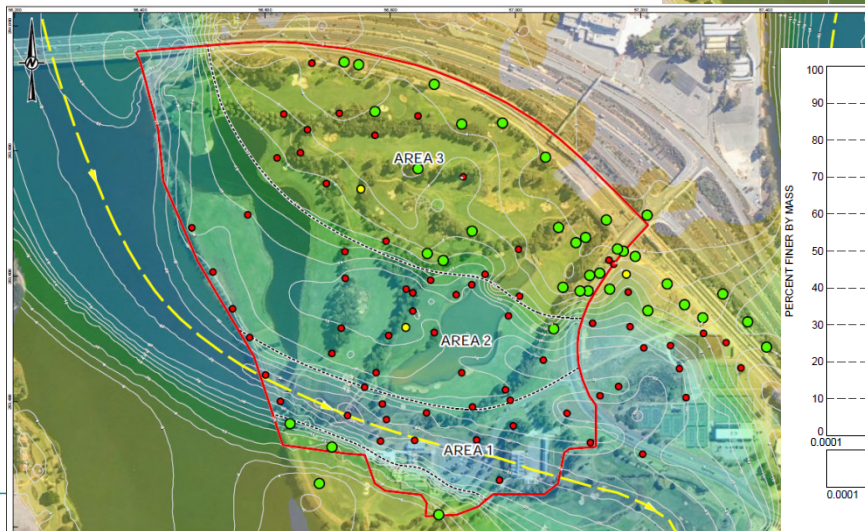
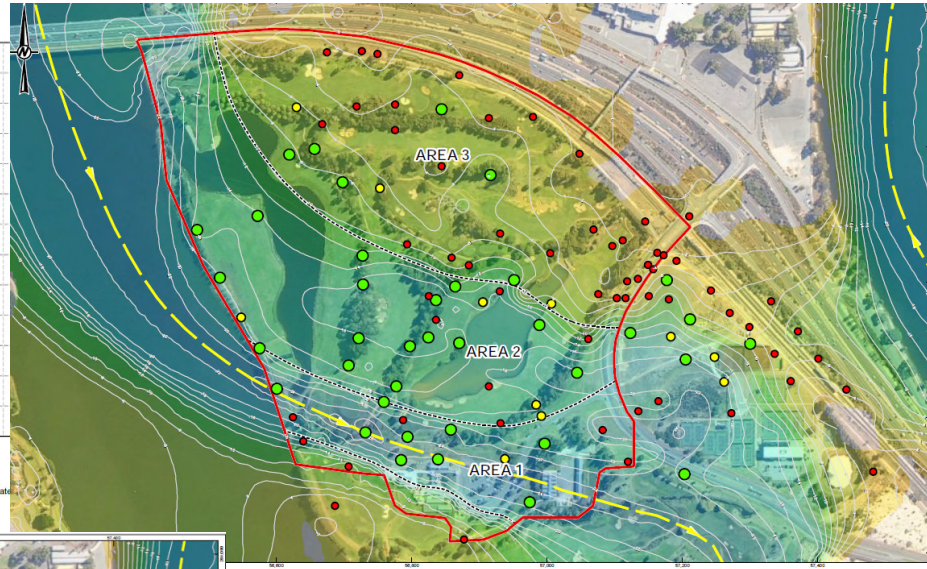
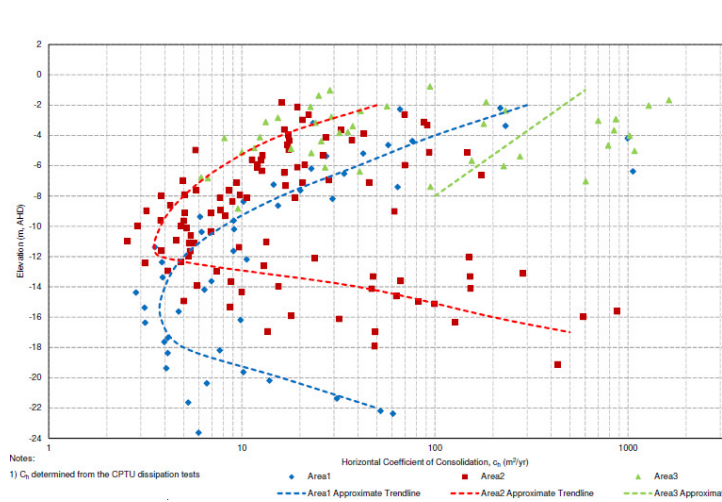
Characteristics of SRA

- Comparison of c_h values from dissipation testing with c_v values from oedometer test results





Characteristics of SRA



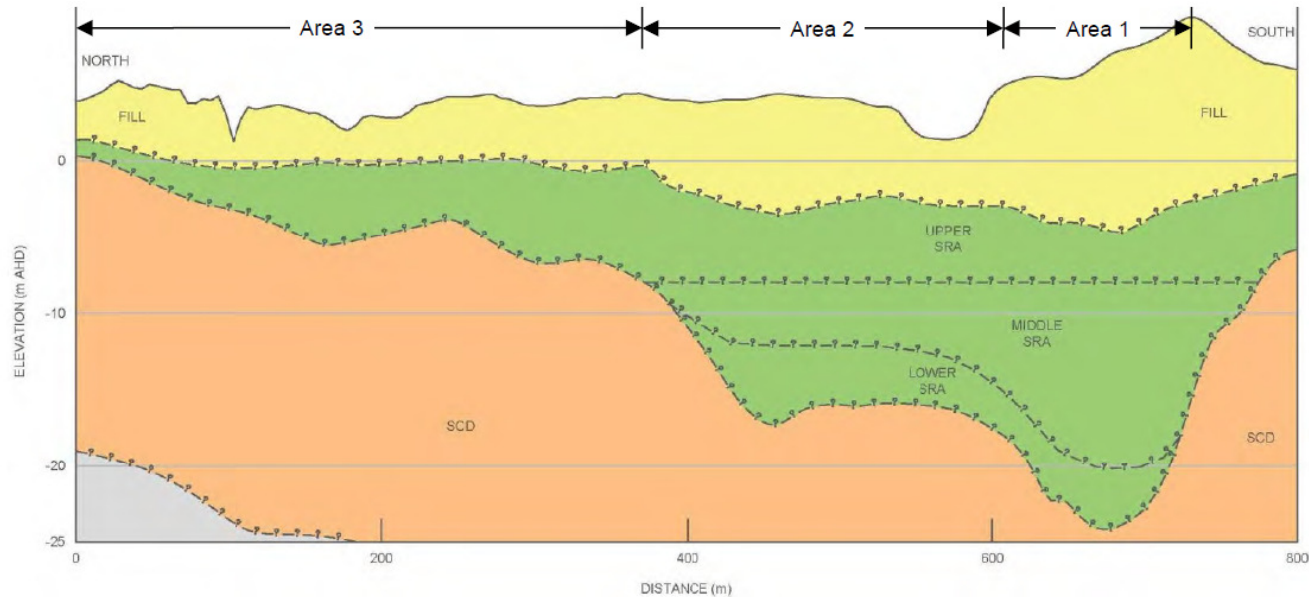
October 31,

<p>LEGEND</p> <ul style="list-style-type: none"> ● (Blue) SRA ● (Red) SRA ● (Green) SRA 	<p>NOTES</p> <p>CONTOUR INTERVAL: 100mm (VERTICAL)</p> <p>SCALE: 1:1000</p> <p>DATE: 10/31/2011</p>	<p>PUBLIC TRANSPORT AUTHORITY</p> <p>NEW PERTH STADIUM BURWOOD</p> <p>PRESENCE / ABSENCE OF SANDY INTERBEDDING OF SRA IN CPTS AND BASE OF SRA COURTS</p>





Subdivision



Linked to depositional environment (river energy, sea level) and location within the palaeochannel.

- Vertical subdivision – Upper, Middle, Lower
 - Upper/Lower – Higher percentage of silt and sand, more variability, increasing trend with depth for permeability/coefficient of consolidation
 - Middle – more uniform silty clay/clayey silt, relatively constant value of permeability/coefficient of consolidation (and compressibility)



Conclusions/Observations

- Good correlation between methods at CPT999 (cluster location)
- Good agreement with previous testing carried out by UWA
- Based on our experience on the new Perth Stadium project, the standard 100 MPa CPT cone adequate for investigation (provided calibration regularly checked etc.)
- Scope of investigation allowed a subdivision of the SRA with depth and in plan.

- Best method for investigation?
 - In situ vs sample/lab testing.... or both?
 - More than one method.... cross-check of data to give more confidence
 - Methods will depend on budget, size of site, pre-existing data and understanding of material