Past and Current Construction Projects on Swan River Soft Soils

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Australian Geomechanics Society
Soft Soils Seminar 14 November 2014

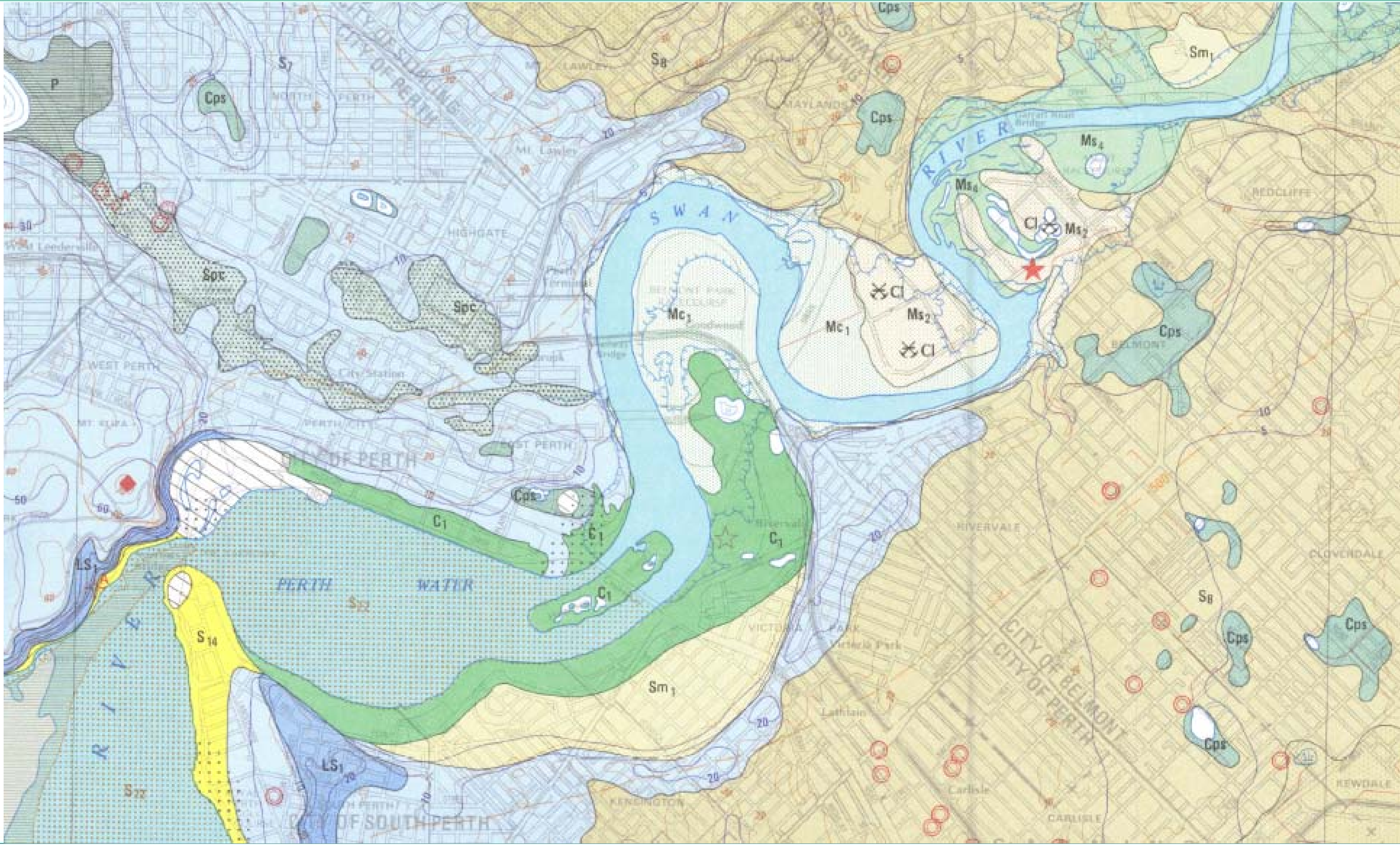
Golder Associates

Overview

- Distribution and formation of Swan River soft soils
- Foreshore reclamation and development:
  - The Narrows and Mounts Bay
  - The Causeway and Burswood
- Design Parameters
- Typical Issues and Solutions

Distribution and Formation of Swan River Soft Soils

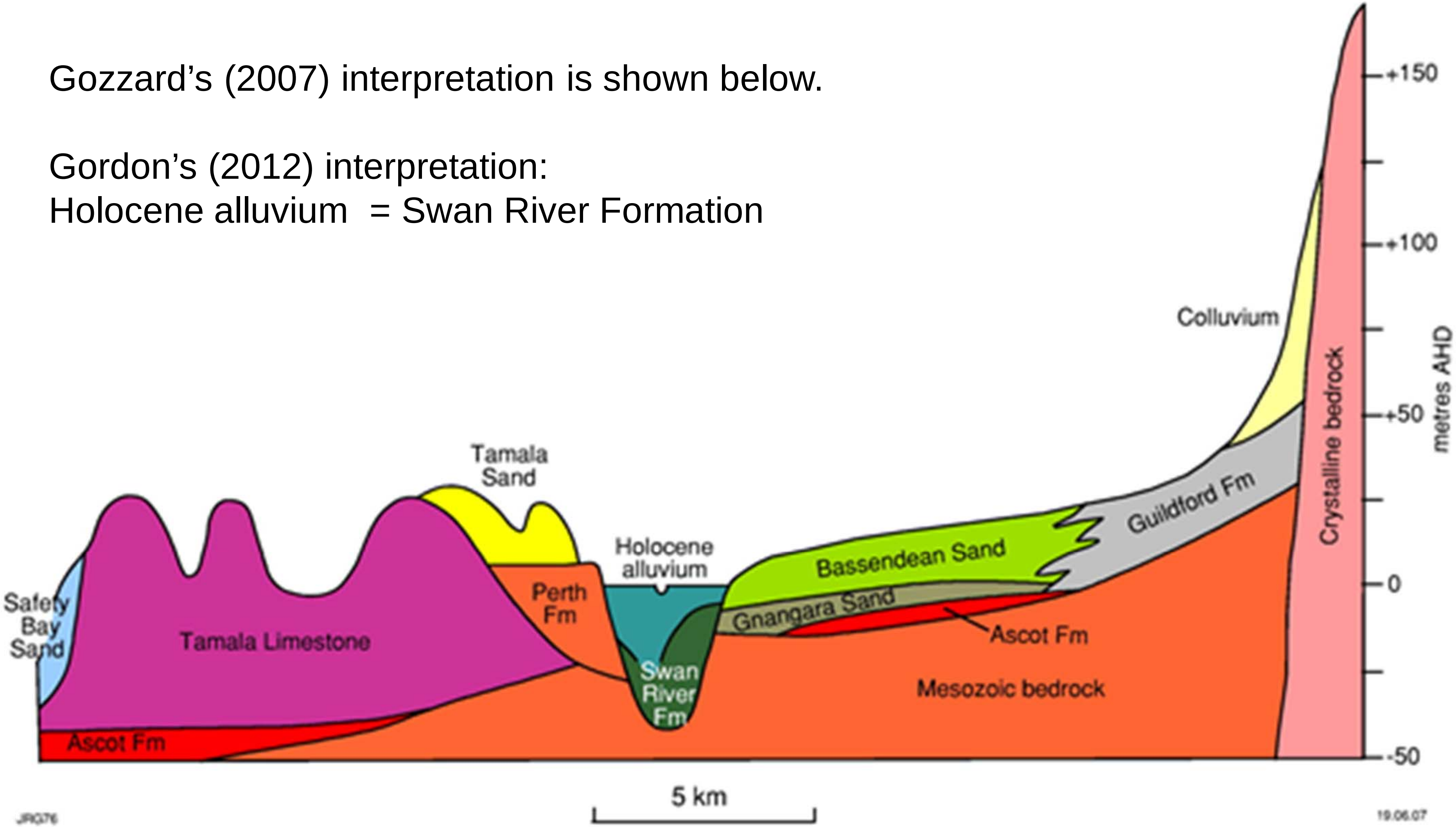
Surface Geology - Perth



Schematic Subsurface Geology

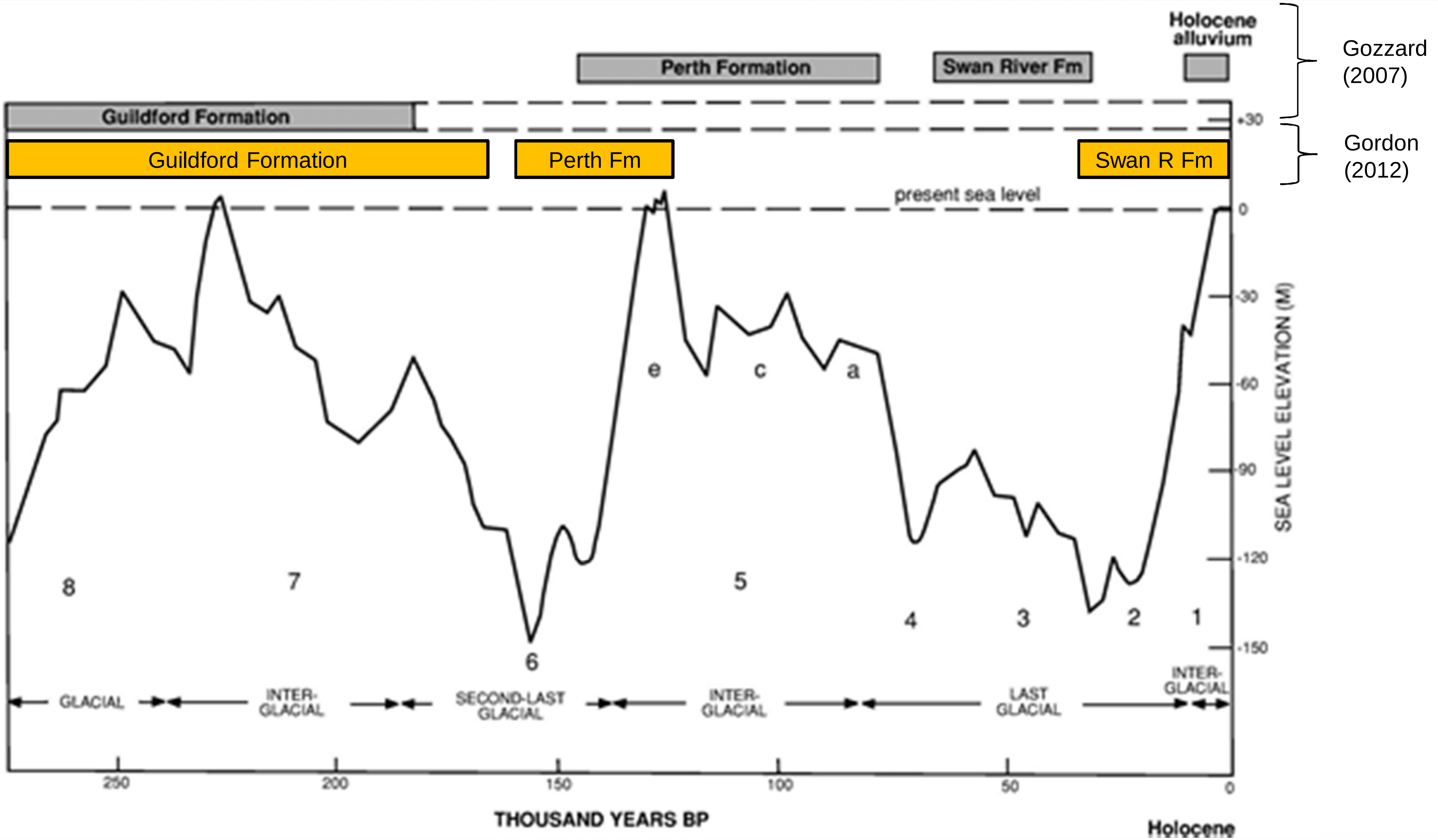
Gozzard's (2007) interpretation is shown below.

Gordon's (2012) interpretation:
Holocene alluvium = Swan River Formation



Gozzard (2007)

Sea Level Changes & Alluvial Geology



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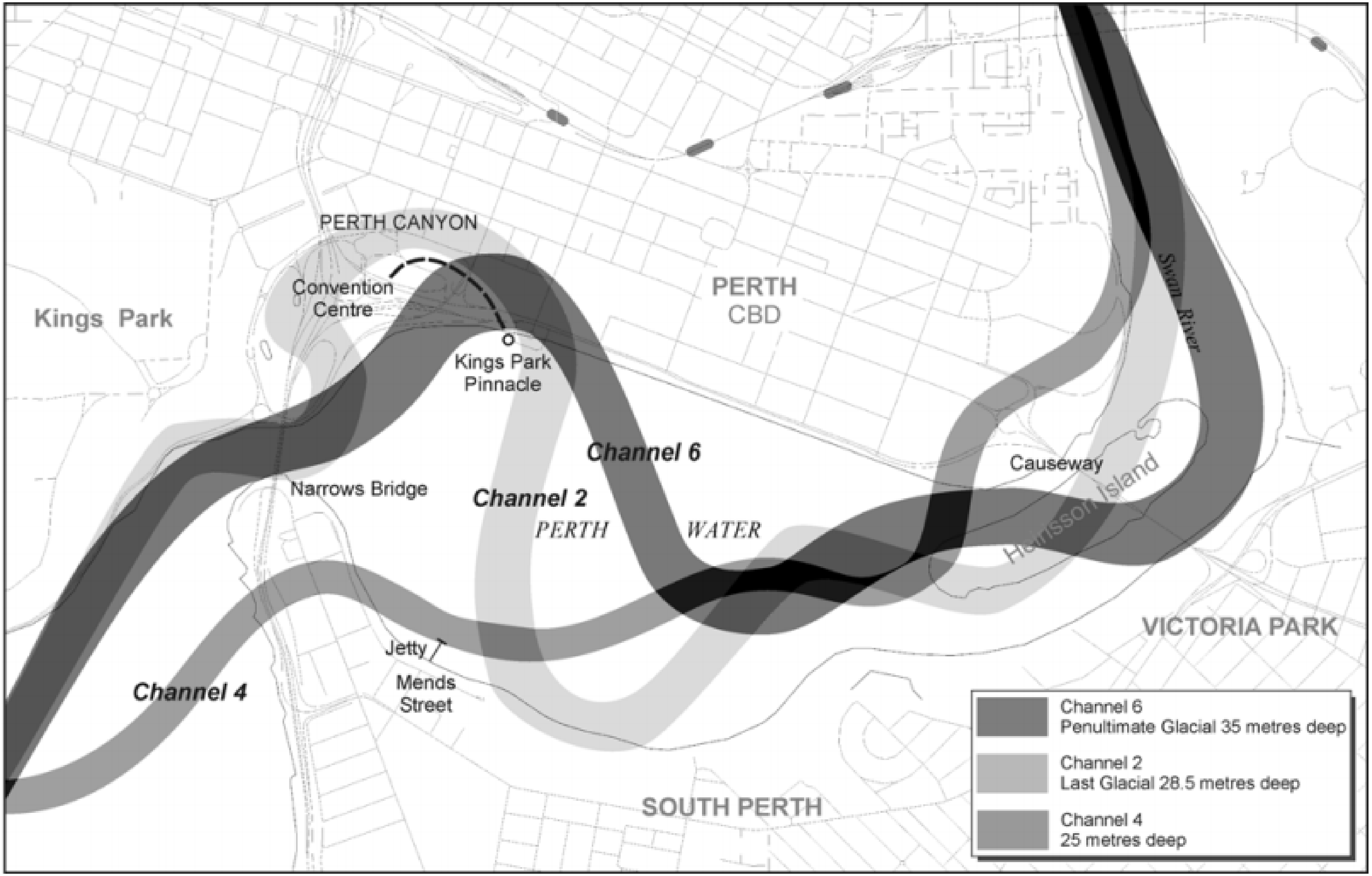
Gordon's (2003) Palaeochannel Map – Perth



Deposition – Perth Area

Narrows Bridge:

- Lower – marine environment, quieter water environment, fossil species still live in Cockburn Sound today, below ~RL-10 to RL-13 m
- Upper – estuarine environment, shells and shell fragments, abundant worm tubes, significant fossil content

Goongoongup Rail Bridge:

- Lower – river mouth/delta, fluvial, below ~RL -17
- Middle – tidal estuary, marine influenced, ~RL-17 to ~RL-6
- Upper – lagoonal/seasonal estuary above ~RL -6 m

Gozzard (2007):

- Lower – contains abundant bivalves typical of a marine gulf environment deposited between about 6700 years and 4500 years ago
- Upper (younger) – being deposited by the modern erosion cycle.

Variable Composition

Fine bedding

Concave upwards and downwards shells

Sub-vertical roots

Oyster shell beds exposed on river bank

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Variability With Depth

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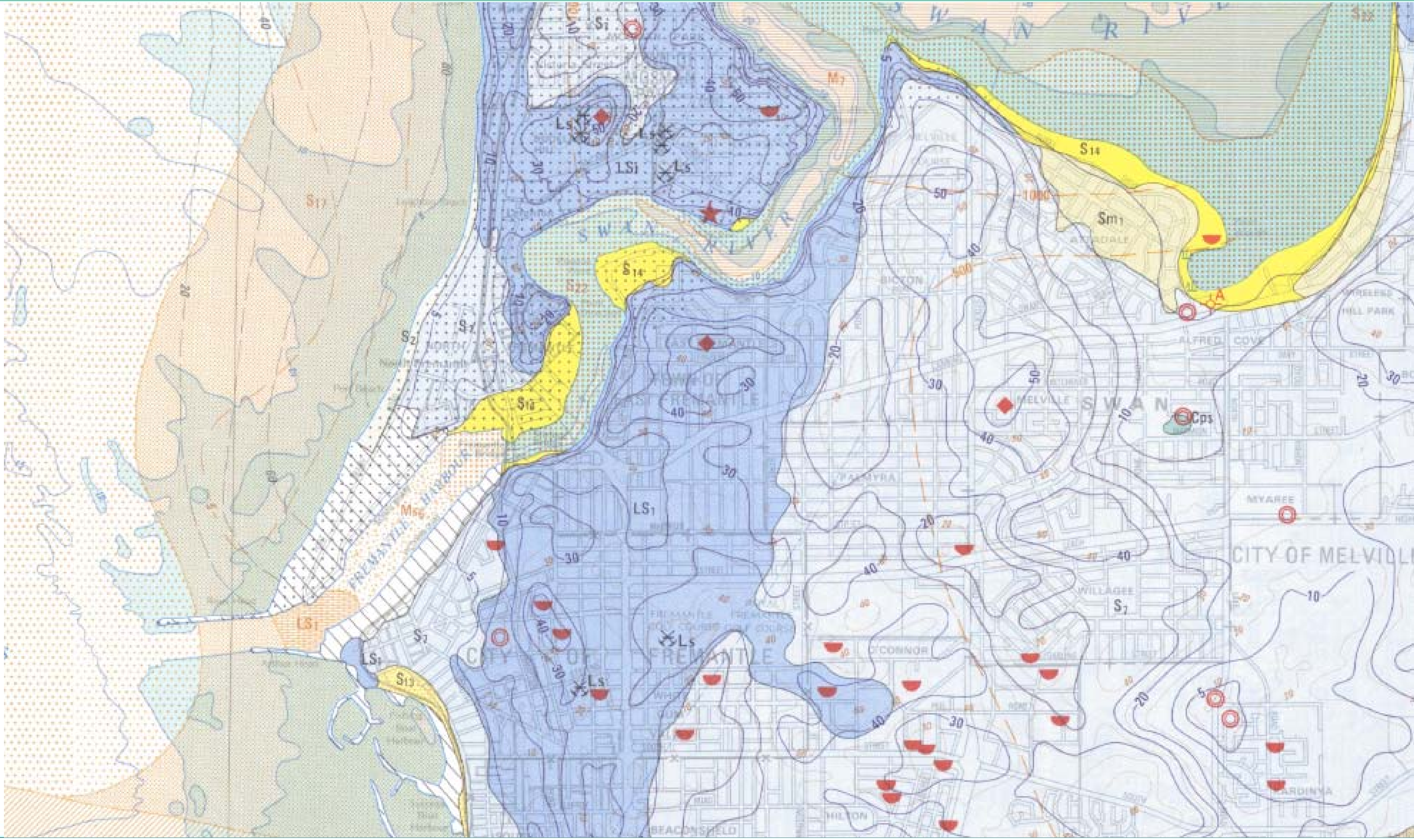
Surface Geology - Fremantle



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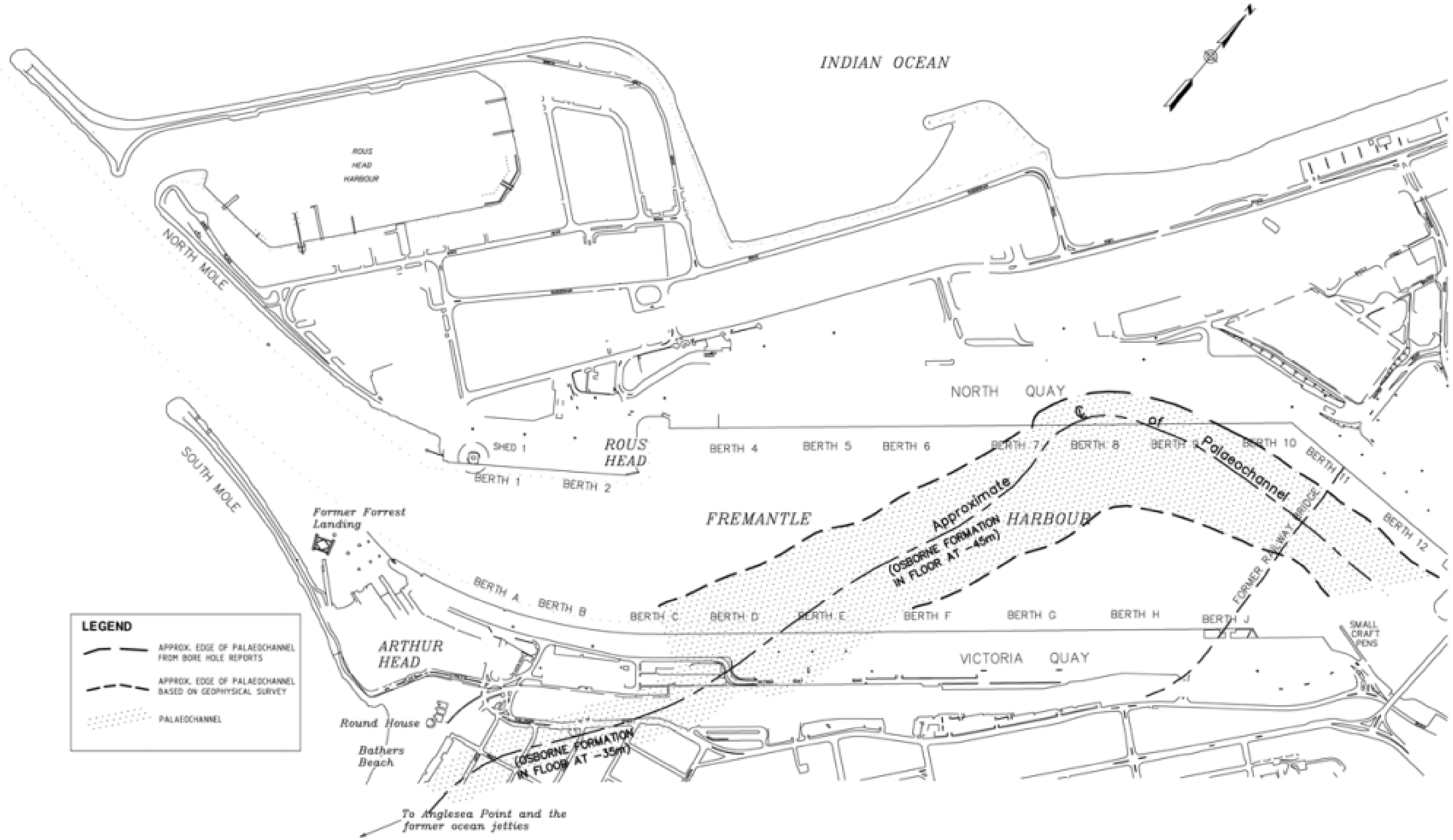
Tutton (2003) Palaeochannel Map – Fremantle



Section 2

The Narrows and Mounts Bay

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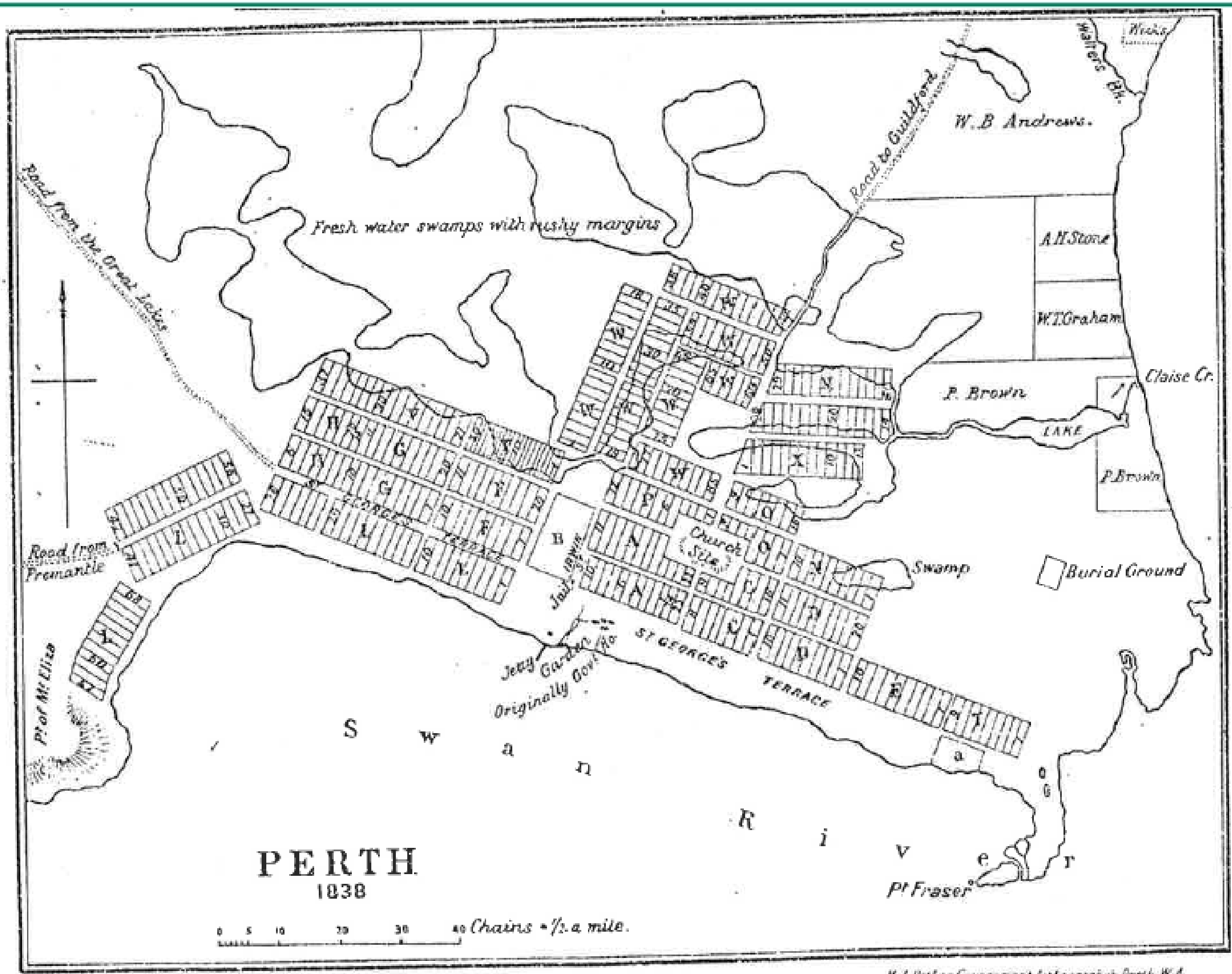
Mounts Bay to Causeway – 1838



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Perth Water – 1847

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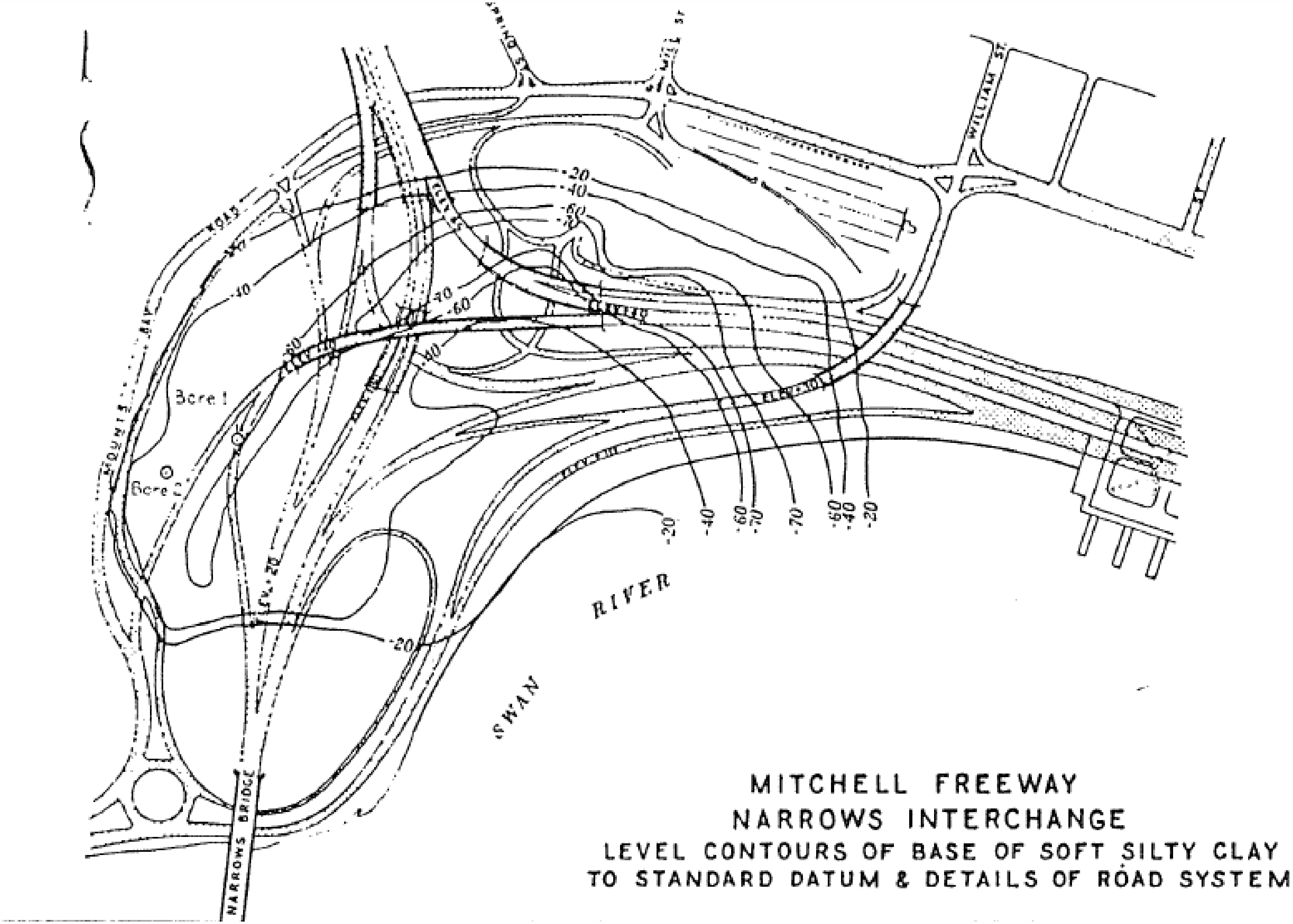
Perth Water – 1897

Utilising and adapting available technology the reserve was created through a process of infill, using dredged mud from the river, and 'wharfing out', using street sweepings, including sand, horse and cow droppings and the like. The Reserve was largely completed between 1870 and 1880, taking up an area between the William and Barrack St jetties.

Summers (2011)

Narrows Interchange Palaeochannel



Marsh (1967)

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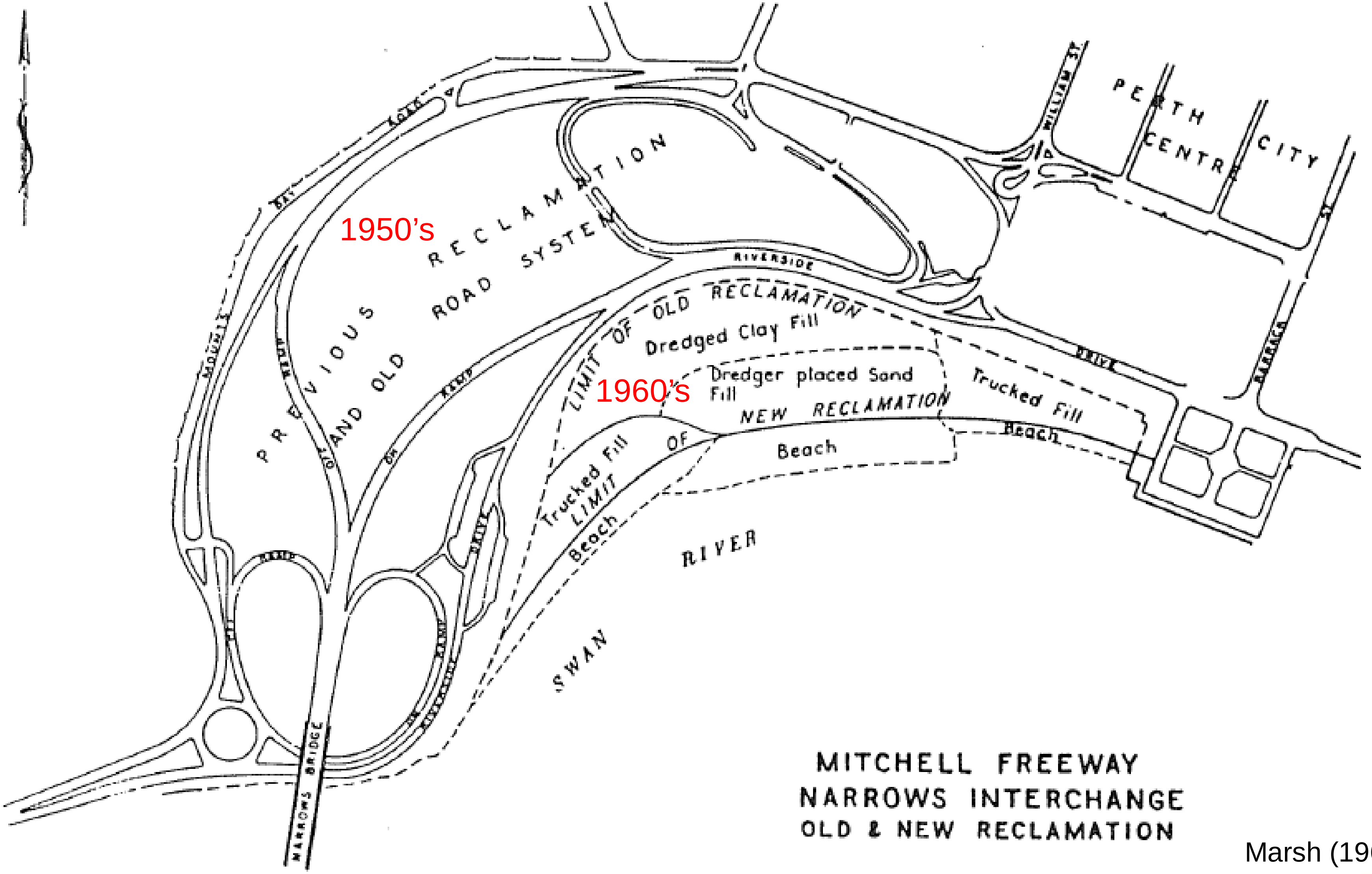
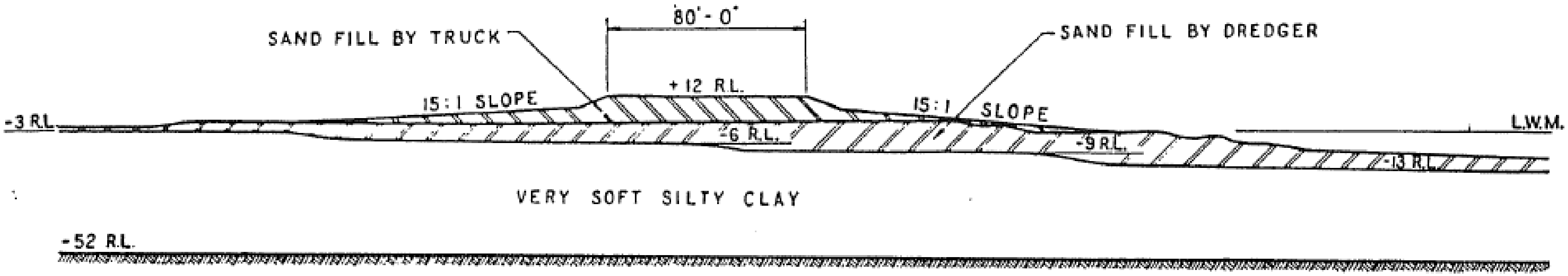
Narrows Reclamations



Marsh (1967)

Narrows Reclamations



MITCHELL FREEWAY - RECLAMATION
SECTION THROUGH RIVER WALL

- River bed in reclamation area typically at about RL -1 m.
- River wall formed with sand.
- Silty clay pumped from the river bed elsewhere to about RL 1 m.
- Covered with about 1 m of sand.
- Sand drains installed.
- Sand fill placed – preload and surcharge ~ 2.5 million m^3 of trucked fill.

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Narrows Reclamation – 1957

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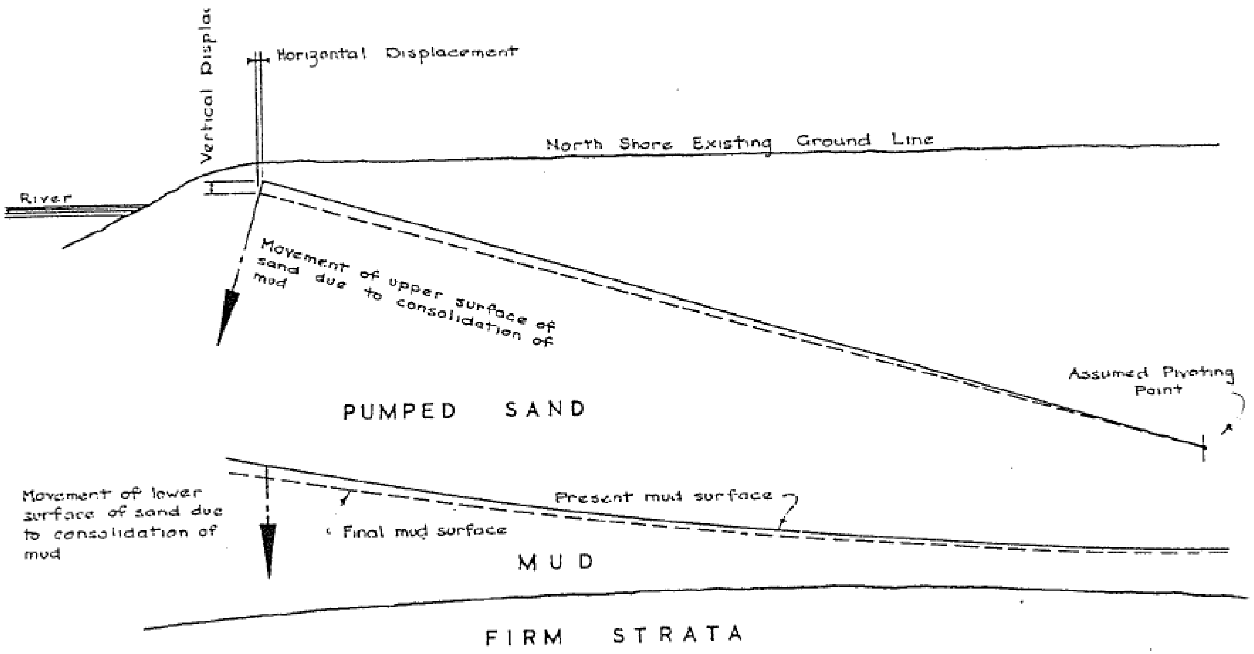
Narrows Reclamation and Bridge – 1960

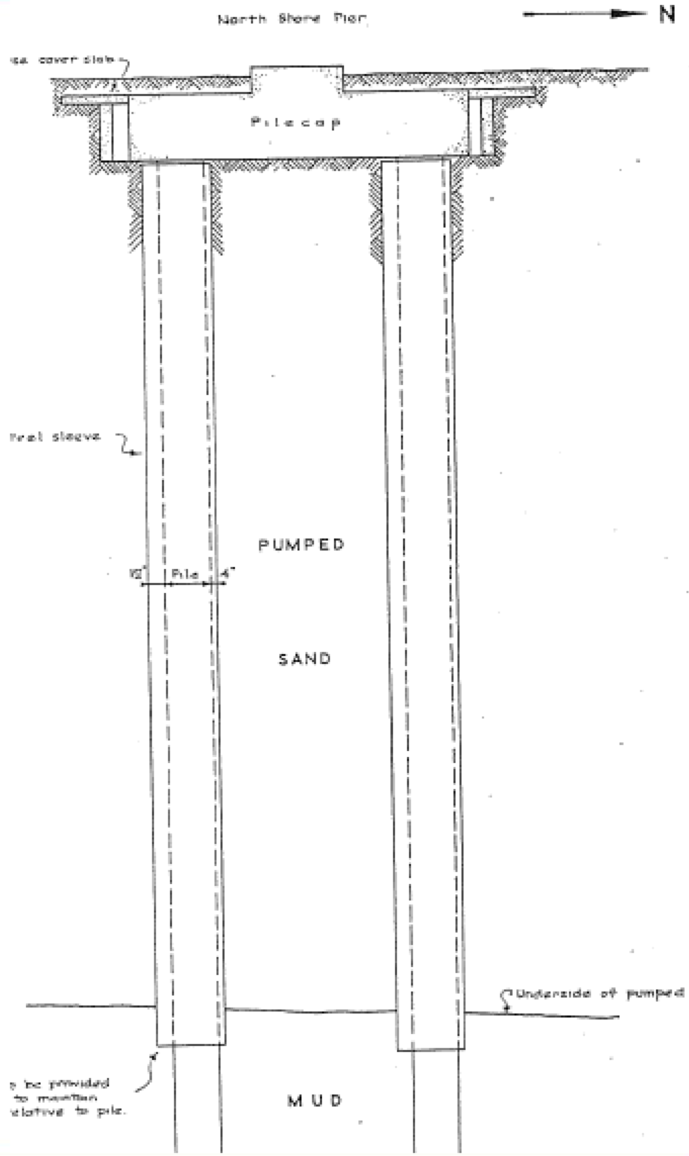
Sand Drain Installation

- Mandrel with end flap driven with drop hammer.
- Mandrel filled with sand and extracted.
- Typical mandrel diameter = 380 mm
- Typical constructed drain diameter = 450 mm
- Drain spacing = 1.4 m to 2.4 m
- 43,000 drains installed
- On average 30 drains/day installed to 18 m depth

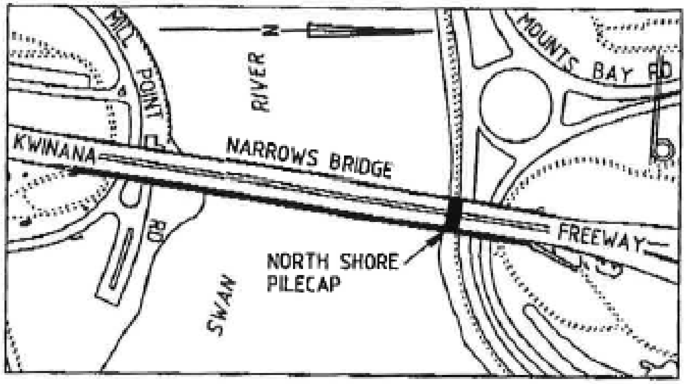
Narrows Bridge Construction

- North shore – mud largely displaced.
- Wedge of mud trapped below sand.
- Maximum 150 mm horizontal soil movement predicted (1958).
- Driven piles shielded from horizontal soil movement by eccentrically positioned casings with 300 mm gap.

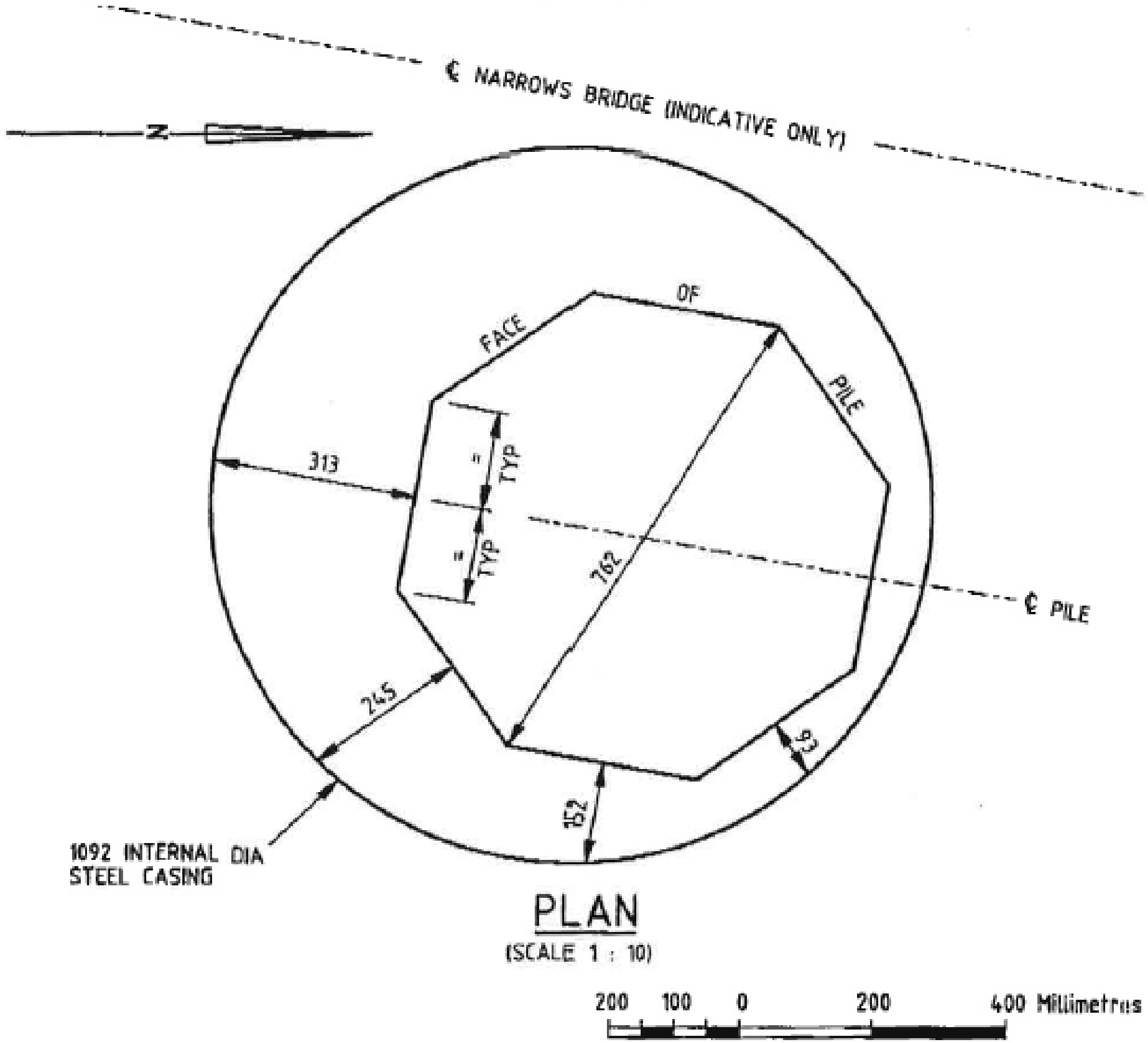




Exposed North Shore Pile – 1998



LOCALITY PLAN



PLAN
(SCALE 1 : 10)

- Piles exposed prior to design of Narrows Bridge duplication.
- About 200 mm soil movement.

Exposed North Shore Pile – 1998

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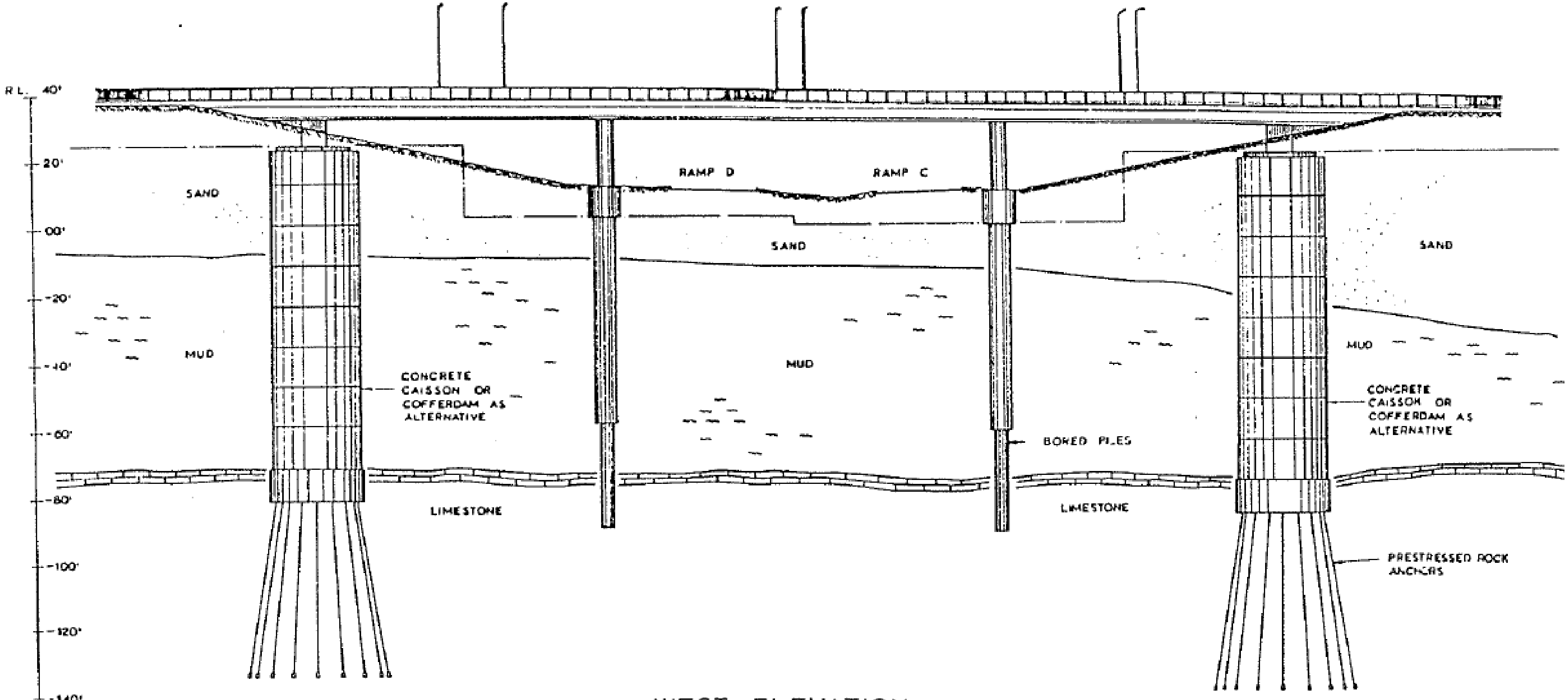
Interchange Bridges



— WEST ELEVATION —

SECTION BELOW GROUND

Narrows Bridge Duplication

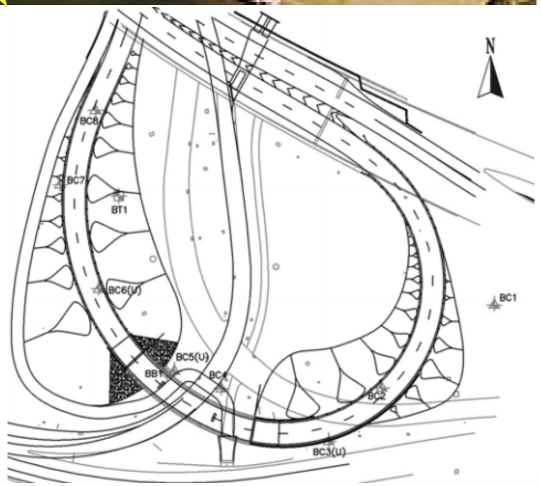
- Requirement to cause no adverse effect on existing bridge
- New bridge abutments allowable horizontal movement = 40 mm over 7 years and 150 mm over 100 years
- Fill placement limited 63 m from north abutment and 118 m from south abutment
- Piled approach slabs

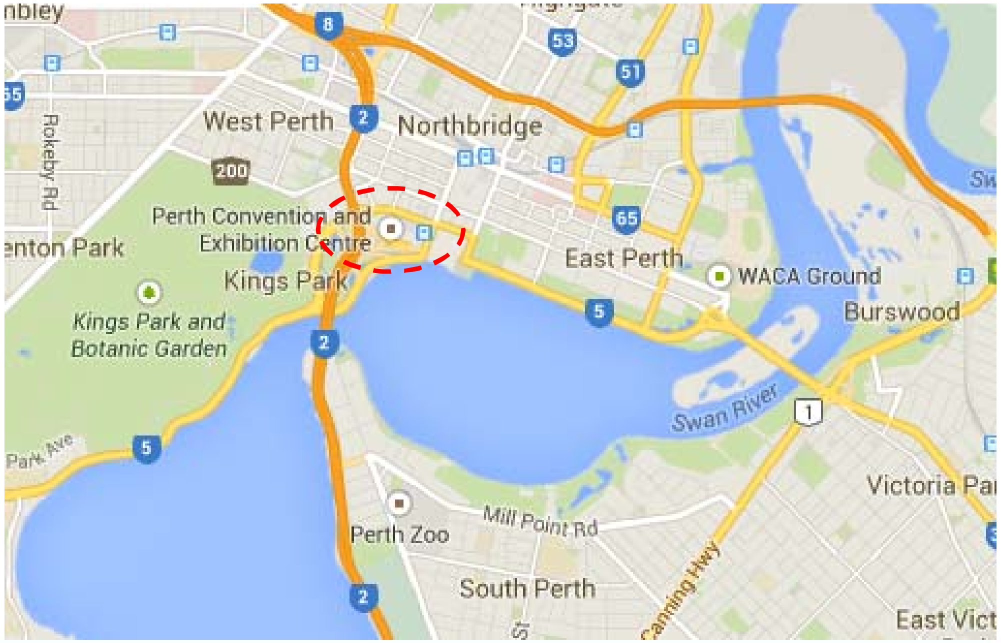
Novello and Woodward (2003)

PCEC

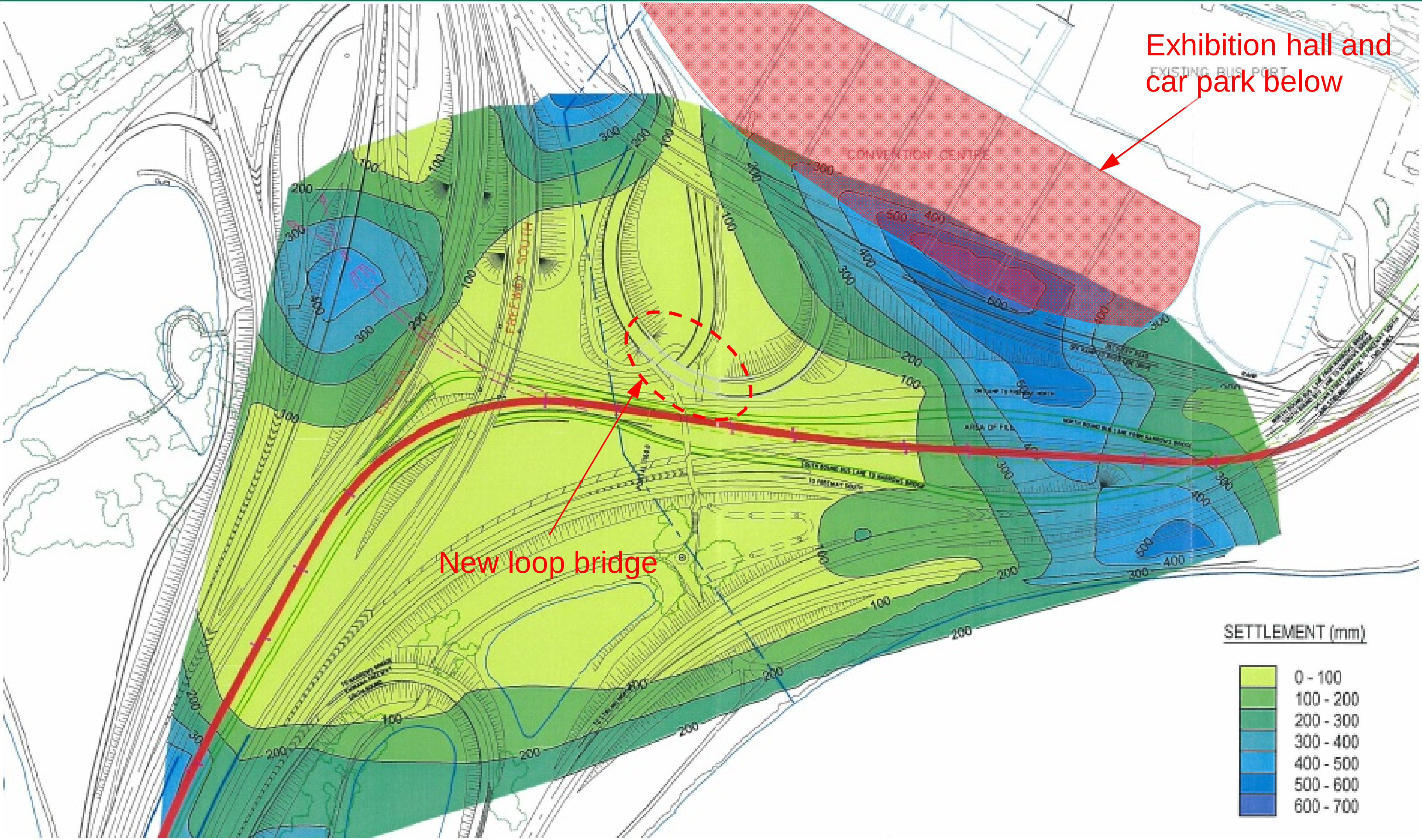
Perth Convention and Exhibition Centre
Included loop bridge on freeway off-ramp.
Constructed 2001 to 2004.

Located within Narrows Interchange reclamation.

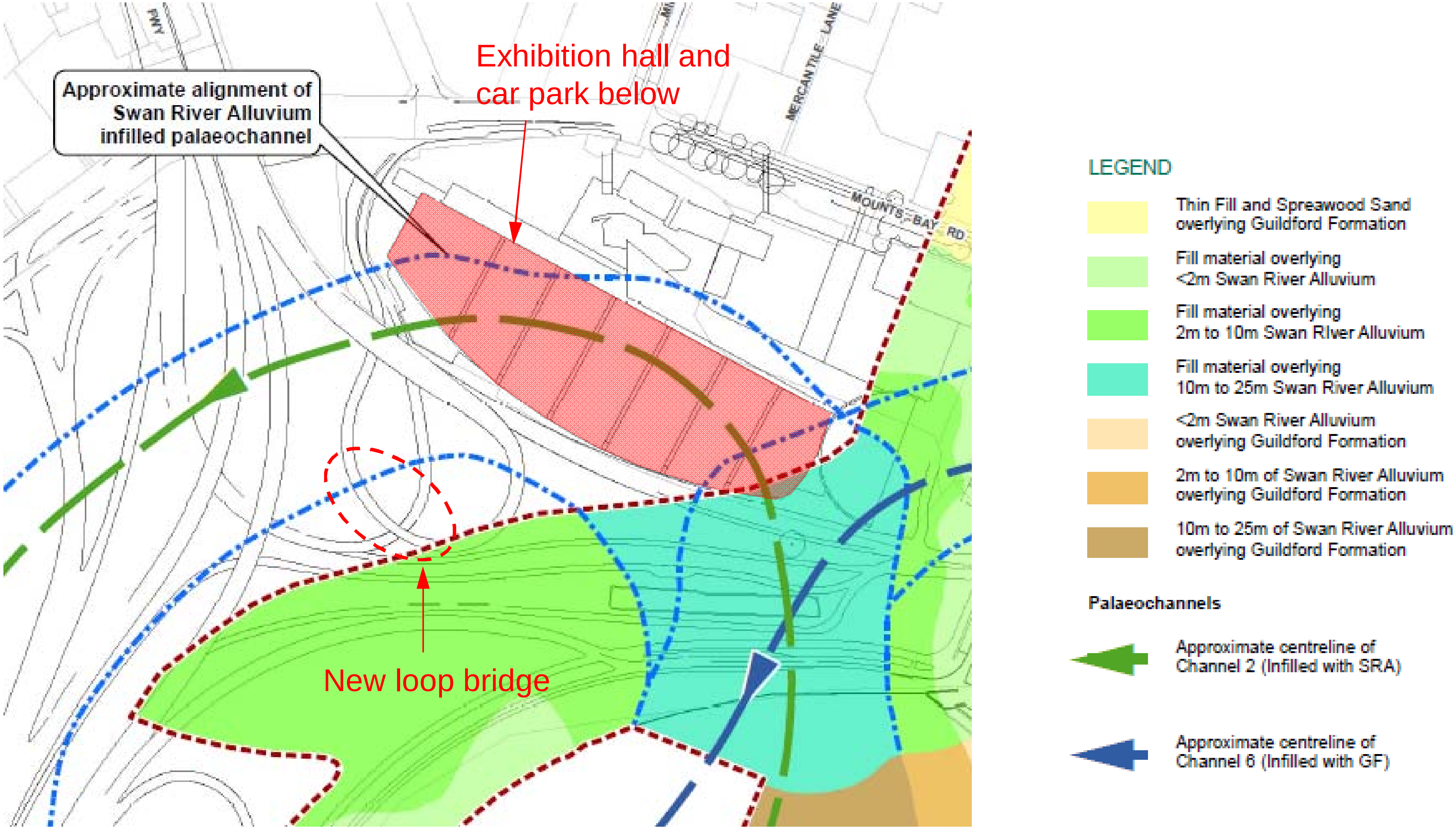




MRWA Measured Settlements 24 yrs to 1997



SRA-Infilled Palaeochannel



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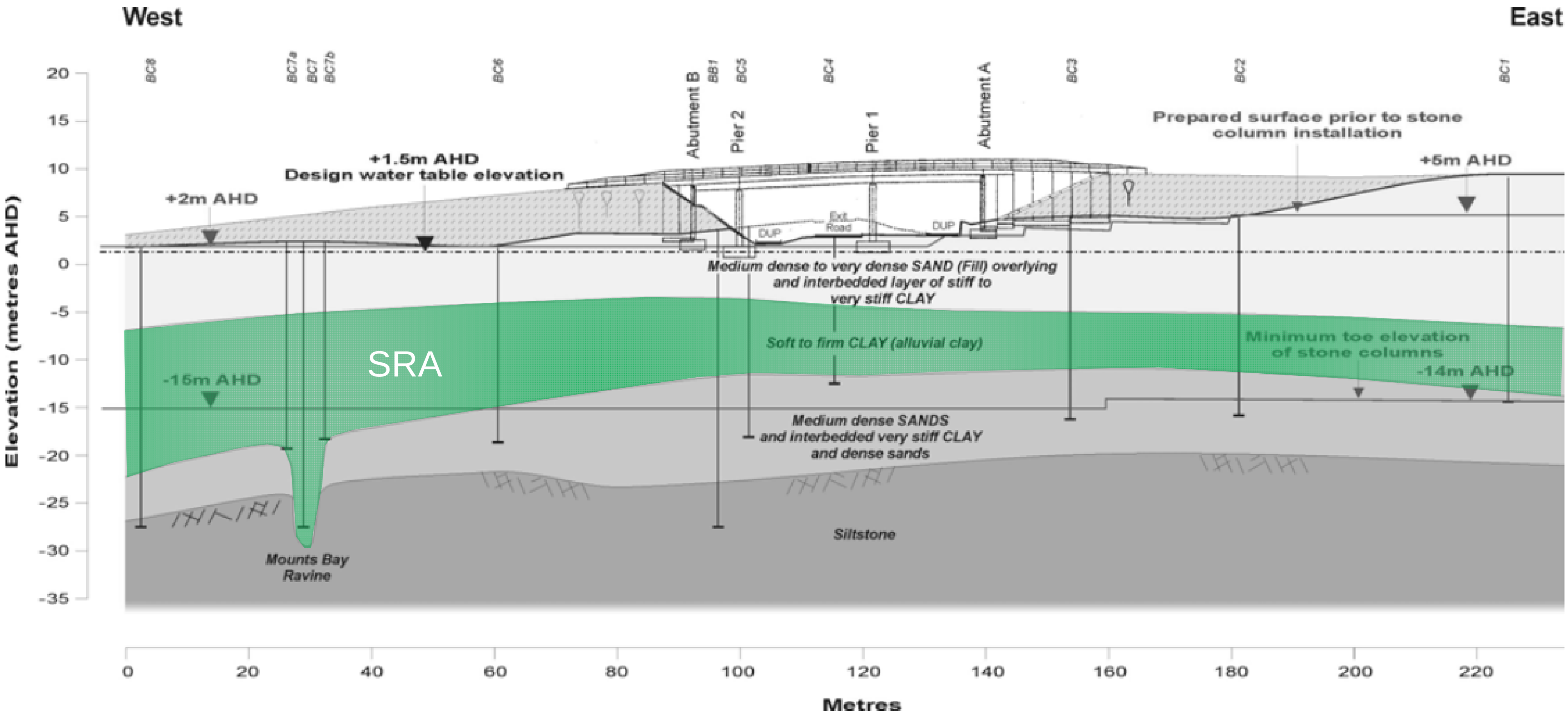
New Loop Bridge

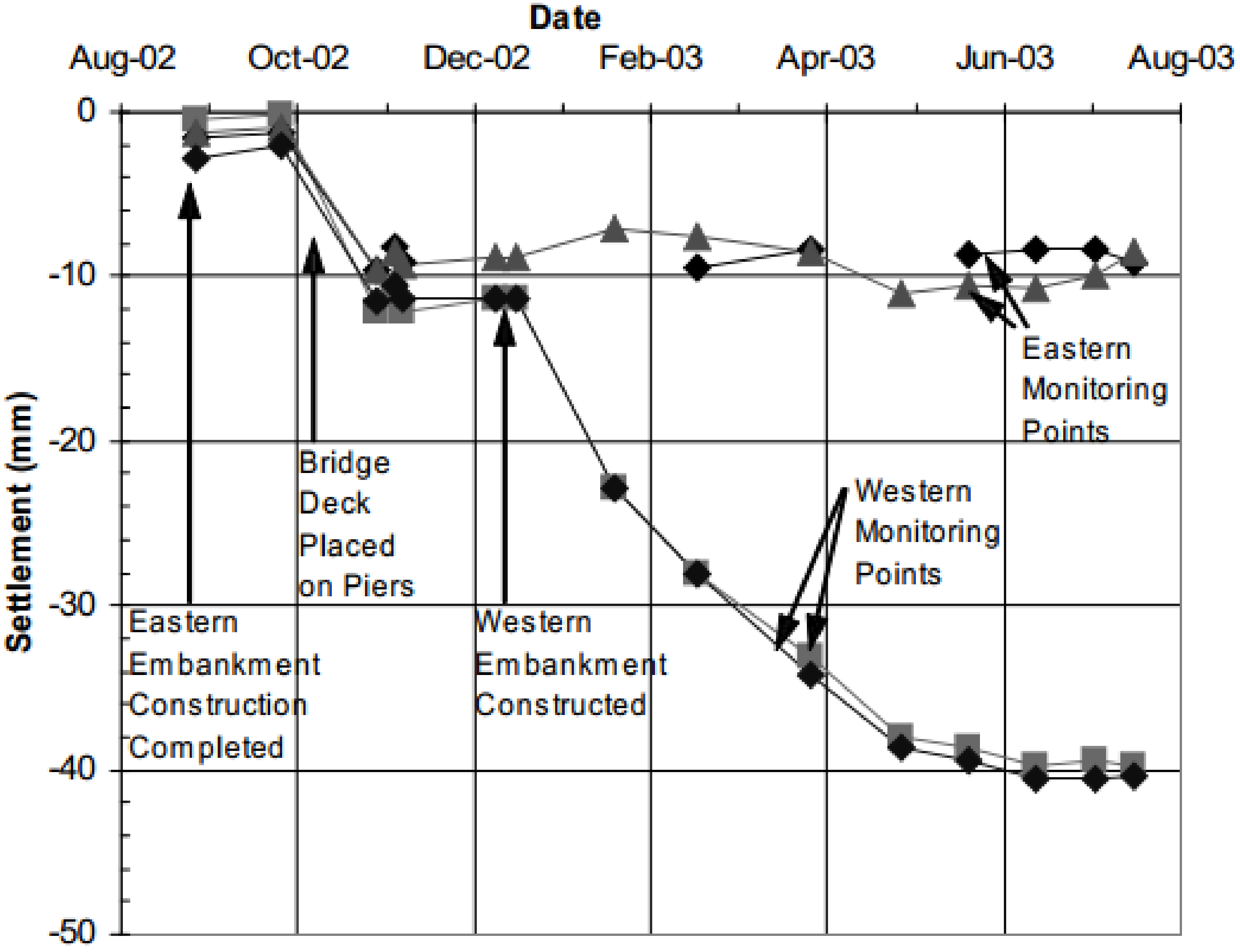
Bridge founded on pad footings.
Stone columns 0.8 m dia at 2.8 m spacing below abutments and 2.8 m to 4 m below embankments.

Wardrop and Pennington (2003)



New Loop Bridge

Wardrop and Pennington (2003)



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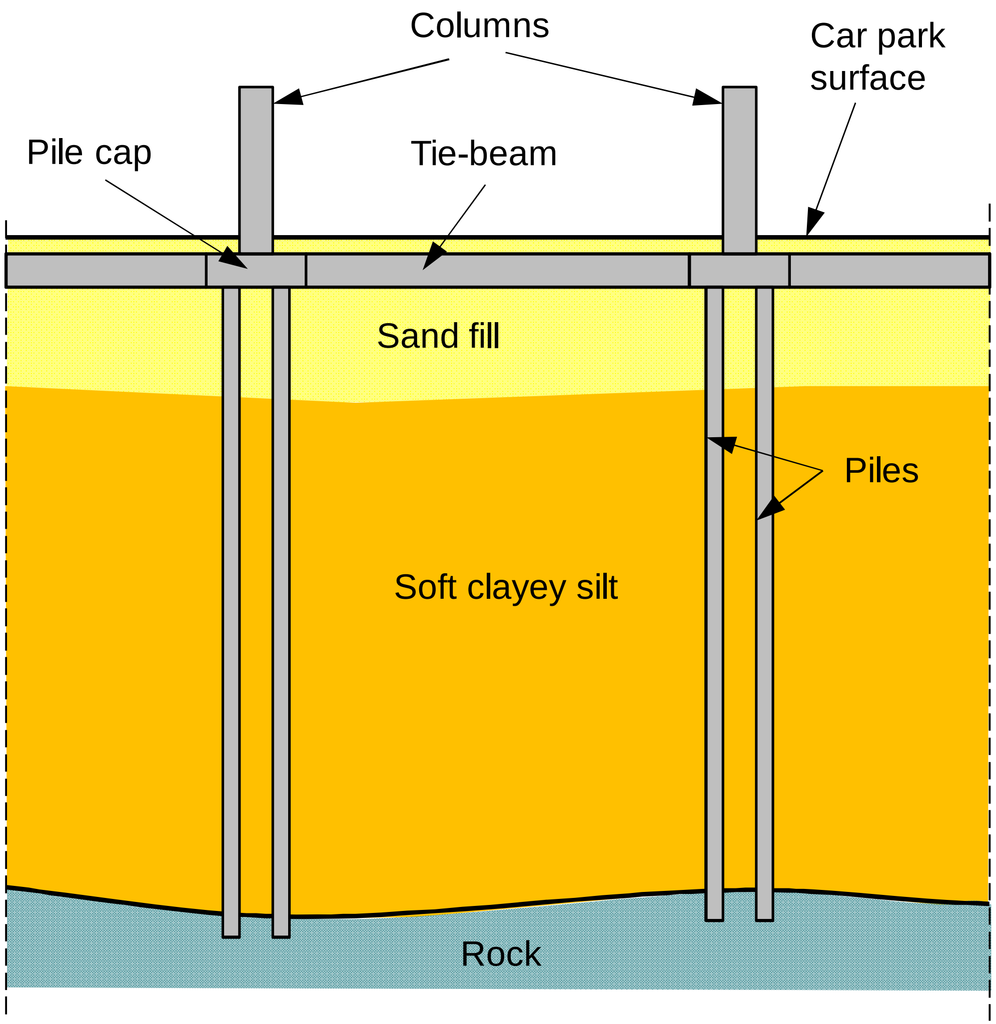
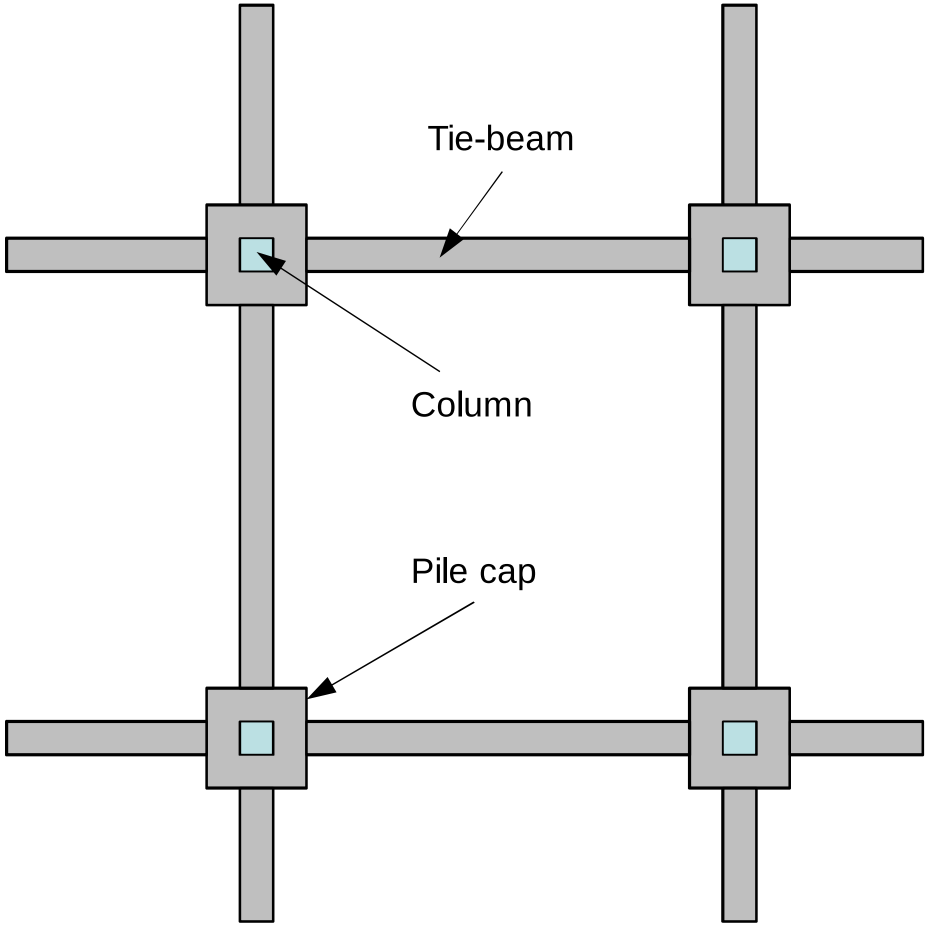
Bumps in Car Park Surfacing

Foundations Below Car Park



Subsurface Section

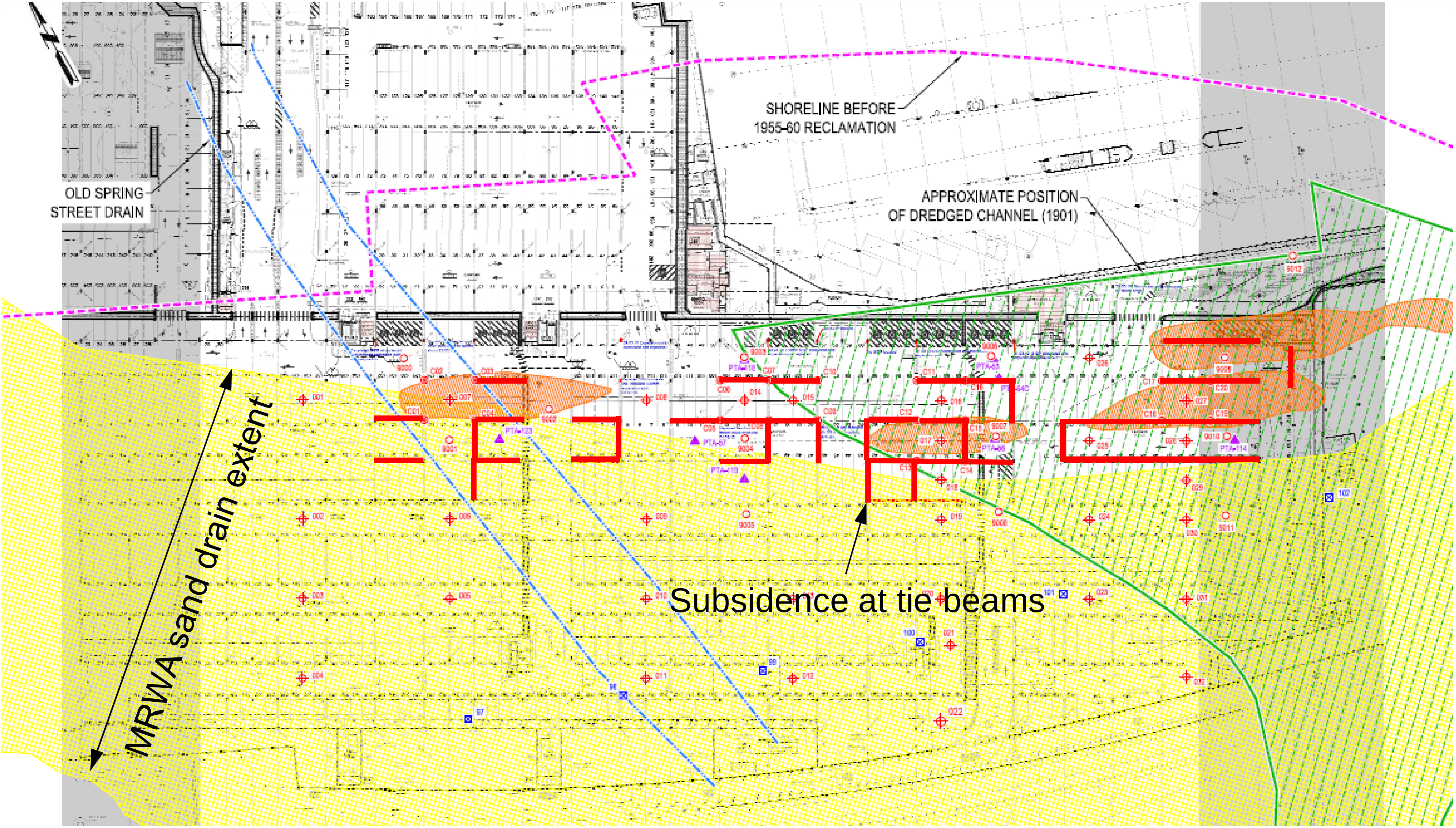


Plan of Foundations

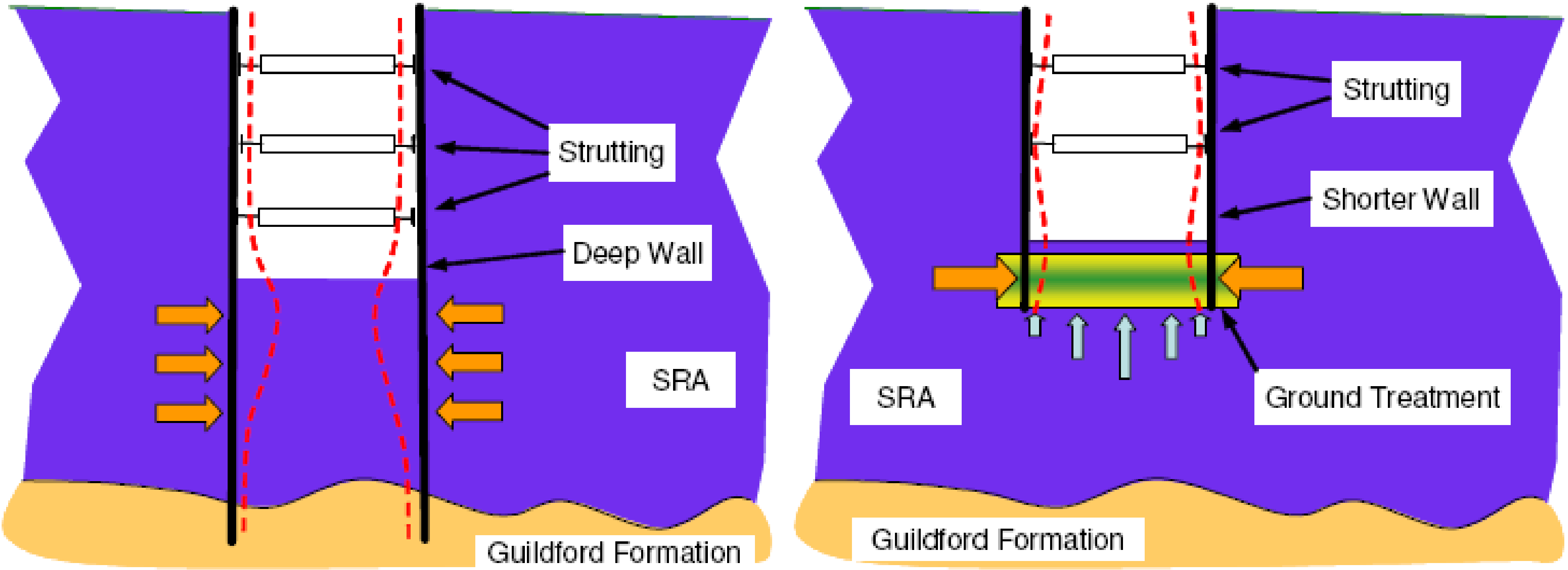
Effects of Settlement

- Resurfacing of the settlement affected areas, placement of an asphalt overlay and replacement of concrete paths
- Re-profiling of the asphalt surface at high points over the top of the tie-beams
- Injection of urethane to fill voids beneath the tie-beams as the ground settled away below the beams
- Repairs to in-ground services: fire hydrant water pipes, main sewer.

Historical Features & Areas of Subsidence



New MetroRail Project

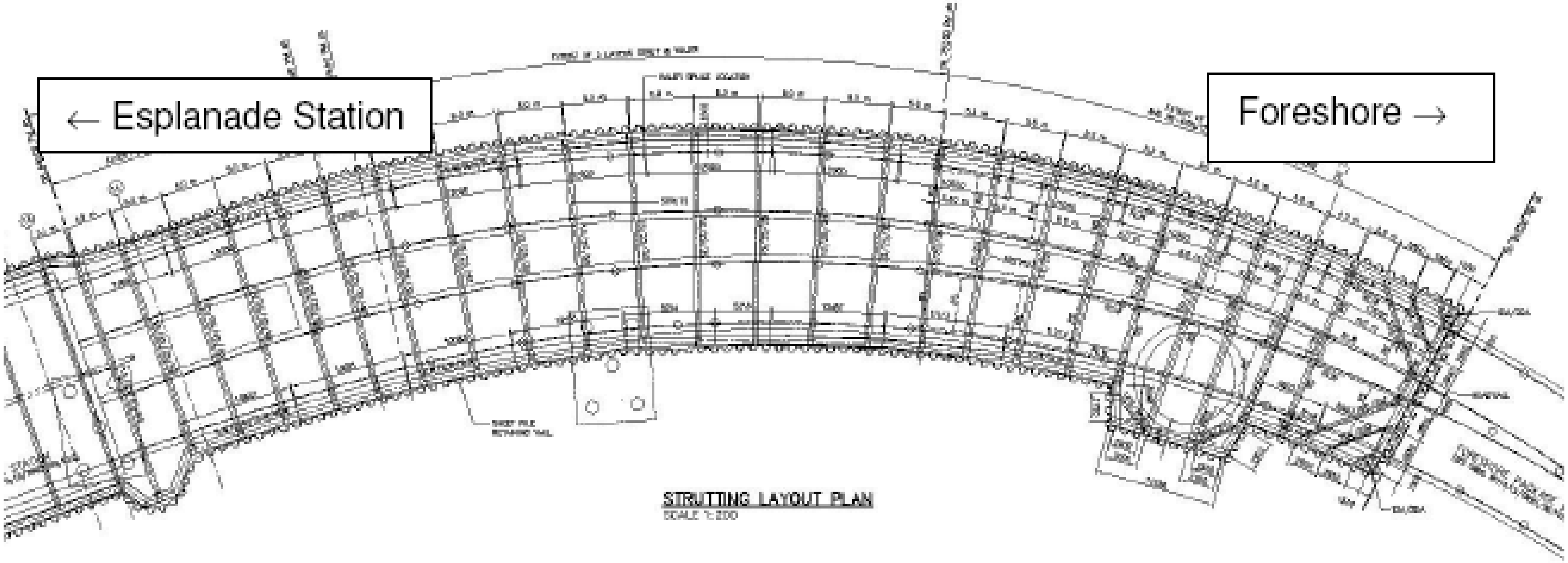


(a) Deep Wall – No ground treatment

(b) Short Wall – Ground treatment

Sigl et al.(2007)

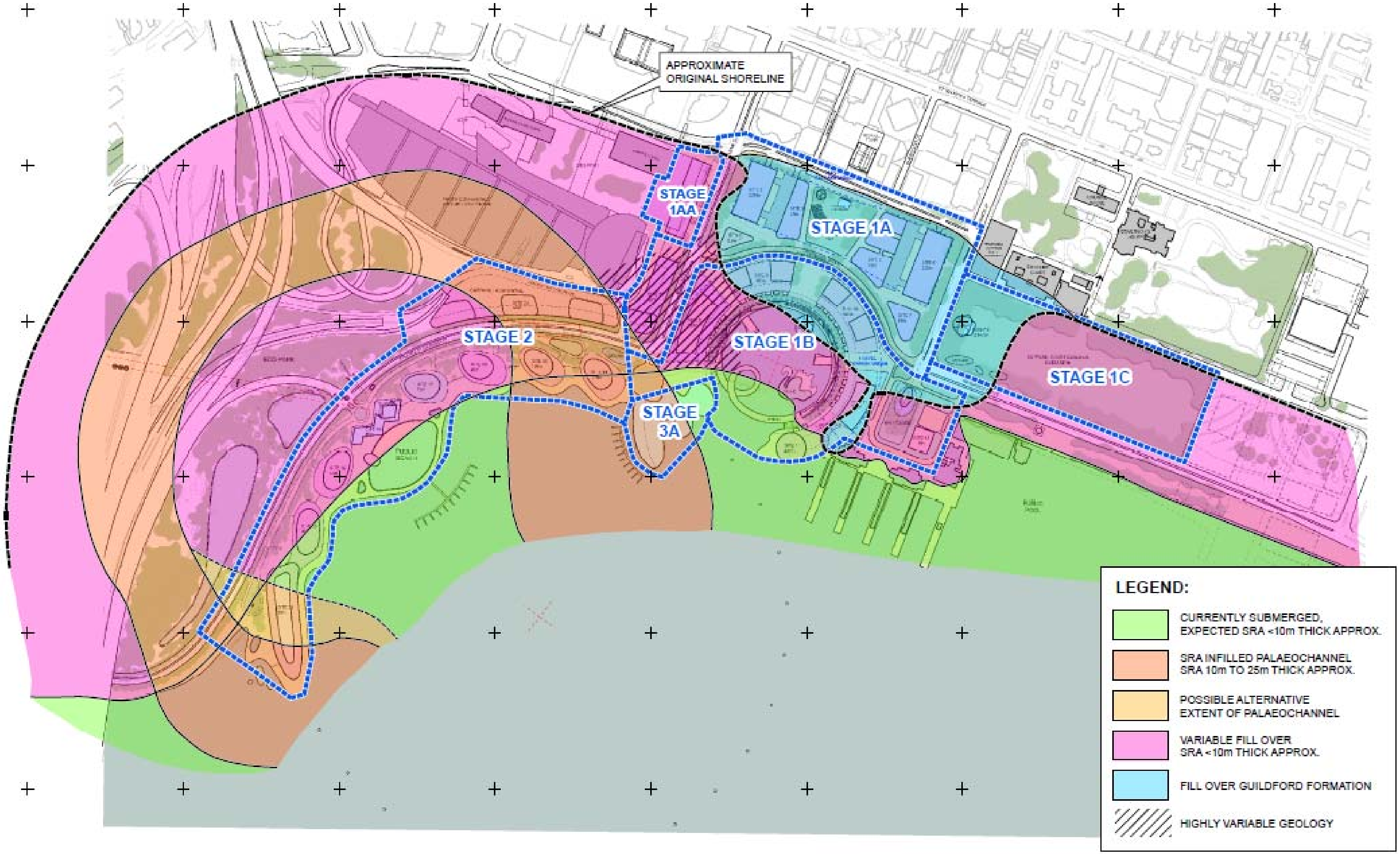
New MetroRail Project



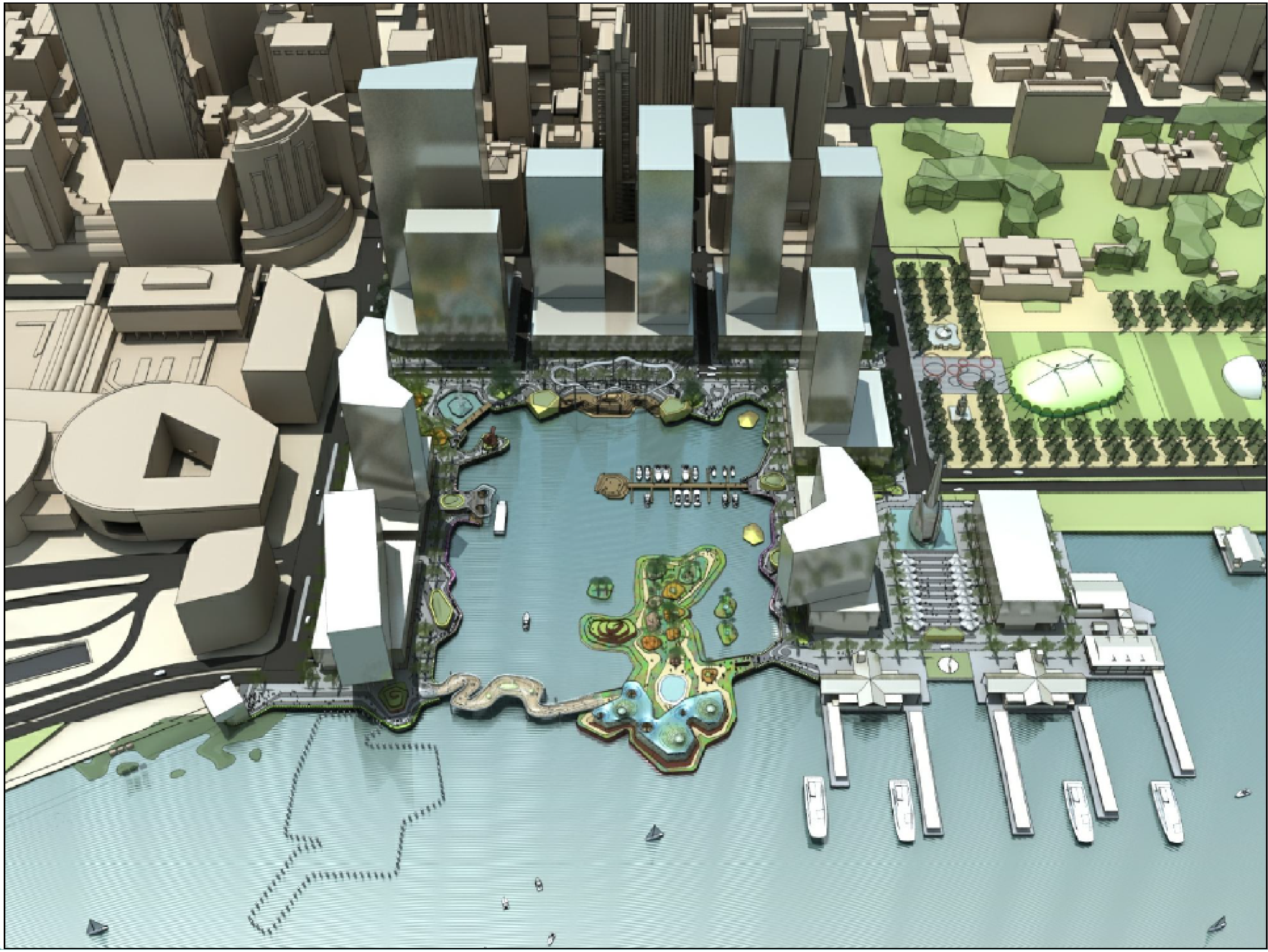
Sigl et al.(2007)

Elizabeth Quay Master Plan 2007

Planning Level Investigation – 2008



Revised Master Plan – 2010



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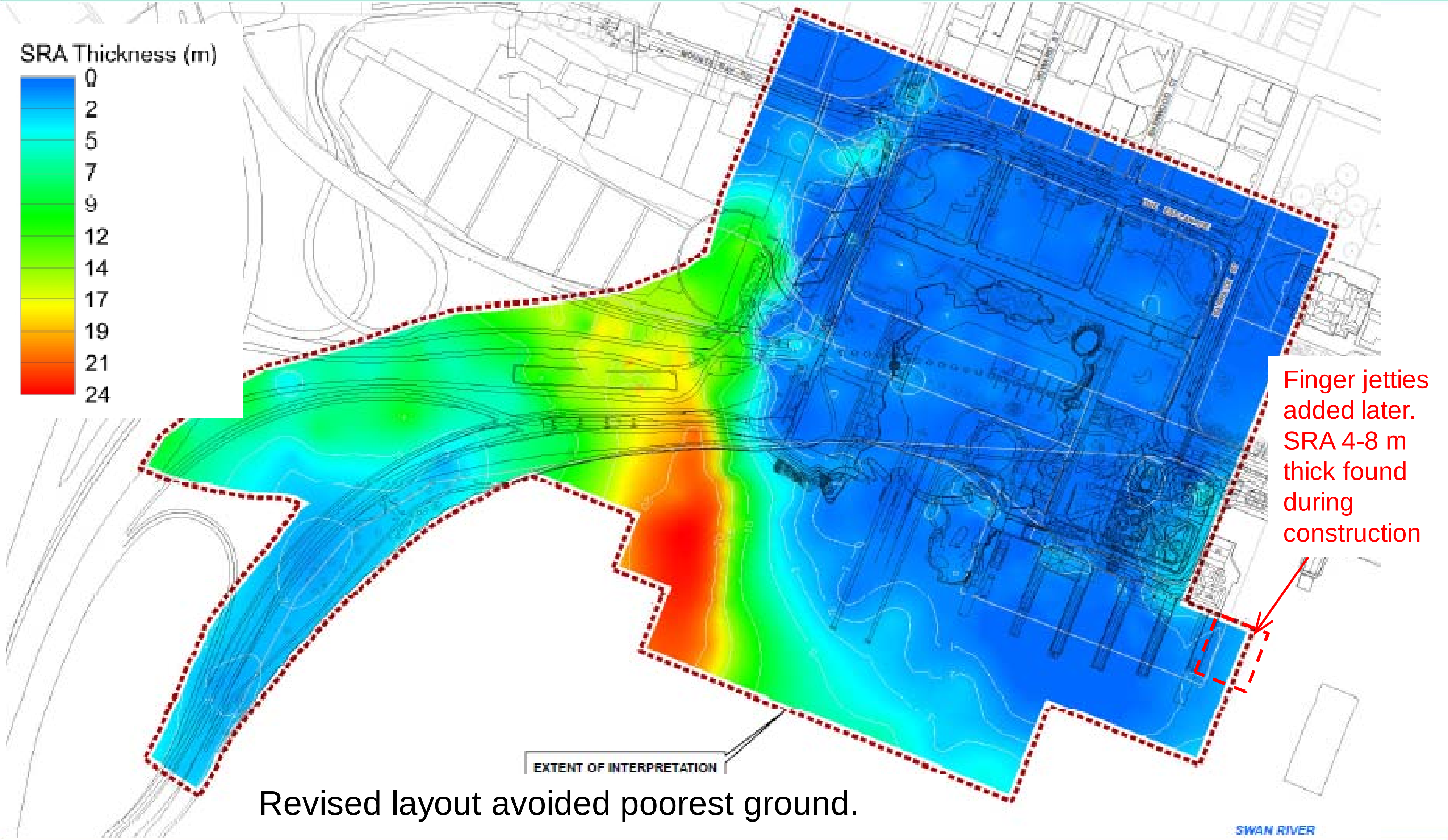
Detailed Investigation – 2010



Revised layout avoided poorest ground.

Section 3

The Causeway and Burswood

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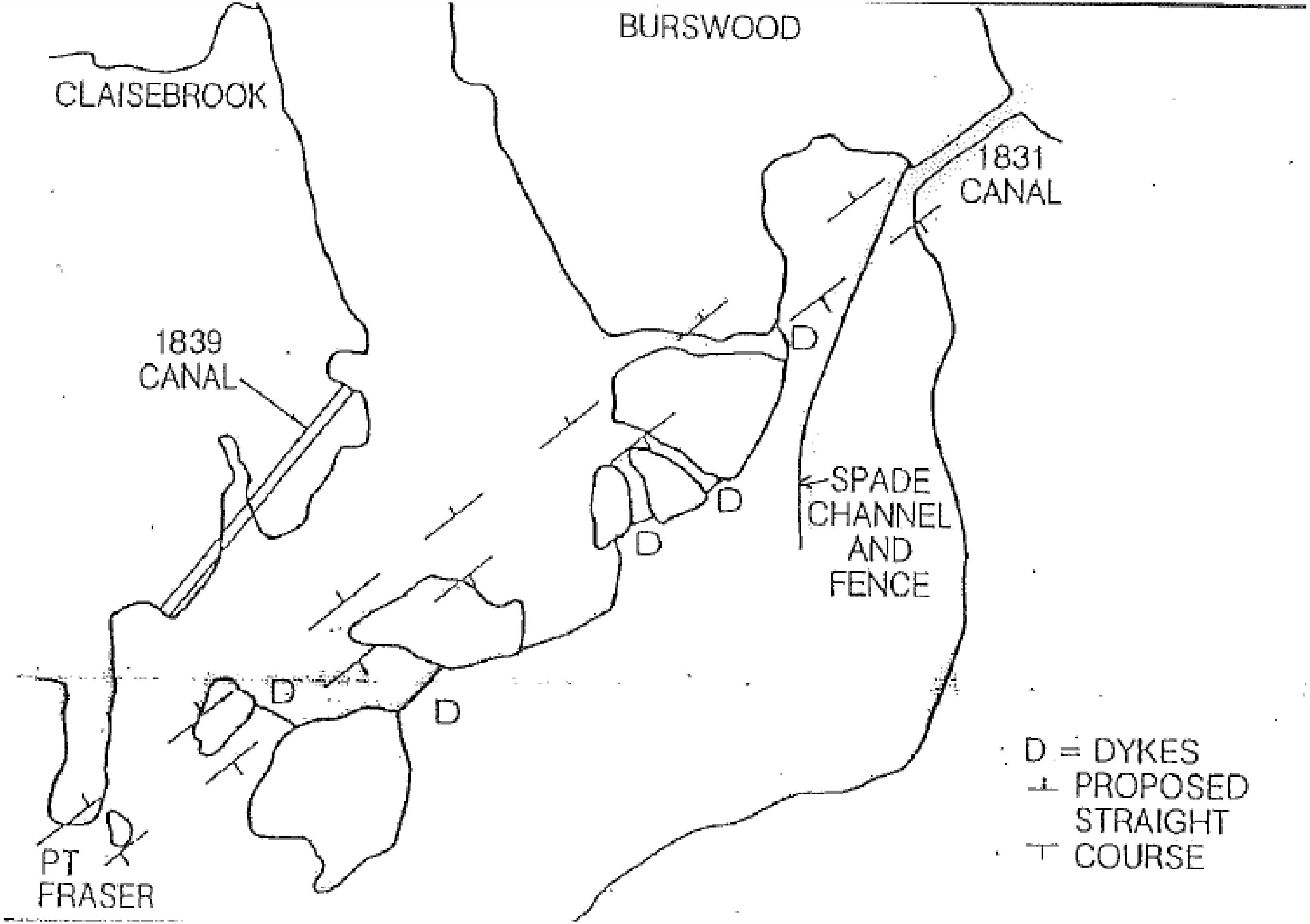
Causeway and Burswood – 1839



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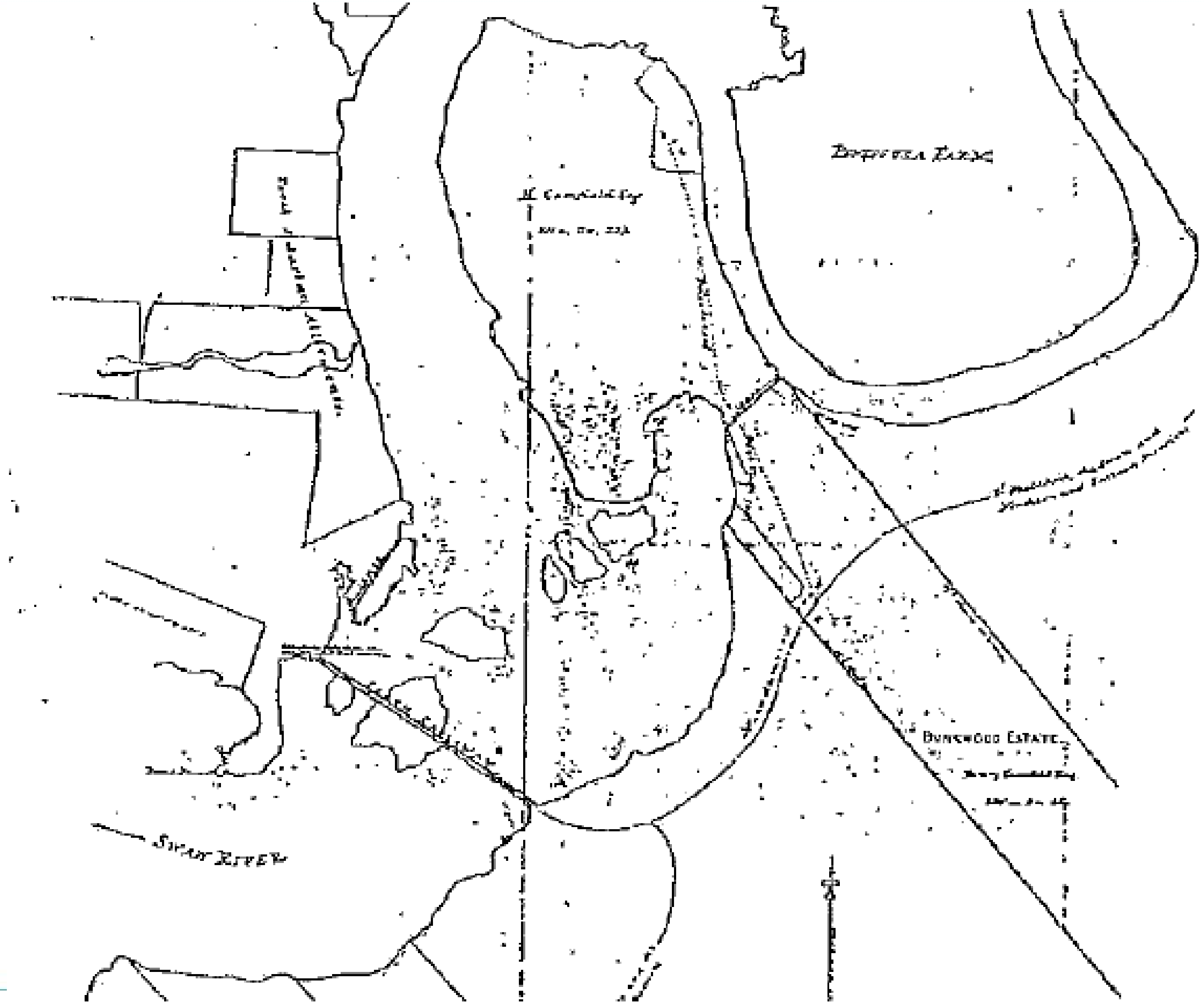
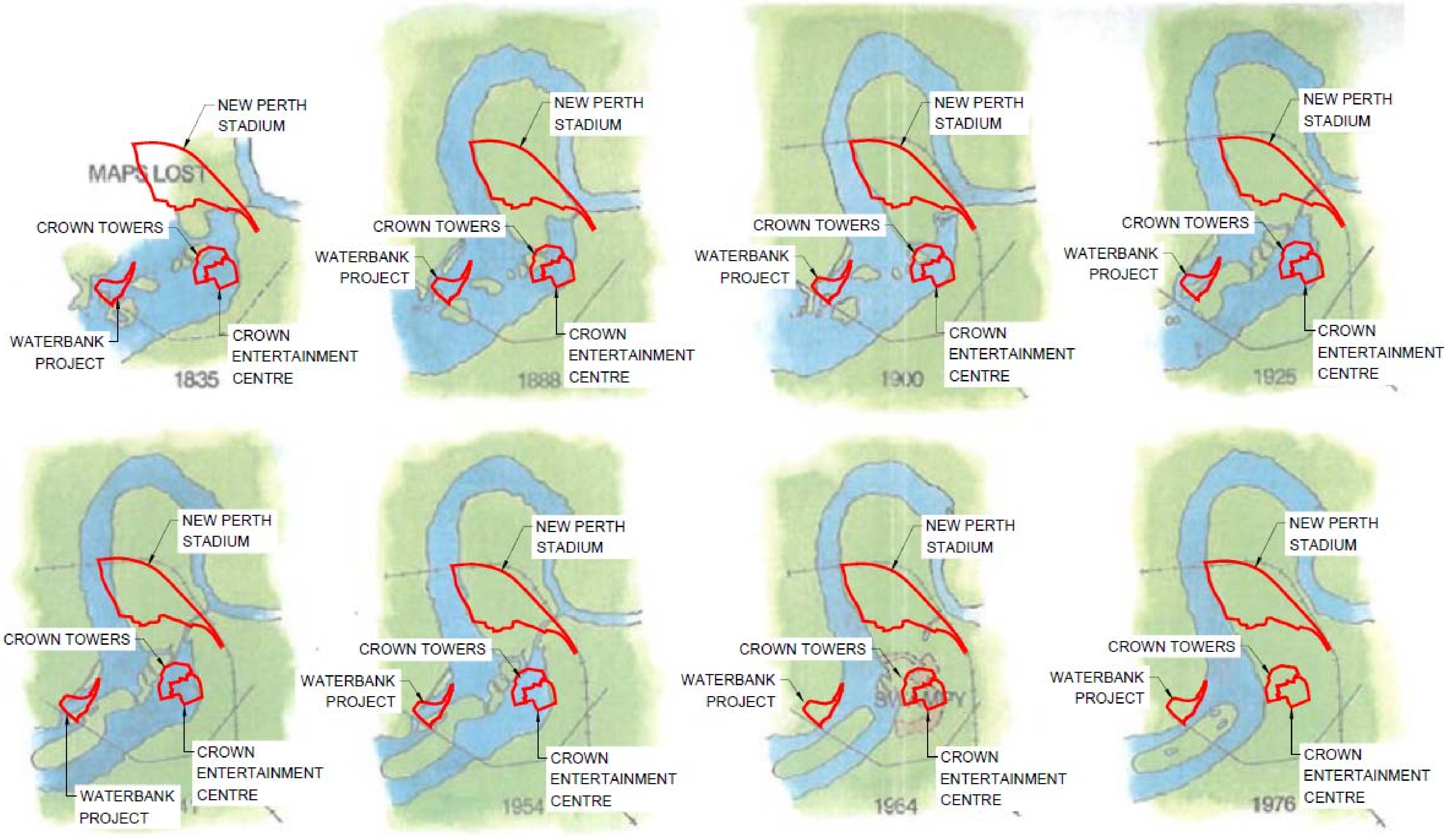
Causeway and Burswood – 1851



Causeway and Burswood



Causeway Bridge No. 1

Perth's first bridge opened in 1843. It became weakened by heavy use and was almost completely submerged by the 1862 floods.

1/5 First Bridge over the Causeway. Battye Library [012233D]

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Causeway Bridge No. 2

A new Causeway was built and the opened in 1867. This second Causeway was made up of three bridges. Lack of funds meant that the bridges were structurally quite weak, uneven and narrow.

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Causeway Bridge No. 3

The current bridge was built upstream of the previous bridges in conjunction with the new channels and reclamation taking place as part of the Swan River Improvement Act 1925.

The Causeway bridges were constructed over the five year post war period during which time it was difficult to find the funds required. The two bridge structure meeting at Heirisson Island was finally completed in 1952.

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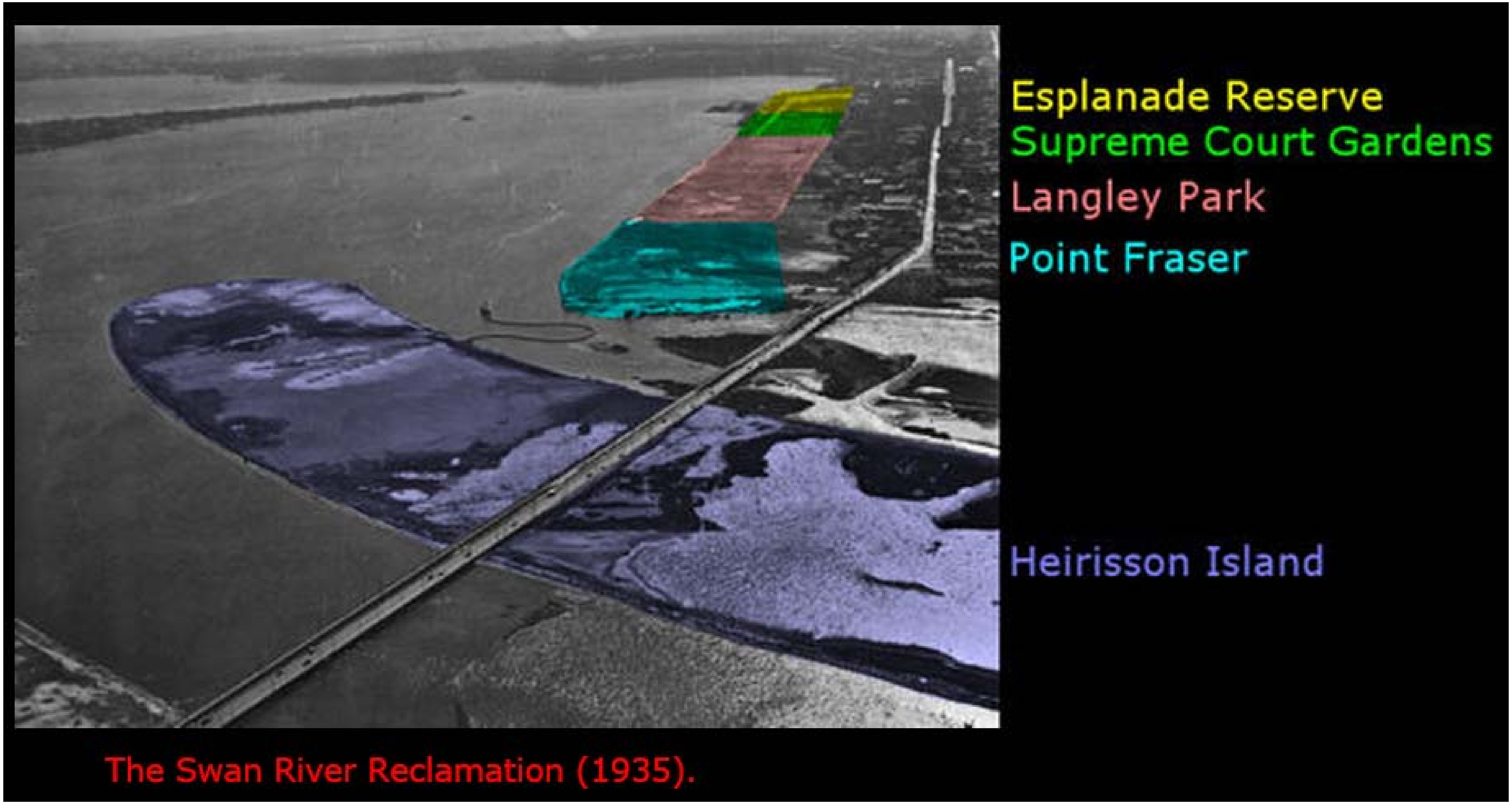
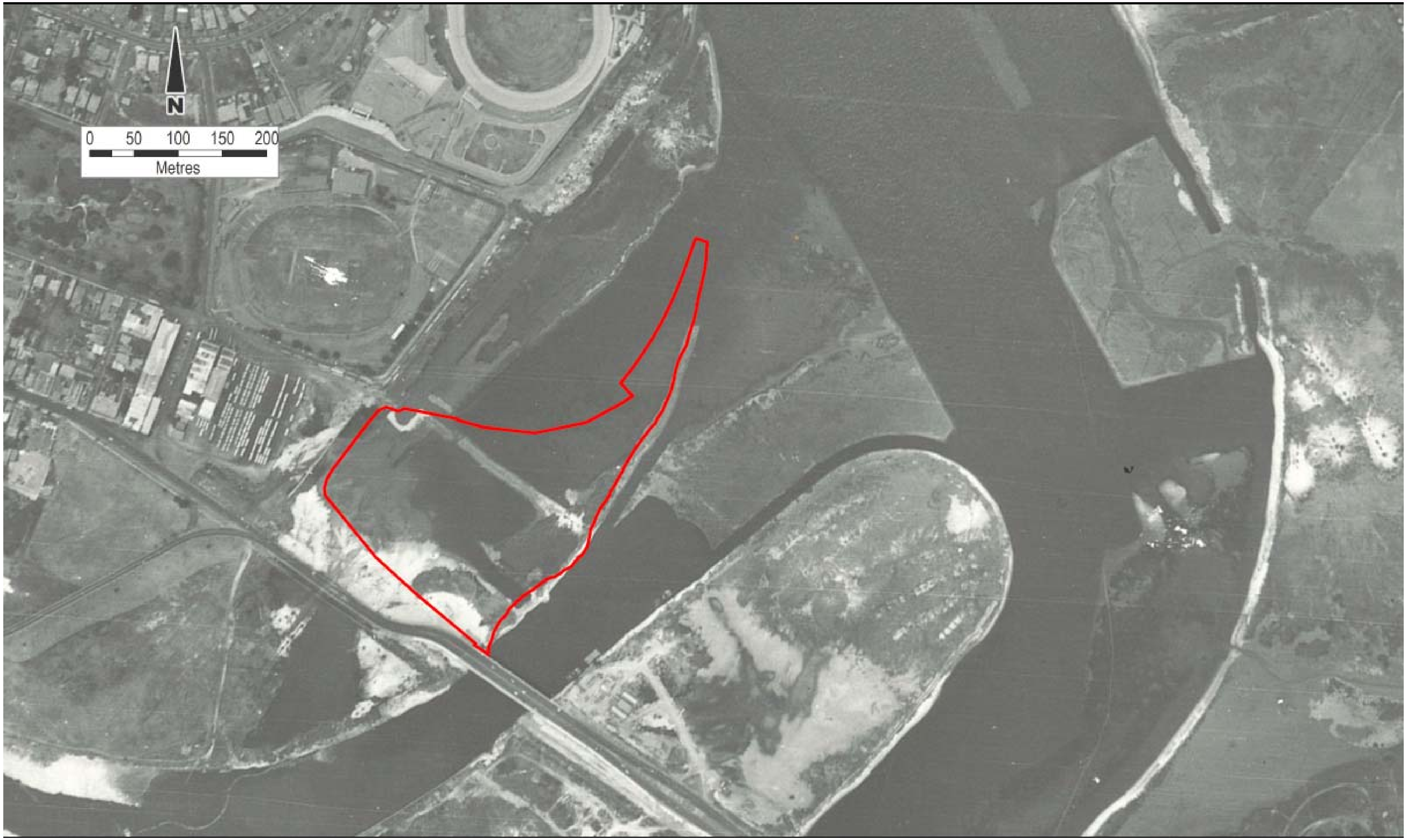
Reclamation Works – 1935



http://www.lifeonperth.com/swan-river-reclamation.htm

Reclamation Near the Causeway - 1953



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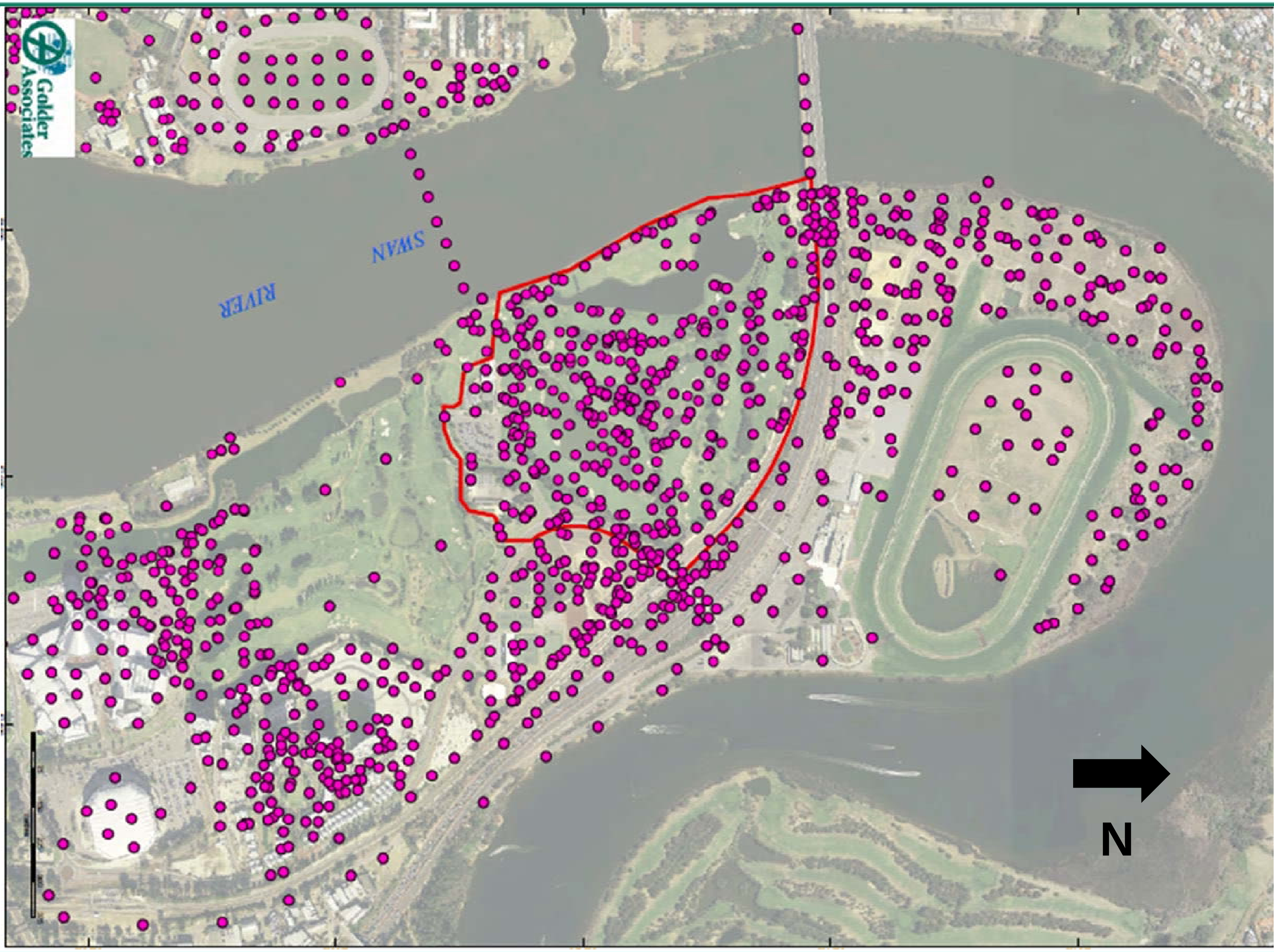
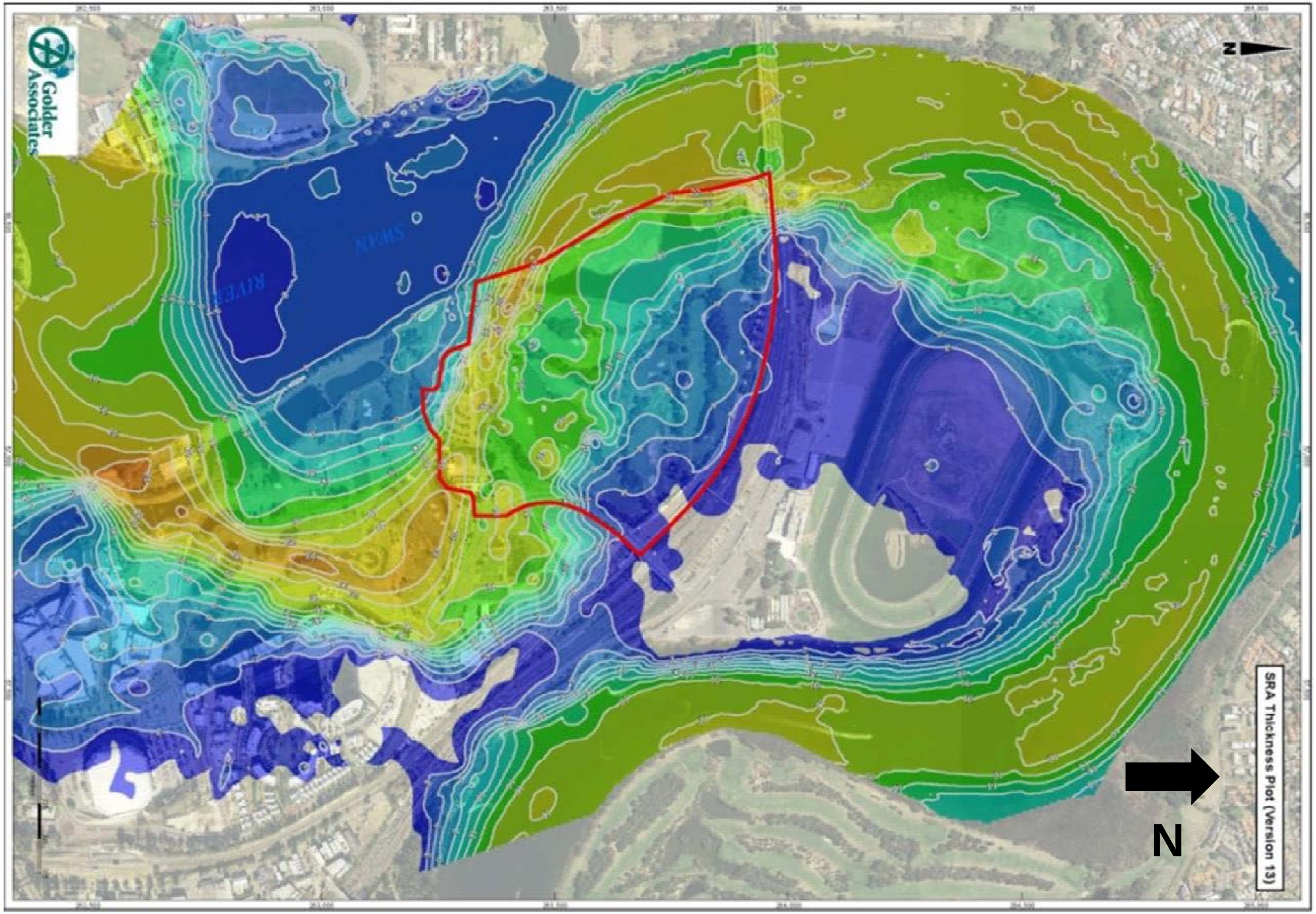
Obstructions in Reclamation Materials

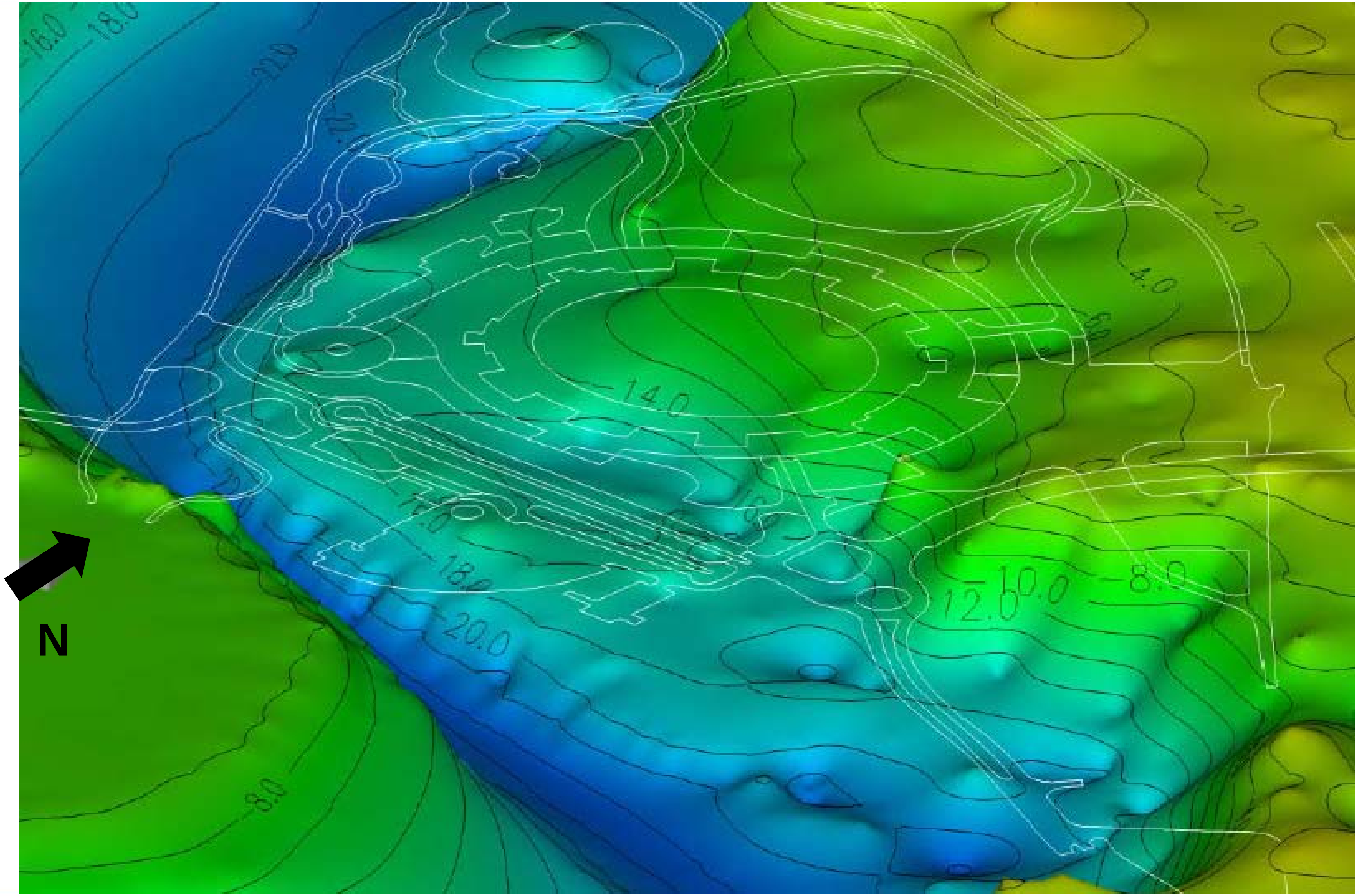
Burswood Peninsula Investigations



Burswood SRA Thickness



Base of Palaeochannel



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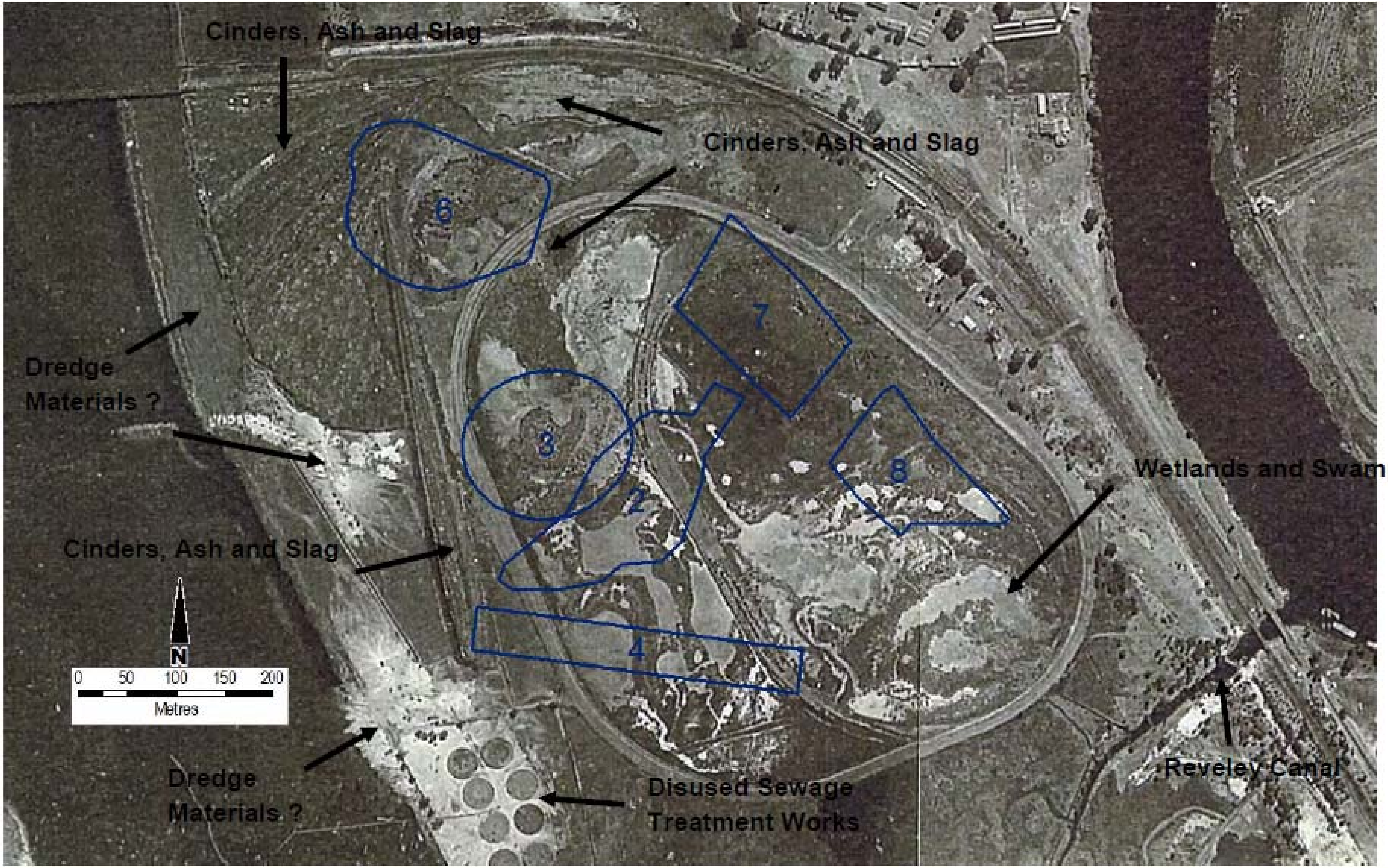
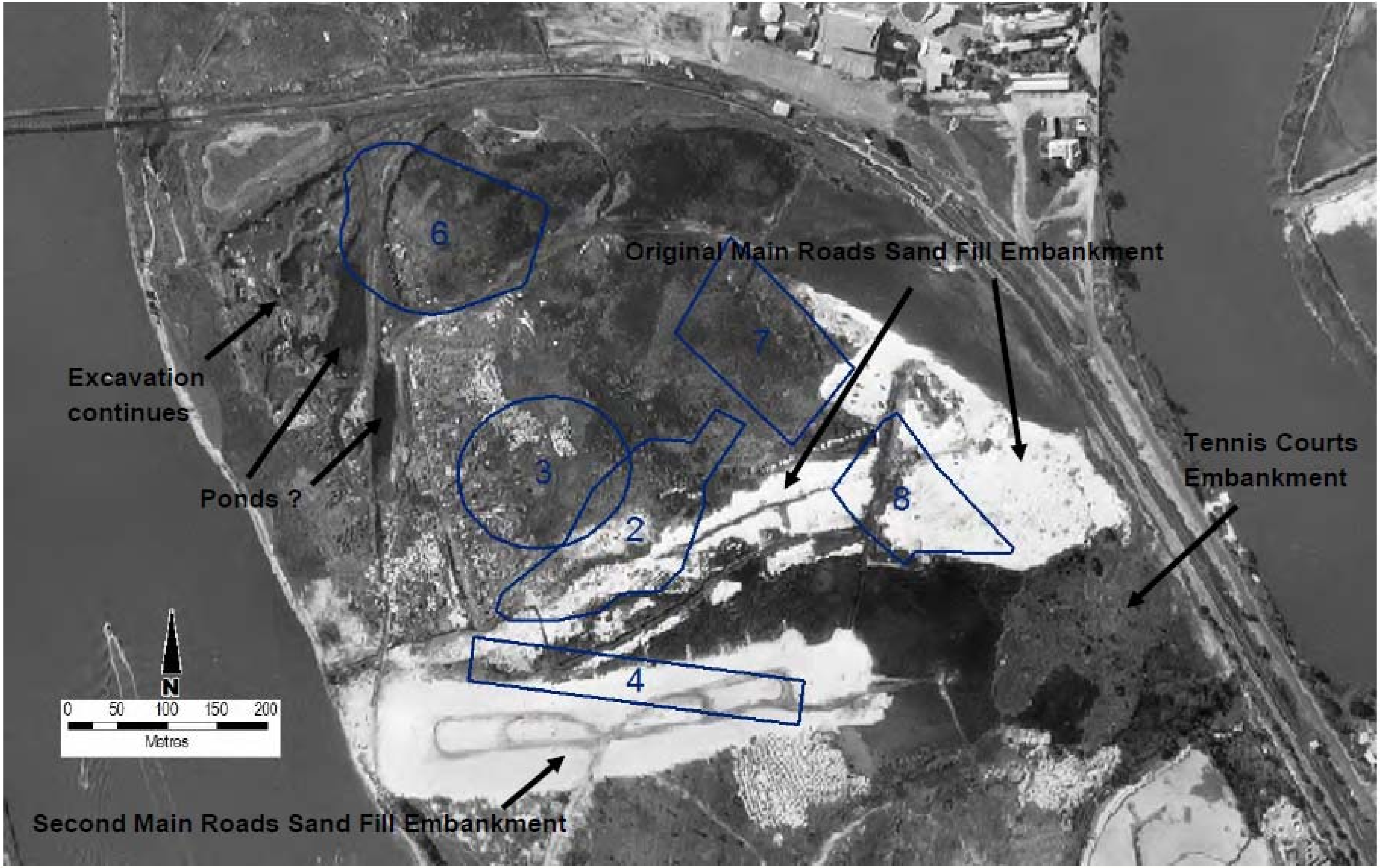
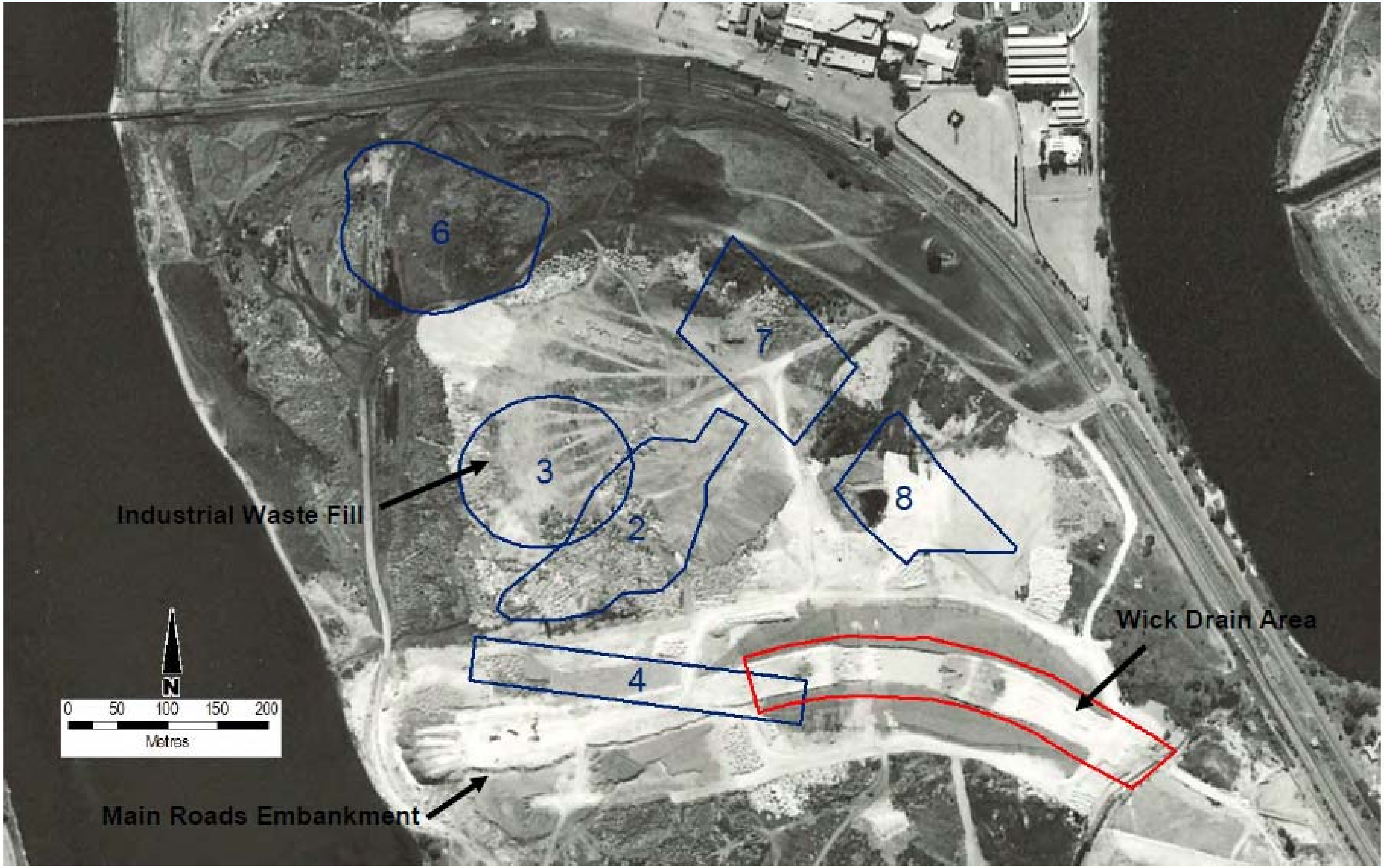
Burswood – 1948



Burswood – 1974



Burswood – 1985



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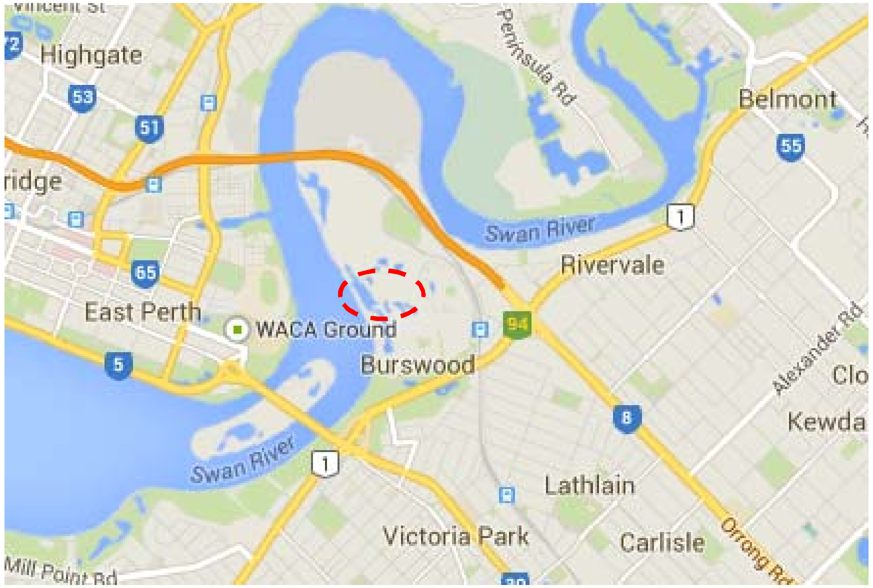
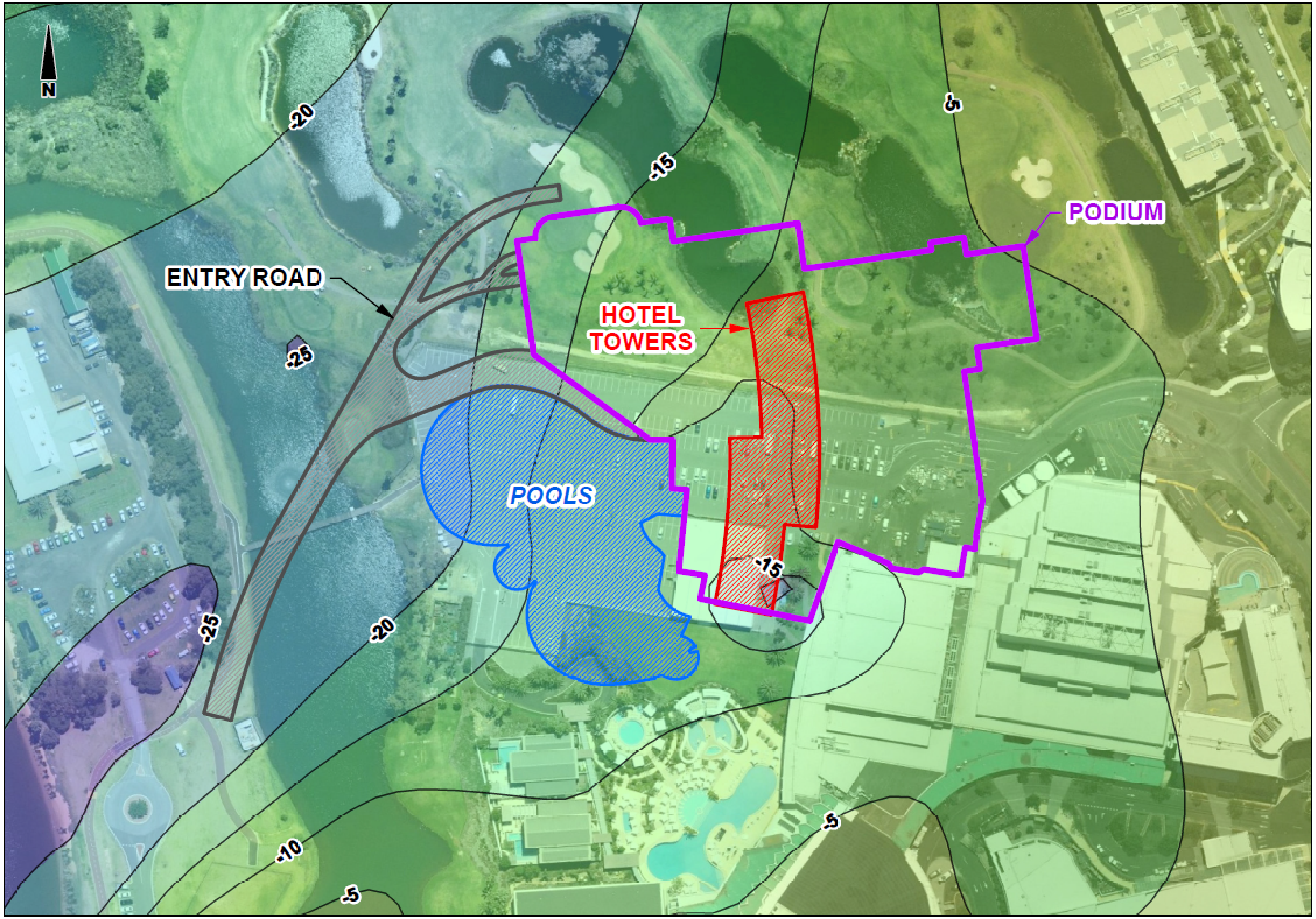
Burswood – 2012

Crown Towers Perth

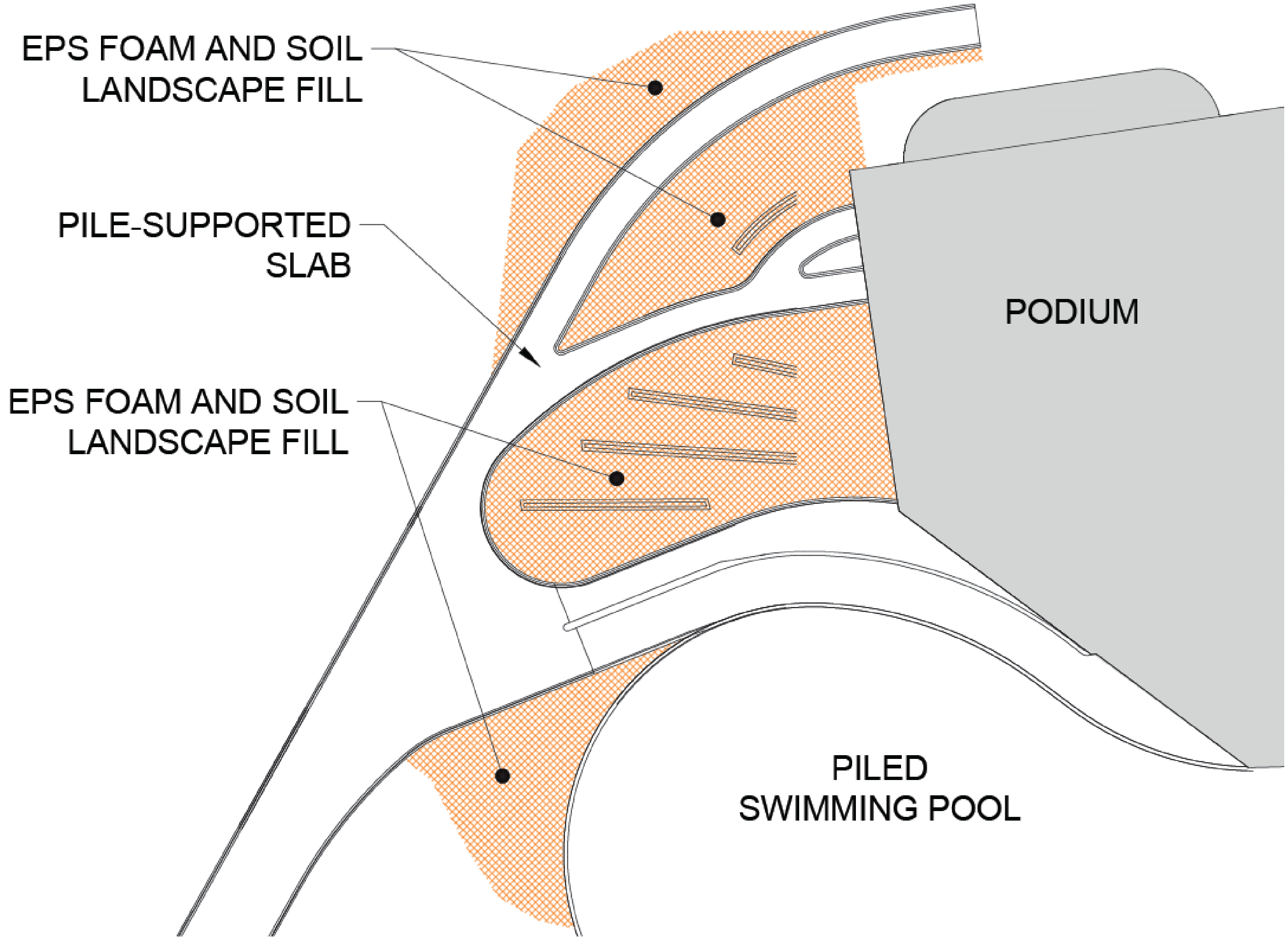
- 500 room 6-star hotel with 25 storey main tower
- Entry road rises from ~RL 2 m AHD on Camfield Drive, crossing an existing lake
- Elevated porte cochere at RL 7 m AHD
- Swimming pool



Crown Towers Perth – Level of Base of SRA



Entry Road Support



Crown Towers Perth

Geotechnical issues addressed in design and construction include:

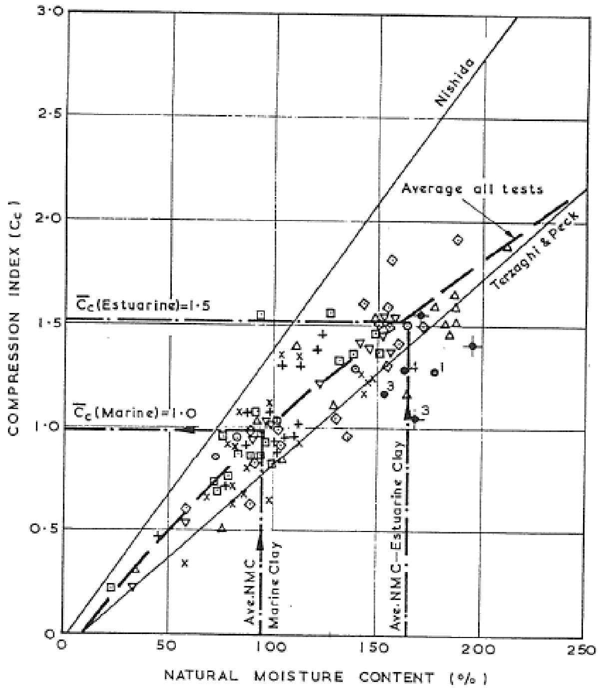
- Tight approvals and construction program
- Poorer subsurface conditions than remainder of complex
- Thickness of SRA varies from about 5 m to 25 m
- Previous landfill
- Elevated entry road
- Weaker zone at top of Mullalloo Sandstone in parts of site
- Support of services below piled ground slab

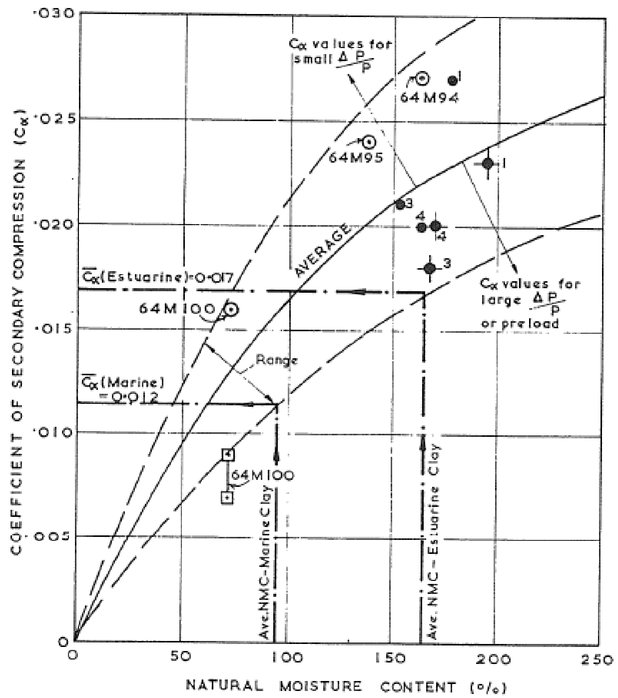
Section 4

Design Parameters

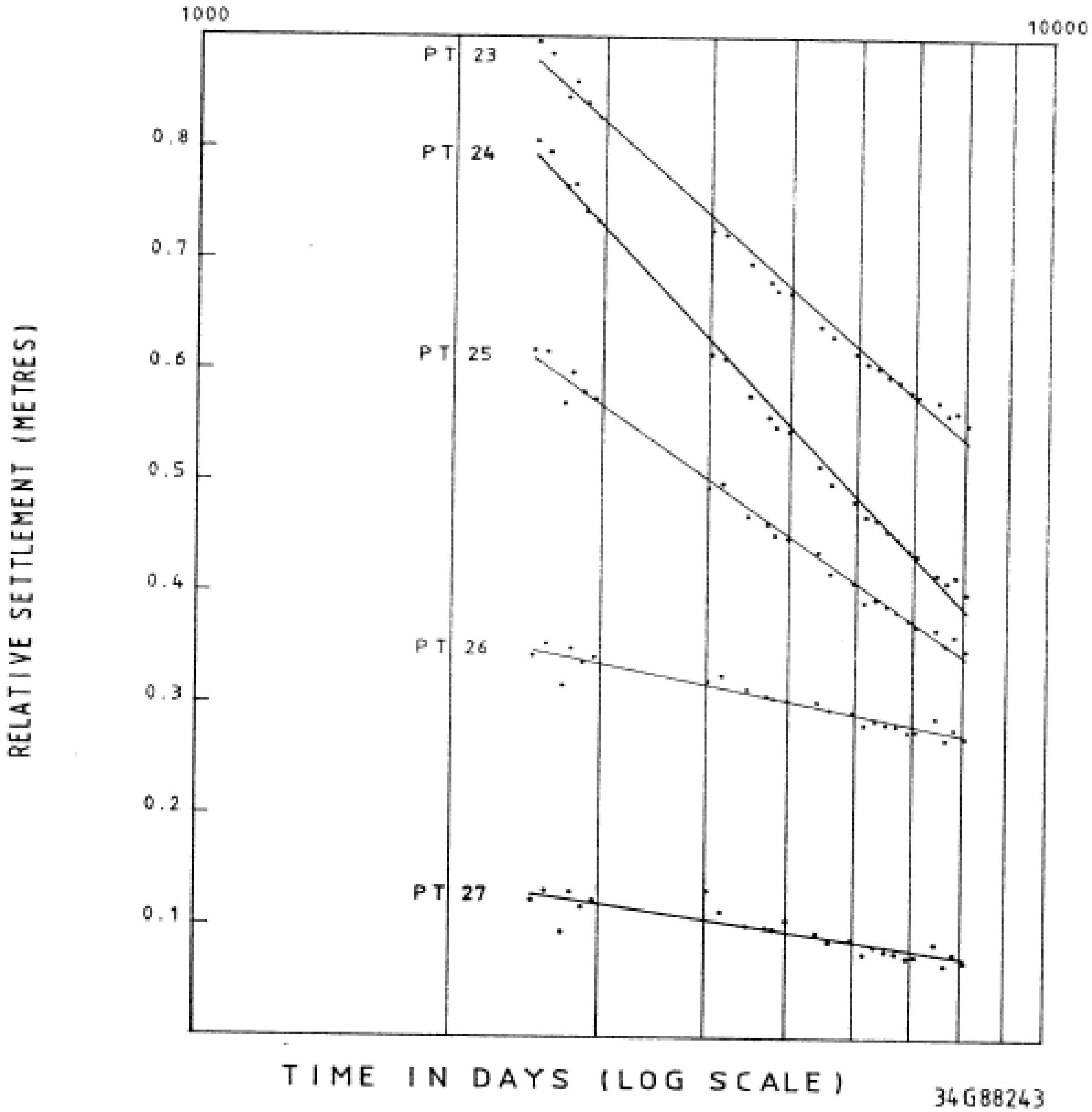
SRA Parameters – Narrows Interchange

Zone	Origin and Fossils	Compression Index, C_c	Coeff. Of Consolidation, c_v
Upper: Above ~RL -10 m to RL -13 m	Estuarine, shells and shell fragments, abundant worm tubes, significant fossil content	1.0 to 2.0 Average = 1.5	0.35 to 0.85 m^2/yr
Lower: Below ~RL -10 m to RL -13 m	Marine, change in type of fossils, quieter water during deposition, fossil species still live in Cockburn Sound today	1.0 to 0.7 decreasing with depth	0.25 to 0.35 m^2/yr





Narrows Interchange Measured Creep Settlement



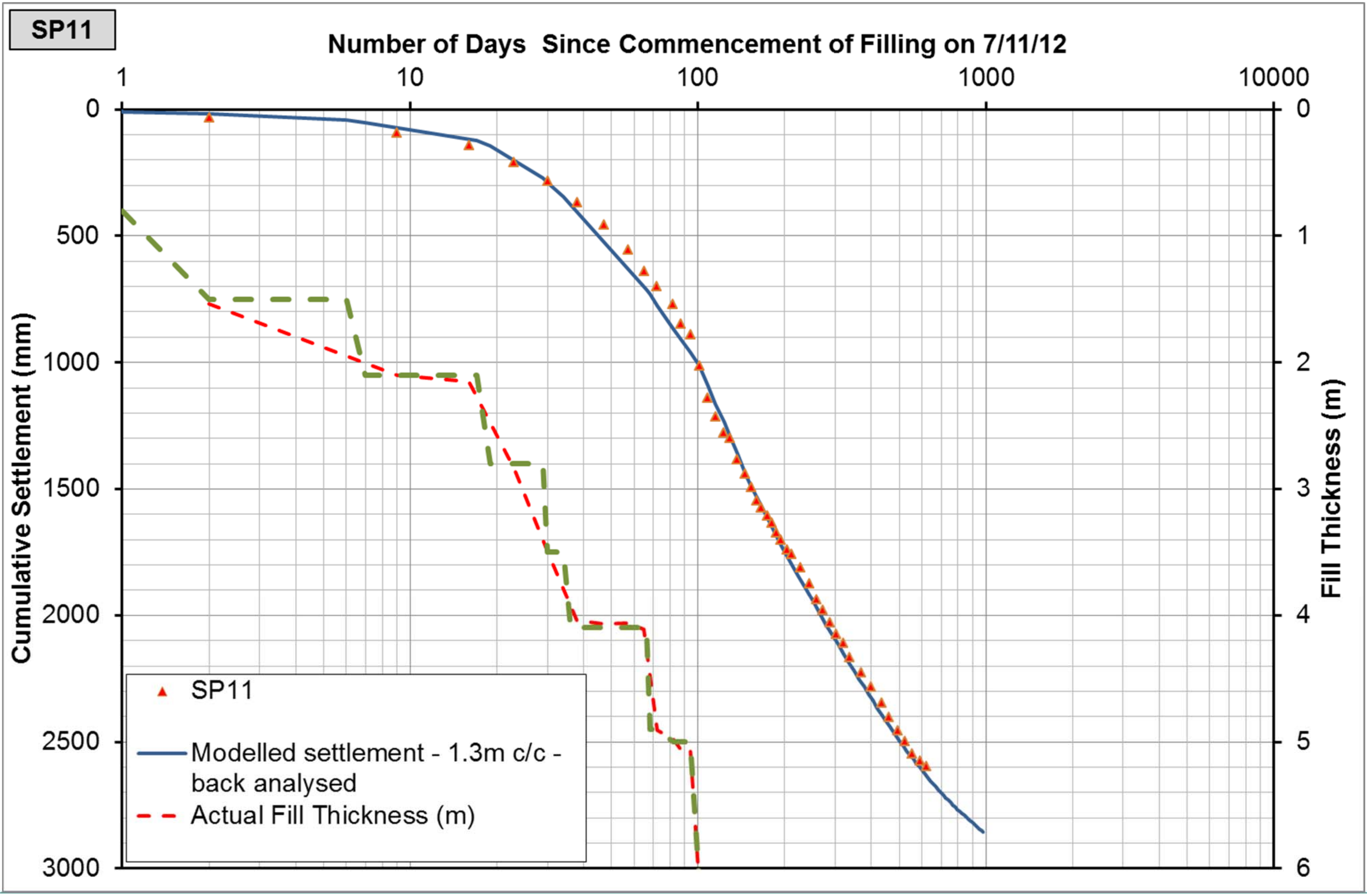
Wagner and Cray (1989):

110 settlement stations back-analysed giving $C_{\alpha\varepsilon}$ average = 0.024.

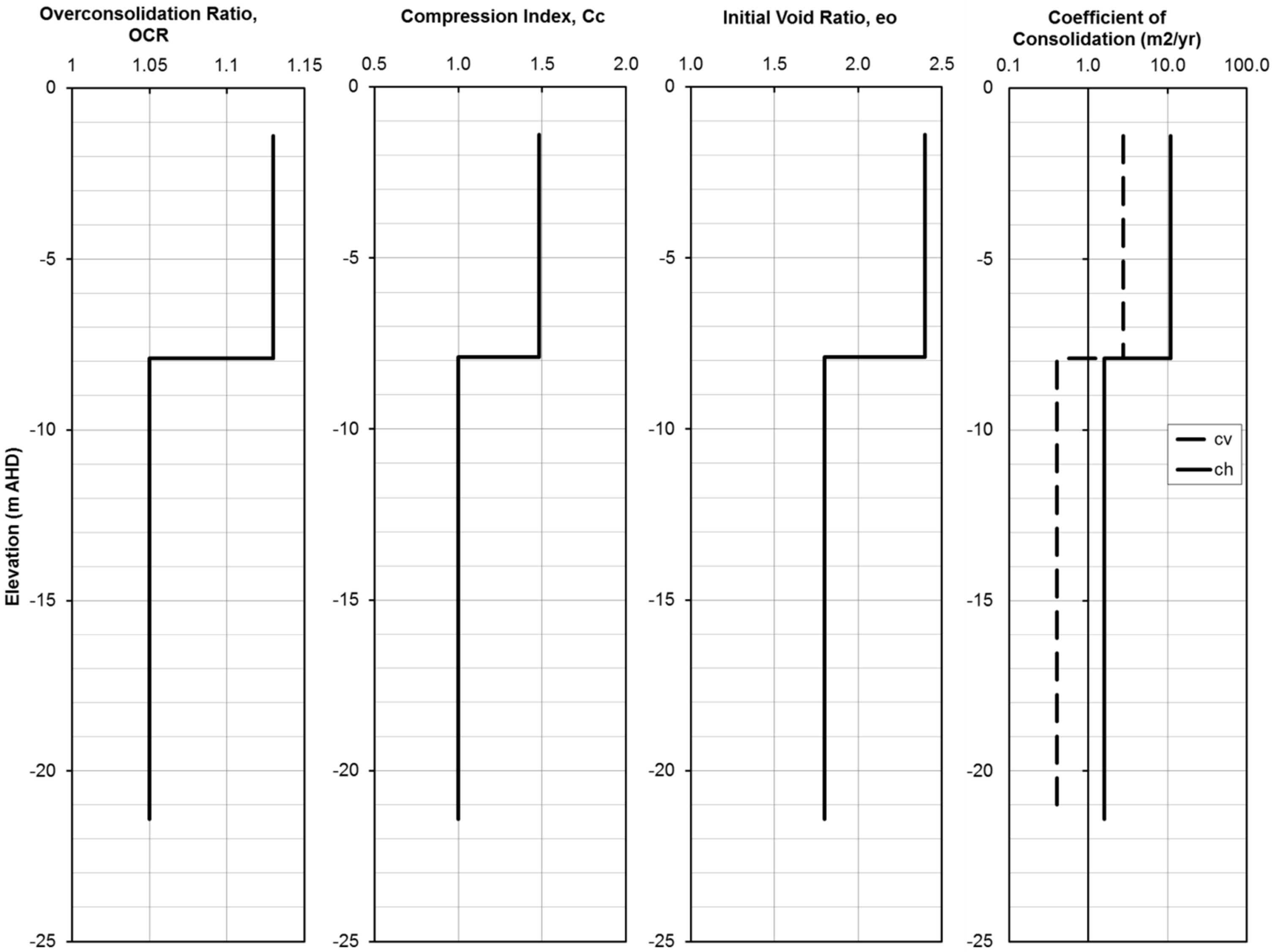
Similar range of $C_{\alpha\varepsilon}$ values were found in laboratory tests.

During the design stage (1960's) the laboratory $C_{\alpha\varepsilon}$ values were thought to be high and it was hoped that much of the secondary compression would occur during primary consolidation.

Waterbank Back Analysis



Waterbank Back Analysis



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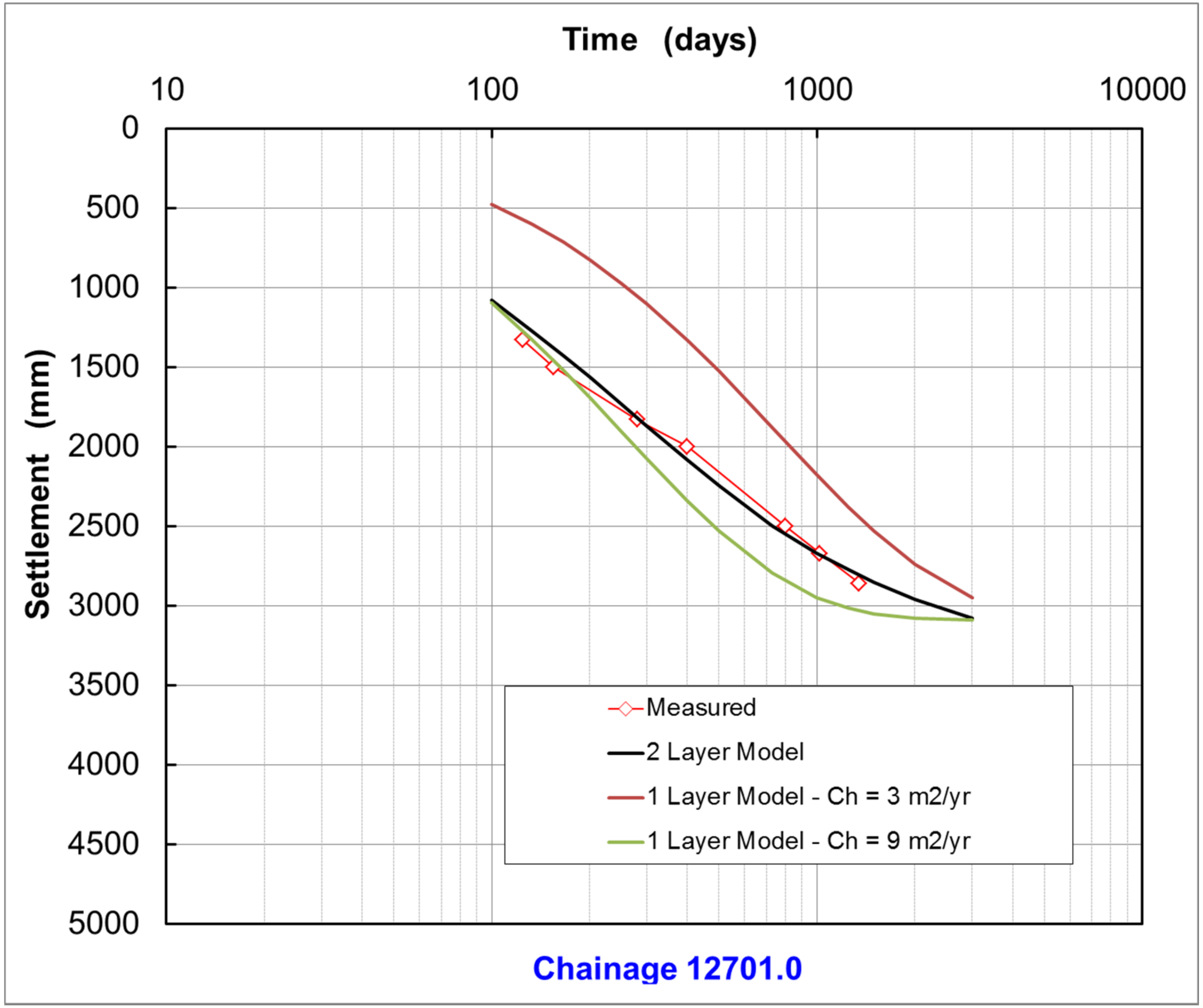
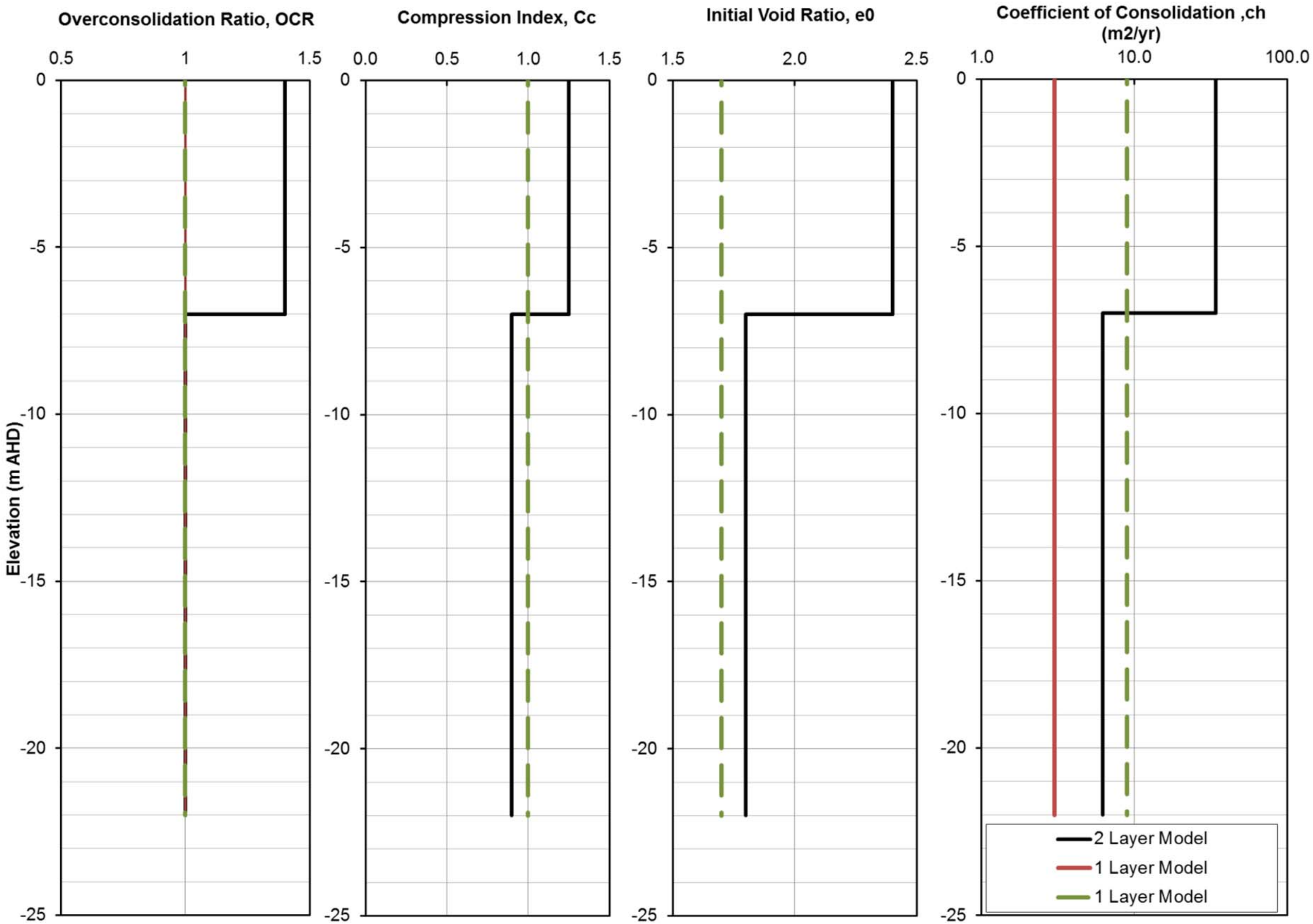
MRWA Abandoned Alignment – Burswood



MRWA Abandoned Alignment – Burswood



Conclusions on Parameters & Analysis

- Site investigation data, back-analysis of settlement data and multi-level extensometer data provides clear evidence of:
  - Compression index reducing with depth
  - Permeability/coefficient of consolidation reducing with depth
- Overconsolidation ratio depends on site history
- Wick drains will not be vertical
- Combined effect of non-vertical drains and reduced permeability with depth can lead to slower consolidation
- Post-surcharge (i.e. post-construction) settlements can be significant and may be influenced by deeper slowly consolidating layer

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Section 5

Typical Issues and Solutions

Typical Geotechnical Issues

- Services damaged or drainage falls reversed.
- Steps between piled structures and surrounds.
- Differential settlement and deformation of surfacings.
- Drainage problems caused by uneven settlement.
- Foundation failure through soft soil.
- Horizontal soil movement loading piles and displacing structures.
- Deciding on performance criteria and acceptable maintenance.
- Changes to design or construction after investigation is complete.
- Corrosive conditions for piles

0.5 m Settlement Below a Piled Slab

Differential Settlement

Settlement Around Deep Bore Casing

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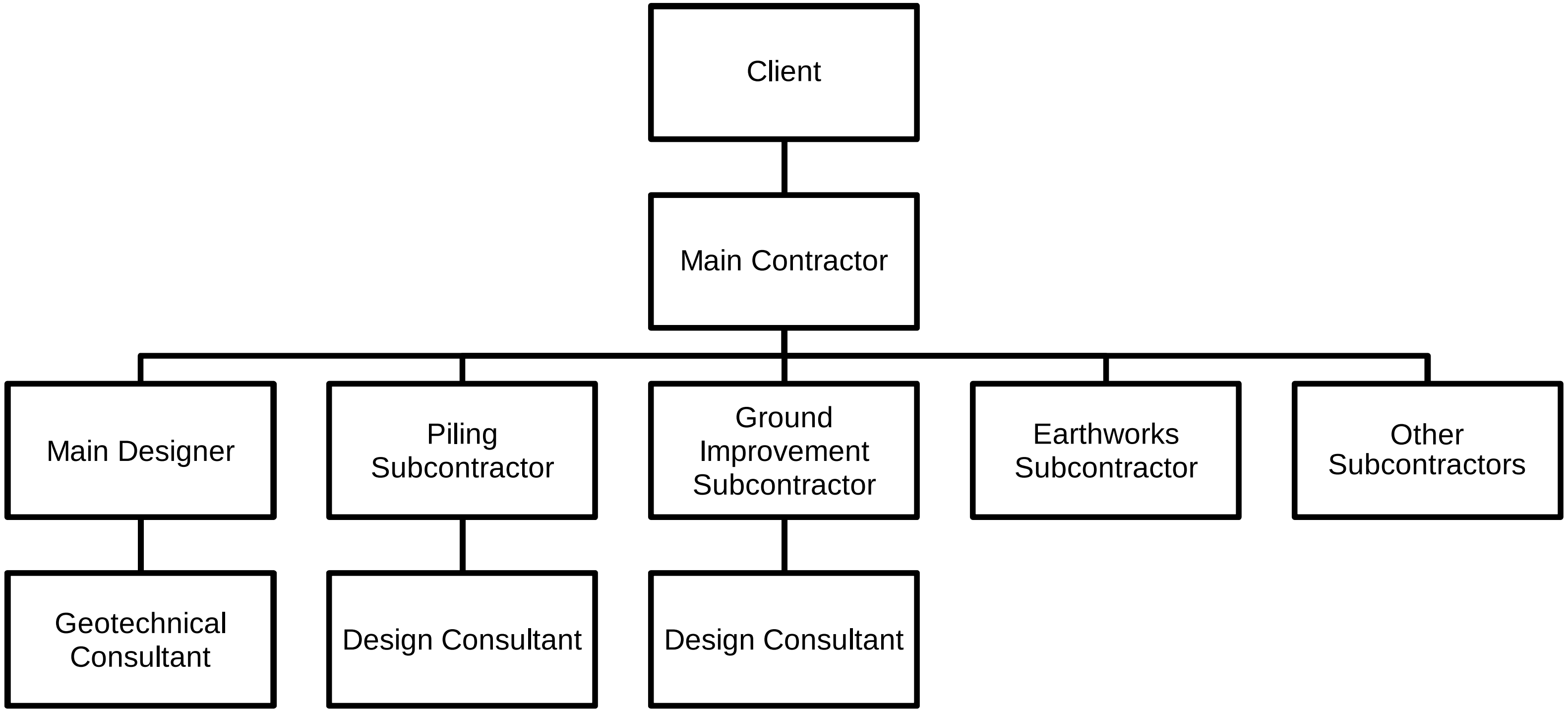
Typical Contractual Issues

- Risk introduced by disconnect in responsibility and communication between different parties over the full design and construction period.



- Technical reviewers may not have full access to technical information or a full understanding of responsibility of various parties.

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Acknowledgements

- Main Roads WA
- Public Transport Authority
- Department of Treasury
- Metropolitan Redevelopment Authority
- Brookfield Multiplex
- Crown Perth
- Lend Lease
- BG&E Pty Ltd

- Doug McInnes, Eric Hudson-Smith, Shane Greene, Jack Tagg, Andrew Websper, Su Kwong Tan

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References

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