When you think with a global mind problems get smaller

Control of groundwater to excavations: Barriers and dewatering

Presented to IAH – NSW Branch
June 2018

Control of groundwater to excavations
Content

Purpose

Control Methods

Assessment Tools

- Empirical
- Analytical
- Semi-analytical
- Numerical

Examples

References

01
Purpose

Control of groundwater to excavations Purpose

Why control groundwater to excavations?

Design

- Make inflows/levels more predictable

Construction

- Make the site more manageable
- Reduce treatment volume
- Reduce impacts

Operation

- Reduce on-going cost of pumping/treatment
- Comply with regulatory requirements
- Reduce impacts
- Reduce risk from contamination

Typical introduction to groundwater dewatering

02
Control methods

Control of groundwater to excavations
Control methods - Barriers

Diaphragm Wall

- Panel construction under bentonite, full reo cage
- Excellent control, Seepage: anchor penetrations & base

Secant pile

- Overlapping piles (hard/soft), reo cage in half piles
- Good control, Limited depth – gaps from splay

Cutter Soil Mix

- Installed in panels like D Wall, soil mixed with cement
- Reinforcement limited to I beams

Jet grout

- Spinning jet cuts and mixed soil with grout
- Can provide good control – typically temporary
- Can be used with secant pile/contiguous piles

Control of groundwater to excavations
Control methods - Barriers

Soil mix wall

- Soil mixed with bentonite in trench
- Low permeability, non structural
- Control of groundwater flow only

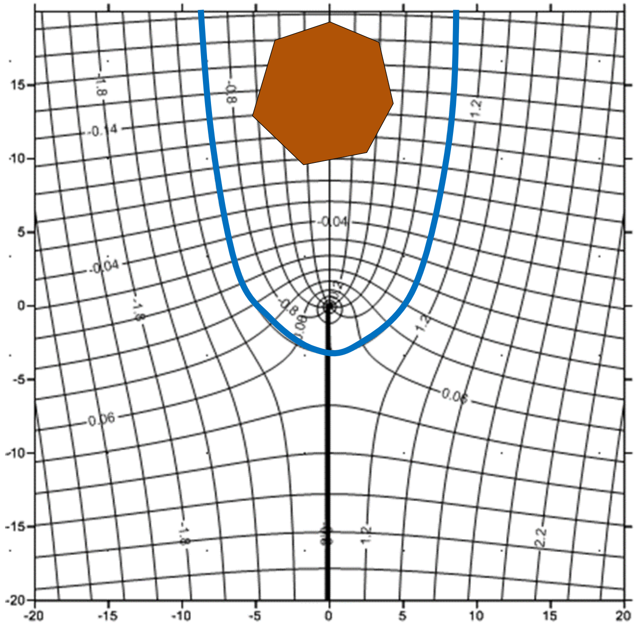
Sheet pile walls

- Interlocking steel sheets
- Typically temporary, sheets reusable
- Vibration during installation can be problematic

Control of groundwater to excavations
Control methods – Recharge / Extraction

Recharge wells and trenches

- Recharge of clean water to prevent adverse impacts
- Harder to get water into the ground



Extraction wells – capture contaminated water

- Pumping downgradient to capture contaminated groundwater
- Need to assess existing gradient and flow rate
- Extract at a rate equal to width time the flow rate

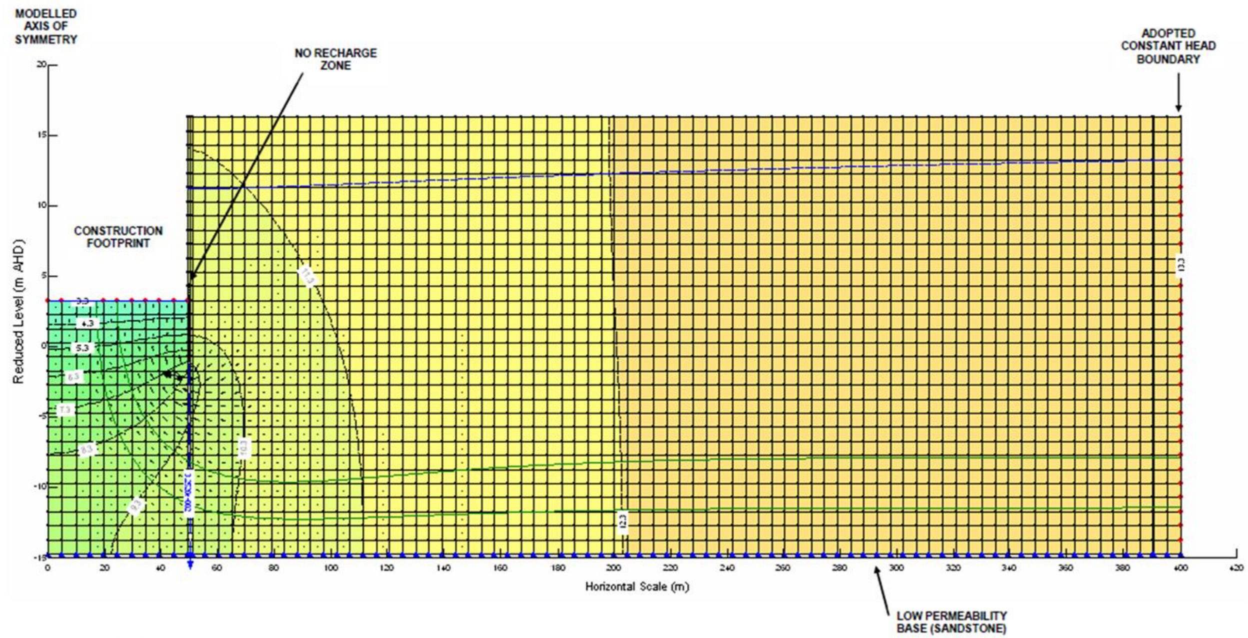
03
Tools

Control of groundwater to excavations - Tools
Making predictions

Analysis methods

- Empirical
- Analytical
- Semi-analytical
- Numerical

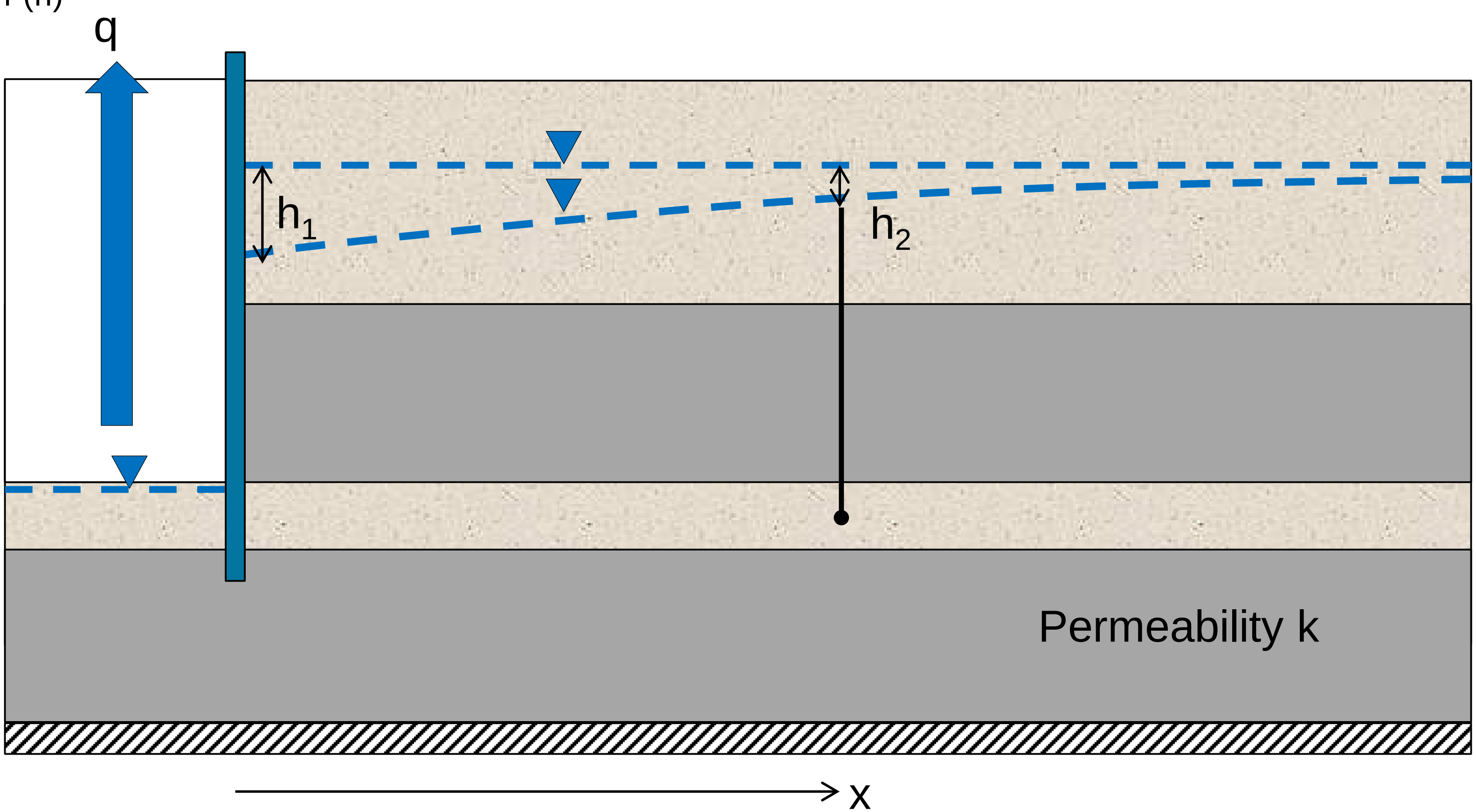
Finite element / finite difference / boundary element



Control of groundwater to excavations - Tools
Making predictions

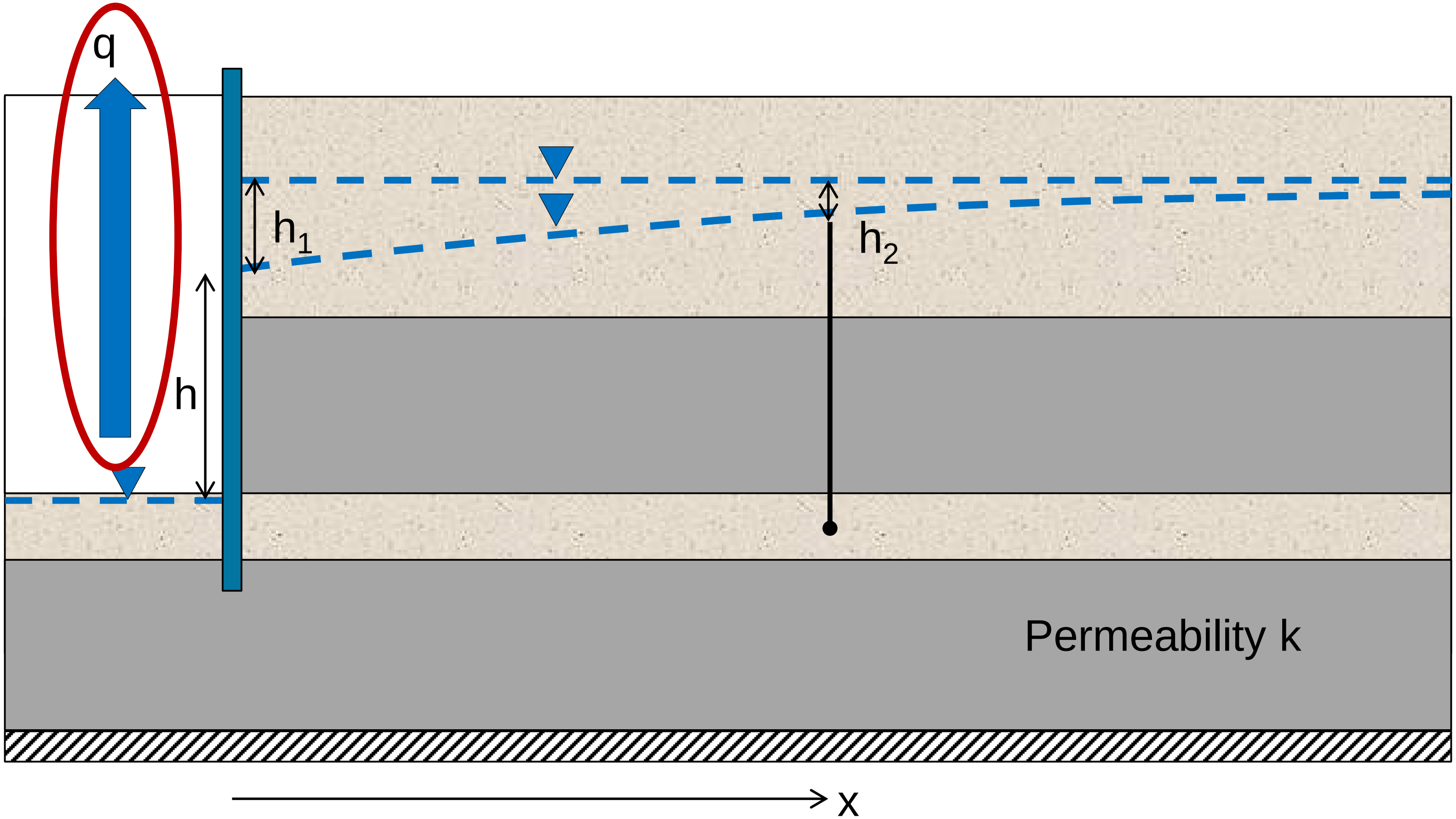
Illustrative section – things of interest

- Flow (q)
- Drawdown (h)



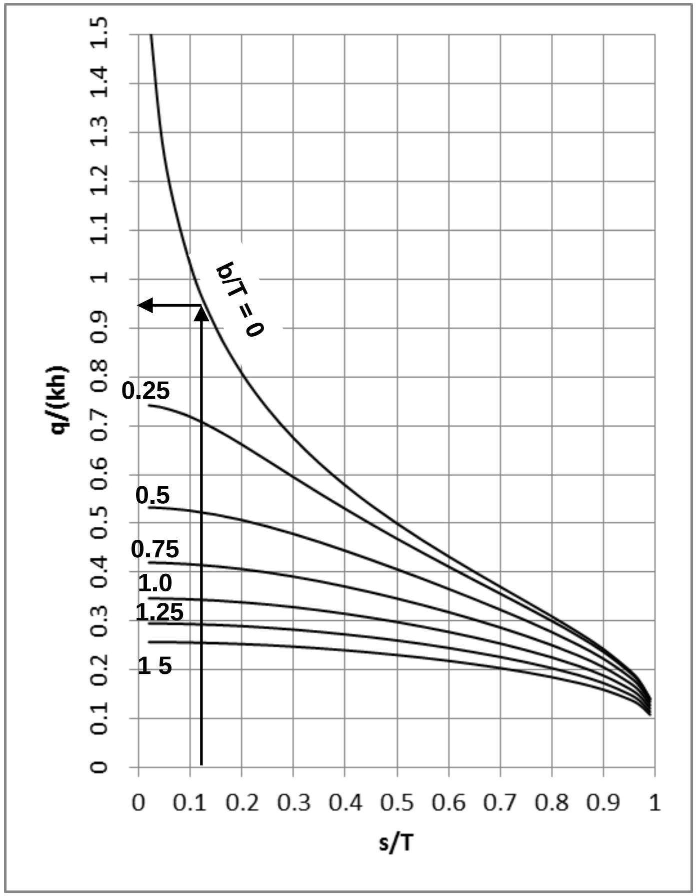
Control of groundwater to excavations - Tools
Making predictions – Flow beneath wall

Flow beneath cut off wall



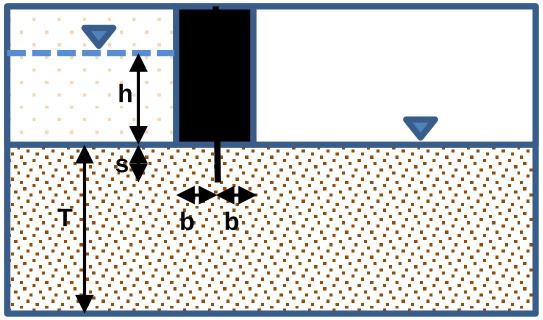
Control of groundwater to excavations - Tools
Making predictions

Flow beneath a wall (Harr 1962 after Polubarinova-Kochina 1952)



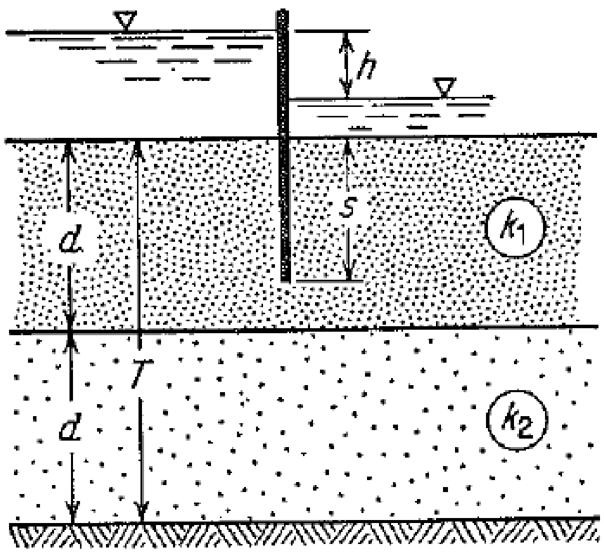
Drawdown h = 12 m
Penetration s = 2 m
Rock permeability k = 0.01 m/d
Rock thickness T = 16 m
s/T = 0.125 -> q/kh = 0.95

q = 0.95 x 0.01 m/d 12 m = 0.114 m^3/d/m

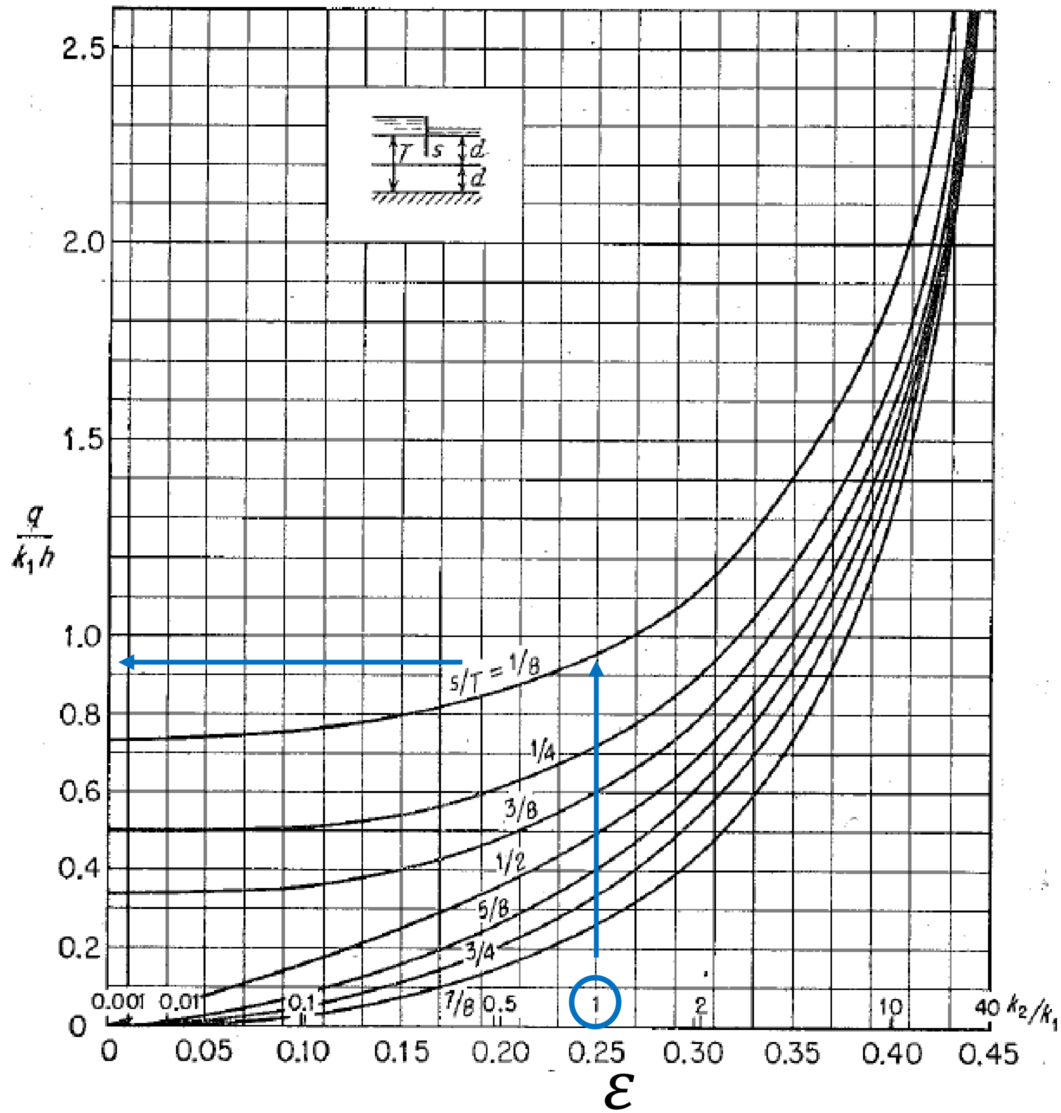


Control of groundwater to excavations - Tools
Flow beneath cut off wall

Further useful result

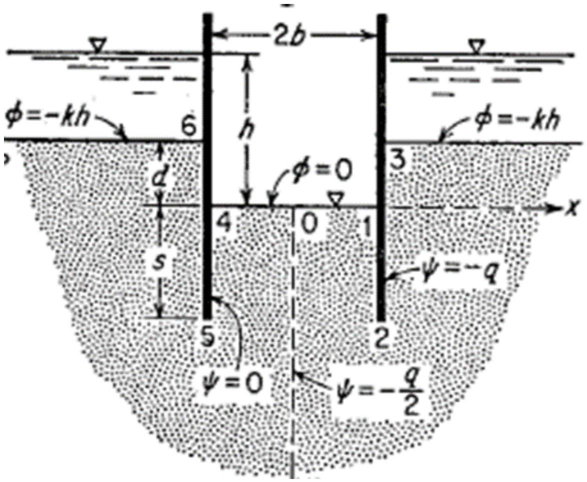


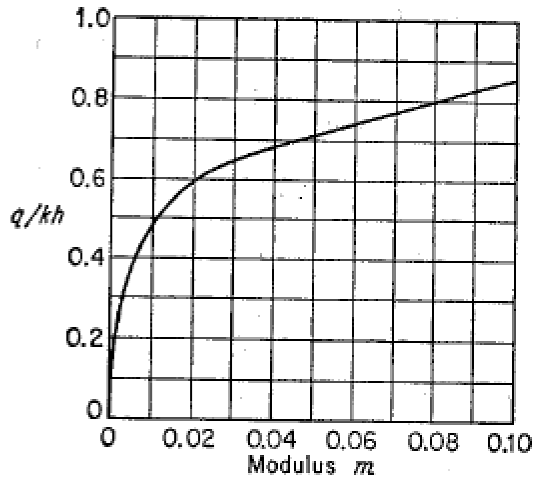
$$\tan \pi \varepsilon = \sqrt{\frac{k_2}{k_1}}$$

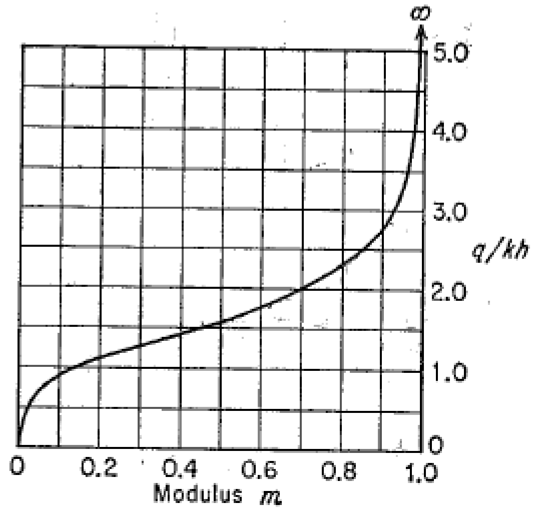


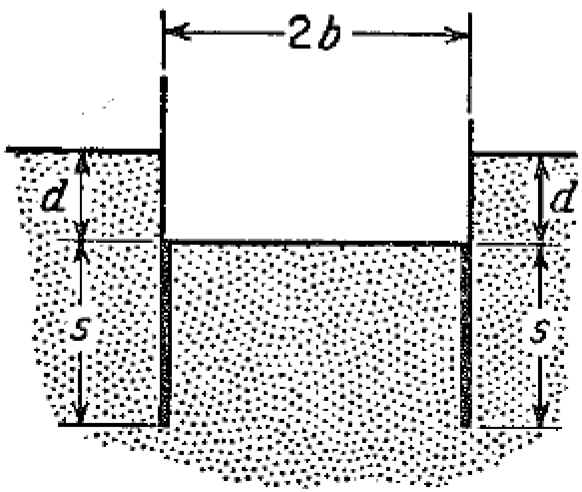
Control of groundwater to excavations - Tools
Flow beneath cut off wall

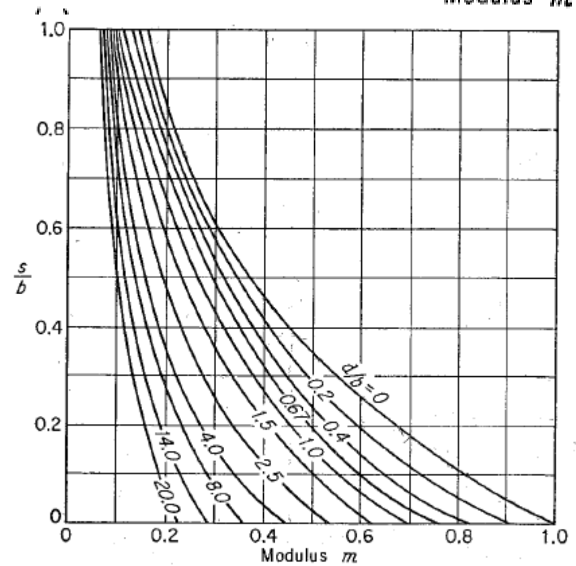
Further useful result – excavation of limited width (trenches) - Harr 1962





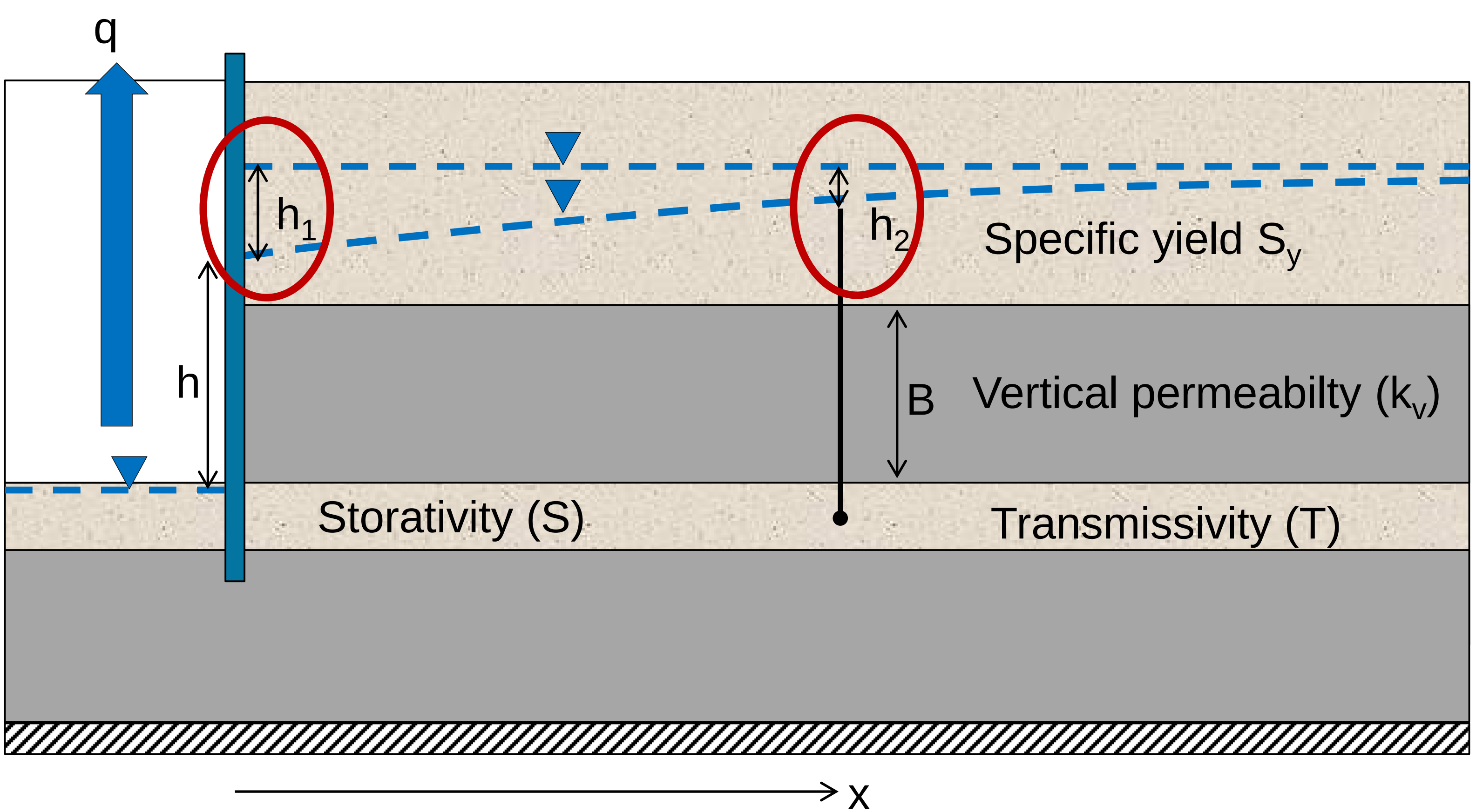




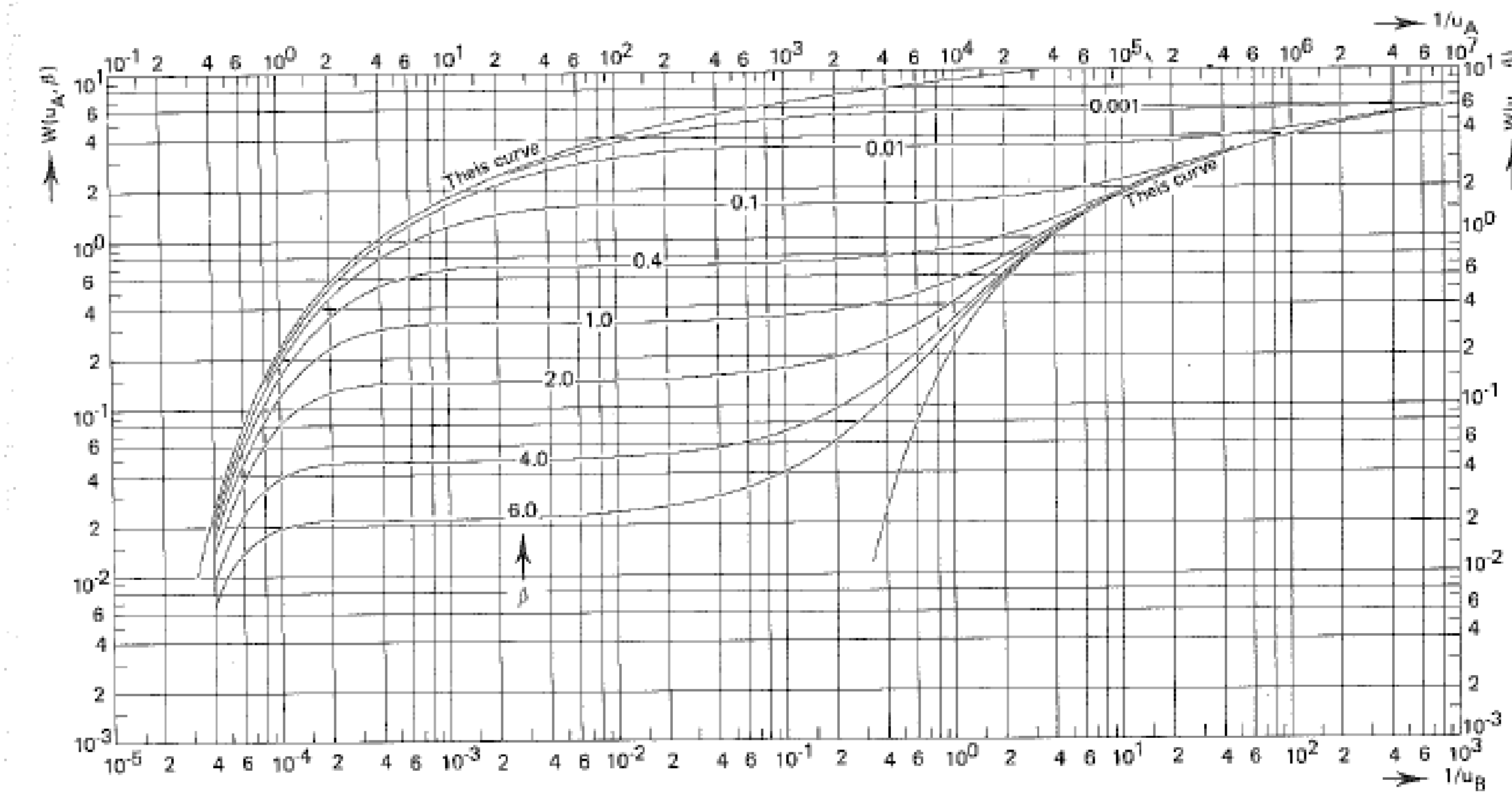


Control of groundwater to excavations - Tools
Making predictions

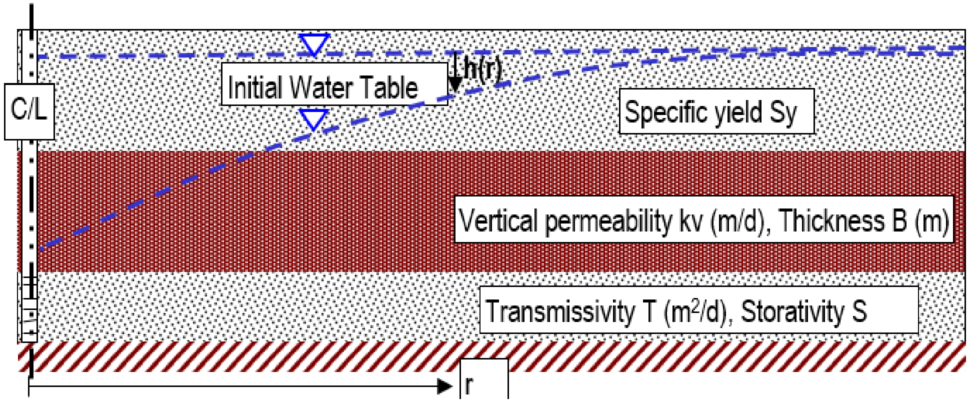
Extent of drawdown – Extensive aquifer



Extent of drawdown – Extensive aquifer (delayed yield – Kruseman and de Ridder (1991) (after Neuman)

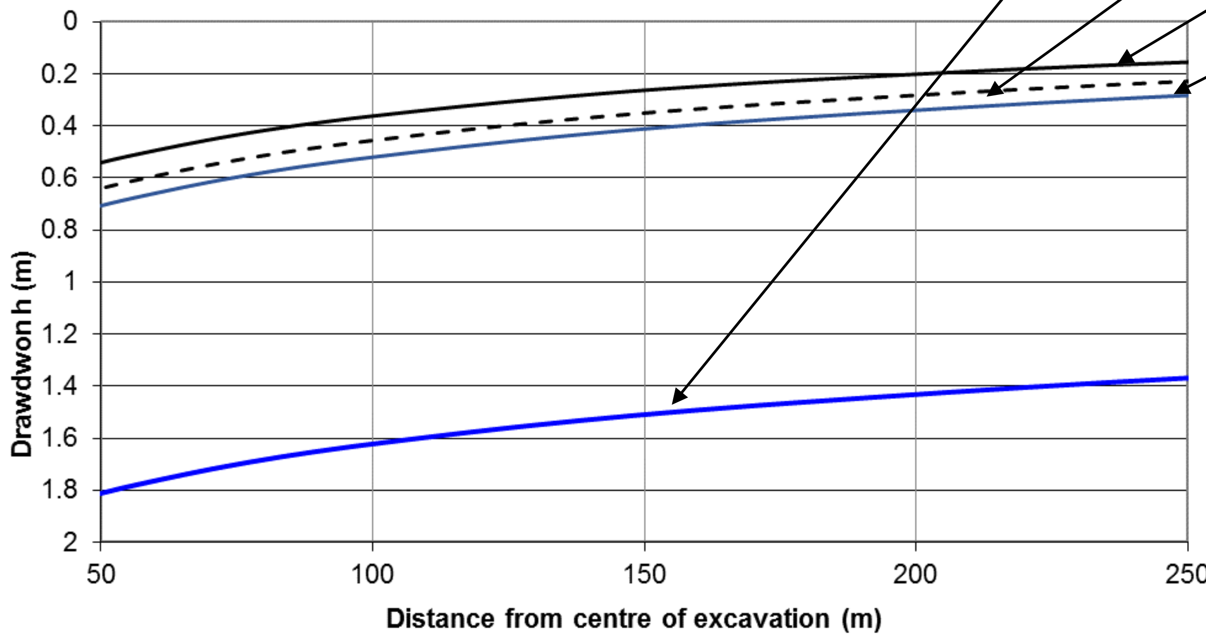


Control of groundwater to excavations - Tools
Making predictions



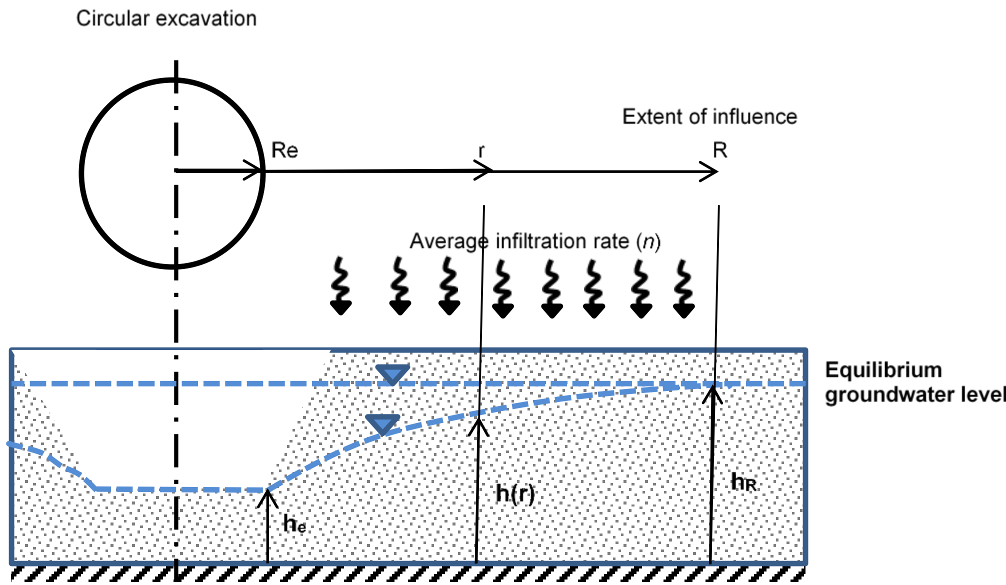
Transmissivity T (m2/d)	50	50	50	50
Storativity S	0.00001	0.00001	0.00001	0.00001
Aquitard thickness B (m)	4	4	4	4
Aqitard permeability kv (m/d)	0.0000001	0.002	0.002	0.002
Upper unit specific yield	100	100	100	0.05
Pumping rate (m3/d)	86.4	86.4	86.4	86.4
Time (d)	180	180	180000	180
	Theis	Hantush	Hantush	Boulton

Hunt (2012) provides spreadsheet tools



Control of groundwater to excavations - Tools
Making predictions

Drawdown extent – recharge balances extraction



$$h(r) = \sqrt{{h_e}^2 + \frac{n}{k}\left(R^2 \ln\left(\frac{r}{R_e}\right) - \frac{(r^2 - {R_e}^2)}{2}\right)}$$

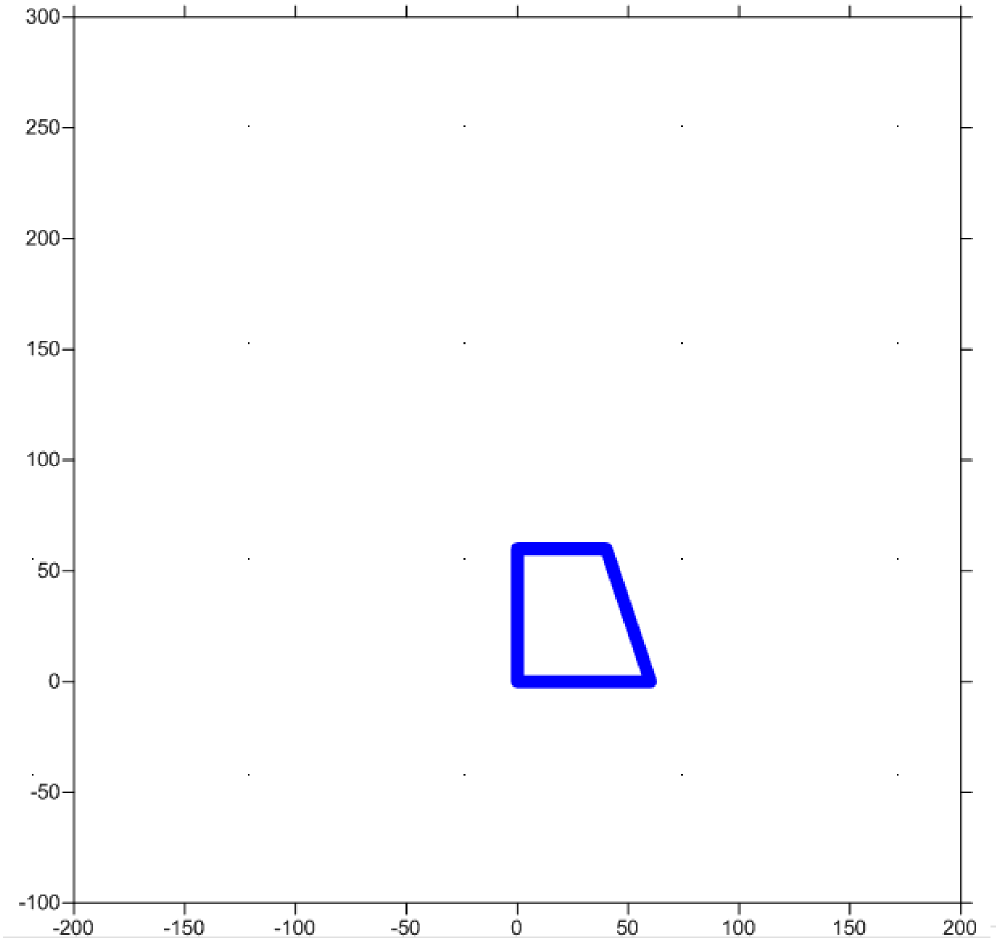
$$Q = \pi\, n\left(R^2 - {R_e}^2\right)$$

Control of groundwater to excavations - Tools
Recharge design

Example – Cut off wall

Trapezoidal shape (about 60 m x 60 m)

Permeable horizon underlain by rock

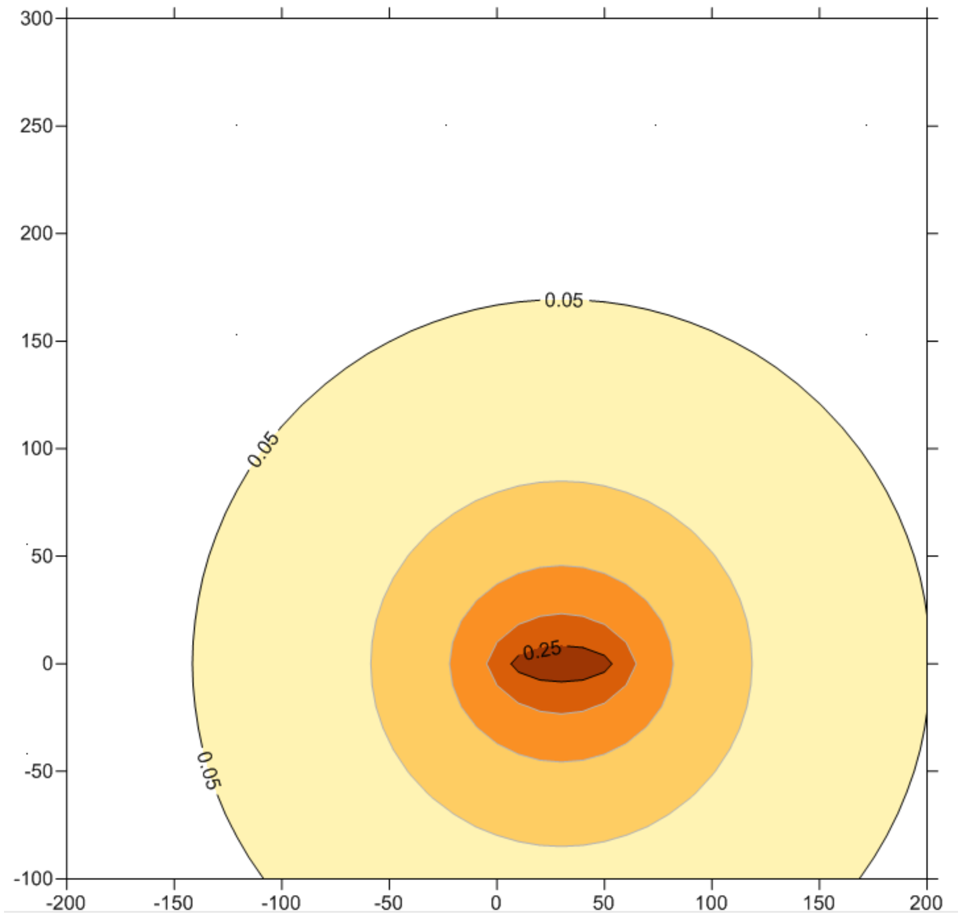


Control of groundwater to excavations - Tools
Recharge design

Example – Cut off wall

Step 1 – Calculate seepage below wall

Step 2 – Integrate aquifer solution per wall



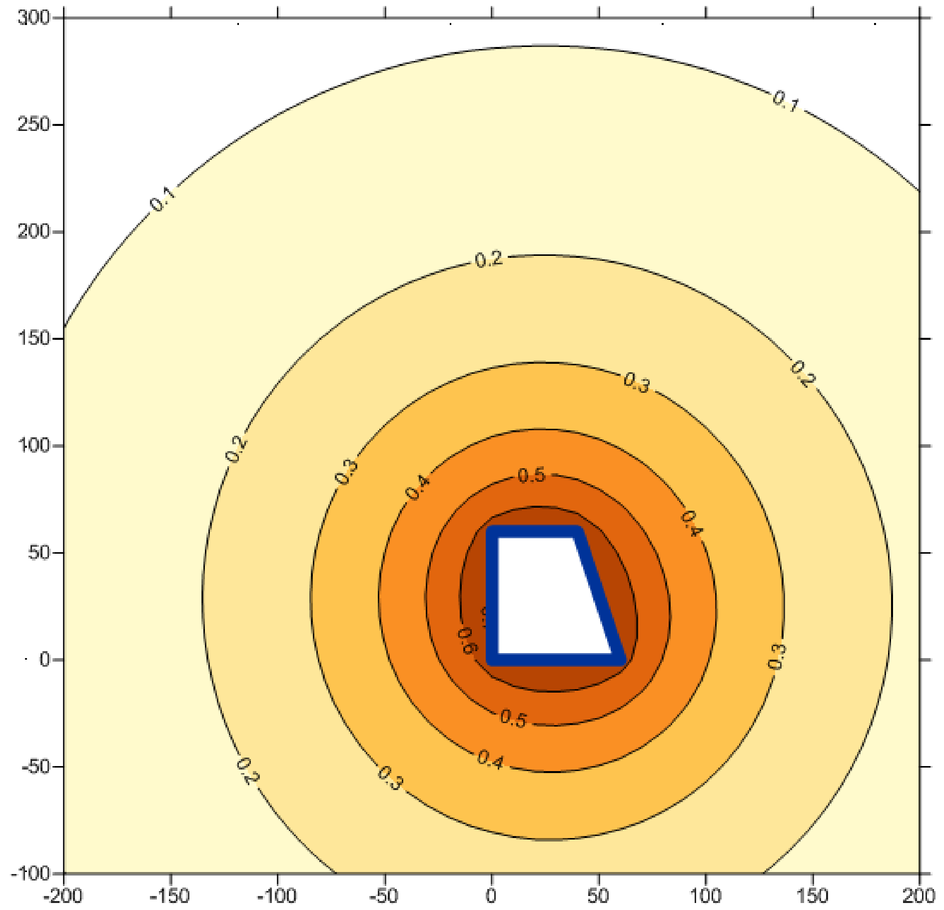
Control of groundwater to excavations - Tools
Recharge design

Example – Cut off wall

Step 1 – Calculate seepage below wall

Step 2 – Integrate aquifer solution per wall

Step 3 – Combine for all walls



Control of groundwater to excavations - Tools
Recharge design

Example – Cut off wall

Step 1 – Calculate seepage below wall

Step 2 – Integrate aquifer solution per wall

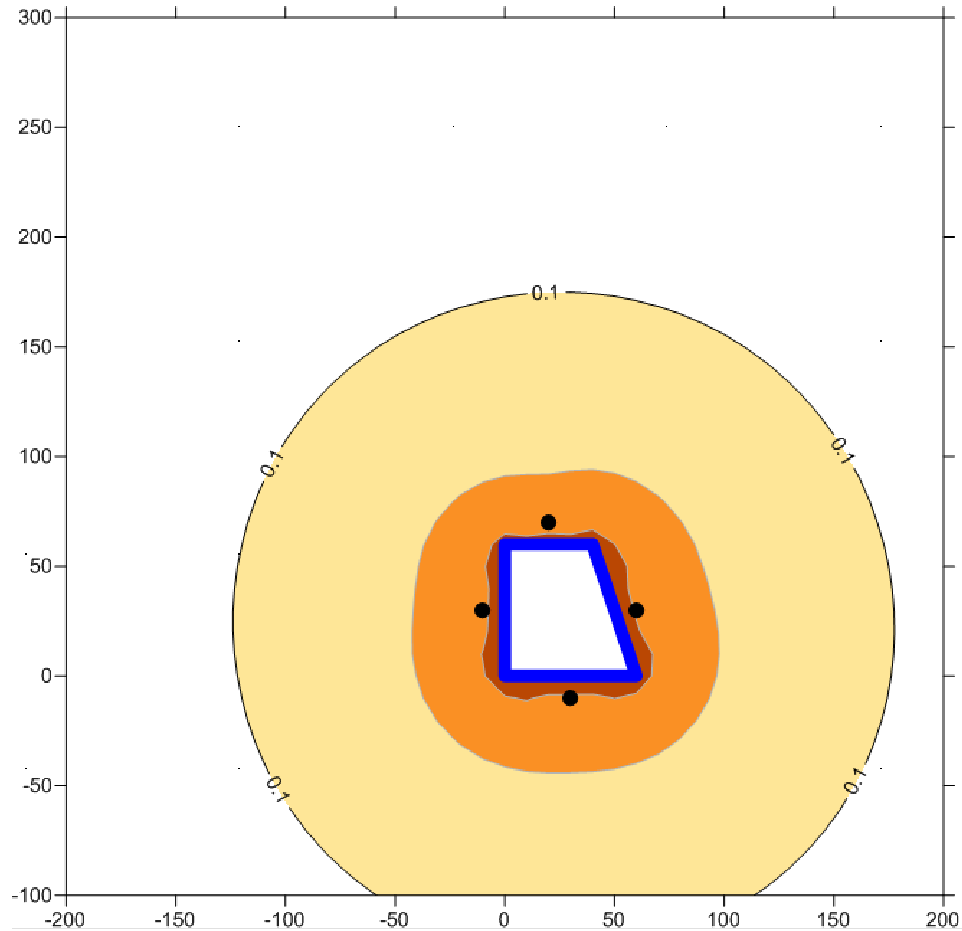
Step 3 – Combine for all walls

Step 4 – Include recharge wells

Excel spreadsheet contains the results

Alternate layouts can be tested

Note with recharge the effects are localised and the nature of the aquifer more widely does not affect the outcome.



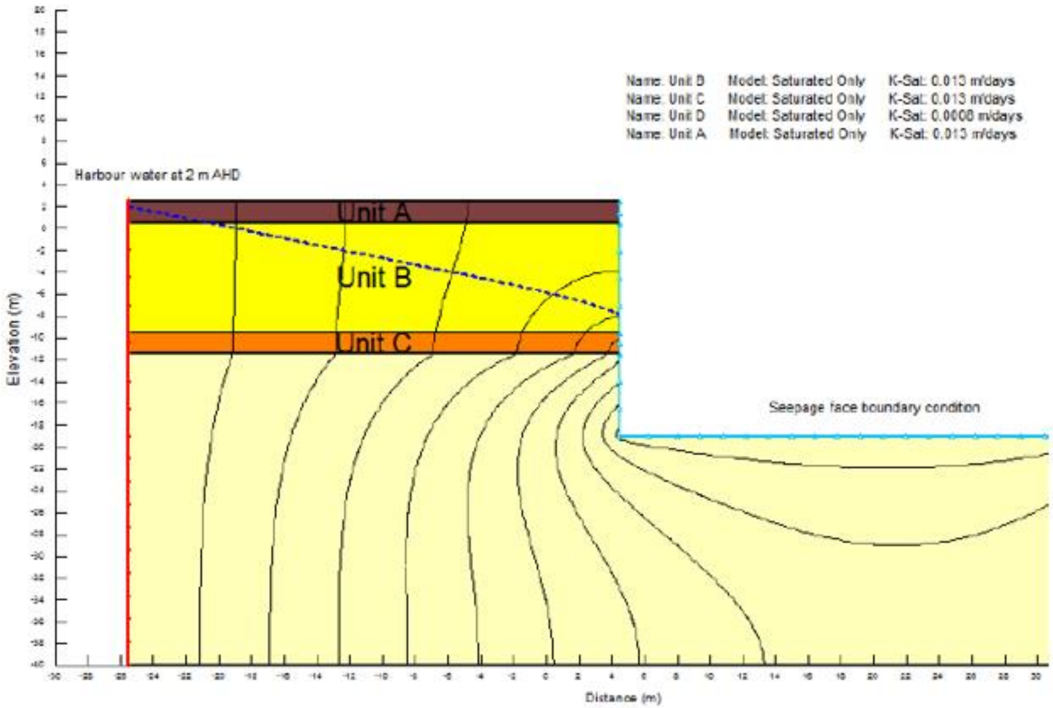
Control of groundwater to excavations - Tools
Numerical methods

Use where analytical methods are too crude

Complex profiles

Free surface problems (drained walls)

Regional impacts



04

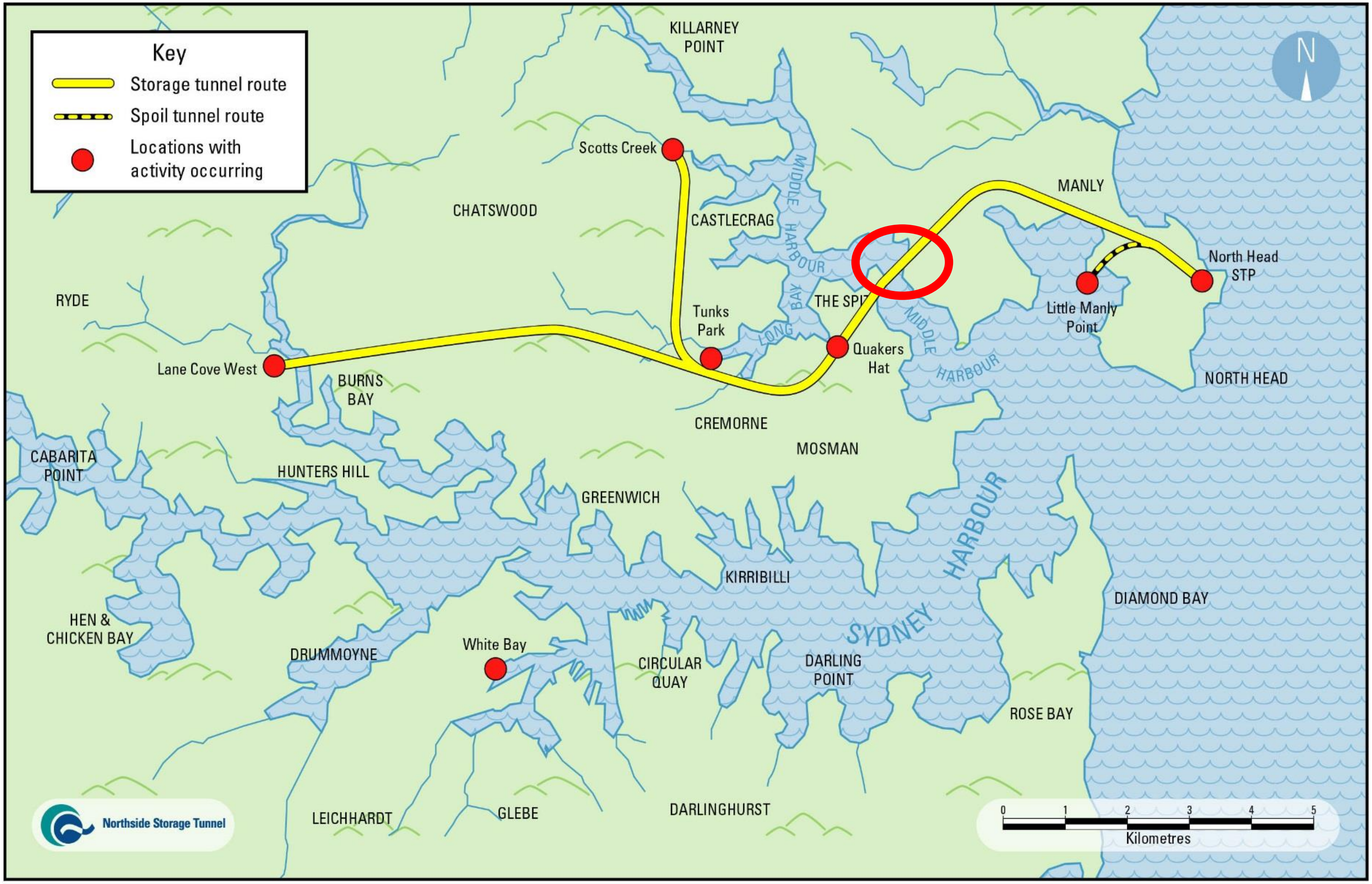
Examples

Northside storage tunnel – grouting control

Tempe – soil mix wall

Barangaroo Stage 1A – diaphragm wall

Northside Storage Tunnel



Location map and tunnel route

NST Background

Sydney Water Project - Collects four main sewer overflows

15.8km from Lane Cove River to North Head STW

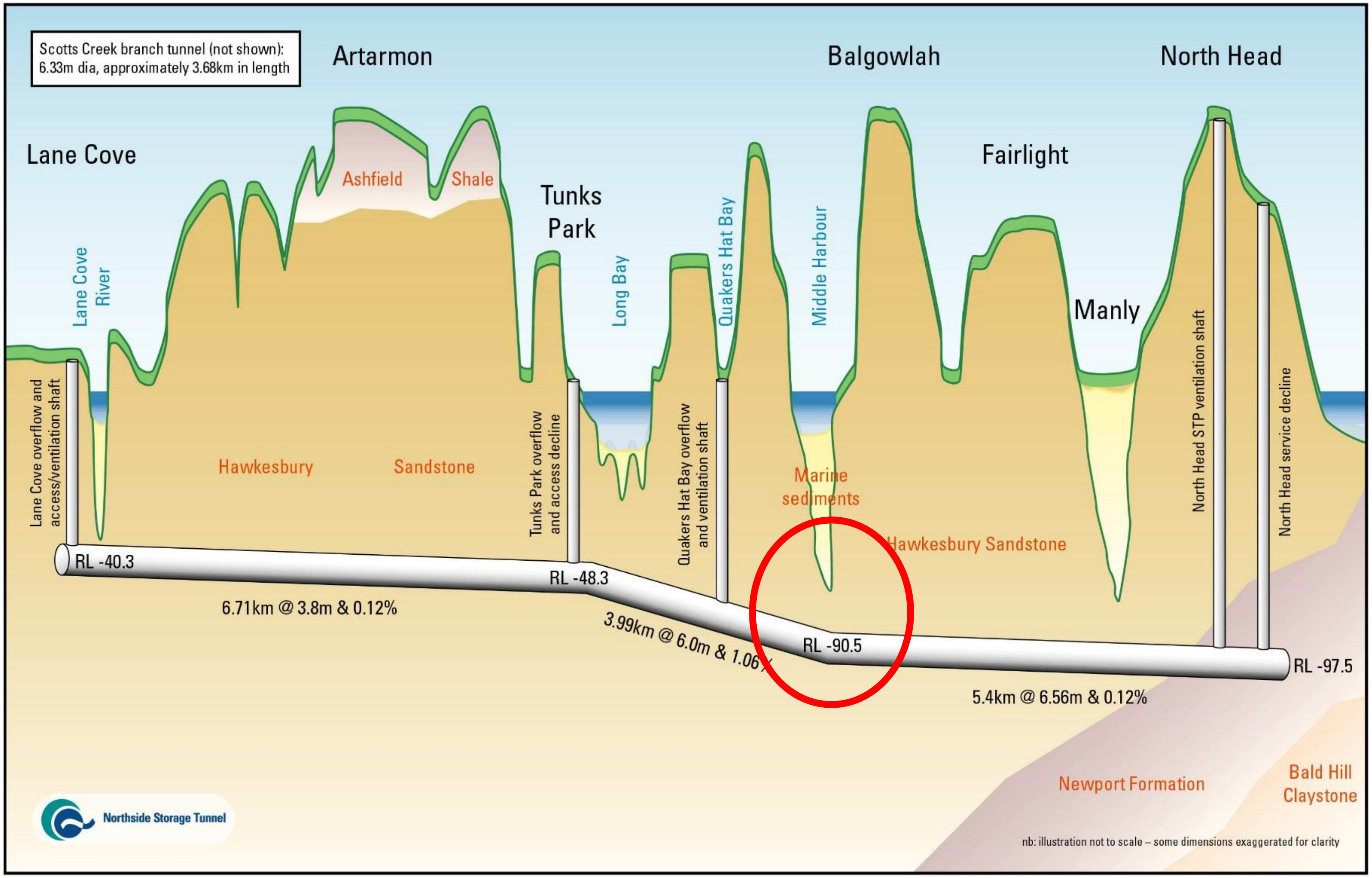
Tunnel invert RL-43m to RL-96.5m

Northern branch tunnel 3.7km long to Scotts Ck. Tunnelling by four TBMs (3.8m to 6.6m dia.)

Tunnel unlined

Project completed before the 2000 Olympics

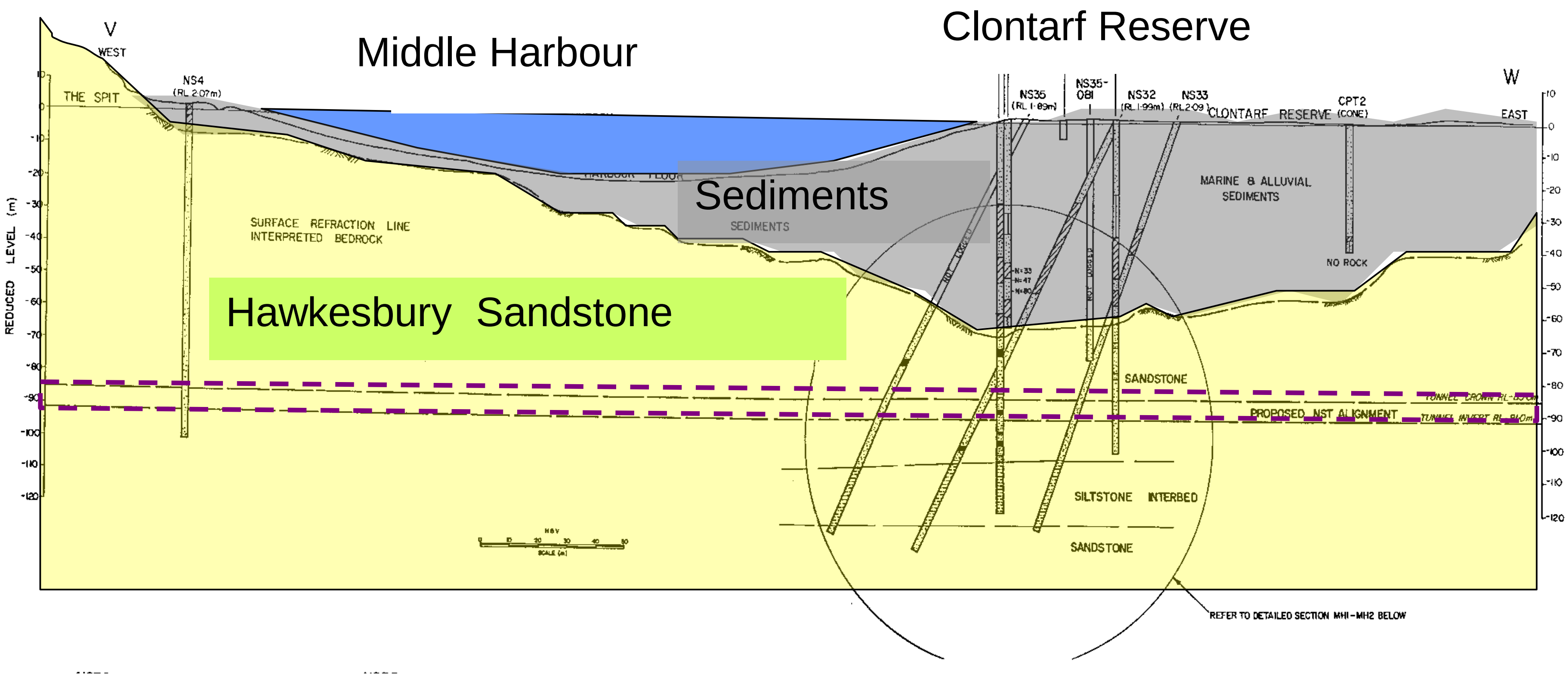
NST – Long Section



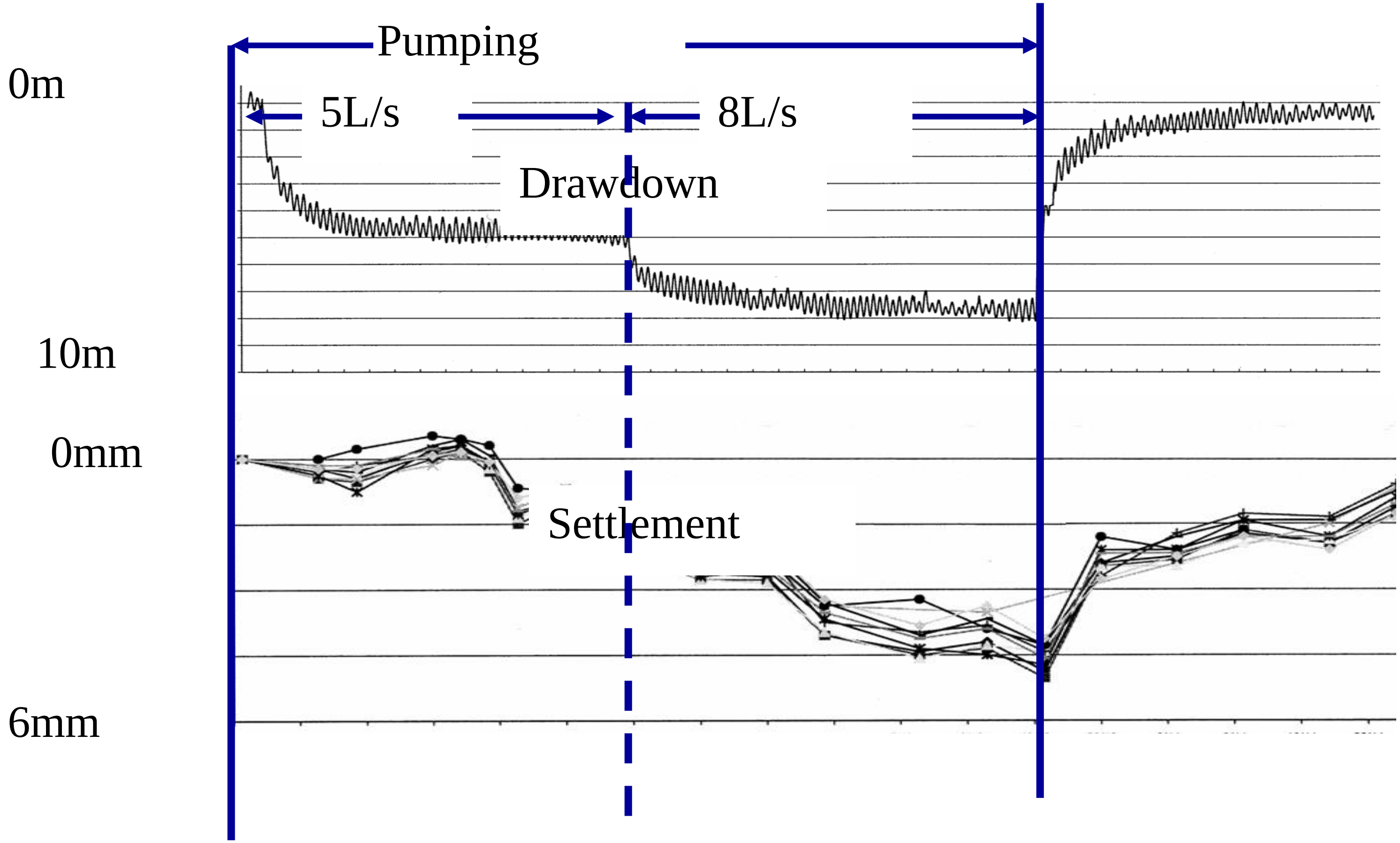
Long section of main tunnel

Northside storage tunnel - Middle Harbour - Clontarf

Middle Harbour Long Section



NS 35-OB1 Drawdown - Trial



Grouting at Clontarf

Probe ahead grouting

Annular patterns of up to 56 holes

Grout take 3.75kg/uL/m

180t cement

Advance slowed from 225m/week to 5m/week (one month for worst 25m)

Inflow limited to 18L/s

Permeability controlled to 1uL

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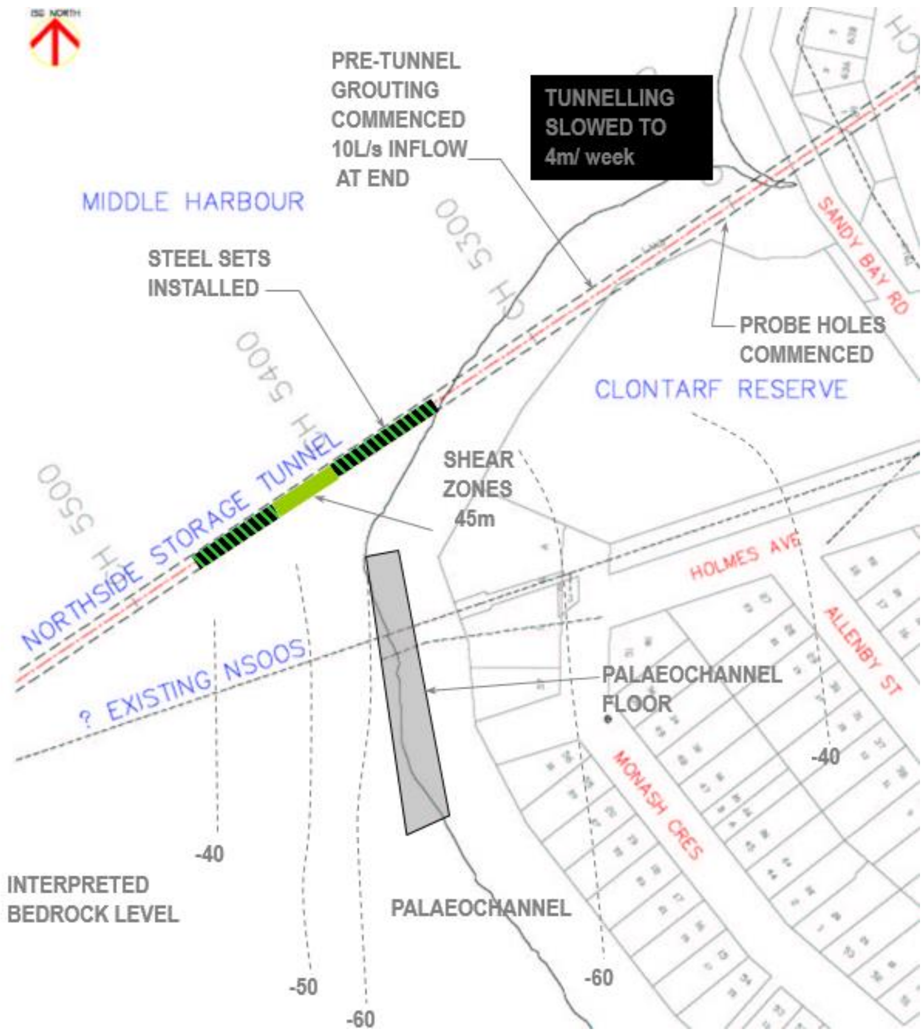
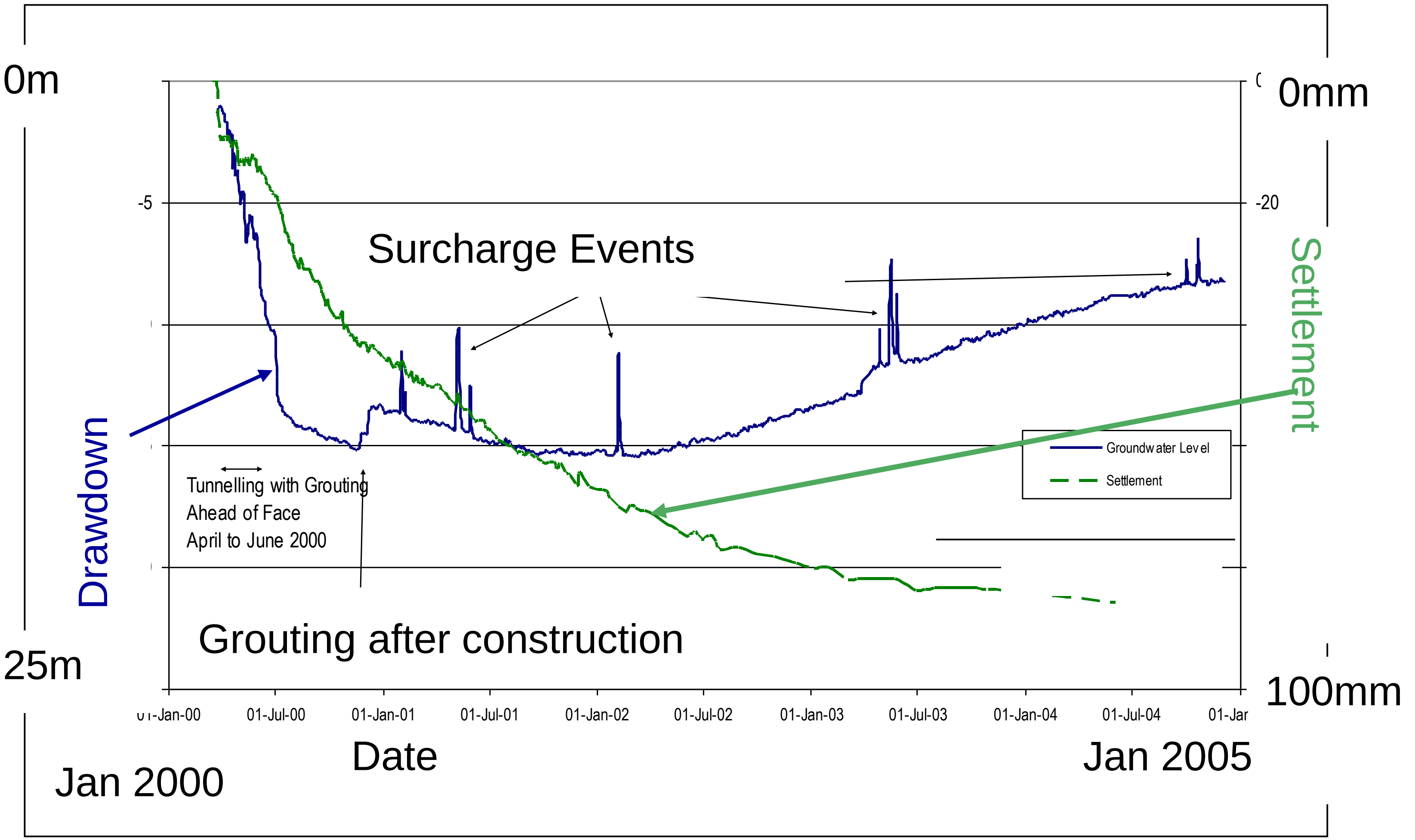


Northside Storage Tunnel – Clontarf



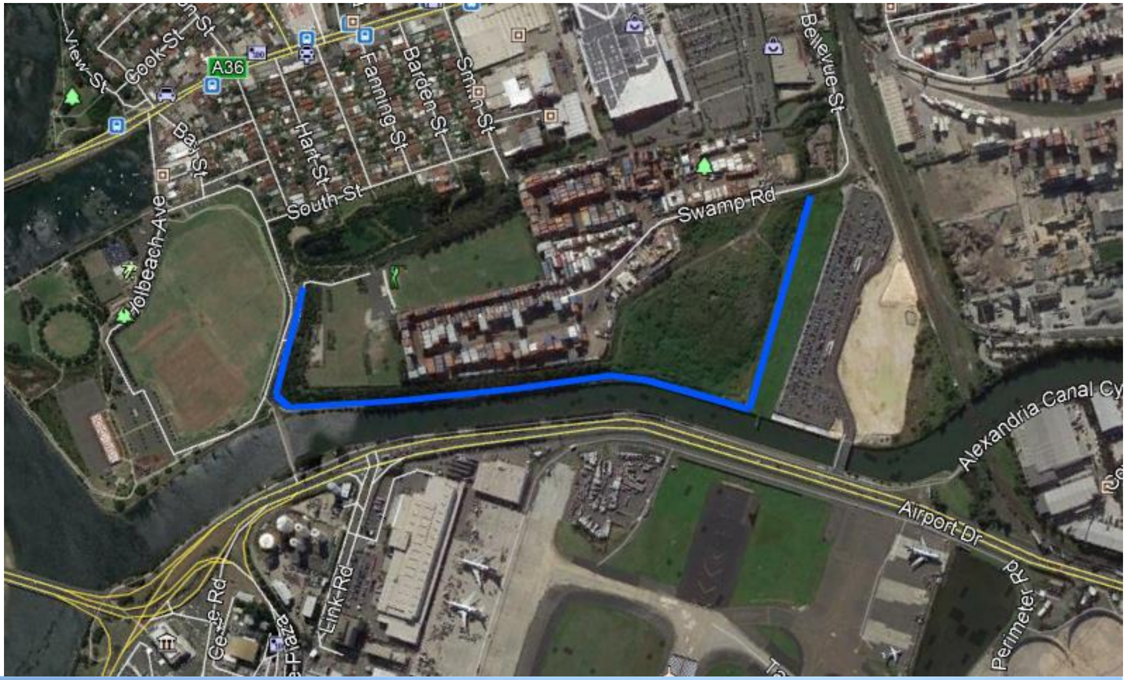
Control of groundwater to excavations
Northside Storage Tunnel

- No numerical modelling – evaluation carried out by direct extrapolation from measurement and simple hand calculation
- Demonstrated construction without grouting control would result in very high inflow (> 100 L/s) and cause settlement of piled syphon
- Grouting proved effective though time consuming
- Early waring allowed rescheduling of other operations to avoid delay to overall program
- Ground – tightened up with time
- Monitoring proved a useful tool to evaluate performance during construction and during operation

Control of groundwater to excavations
Tempe landfill remediation

Tempe Landfill

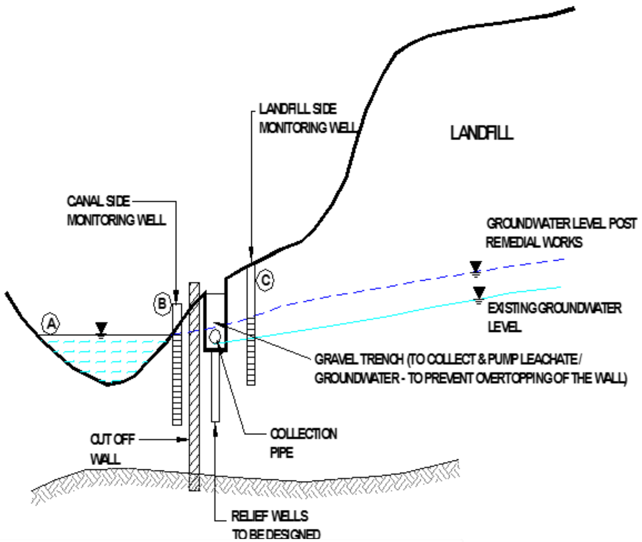
- Operated from early 1900’s
- Up to 17 m fill underlain by alluvial/residual soils and sandstone
- Leachate entering Alexandria Canal
- 1.6 km soil/bentonite wall and drain
- Used long reach excavator (20 m)

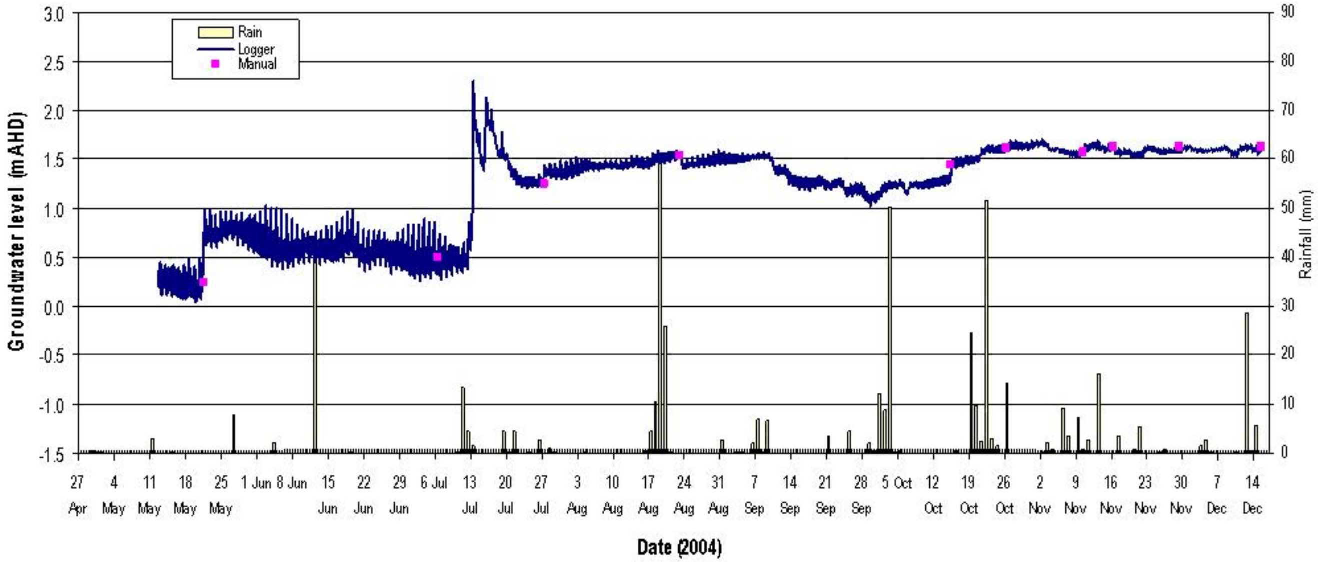


Control of groundwater to excavations
Tempe landfill barrier

Soil mix wall

- Wall performance tested by closed cell – not conclusive
- Alexandria Canal tidal
- During construction monitoring assess performance
- Series of wells either side of alignment
- Monitoring demonstrated stopping of tidal response and raised groundwater level



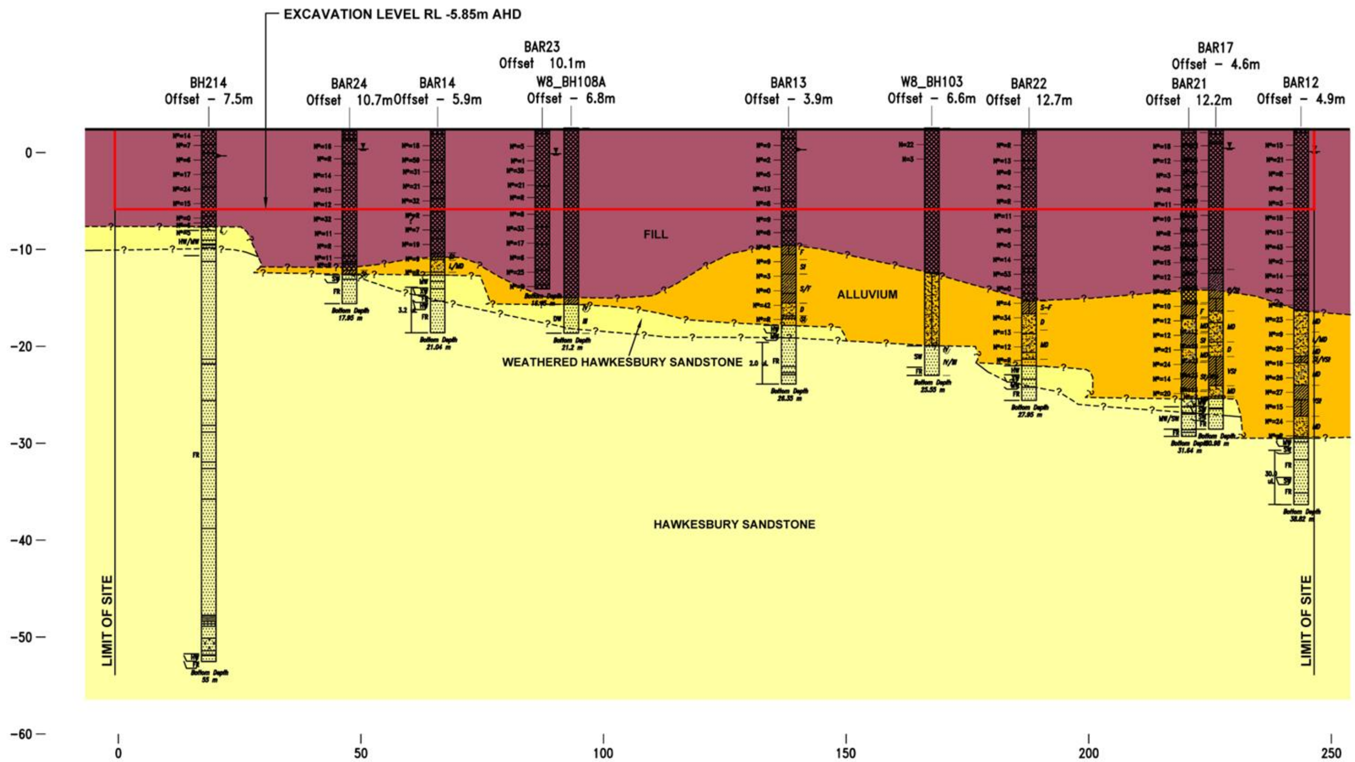


Control of groundwater to excavations Barangaroo Stage 1A

Control of groundwater to excavations Barangaroo Stage 1A

Control of groundwater to excavations
Barangaroo Stage 1A – Ground conditions

- Site contained deep fill (highly transmissive) over alluvium and a sloping rock profile
- Rock profile contained buried cliff lines
- Diaphragm wall constructed to allow excavation 8 m below sea level
- Wall needed to reach rock at depth of up to 30 m
- Tanked structure with tie down piles a thick base slab connected to the diaphragm wall



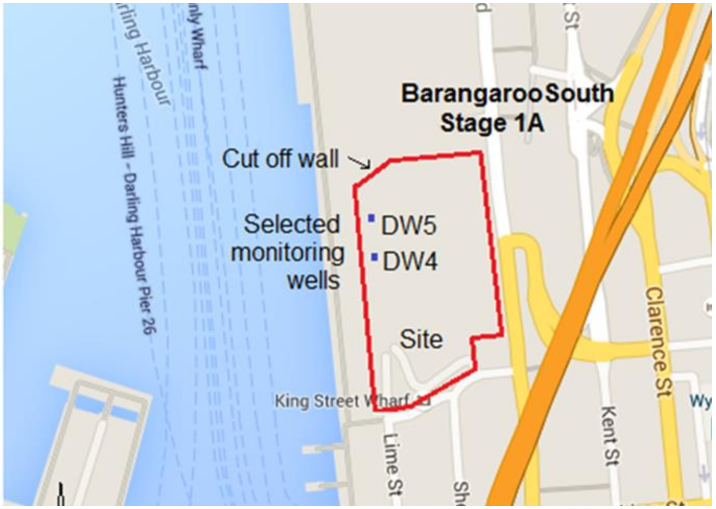
Control of groundwater to excavations
Barangaroo Stage 1A – Ground conditions

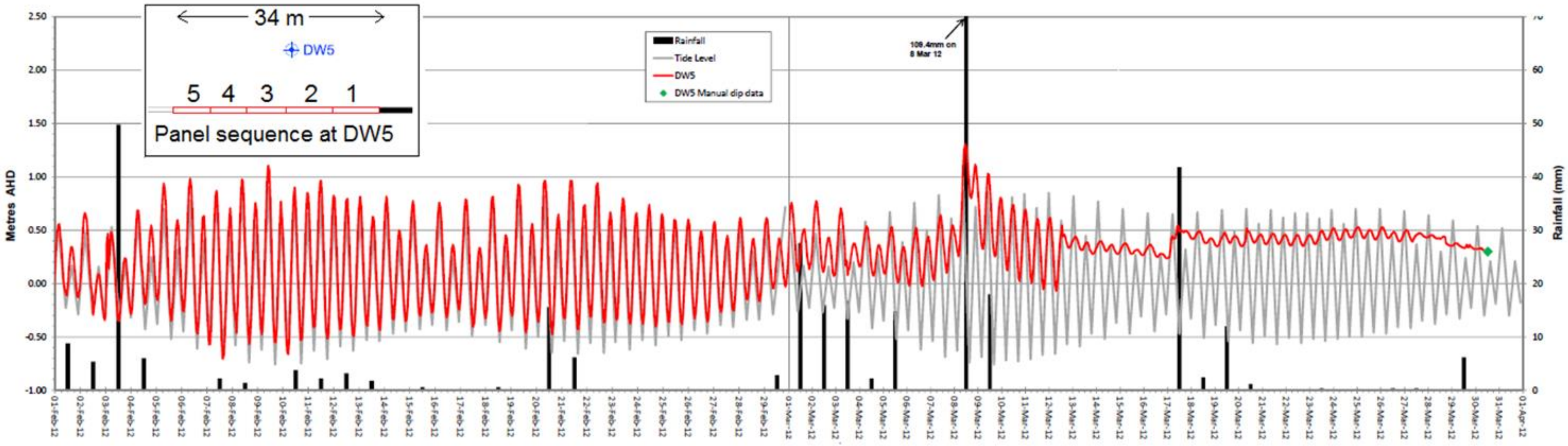
Control of groundwater to excavations
Barangaroo Stage 1A – Ground conditions

- Constructed by Menard Bachy
- 700 m long diaphragm wall (6 m x 1 m panels) up to about 30 m deep performed very well
- Anchors installed above sea level to reduce seepage
- Construction inflows less than 3 L/s (beneath the wall)

Control of groundwater to excavations
Barangaroo Stage 1A – Ground conditions

- Monitoring of piezometers during wall construction
- Full tidal response 40 m back from the water of Darling Harbour
- Tidal response inside the wall dropped dramatically as D wall panels near monitoring bores were completed





05

Closing

Control of groundwater to excavations
Closing

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Comments

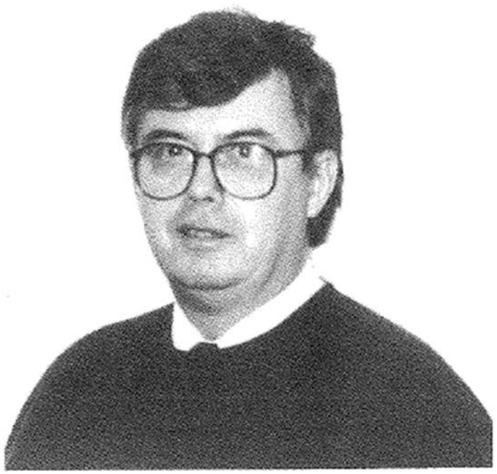
- Various proven groundwater control methods available
- Barrier methods are mature
- Assessment methods revolve around flow estimation and assessment of impact
  - Best to extrapolate for local experience
  - Analytical methods quite satisfactory
  - Semi-analytical methods can address more complex situations
  - Numerical methods
- Examples
  - Monitoring valuable to evaluate performance

Paraphrasing the great John Booker

Use simple hand calculations where possible

If necessary use analytical or semi-analytical methods

If desperate use numerical methods



John Robert Booker 1942-1998

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06 References

Control of groundwater to excavations References

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