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Dubai Metro – Project Outline

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Dubai Metro – Project outline

Red & Green lines under construction

- Red Line – Opened Sept 2009
- Green Line – Opening 2011

Other lines to follow:

- Purple line
  - Airport express
- Blue line
  - Along Emirates Road

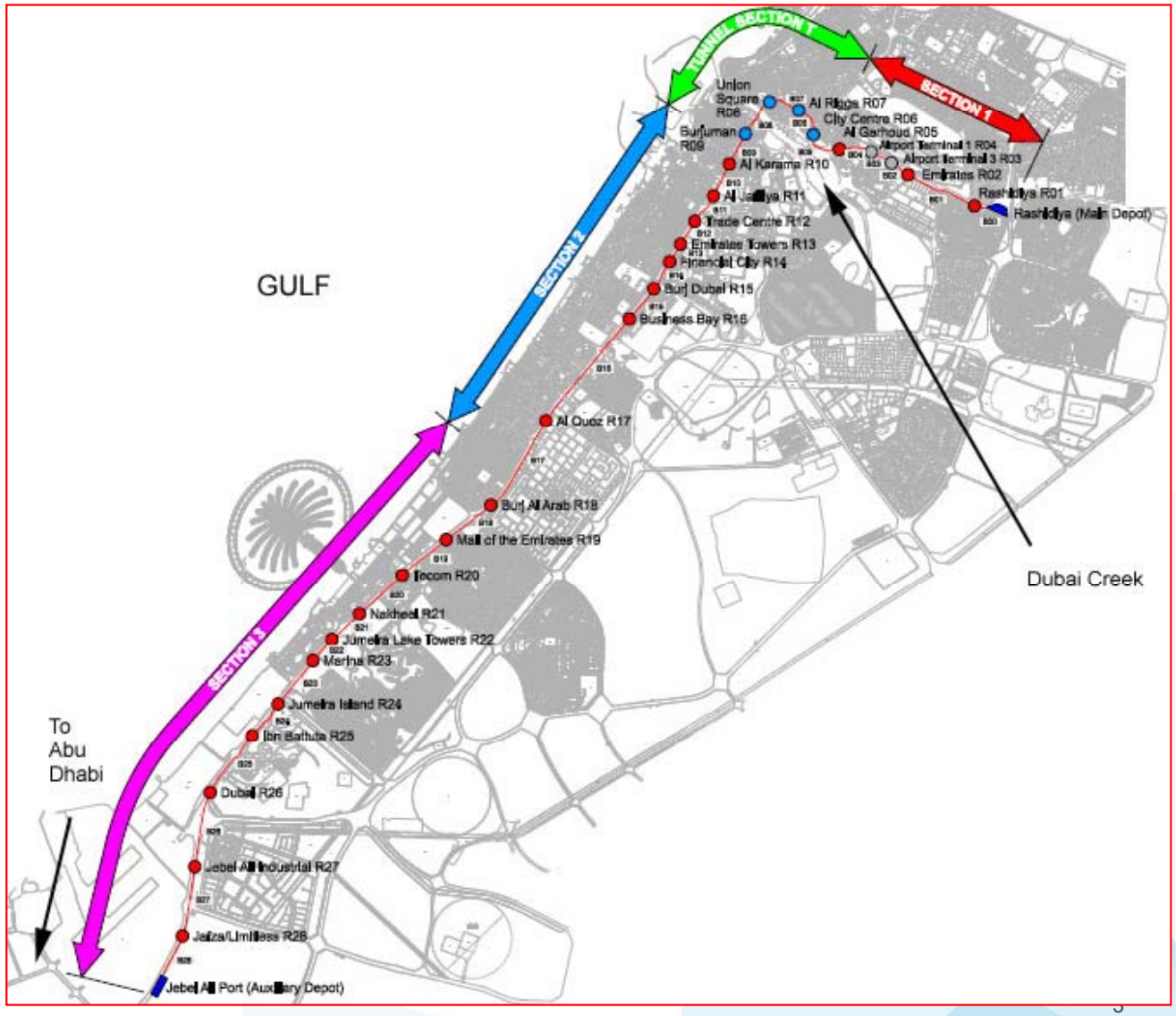
Dubai Metro will be:

- Driverless
- Fully-automated
- Longest in the world

Dubai Metro – Project outline

Red line

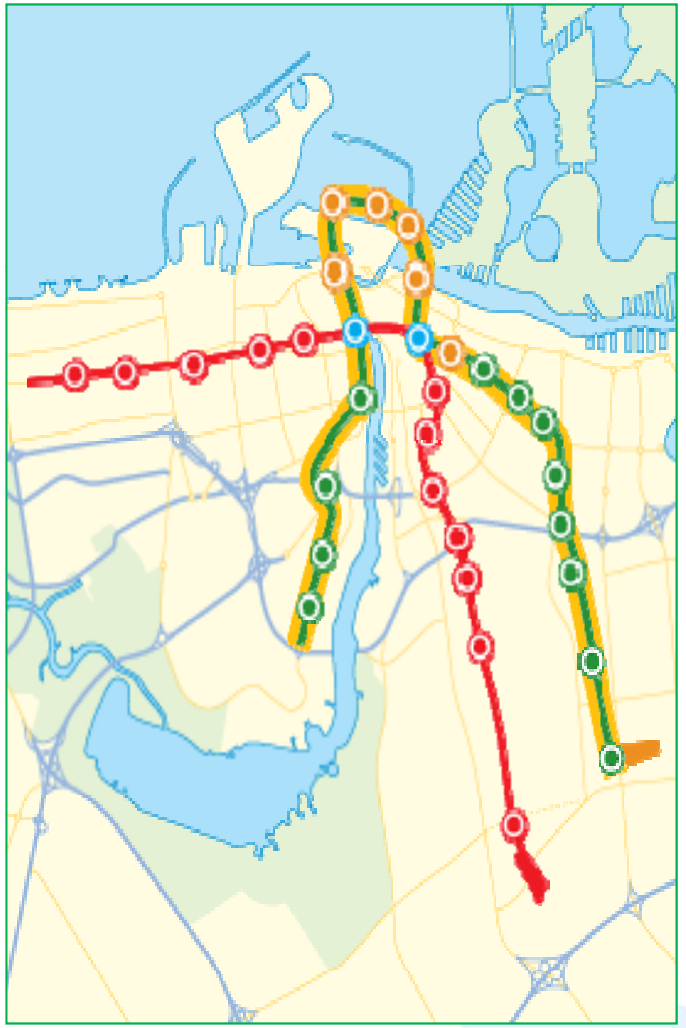
- 52 km route
- 42 km viaduct
- 22 overground stations
- 5.5 km tunnels
- 4 underground stations
- 2 depots



Dubai Metro – Project outline

Green line

- 24 km route
- 16 km viaduct
- 12 overground stations
- 7.0 km tunnels
- 8 underground stations
- 1 depot



Dubai Metro – Project organisation

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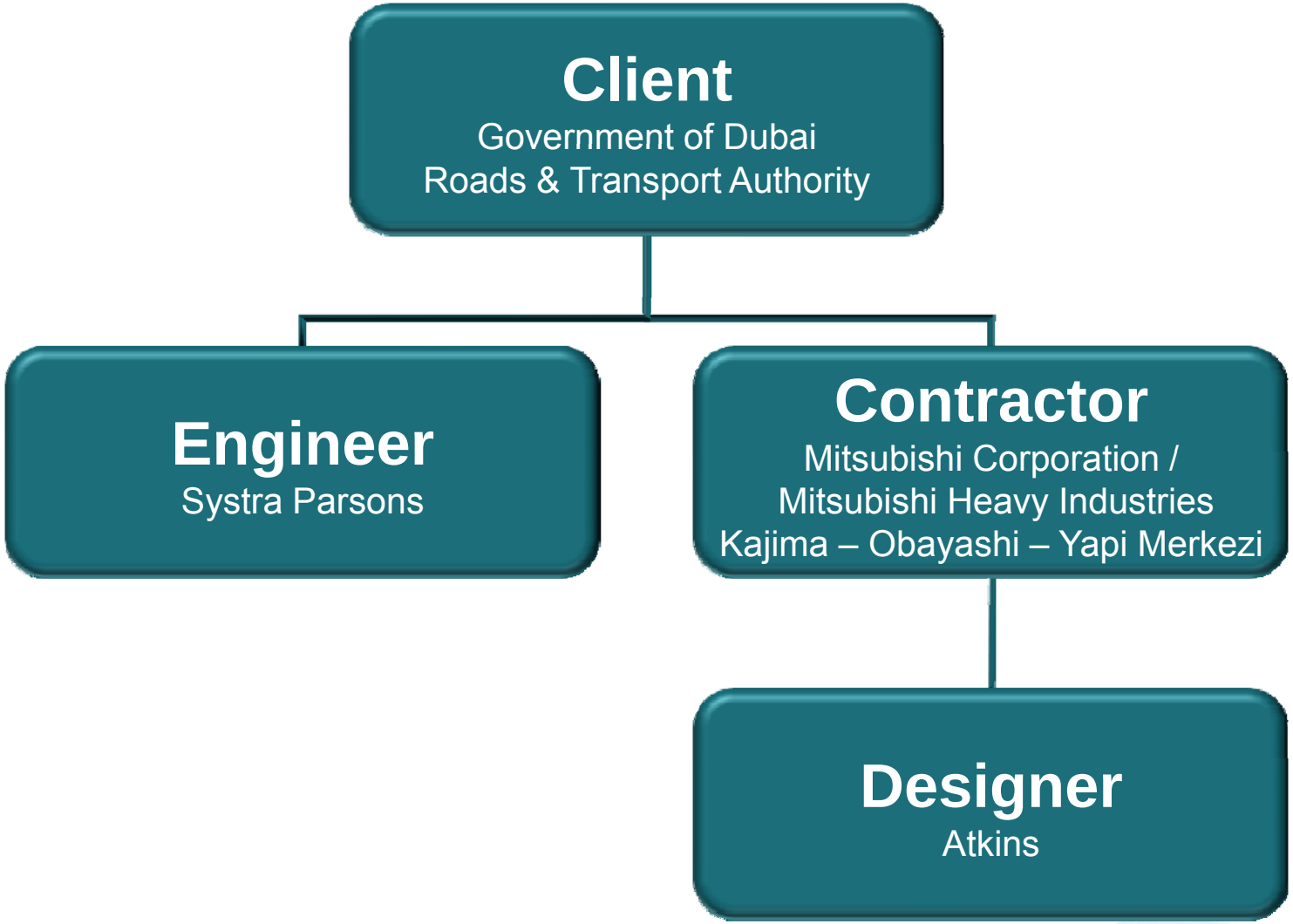

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Dubai Metro – Geological Setting

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Dubai Metro – Geological Setting

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Recent

- Unit 1: Dune Sands & Sabkha Deposits

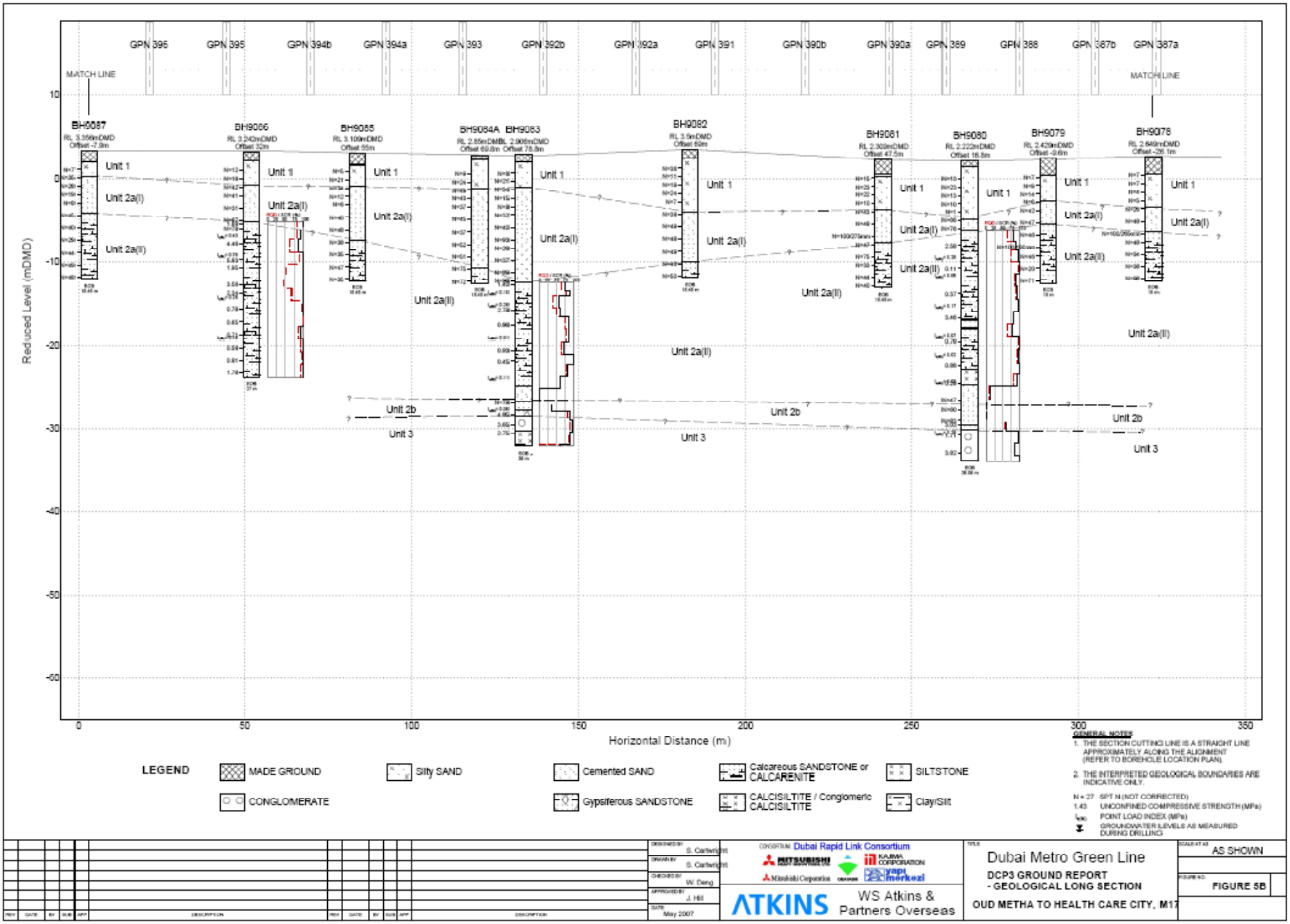
Pleistocene (2 million years)

- Unit 2a(i): Marine Sands, weakly cemented
- Unit 2a(ii): Marine Calcarenite, very weak to weak
- Unit 2b: Aeolian Gypsiferous Sandstone, very weak to weak

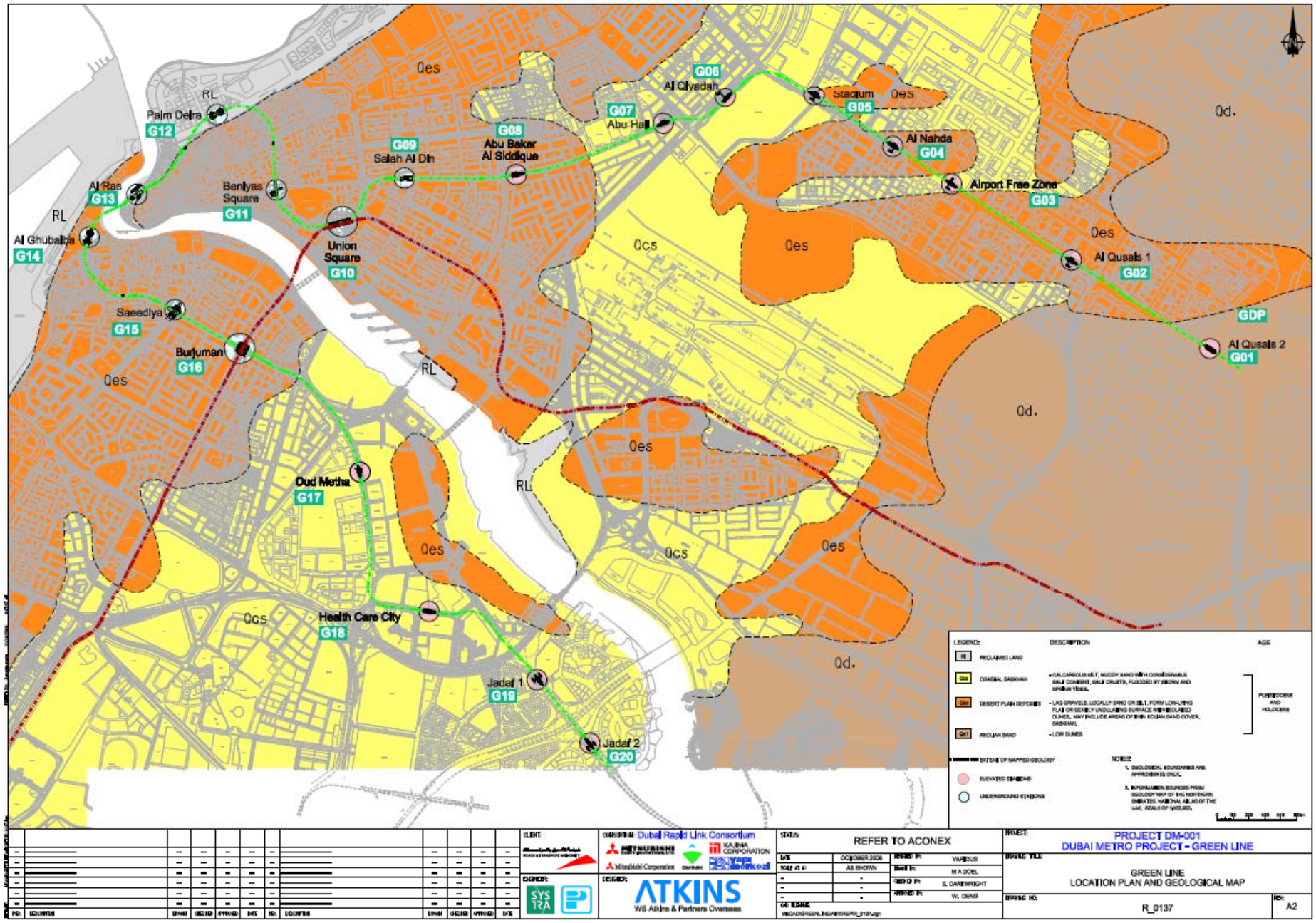
Mio-Pliocene – Barzaman Formation (20 million years)

- Unit 3: Conglomerates, mudstones and siltstones (Wash from Hazar Mountains)

Dubai Metro – Geological Setting



Dubai Metro – Geological Setting



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Dubai Metro – Geological Investigation

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Dubai Metro Ground Investigation

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Red Line: Over 1200 boreholes and CPTs

Green Line: Over 600 boreholes and CPTs

Dubai Metro – Ground Investigation

Cable Percussion Boring & Cone Penetration Testing

- Sands and Weakly Cemented Sands

Rotary Coring

- Sandstone, Calcisilitite, Conglomerate

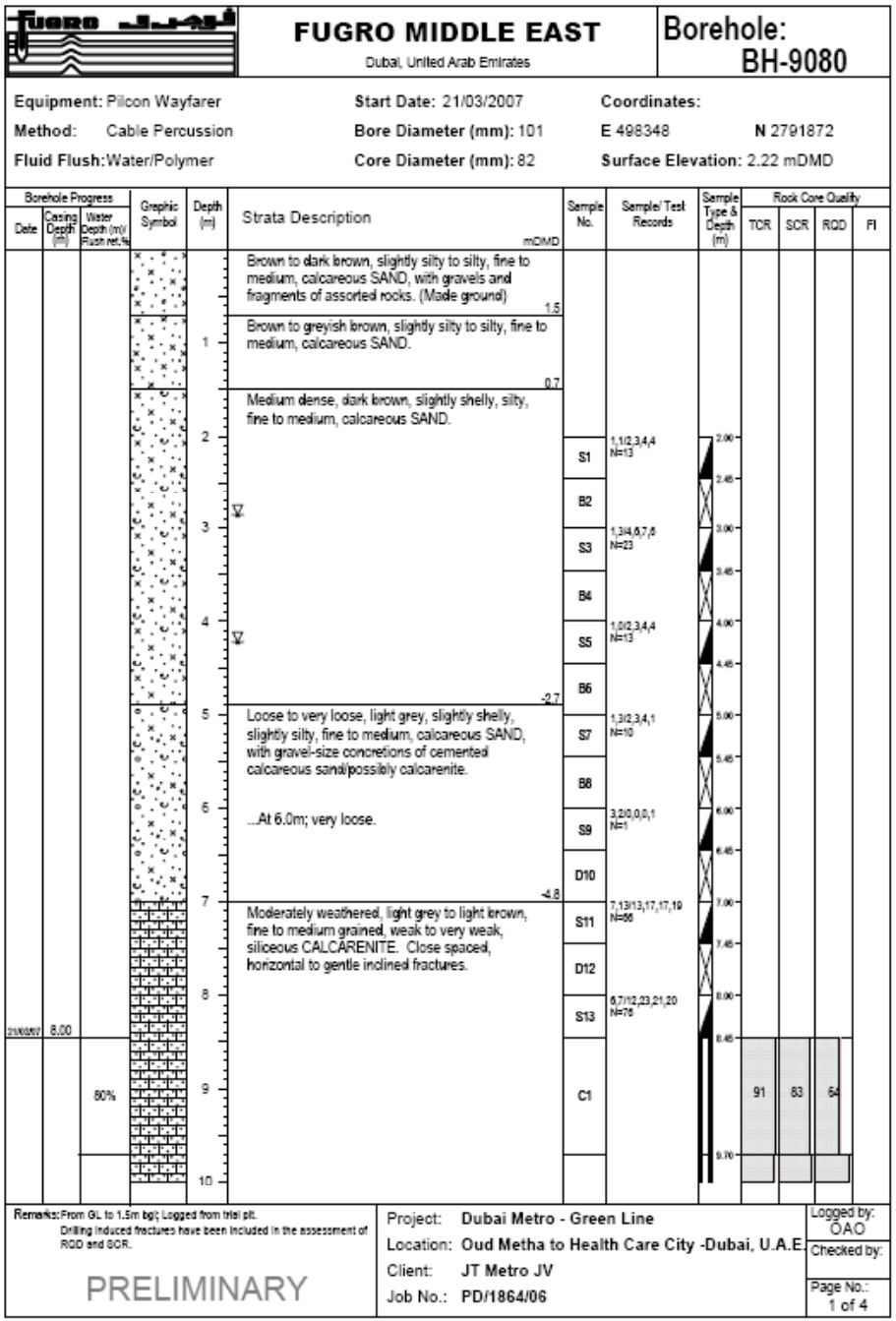
In situ testing

- SPT
- In situ permeability

Laboratory Testing

- Moisture Content, PSD, Sulphate, pH on soils
- Point Load, Unconfined Compressive Strength on Rock

Dubai Metro – Ground Investigation



FUGRO MIDDLE EAST
Dubai, United Arab Emirates

Borehole: BH-9080

Equipment: Pilcon Wayfarer
Method: Cable Percussion
Fluid Flush: Water/Polymer

Start Date: 21/03/2007
Bore Diameter (mm): 101
Core Diameter (mm): 82

Coordinates:
E 498348 **N** 2791872
Surface Elevation: 2.22 mDMD

Borehole Progress: Date	Casing Depth (m)	Water Depth (m)/ Flush ret.%	Graphic Symbol	Depth (m)	Strata Description (mDMD)	Sample No.	Sample/ Test Records	Sample Type & Depth (m)	Rock Core Quality: TCR	SCR	RQD	FI
					Brown to dark brown, slightly silty to silty, fine to medium, calcareous SAND, with gravels and fragments of assorted rocks. (Made ground) 1.5							
				1	Brown to greyish brown, slightly silty to silty, fine to medium, calcareous SAND. 0.7							
				2	Medium dense, dark brown, slightly shelly, silty, fine to medium, calcareous SAND.	S1	1,1/2,3,4,4 N=13	2.00				
						B2		2.45				
				3		S3	1,3/4,6,7,6 N=23	3.00				
						B4		3.45				
				4		S5	1,0/2,3,4,4 N=13	4.00				
					-2.7	B6		4.45				
				5	Loose to very loose, light grey, slightly shelly, slightly silty, fine to medium, calcareous SAND, with gravel-size concretions of cemented calcareous sand/possibly calcarenite.	S7	1,3/2,3,4,1 N=10	5.00				
						B8		5.45				
				6	...At 6.0m; very loose.	S9	3,2/0,0,0,1 N=1	6.00				
					-4.8	D10		6.45				
				7	Moderately weathered, light grey to light brown, fine to medium grained, weak to very weak, siliceous CALCARENITE. Close spaced, horizontal to gentle inclined fractures.	S11	7,13/13,17,17,19 N=66	7.00				
						D12		7.45				
21/03/2007	8.00			8		S13	6,7/12,23,21,20 N=76	8.00				
		80%		9		C1		8.45	91	83	64	
				10				9.70				

Remarks: From GL to 1.5m bg; Logged from trial pit.
Drilling induced fractures have been included in the assessment of RQD and SCR.

PRELIMINARY

Project: Dubai Metro - Green Line
Location: Oud Metha to Health Care City -Dubai, U.A.E.
Client: JT Metro JV
Job No.: PD/1864/06

Logged by: OAO
Checked by:
Page No.: 1 of 4

Dubai Metro – Ground Investigation

Unit 2a(i)

Unit 2a(ii)

Dubai Metro – Ground Investigation

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Unit 2b

Unit 3

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Dubai Metro – Derivation of Design Parameters

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Dubai Metro – Derivation of Design Parameters

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- Design parameters derived by Atkins Dubai and agreed with the Engineer in Dubai
- Atkins Dubai produce a Ground Report and Pile Length Report
- No opportunity to re-negotiate design parameters
- Design parameters in soil and rock derived from SPT- N value and Unconfined Compressive Strength (UCS) respectively

Dubai Metro – Derivation of Design Parameters

ATKINS

- Φ_{soil} from SPT N-value after Peck, Hanson and Thorburn
- Φ_{rock} from triaxial test results
- c'_{rock} from $c' = UCS_{mass}(1-\sin \Phi)/2 \cos \Phi$

- $E'_{soil} = 2.3N_{60}$ MPa
- $E'_{rock} = 215 \times UCS^{0.5}$

- $f_{s(soil)} = 1.6N + 6$ kPa after Decourt (1995)
- $f_{s(rock)} = 02.5$ or $0.35 \times (UCS_{design})^{0.5}$ after Zhang & Einstein (1998)
- $f_{b(rock)} = 2.5 \times (UCS_{design})^{0.5}$

Dubai Metro – Derivation of Design Parameters

ATKINS

Typical Design Parameters

		ν	γ_b (Mg/m^3)	c' (kN/m^2)	ϕ (°)	f_s (kN/m^2)	E_{sv}' (kN/m^2)	E_{sh}' (kN/m^2)
Soil	Unit 1	0.25	1.9	0	30	14	21	15
	Unit 2a(i)	0.25	1.9	5	36	38	69	48
Rock	Unit 2a (ii)	0.2	2.0	72	39	270	180	126
	Unit 2b	0.2	2.0	60	39	210	167	117
	Unit 3	0.2	2.0	90	35	275	215	151

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Dubai Metro – Viaduct Substructure Design

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Dubai Metro – Viaduct Substructure Design

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Viaduct arrangement

- Precast segmental construction
  - Single spans of 20m to 36m
  - Twin spans of either 44m+44m or 40m+40m made continuous after deck erection
  - 3-span continuous structures made by balanced cantilever method with main spans of 66m to 74m
  - 3-span or 4-span continuous structures of 30m to 36m through elevated stations

Dubai Metro – Viaduct Substructure Design

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Pile design

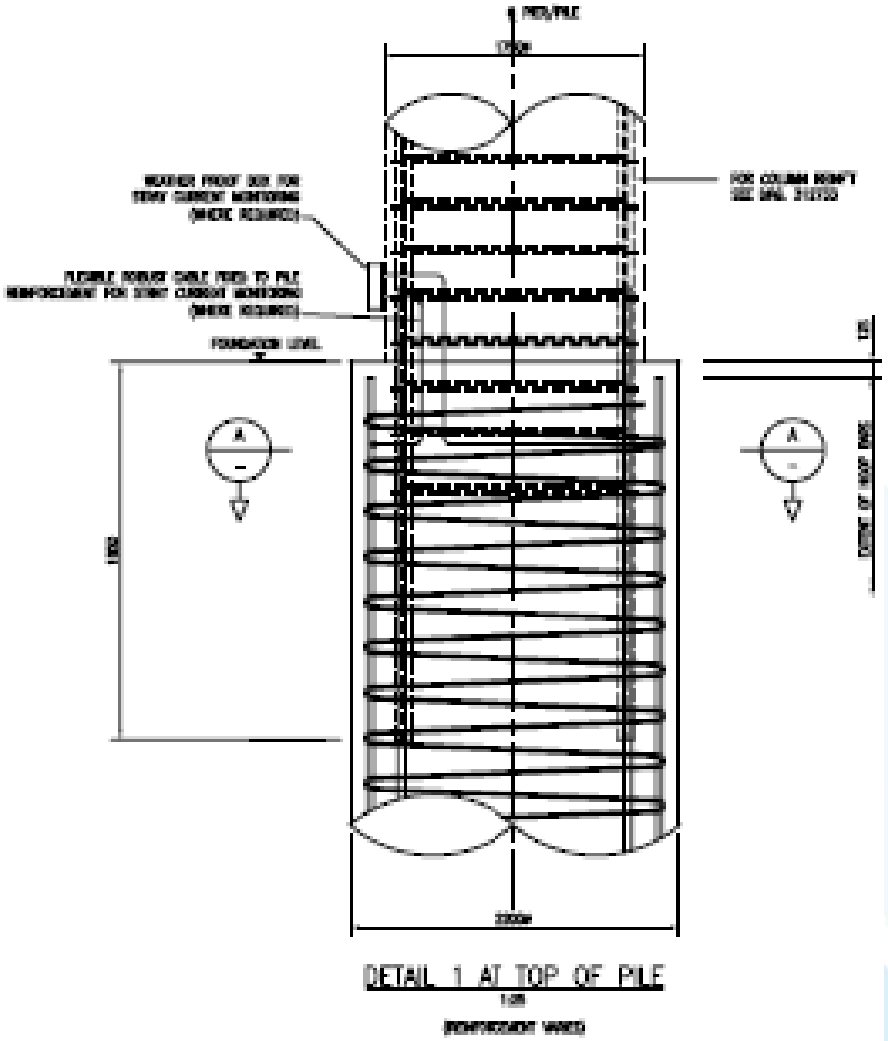
- Single central piers typically 2.2m to 2.8m diameter
- Twin-pile groups, typically 1.6m to 1.8m diameter, used to span over existing services
- 4-pile groups, typically 1.6m to 1.8m diameter, for more heavily loaded internal piers of continuous spans
- Piles up to 40 metres long
- Lengths determined from critical SLS or ULS cases
  - Based on skin friction safety factors of 2.5 and 1.5 respectively
  - End bearing ignored

Dubai Metro – Viaduct Substructure Design

Pile Design (continued)

- Designed for durability in aggressive environment
  - Addition of waterproofing membrane to protect against chloride attack
  - Pile cover of 120mm to protect against sulphate attack

- Horizontal ground acceleration coefficient of 0.12g (ULS only)
- Centrifugal loading (plan curvature down to 300m)
- Self-weight of deck on curved sections of deck
- Wind
- Collision loads
- Rail-structure interaction



Dubai Metro – Viaduct Substructure Design

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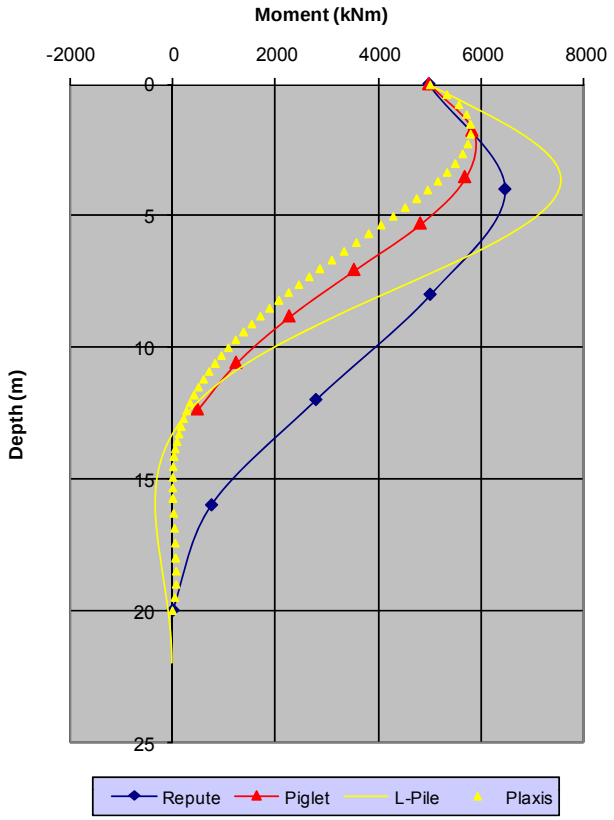
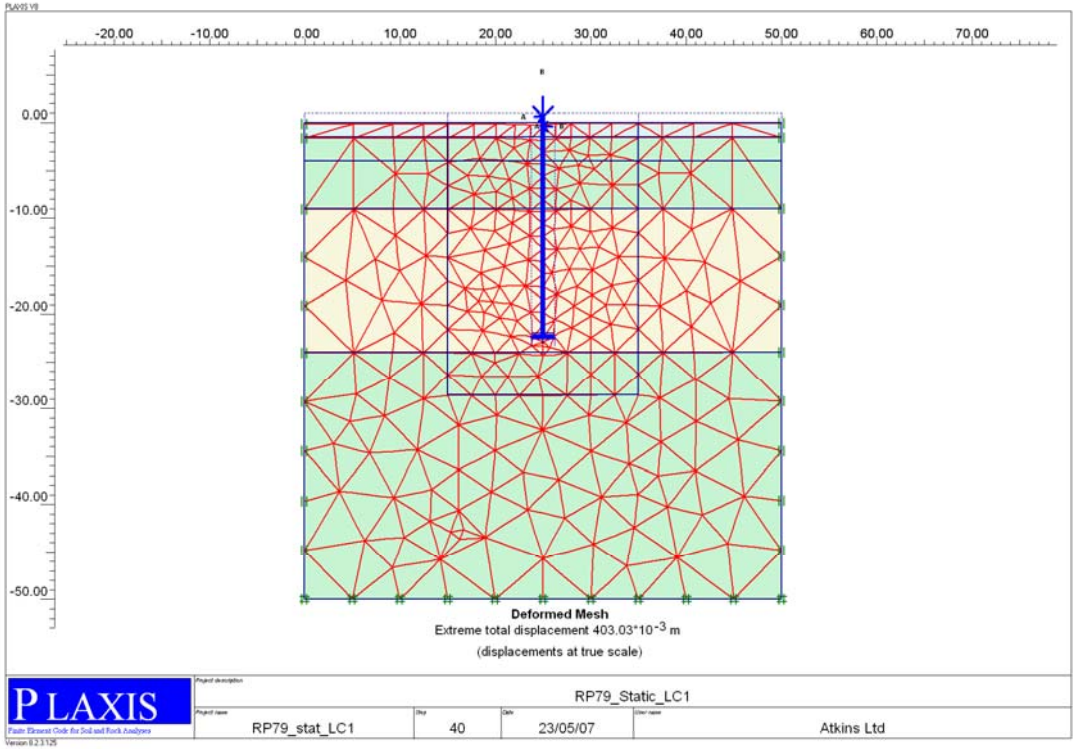
Pile Analysis

- Load effects for reinforcement design generated by analysis using REPUTE program and verified using PLAXIS, PIGLET & L-PILE





Dubai Metro – Viaduct Substructure Design

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Pile Testing

- 3no piles tested
- Showed 2 x calculated ultimate skin friction and 50% calculated end bearing
- Recommended 0.35 $(UCS_{design})^{0.5}$ for polymer supported pile shaft and 0.25 $(UCS_{design})^{0.5}$ for bentonite supported pile shaft as minimum values
- Recommended $Q_{allow} = Qs+Q_b/2.5$

Dubai Metro – Viaduct Substructure Design

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Pile Testing (continued)

Pile No.	Diameter (m)	Length (m)	Design SWL (kN)	Maximum Test Load (kN)	Settlement at SWL (mm)	Settlement at Max Load (mm)
OP1	2.2	20	13,500	54,000	1.4	6.9
OP3	2.2	25	11,000	24,750	2	5
OP4	1.5	20	9,500	38,000	2	12

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Dubai Metro – Union Square Station

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Dubai Metro – Union Square Station

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- First Underground Station to be constructed
- On-line junction of Red and Green Lines
- Internal dimensions 50m x 250m
- Open aspect with few internal columns (25 metre span with internal columns)
- Drive shaft for all Red and Green Line tunnel drives

Dubai Metro – Union Square Station

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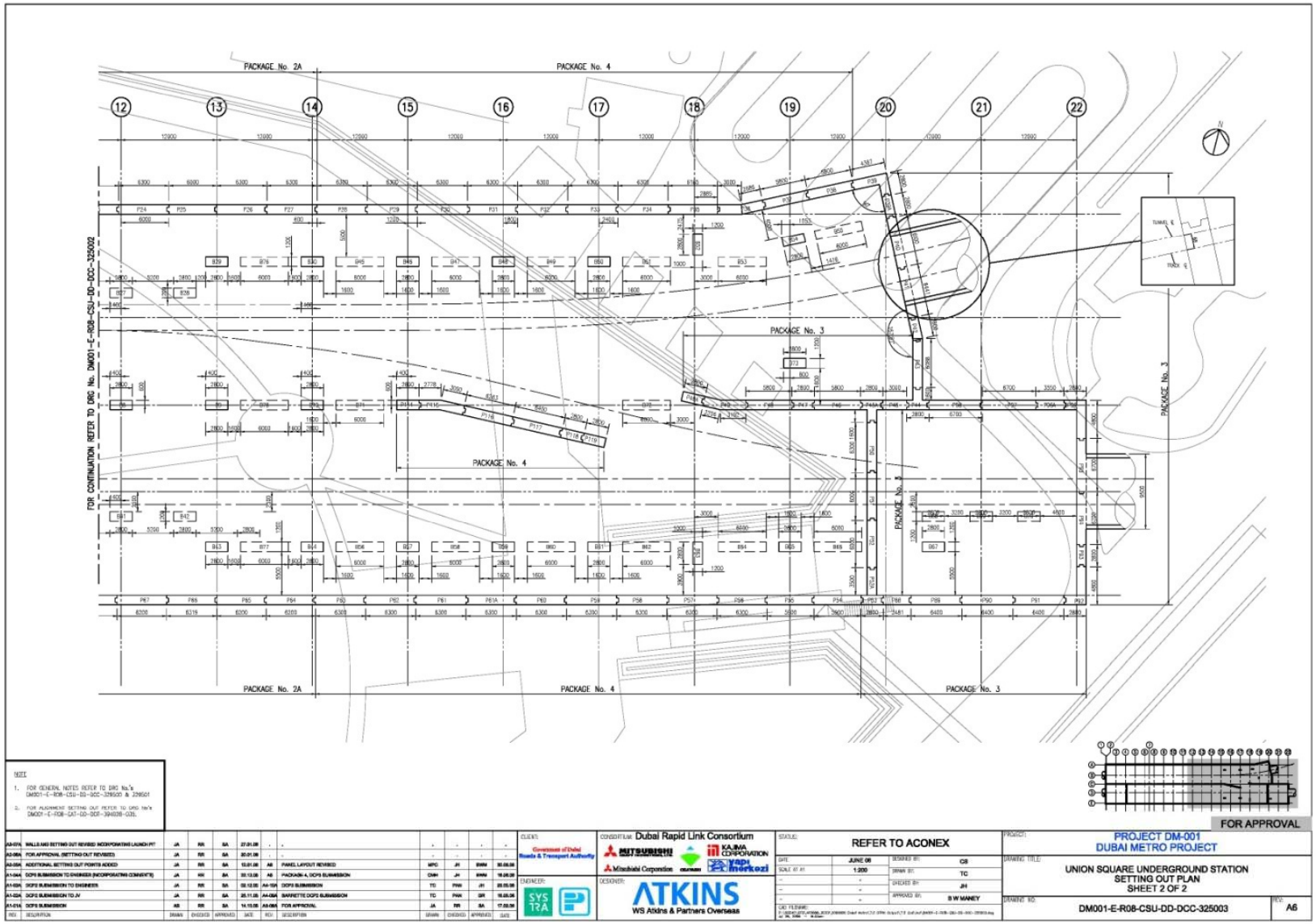
Design Considerations

- Wall depth to -44.6mDMD to provide satisfactory FoS against flotation and reduce water ingress during construction (Tender design had grout plug)
- Base slab design to counteract uplift from 22 metres of water, 2.5 metres thick (tension barrettes)
- Wall design for high moments from large spans of slabs, 1200mm thick to optimise reinforcement density (reverse moment from uplift of base slab)
- Wall design to BS8110 and BS8007 (Reinforcement controlled by 0.2mm crack width requirement)

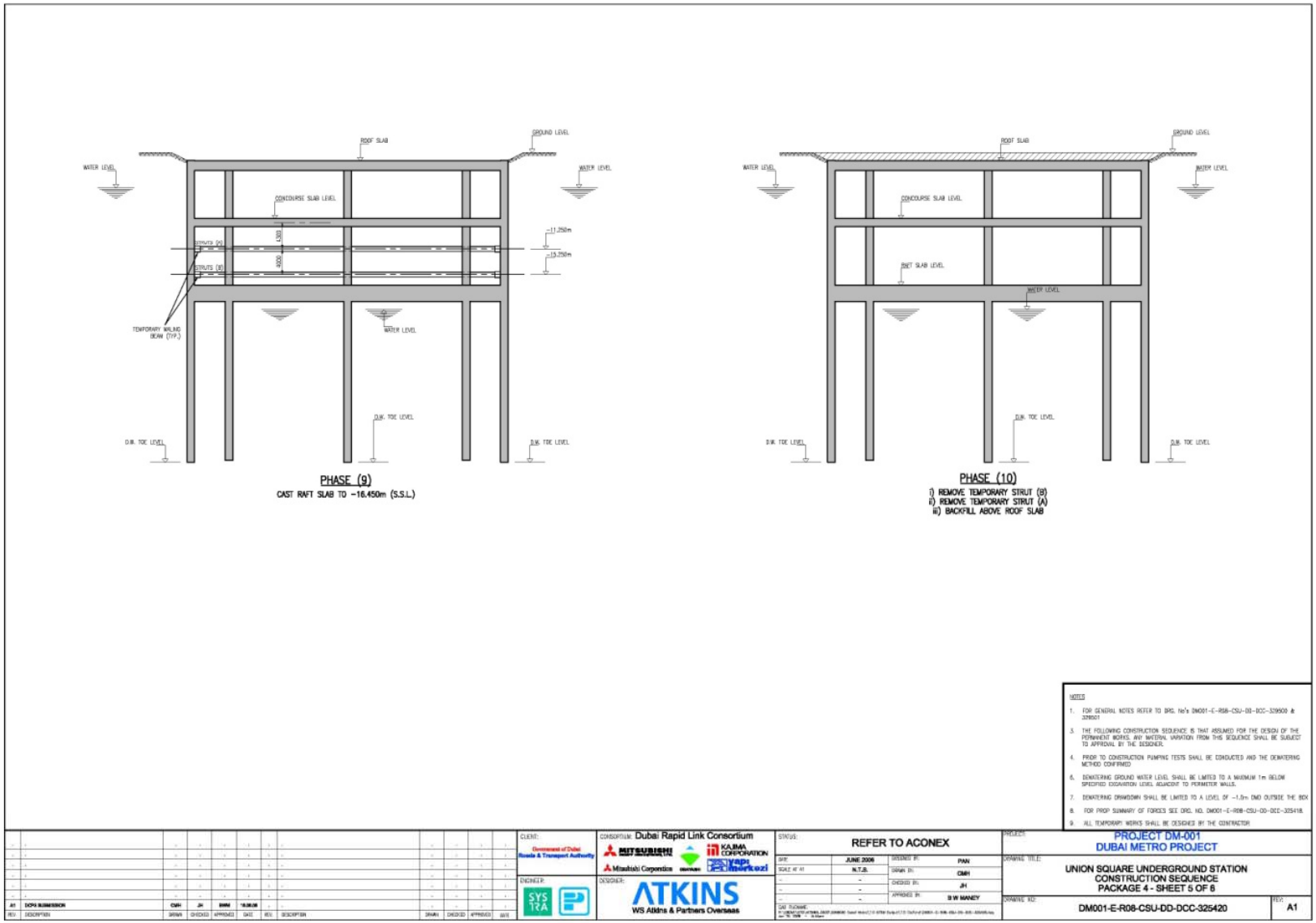
Dubai Metro – Union Square Station

Panel Arrangement – Eastern End of Station Box



Dubai Metro – Union Square Station

Typical sections through box



Dubai Metro – Union Square Station

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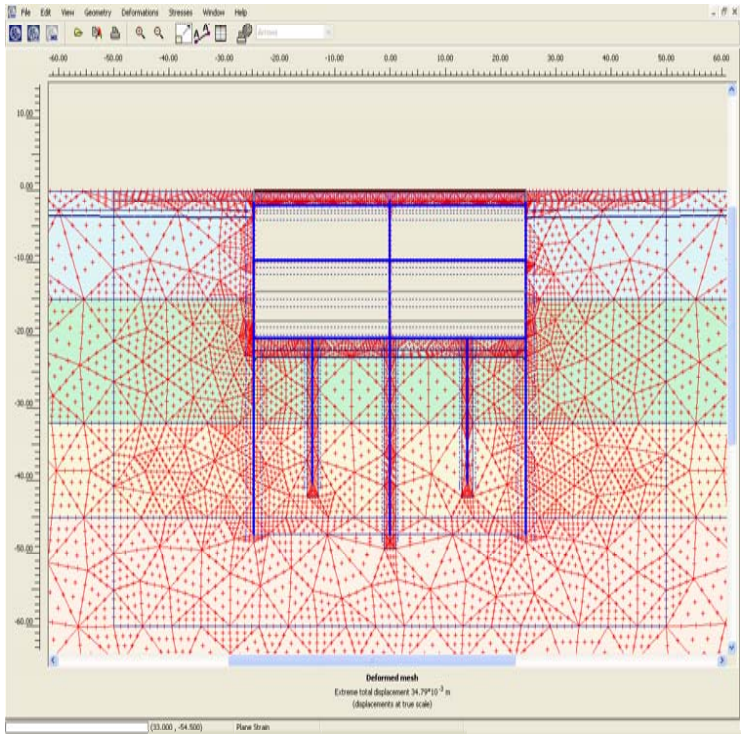
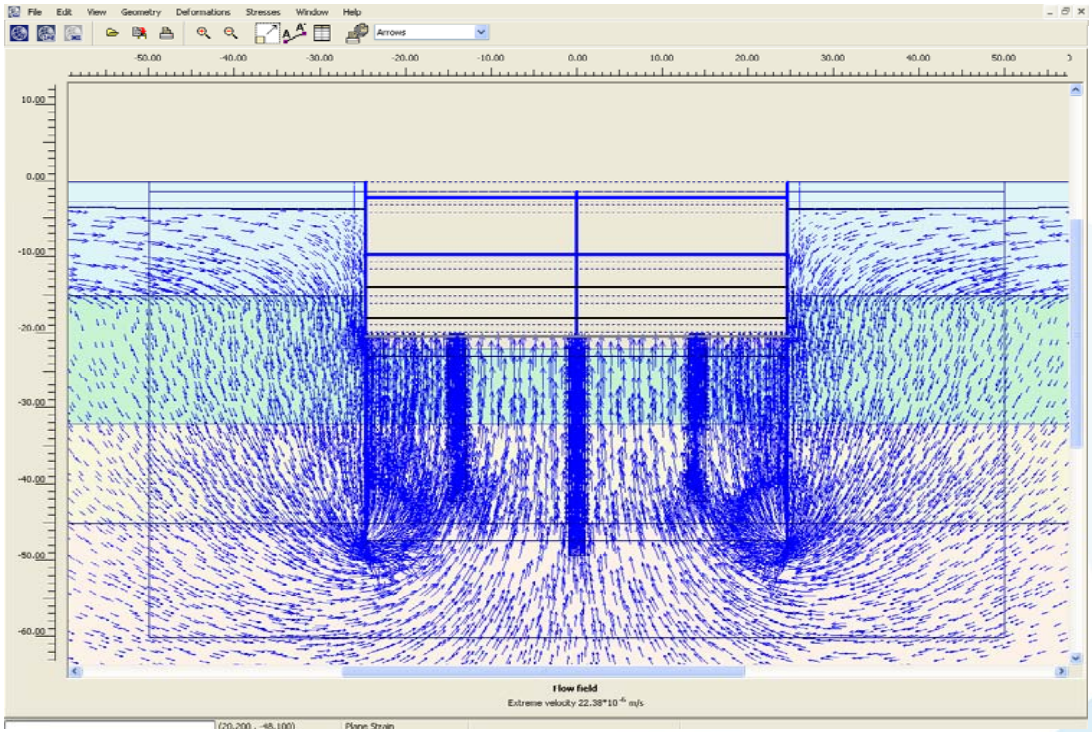
Design analysis

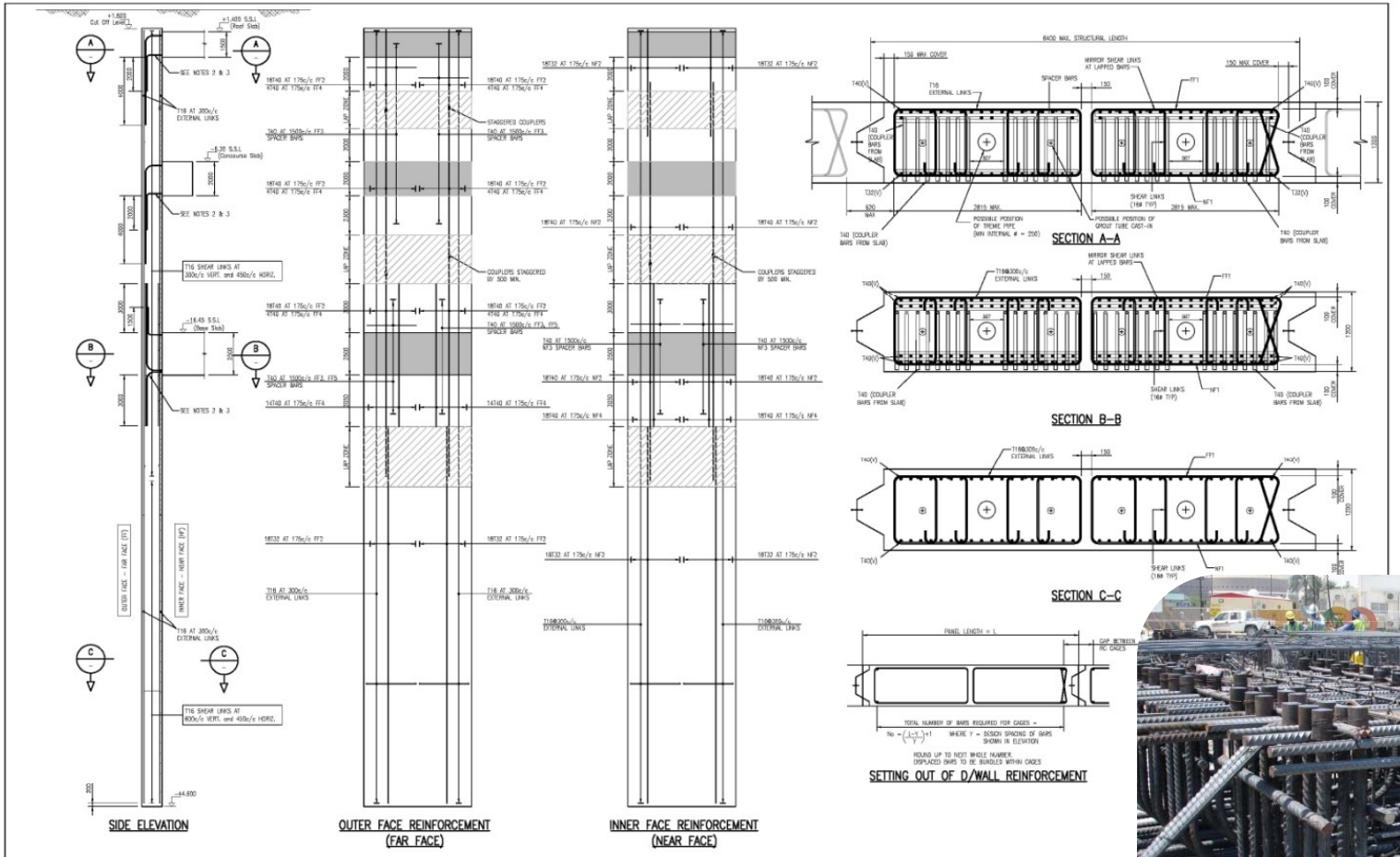
- Wall reinforcement design after CIRIA C580 using PLAXIS
- Flotation design using I. Struct. E. Guidelines for Basement design
- Settlement Analysis using approach after CIRIA C580





Dubai Metro – Union Square Station

Typical Panel Detail



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Dubai Metro – Questions

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Dubai Metro – Substructure design

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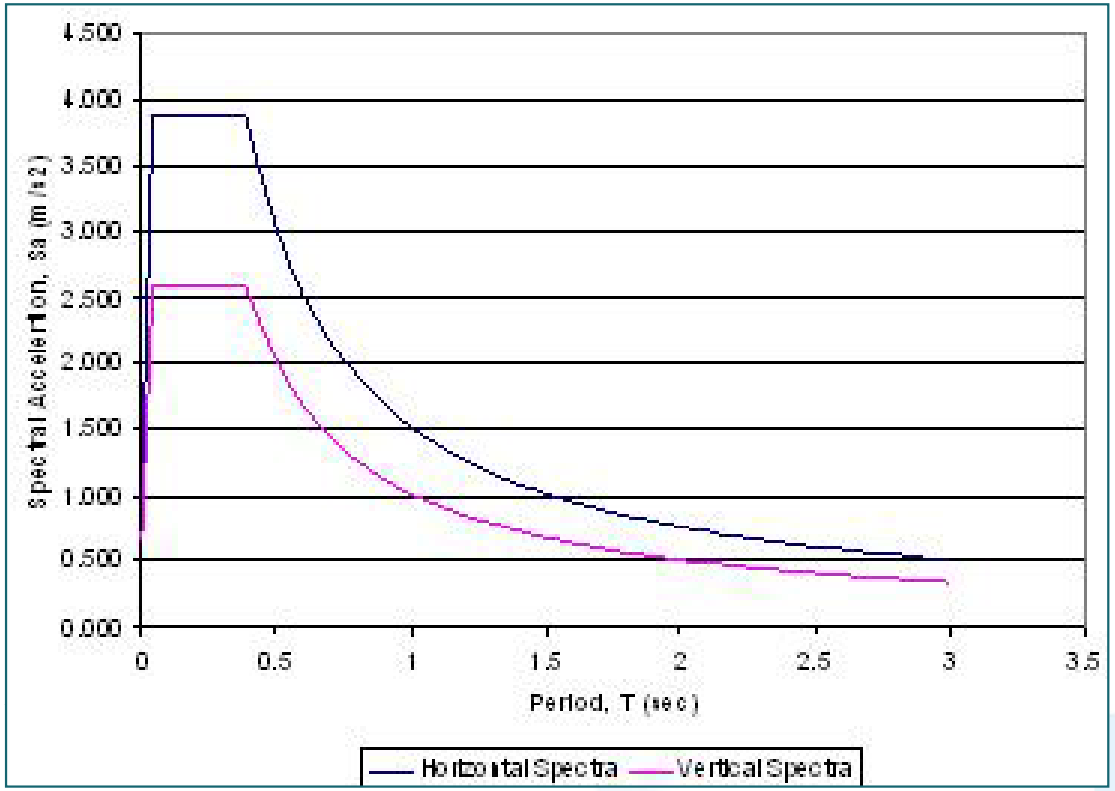
Seismic analysis

- Nearest fault line is 120 km from UAE – Zargos fault line
- Cautious approach because of use for evacuation – “essential” to AASHTO
- AASHTO defined seismic response spectrum used with A = 0.12g
  - Site coefficient dependent on bearing type used



Dubai Metro – Substructure design

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Column and pile design

- **Once rules established, 1400+ unique foundations designed in 9 months**
- **Strict control procedures between design team & setting-out team**
- **Optimisation / automation process developed throughout**
  - Process of seismic analysis and section checking automated by linked macros
  - Enabled peak output of 100 foundations to be designed per week