Eureka Tower

Melbourne

A Bored Pile Foundation Story

Jim Finlayson

Overview of talk

- Background to project
- Initial studies on site
- Comparison of rock socket design methods in use
- Eureka Tower investigations
- Adopted footing solution
- Construction, including Statnamic test piling

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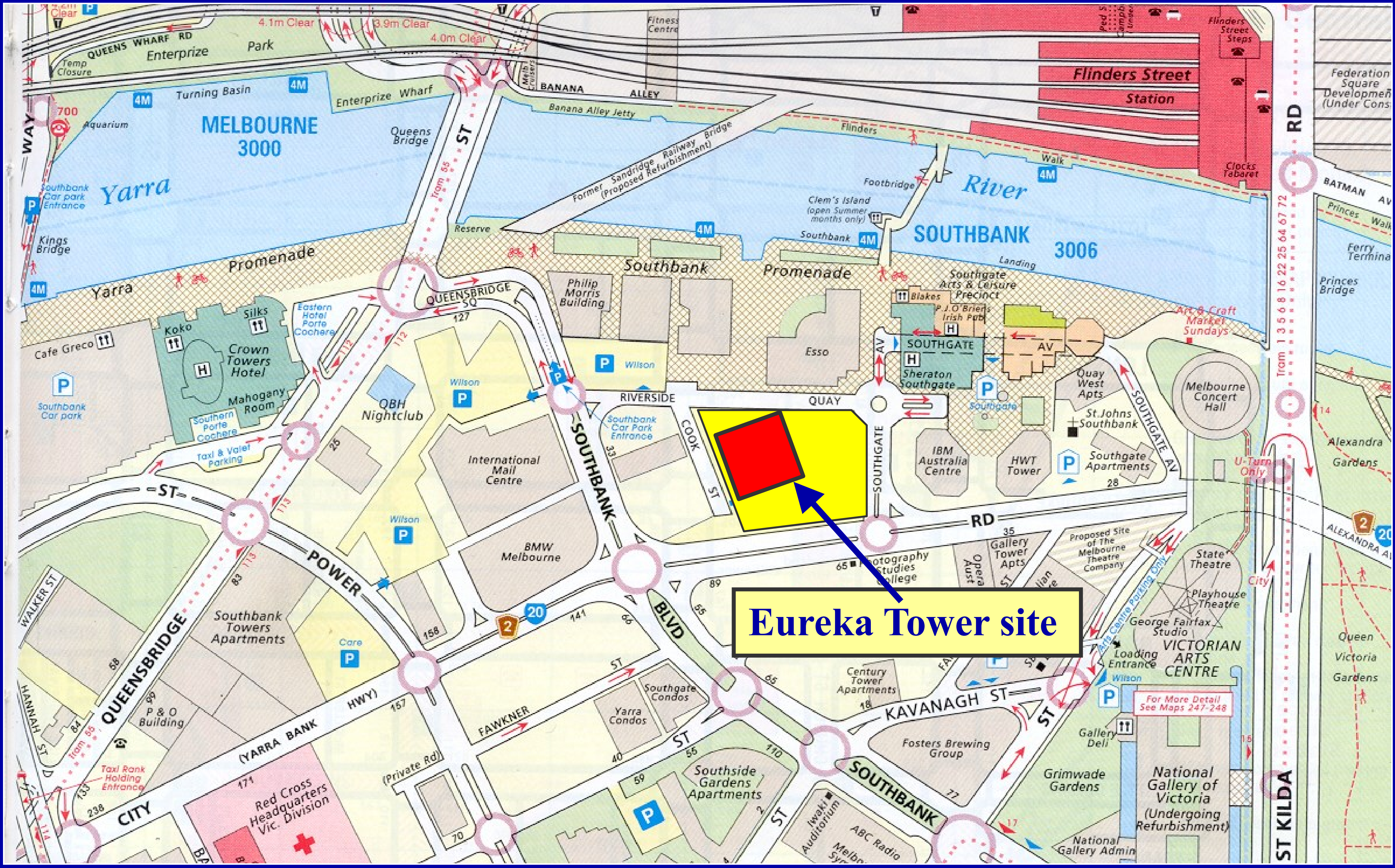
Locality Plan



Eureka Tower

Melbourne

- 300 m high, 92 stories
- One level of basement
- 554 Apartments
- Architect :- Fender Katsalidis
- Geotechnical Engineer:- Golder Associates
- Structural Engineer:- Connell Mott MacDonald
- Builder:- Grocon Constructors
- Completed 2006


An artist's impression of what the tower will look like when it is completed in late 2004.

Background to Project

- Originally an industrial area, on reclaimed land
- 1990:- No 1 Riverside Quay - (30 level commercial)
- Extensive geotechnical investigations, project abandoned
- 1997:- Waterford Tower - (40 level residential)
- Further investigations, project abandoned
- 2000:- Eureka Tower - (world's tallest residential)
- 2001:- Further extensive investigations
- 2001/02:- Foundations constructed
- Completed 2006

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Site Geology

- Published geology shows Coode Island Silt (soft clays)
- Golder Experience in area 1982 - 1985 showed complex sub-surface stratigraphy
- Quaternary basalt below CIS over part of site, possible Tertiary basalt at depth, within alluvial sequence.
- Silurian Siltstone as basement rock at about 35 m
- Siltstone common foundation in this area for high rise buildings

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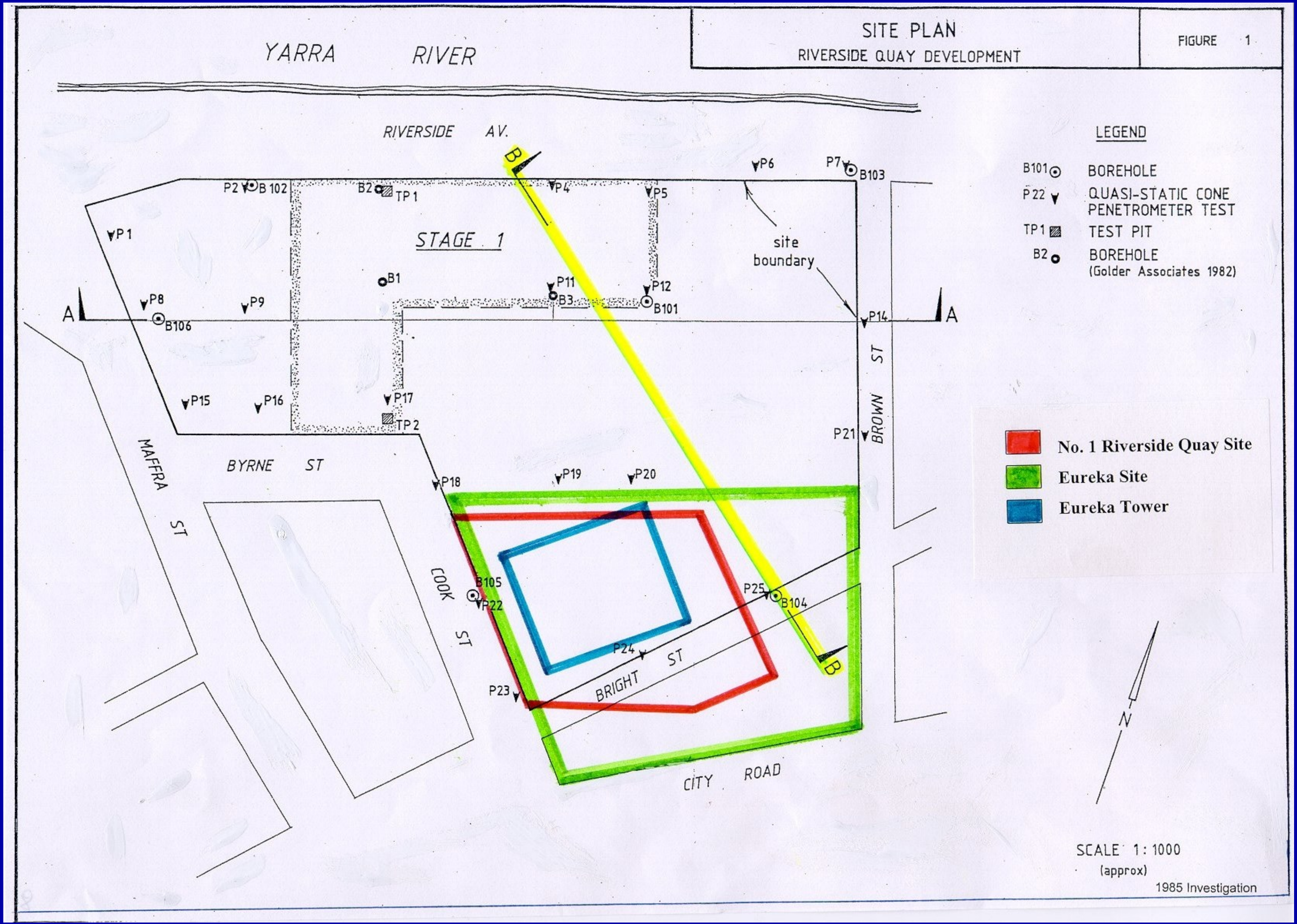
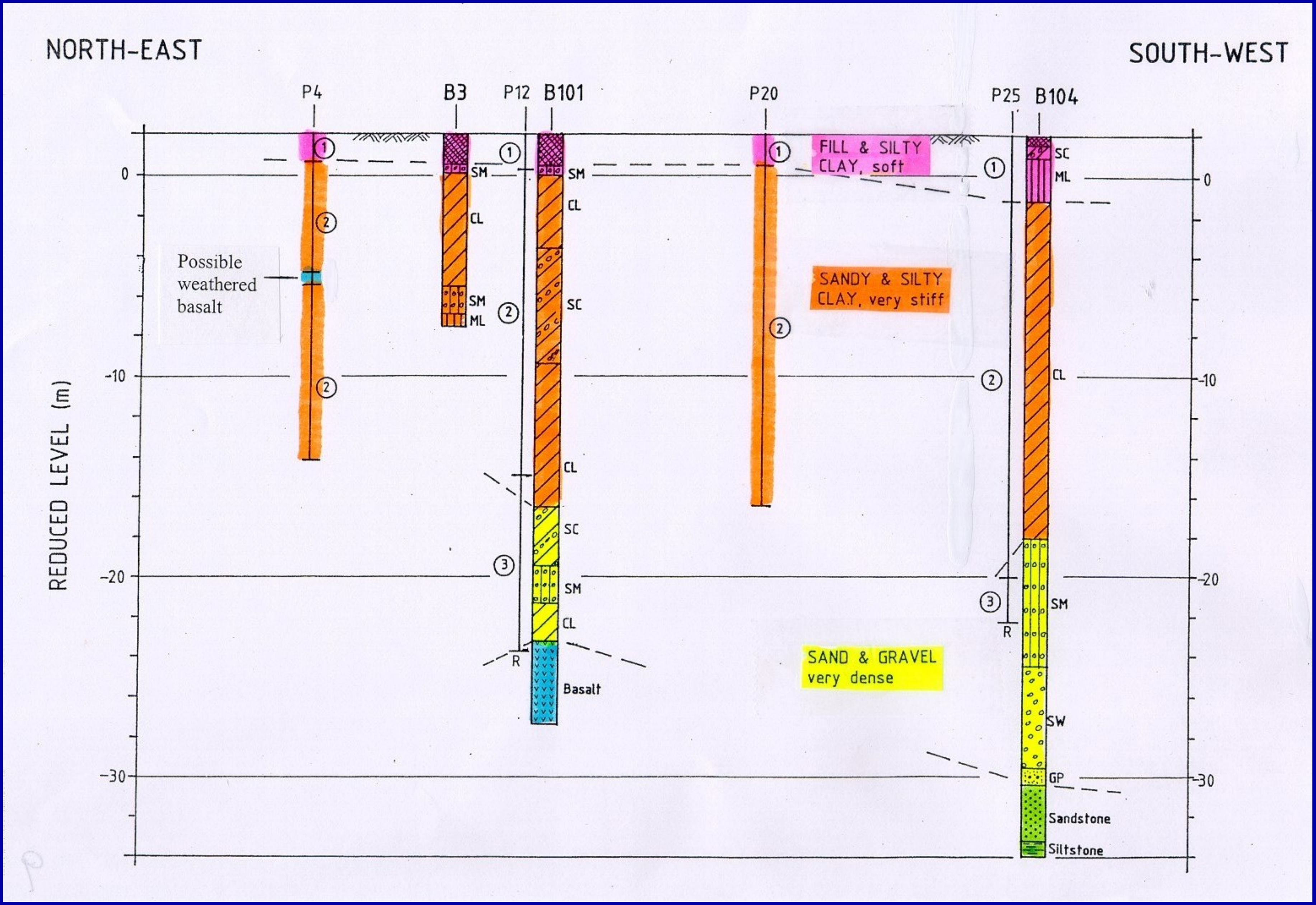
1985 Studies in Area

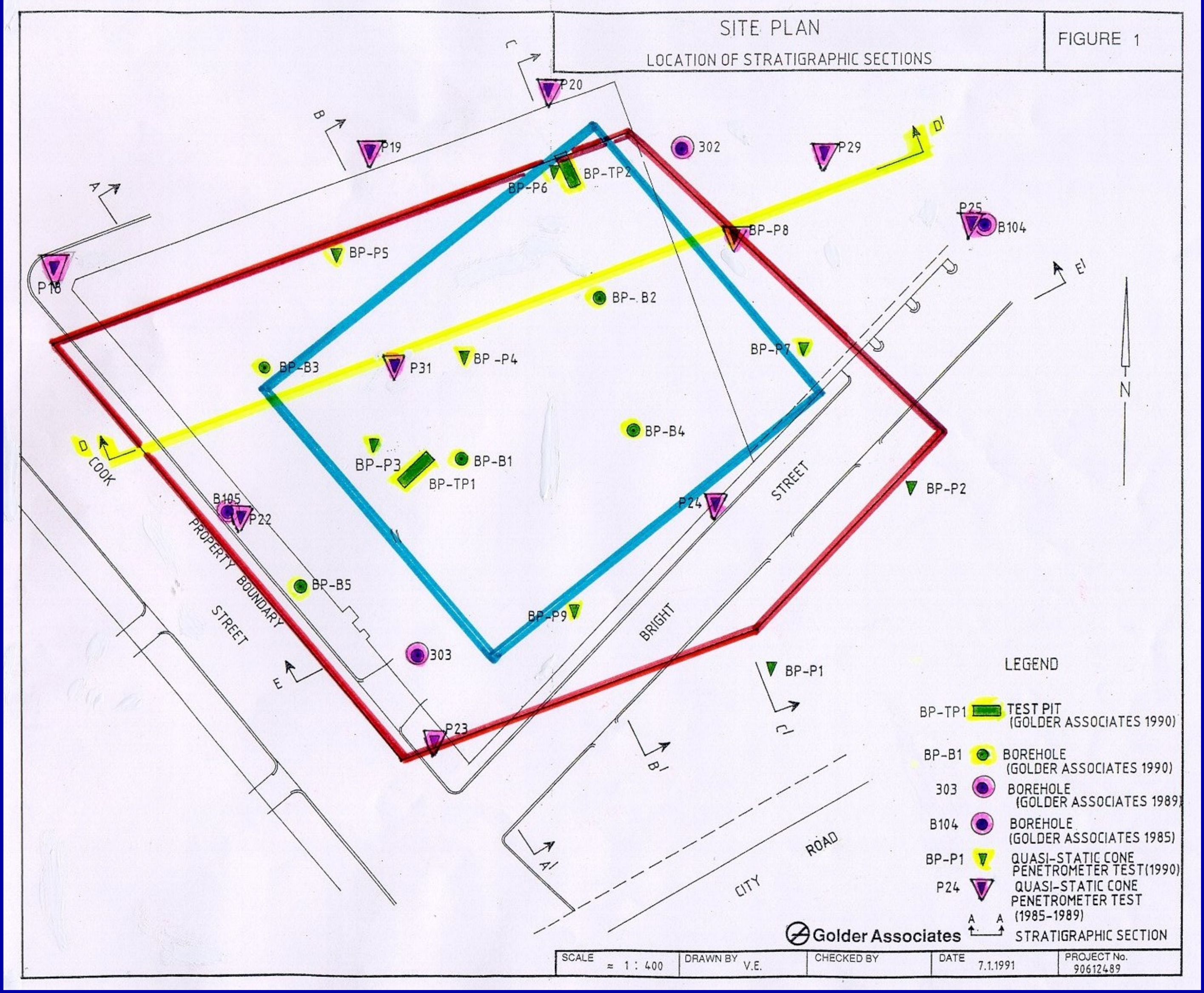


Inferred Stratigraphy:- 1985

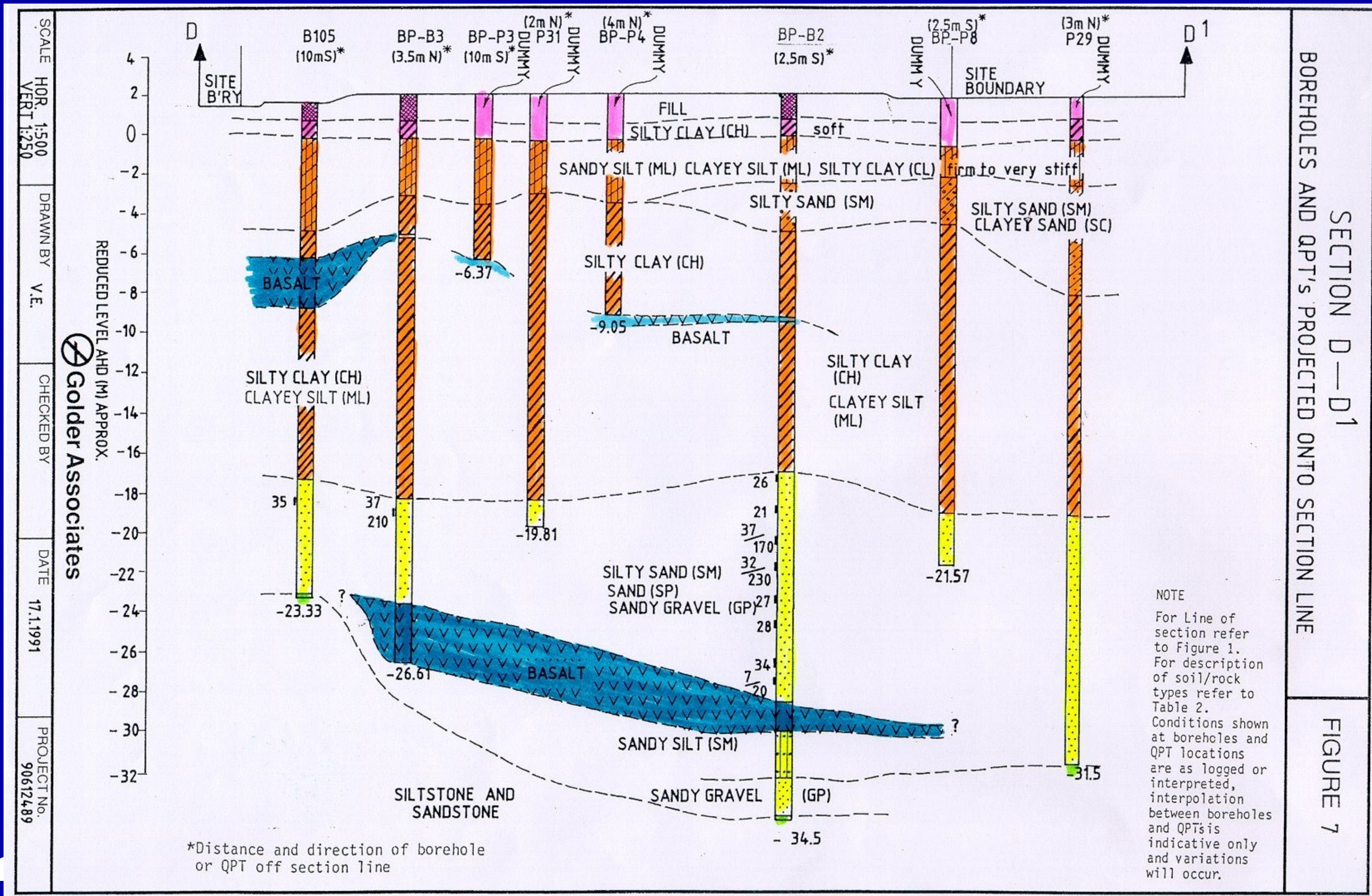


No 1 Riverside Quay

Initial Investigations



Inferred Stratigraphy
Section DD



No 1 Riverside Quay
Initial Investigations

- Showed complex stratigraphy
- Lower basalt of very high strength
- Neither upper nor lower basalt beneath entire site
- Thickness and limits of basalt flows uncertain
- Bored piles founding in lower basalt or siltstone
- Uncertainties in pile schedules
- Proposed drill every second pile, with pressuremeter and extensive UCS testing in rock.
- Design sockets accordingly

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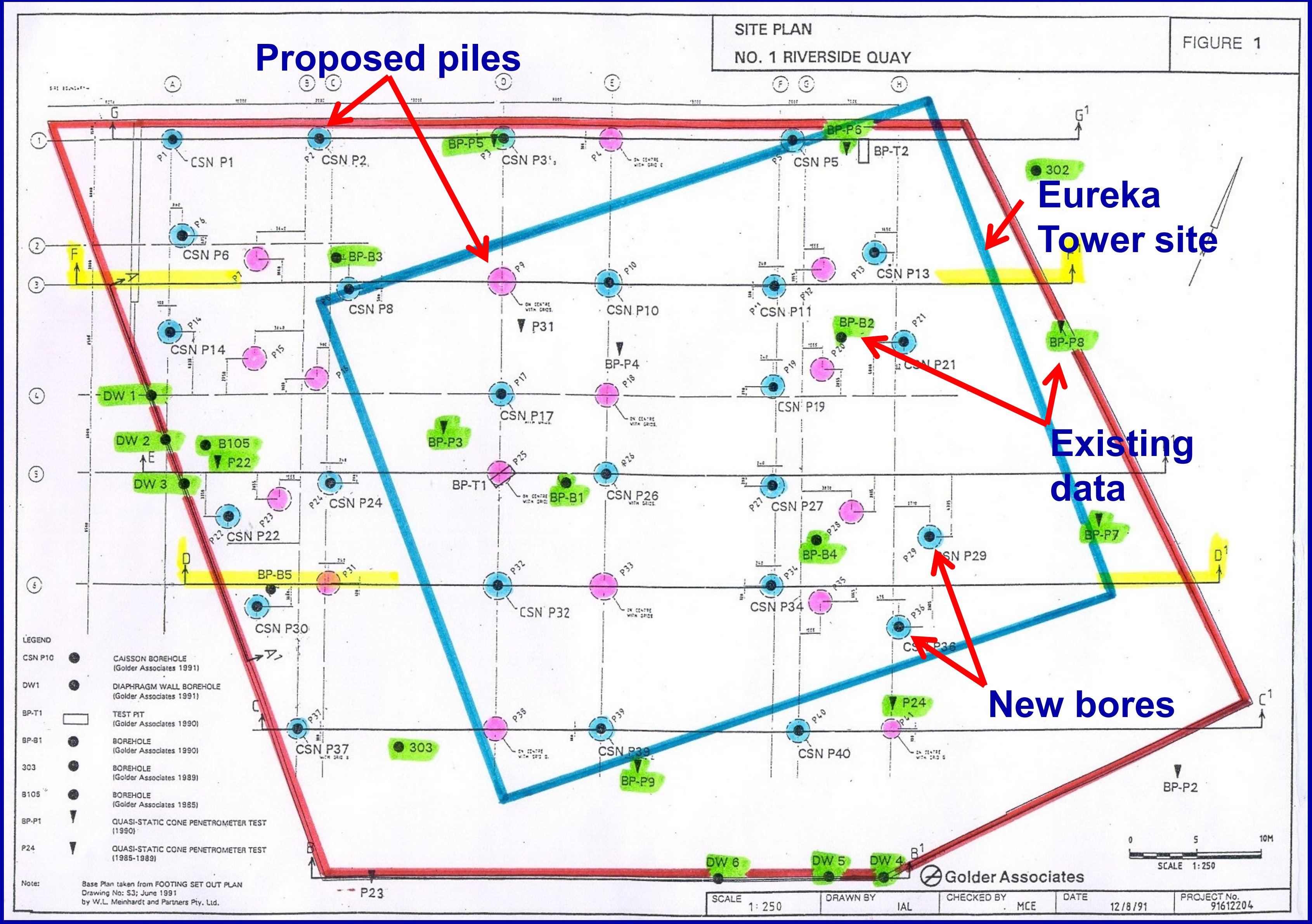
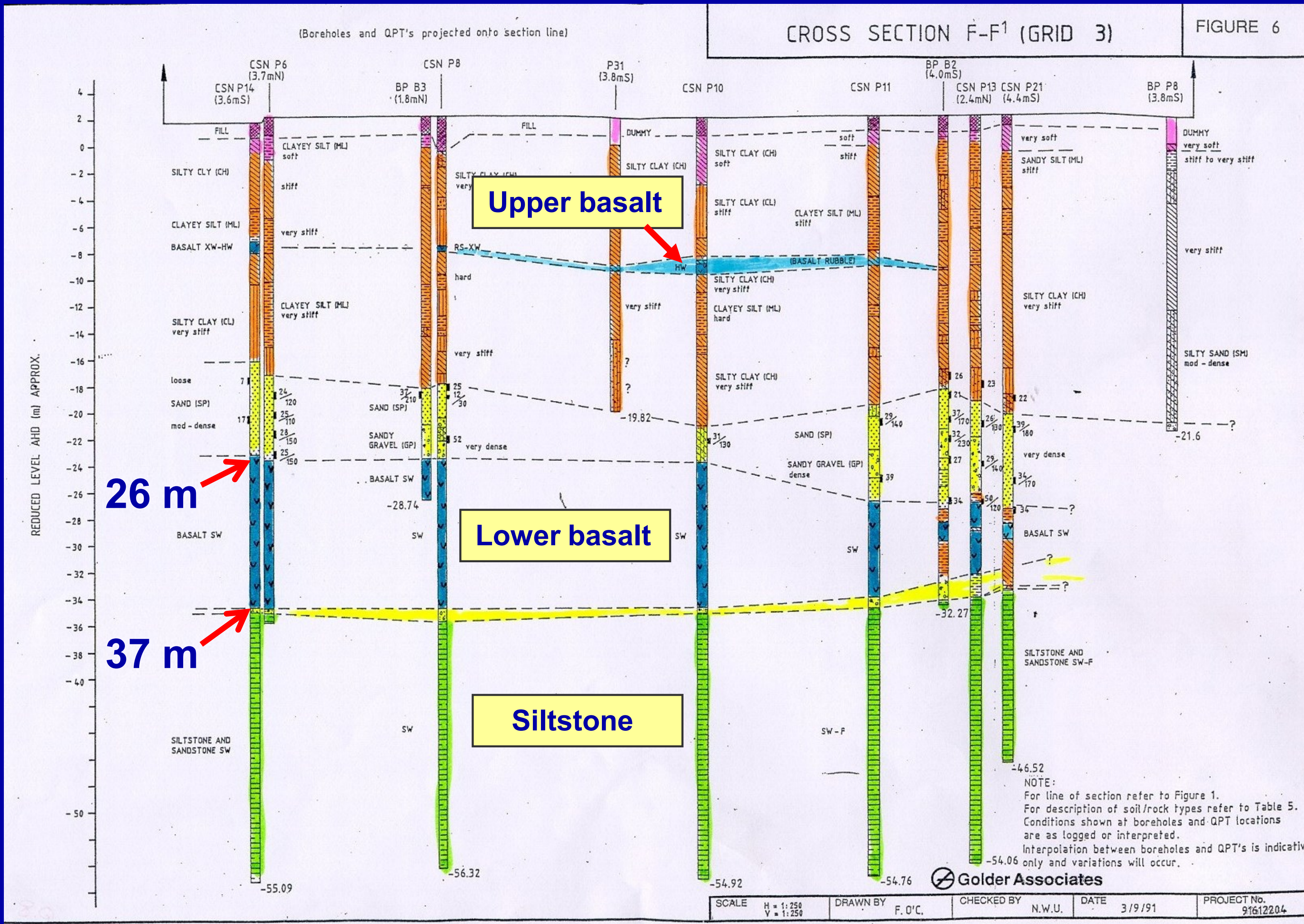
No 1 Riverside Quay
Detailed Investigations

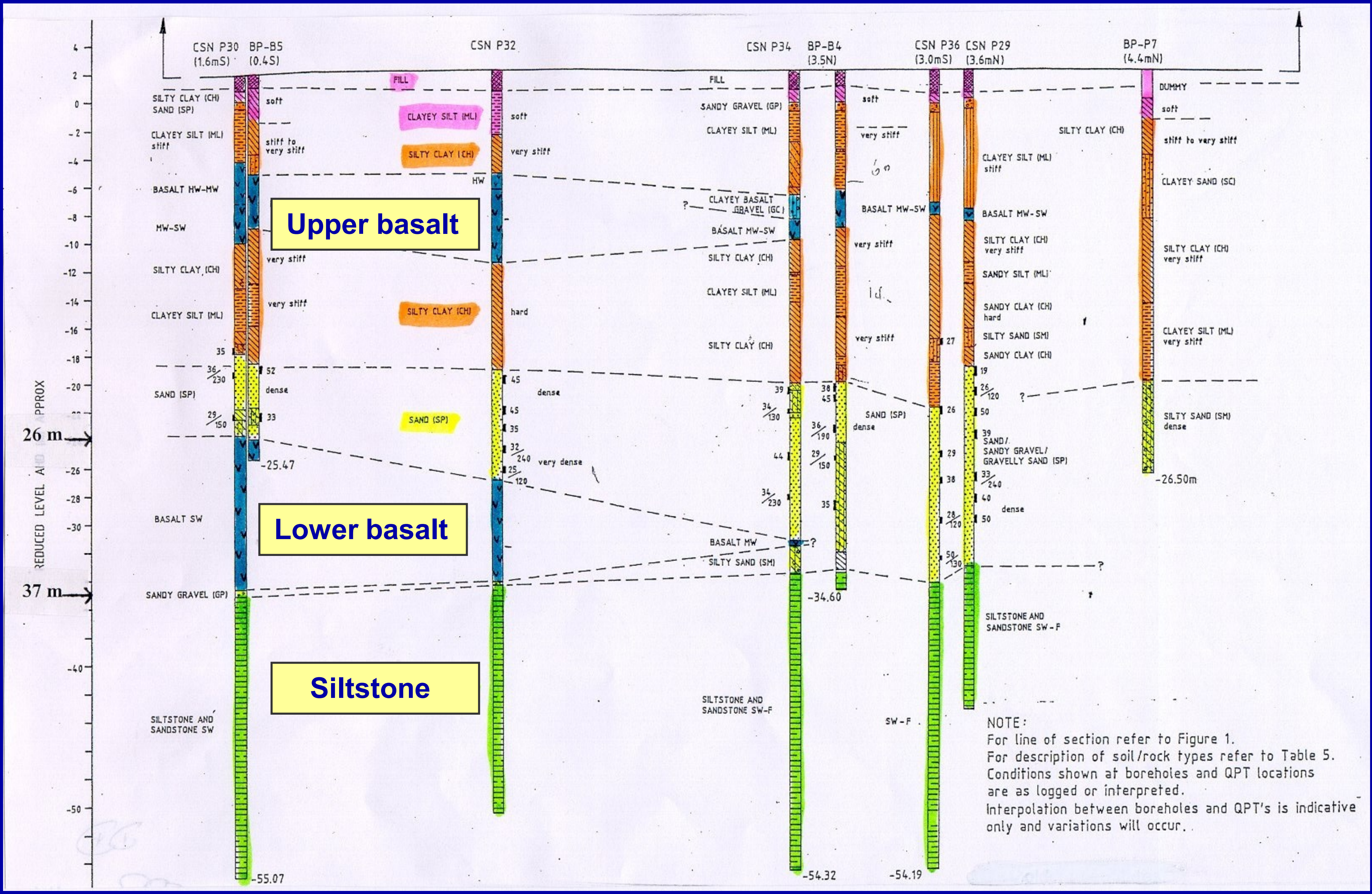


Inferred Stratigraphy

Section FF



Inferred Stratigraphy
Section DD



No 1 Riverside Quay

Design Issues

- Surficial fill and soft clays:- basement retention, settlement
- Base stability for 3 basement option, GWL @ RL 0 m
- Upper basalt layer permeable, discontinuous and of high strength. Unsuitable to support piles due to clays below.
- Lower basalt discontinuous, up to 11 m thick, not always immediately overlying siltstone, widely spaced joints, and of very to extremely high strength:- UCS = 85 MPa to 245 MPa .
- Siltstone of high to very high strength (some Ext. high strength sandstone):- UCS = 16 MPa to 72 MPa (115 MPa)
- $E_{siltstone} > 3,000$ MPa

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No 1 Riverside Quay

Pile Design

- **Historically, design for siltstone based on friction $f_s = 0.1q_b$**
- **For fresh rock, $q_b = 5$ MPa**
- **Minimum socket length of 2 dia.**
- **Pile working loads of 15 MN to 53 MN, dia. = 1.2 m to 1.8 m**
- **Conventional wisdom seemed excessively conservative**
- **For basalt adopted $f_s = 1$ MPa, $q_b = 10$ MPa**
- **Work at Monash (Williams *et al*) suggested more rational settlement based design method, and $q_b = 5$UCS (ult)**
- **In siltstone, program SOCKET used to assess socket lengths for $\rho < 1\%\ \Phi$**

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No 1 Riverside Quay

Pile Design (con't)

- Socket lengths of 3 m to 4.9 m in basalt (18 to 53 MN)
- Socket lengths of 2.4 m to 9 m in siltstone (15 to 53 MN)
- In siltstone, corresponded to f_s= 0.7 MPa to 1 MPa, and q_b = 3.2 MPa to 9 MPa
- Limited $f_s \leq 1$ MPa, and socket $\geq$ 2 dia.
- Piling tenders based on additional data and revised design, $1million less than initial prices (for expenditure of $220,000)
- Illustrates benefit of detailed investigation when warranted

BUT:-!

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The Age, 4 December, 1991

Edited by TIM GRAHAM

COMMERCIAL PROPE

BP scraps $250m plan for its Riverside Quay headquarters

By TIM GRAHAM

BP Australia announced yesterday that it would stop work on its proposed $250 million Australian headquarters on Riverside Quay and cancel the project.

"This has been a difficult and complex decision," BP Australia's managing director, Dr Charles Bowman, said.

"We have invested much work and emotional effort in this project.

"However, the business and economic climate is such that we believe it is not appropriate to make such a major commitment at this time."

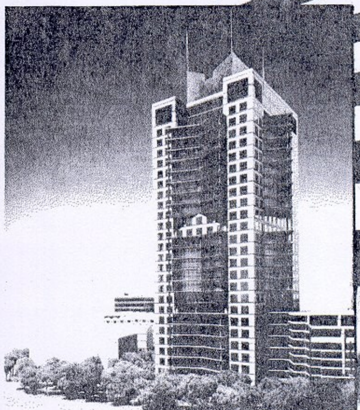
BP's Australian headquarters would remain in Melbourne, Dr Bowman said, but the company will now consider either refurbishing its headquarters at 1 Albert Road and remaining there, or moving to Melbourne Central.

"Other existing buildings which were being considered as possible locations have been ruled out for a variety of reasons," Dr Bowman said.

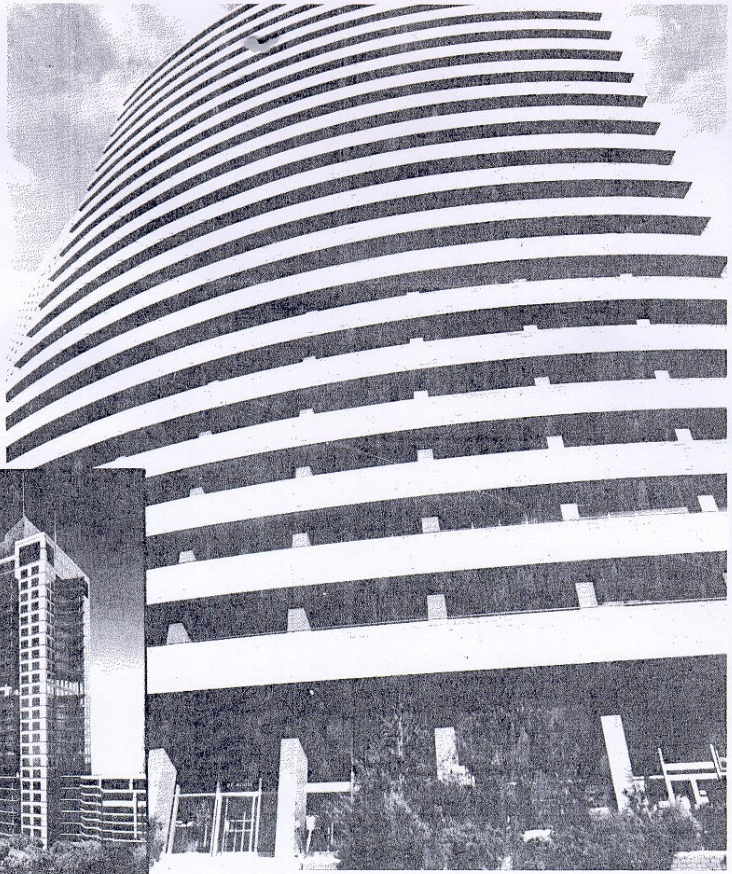
Negotiations with Kumagai Gumi, Melbourne Central's developers, were continuing, he said.

Last week, Esso Australia announced it would develop its site in Riverside Quay, which adjoins BP's 4000-square-metre site.

Esso Australia is currently a tenant in Melbourne Central, where it is basing its Australian headquarters, after deciding last year to move from Sydney.



The dream that BP scrapped will remain an artist's impression.



Back to basics. BP's headquarters at 1 Albert Road (above), will be refurbished if the company decides to stay in preference to moving to Melbourne Central.

Waterford Tower
1997 Investigations

- Residential tower proposed
- Different layout:- 5 more boreholes required
- Not particularly relevant to Eureka Tower
- Project did not go ahead

Eureka Tower Project

A real project at last!

- Initial compilation of available data as pertinent to proposed tower
- Attempted to delineate the basalt flows
- 2000 -Some additional investigations for carpark and hotel sites. These were committed ahead of the Tower
- 2001:- Tower committed and detailed assessment of foundation options undertaken
- Bored piles socketed into basalt and siltstone proposed
- Required boring through basalt at edge of flow
- Needed to accurately delineate the lower basalt

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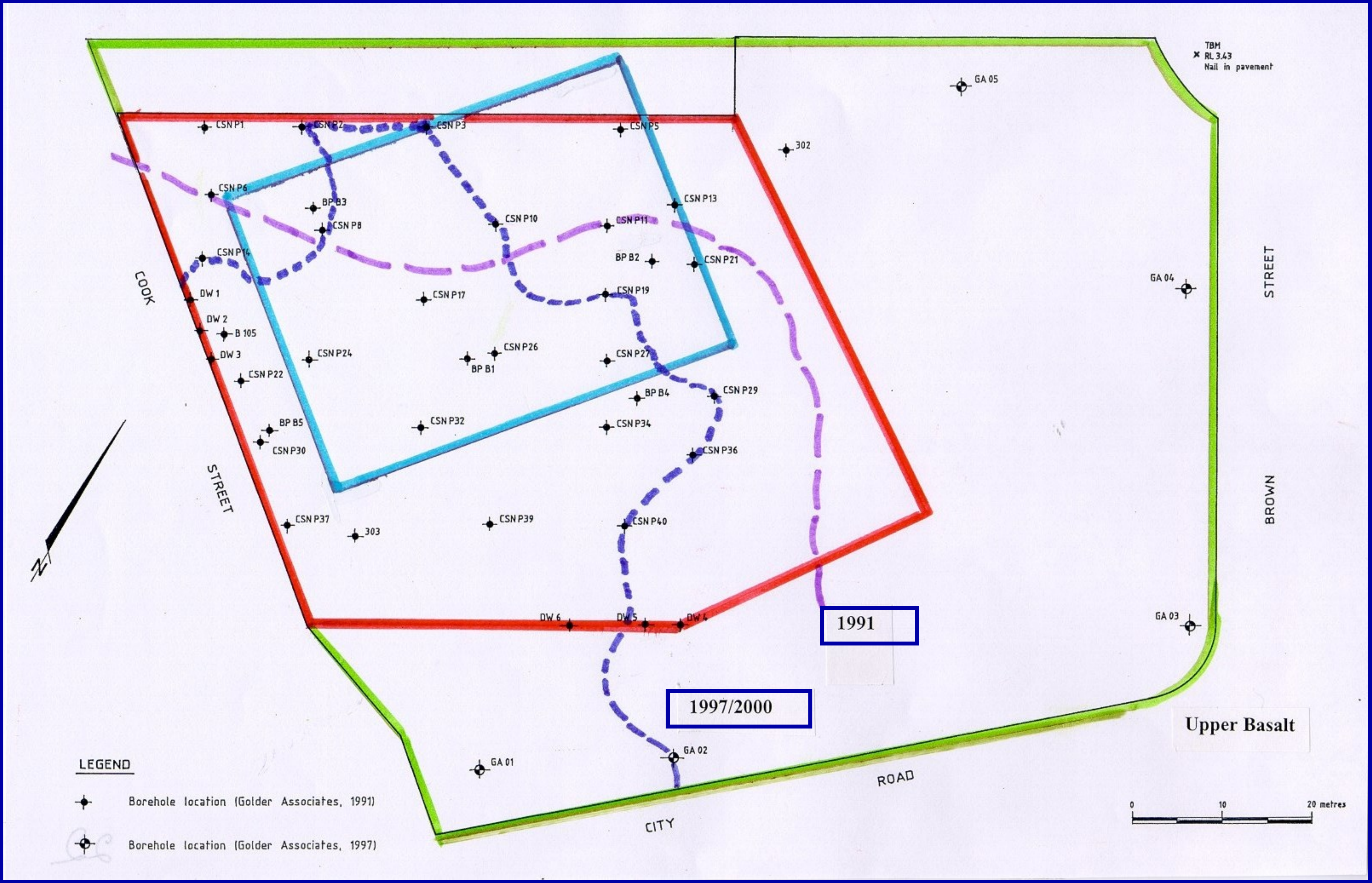
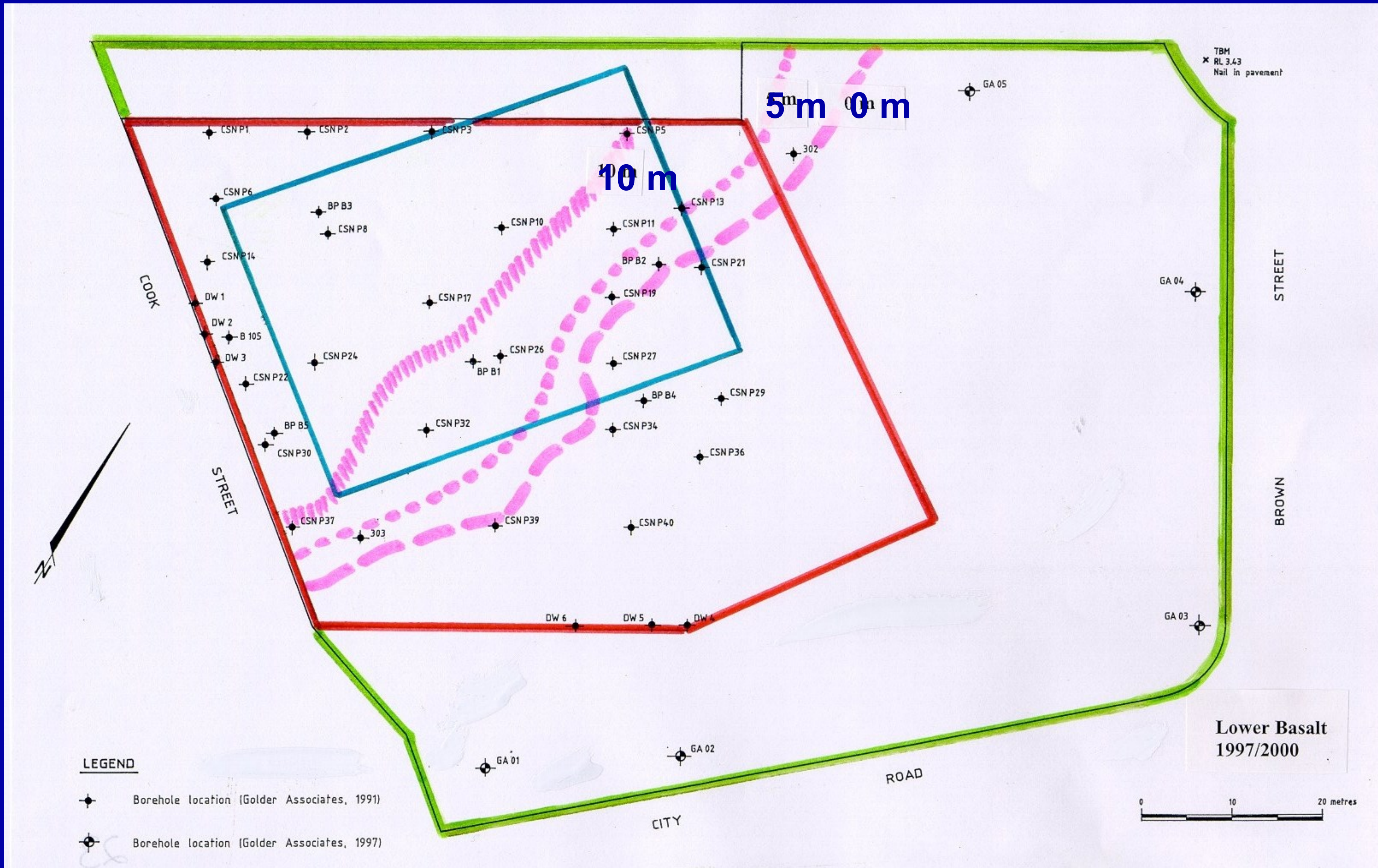
Eureka Tower
Limit of upper basalt

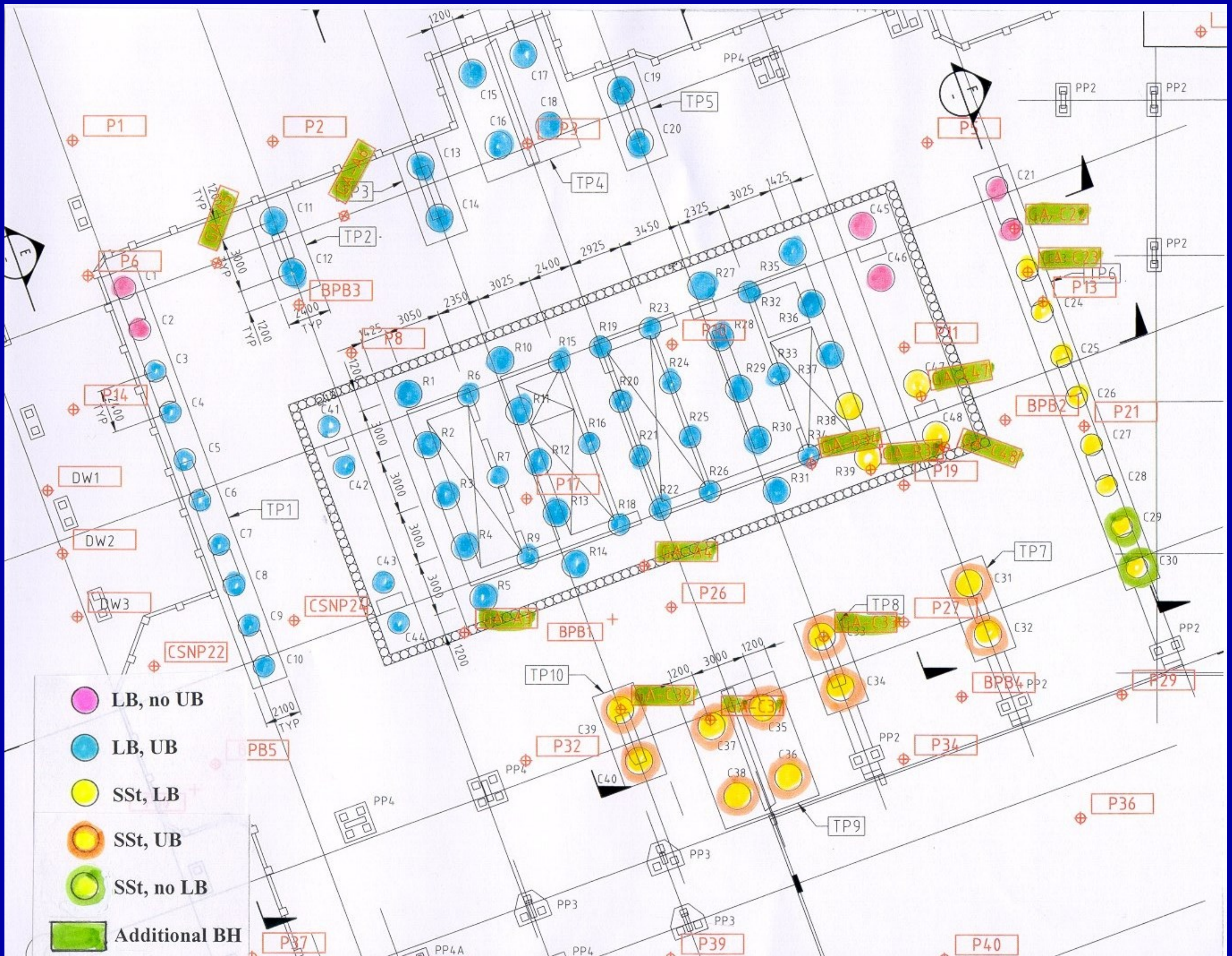


Eureka Tower
Limit of lower basalt

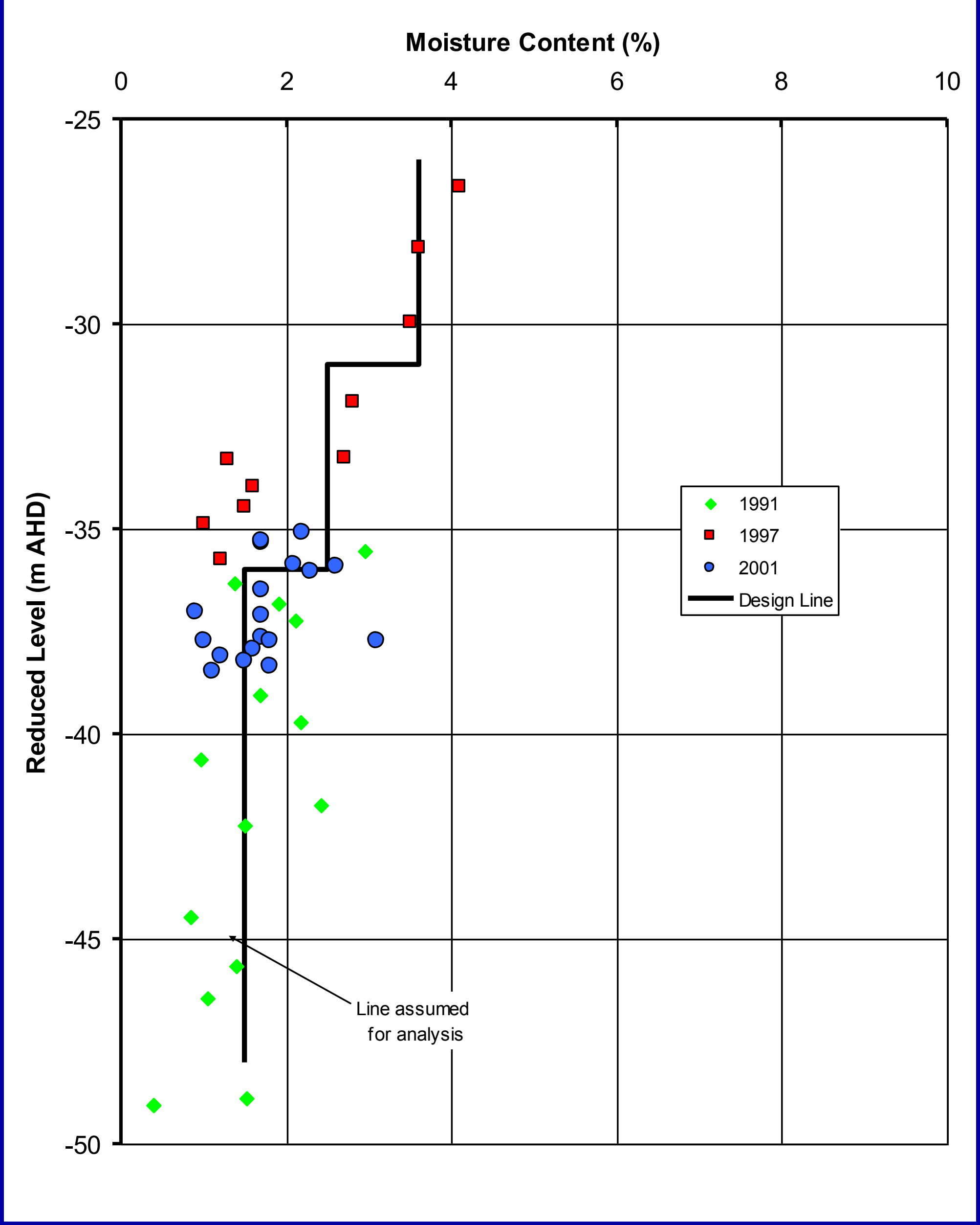


Eureka Tower

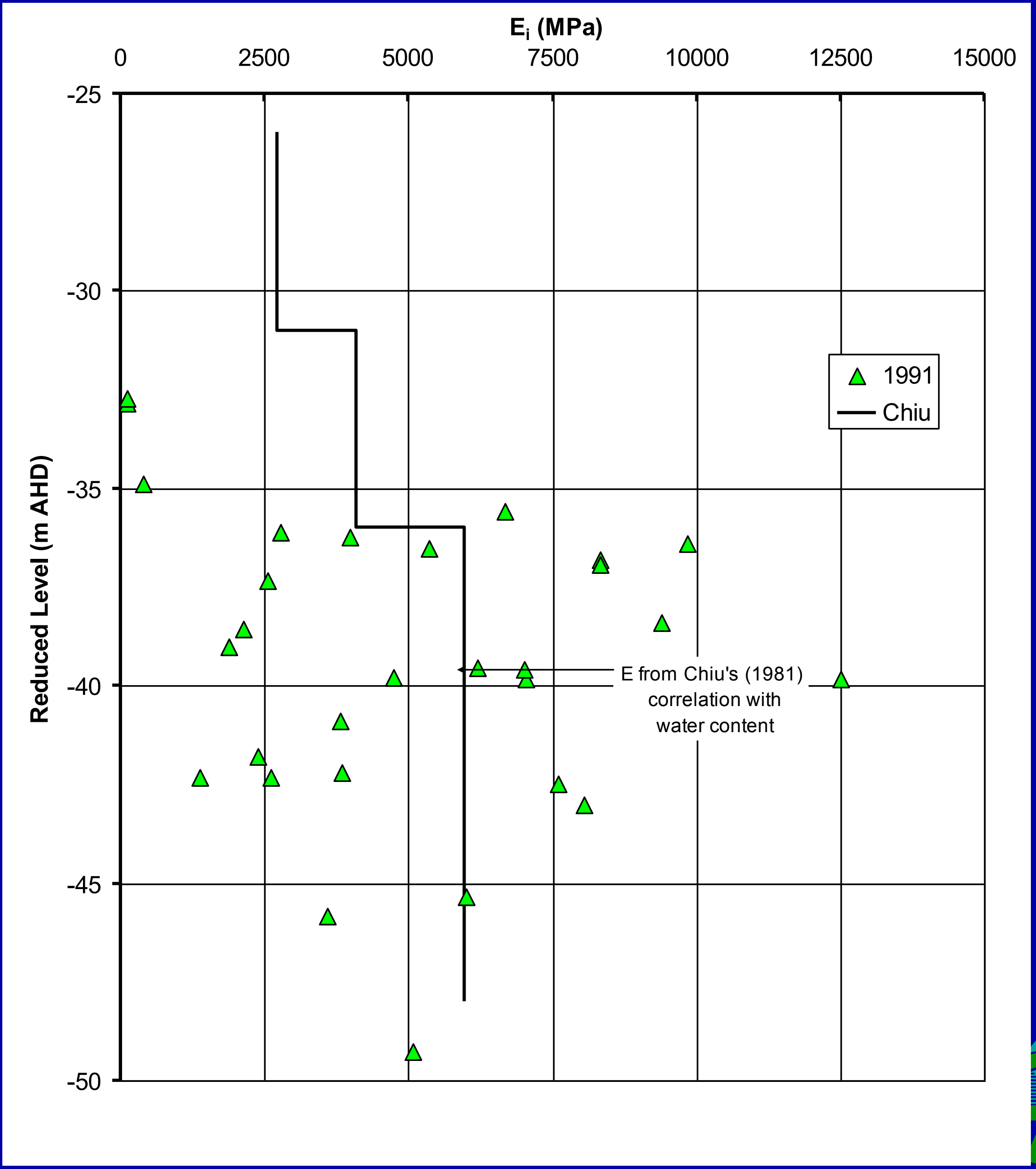
Pile layout , after additional investigation



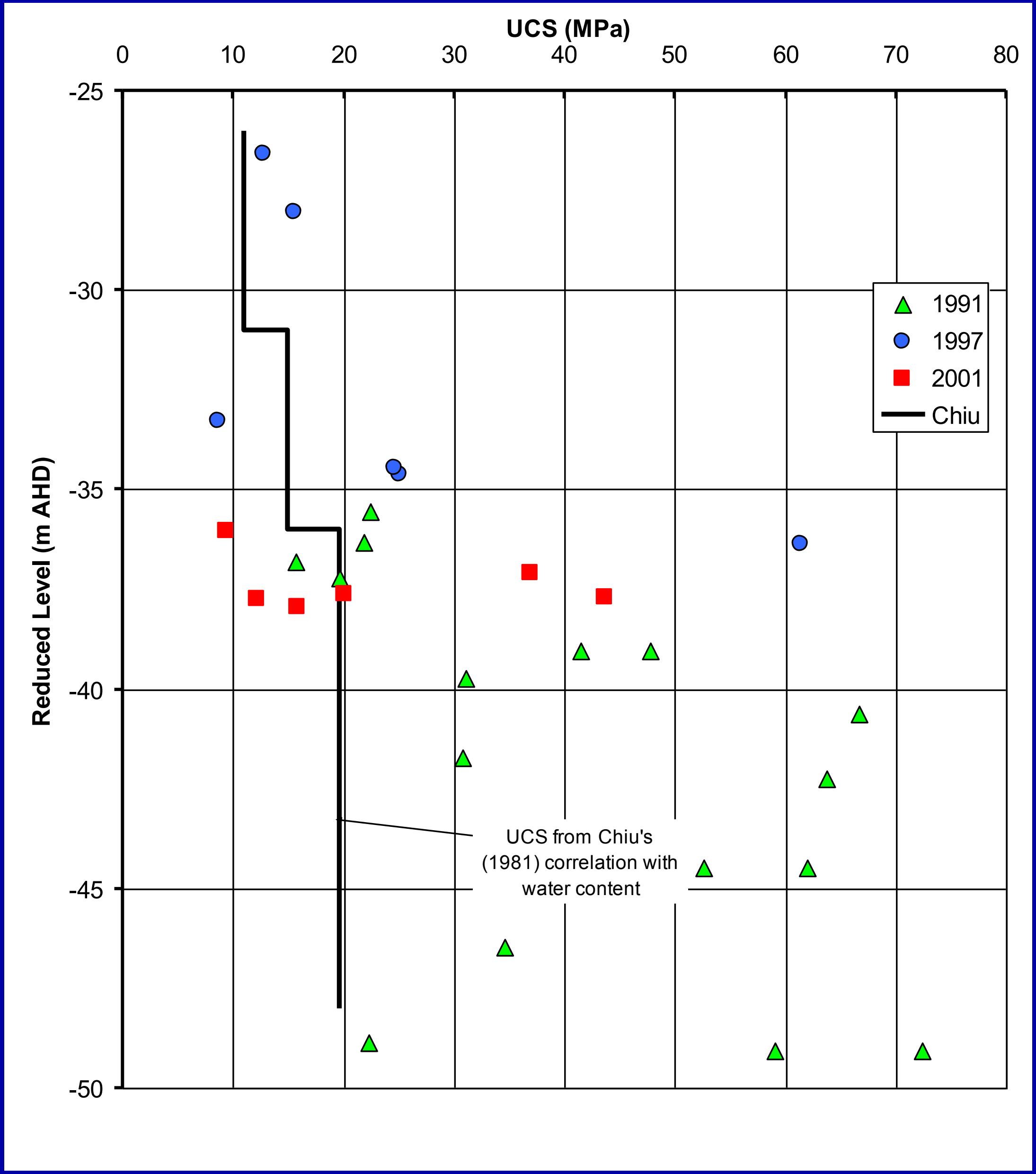
Moisture Content :- Siltstone



Pressuremeter Test Results:- Siltstone

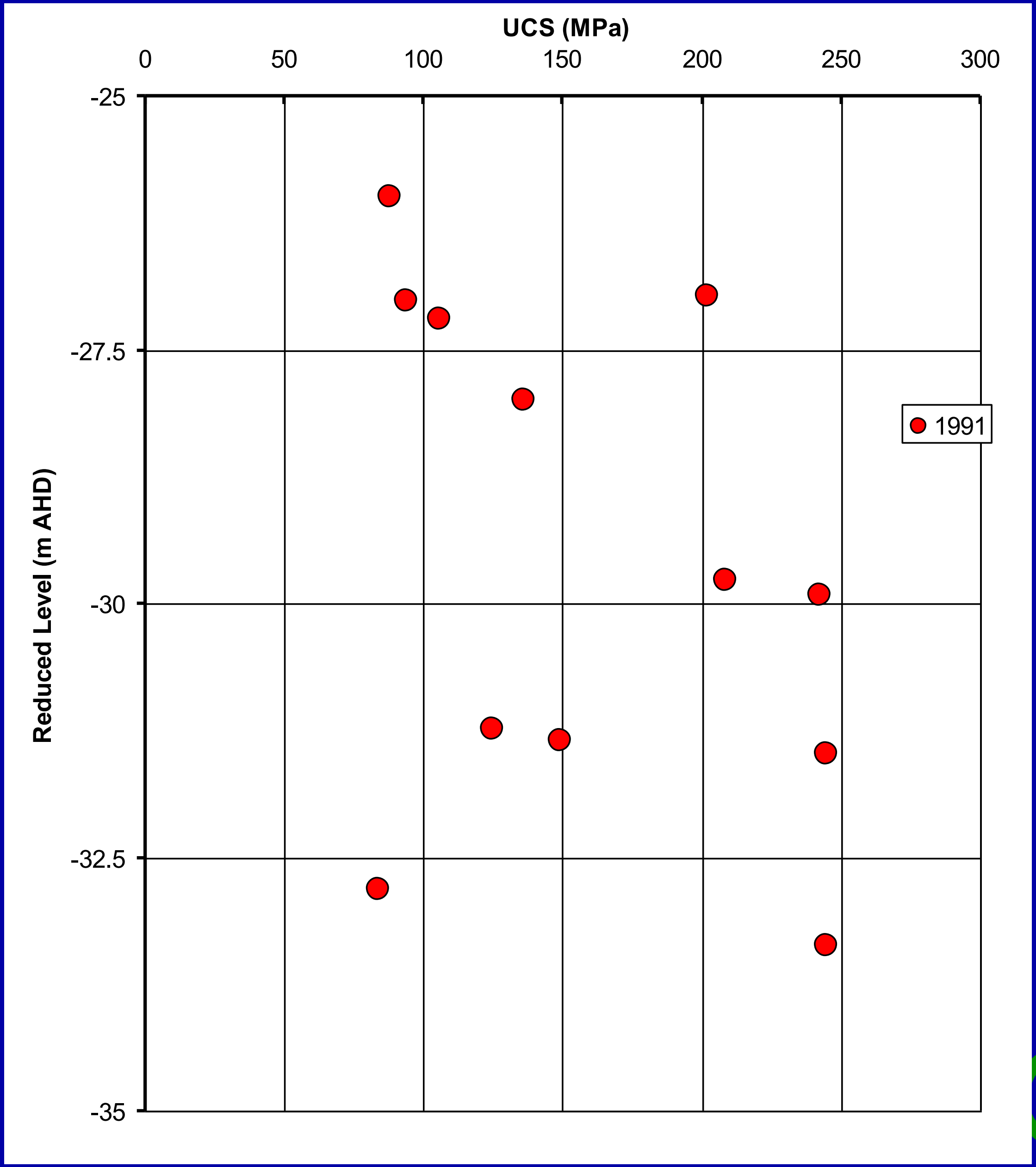


UCS Test Results:-Siltstone



Eureka Tower
Siltstone Core

UCS Test Results:- Lower Basalt



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Eureka Tower

Basalt Core

Eureka Tower
Adopted Bored Pile Solution

- Ignore upper basalt (group effects)
- For basalt adopt end bearing only, with f_b = 20 MPa (essentially intact rock)
- Adopt minimum socket of 0.8 m in lower basalt
- For siltstone, design using ROCKET, and limit design top of socket settlement to 6 mm (compatibility with basalt)
- In siltstone adopt 4.5 m long sockets (upper metre or so is more jointed)
- For siltstone piles, structural load based on up to 25 MPa concrete stress
- 70 MPa concrete

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Eureka Tower
The Bored Pile Dilemma

- Tenders called
- Construction time required for adopted solution incompatible with Builder’s program
- Considerable machinations
- Vibropile/Franki joint venture propose use of CFA piles founding on the basalt in lieu of the more conventional bored pile solution proposed
- Had appealing cost and time implications

Eureka Tower
The CFA Alternative

- 0.75 dia, 6.5 MN, end bearing on basalt @ 14.7 MPa
- some concerns re seating into basalt, esp. if basalt sloping
- Proposed Statnamic testing to 16 MN of 2 piles
- One test pile to be drilled to refusal (construction intention), and the other with drilling stopped top of rock
- Subsequent dynamic testing to correlate with proposed testing of 5% of production piles
- Production testing to concentrate in areas where basalt surface could be sloping
- If in doubt, adopt bored pile drilled through basalt and founding in siltstone

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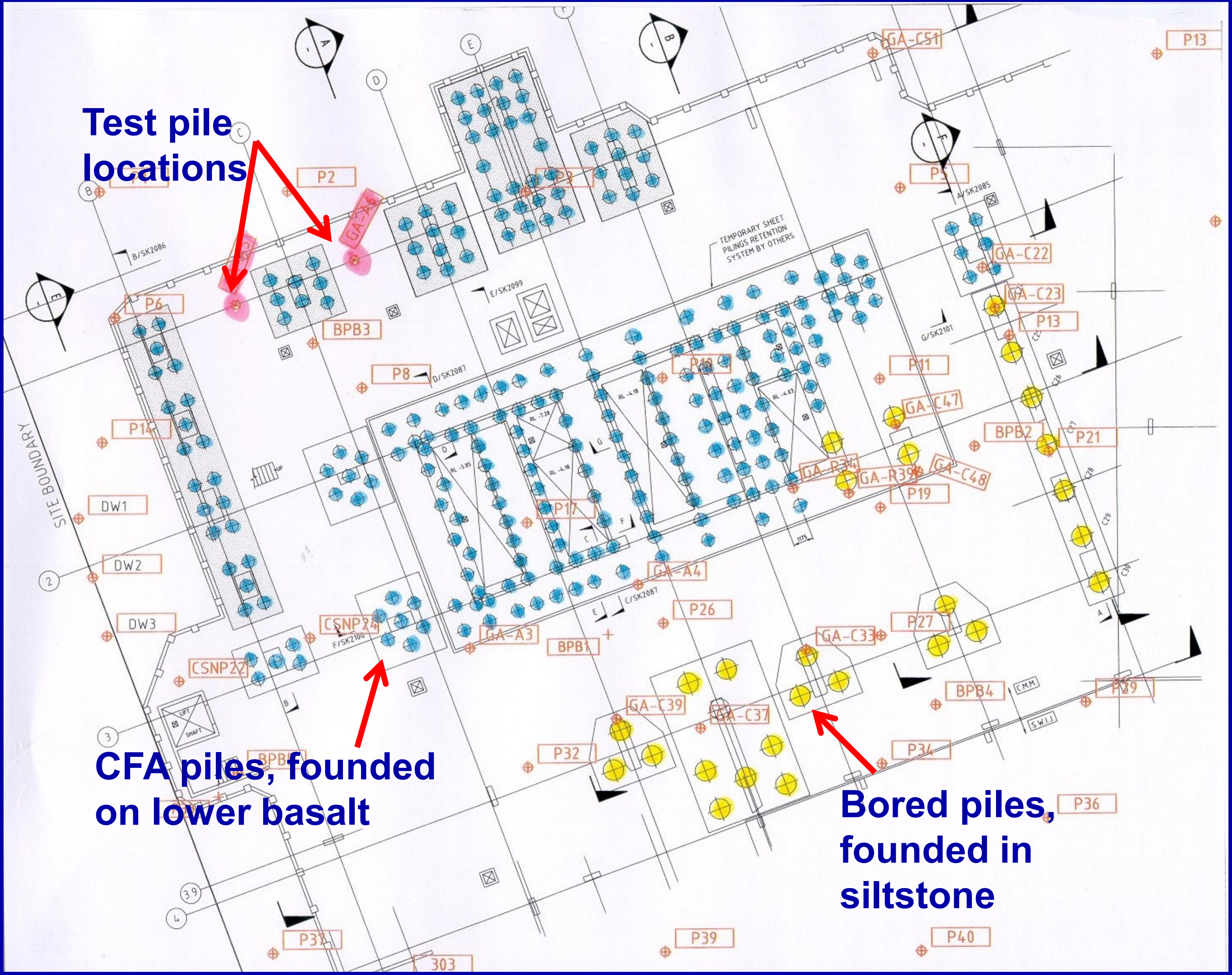
The hybrid CFA and Bored Pile solution



Statnamic Testing

- Developed to allow "cost effective" load testing of high capacity piles (up to 30 MN equipment available)
- Requires mobilisation of a reaction mass typically 5 % of the required test load
- Utilises solid pellet rocket fuel to apply load for 120 ms, *cf.* 4 ms for dynamic testing
- Simple case of F = ma, with reaction mass accelerated at 20g
- No tensile stress wave to damage the pile
- ie little bit *static*, little bit *dynamic* = Statnamic

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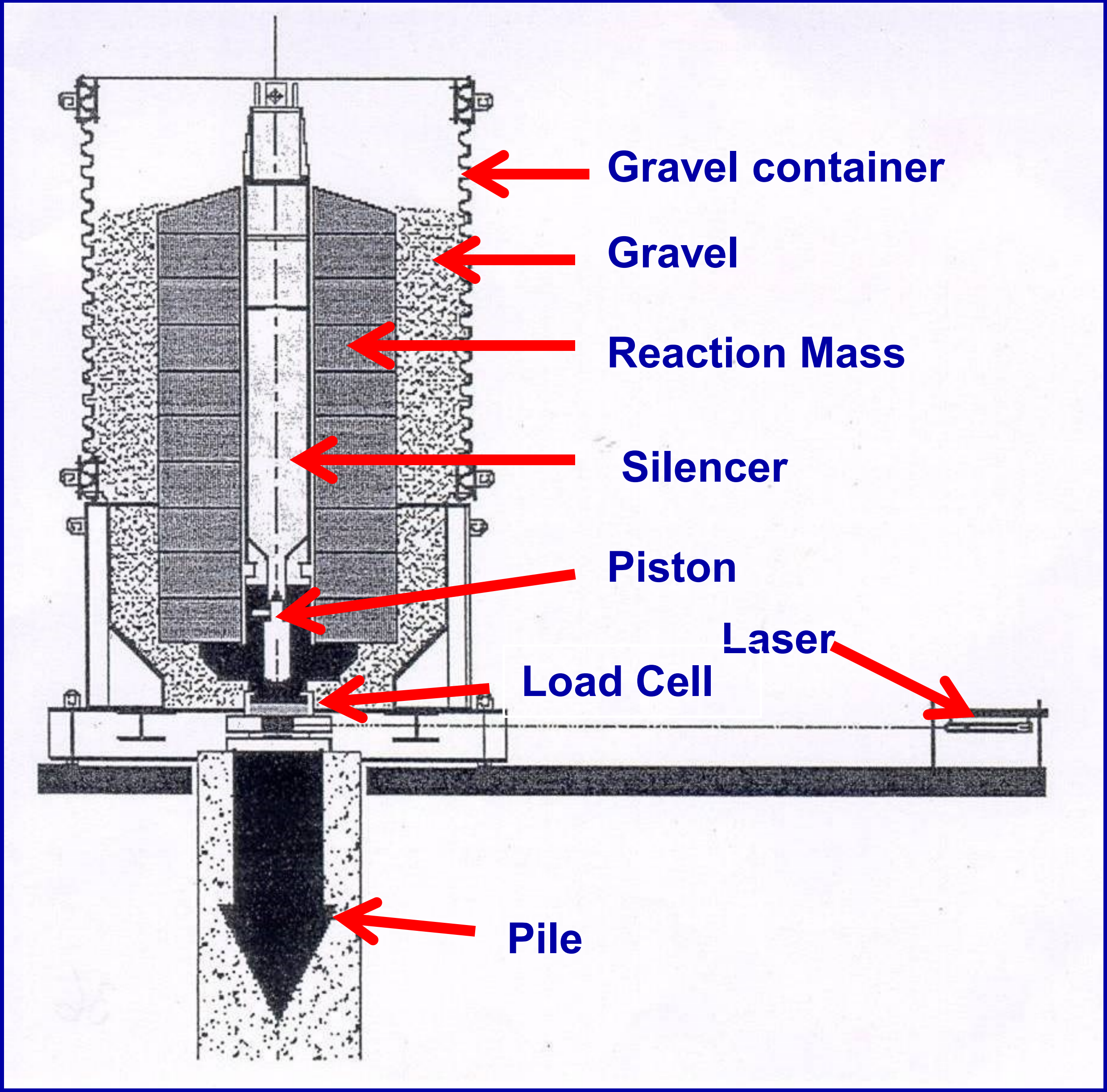
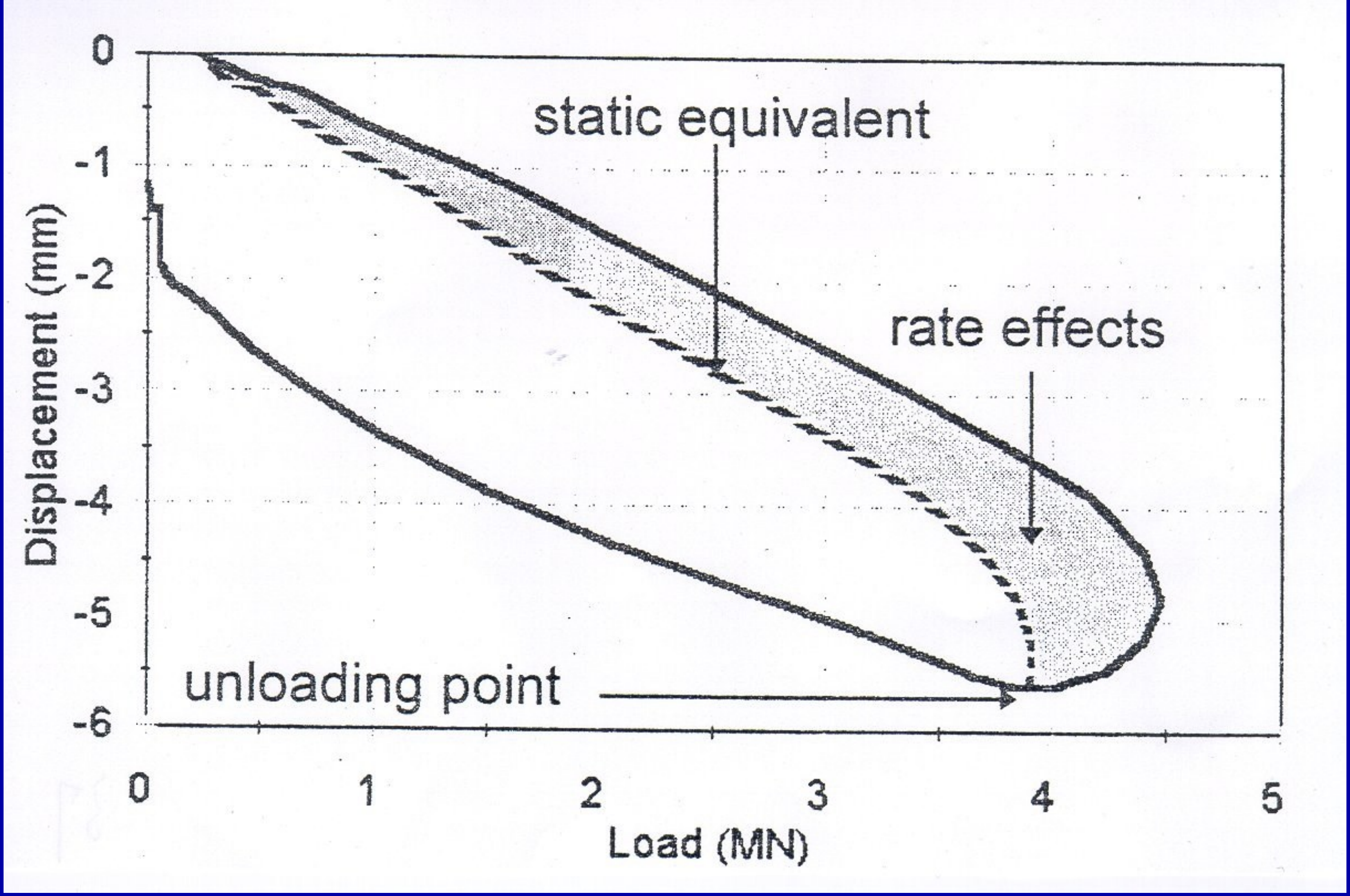
Statnamic Testing Device



Statnamic Testing
Load-Displacement Curve



Statnamic Test

Piston

Statnamic Test

Silencer

Statnamic Test
Gravel container

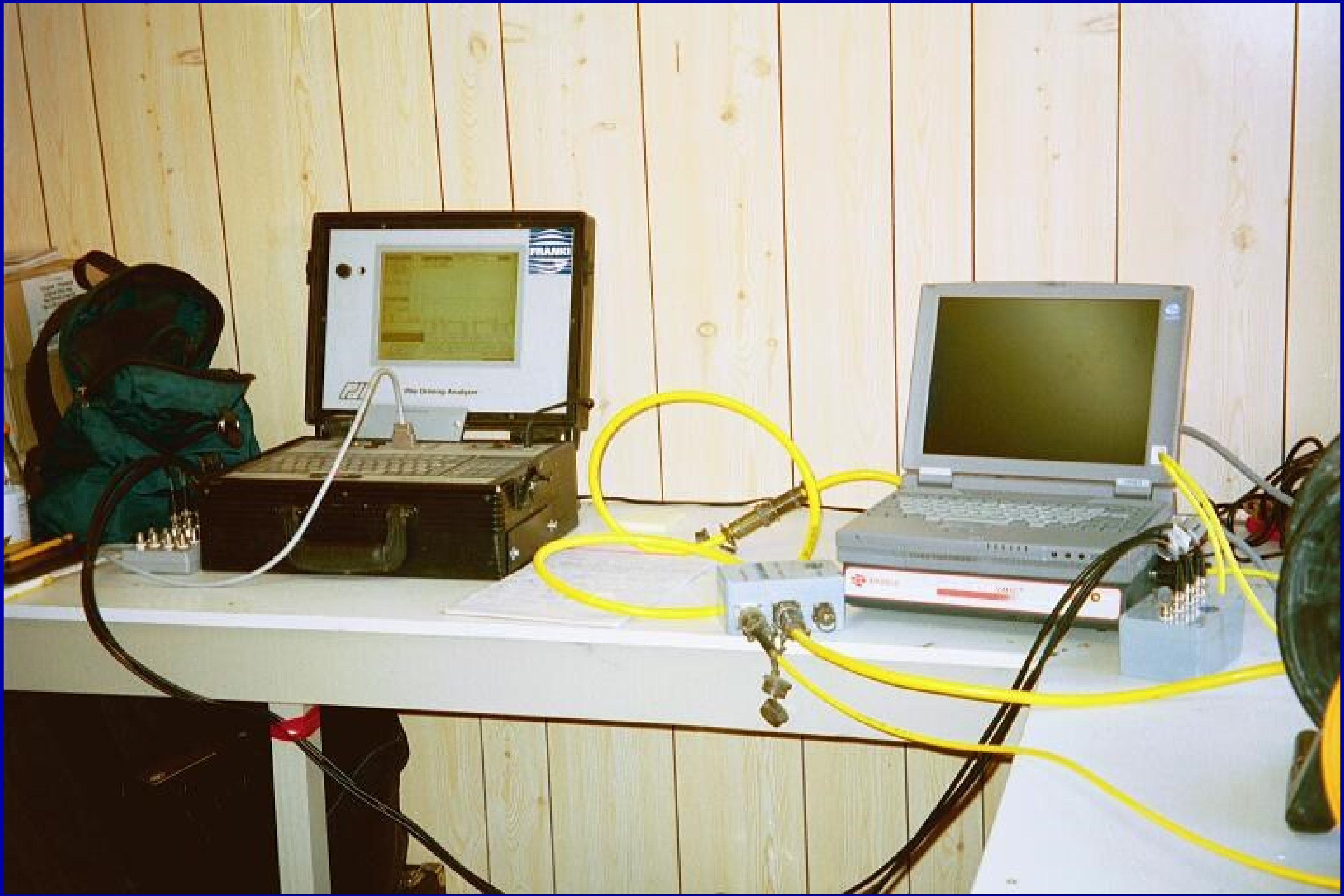
Statnamic Test
Reaction Weights

Statnamic Test
Adding the gravel

Statnamic Test
Laser Displacement Measurement

Statnamic Test

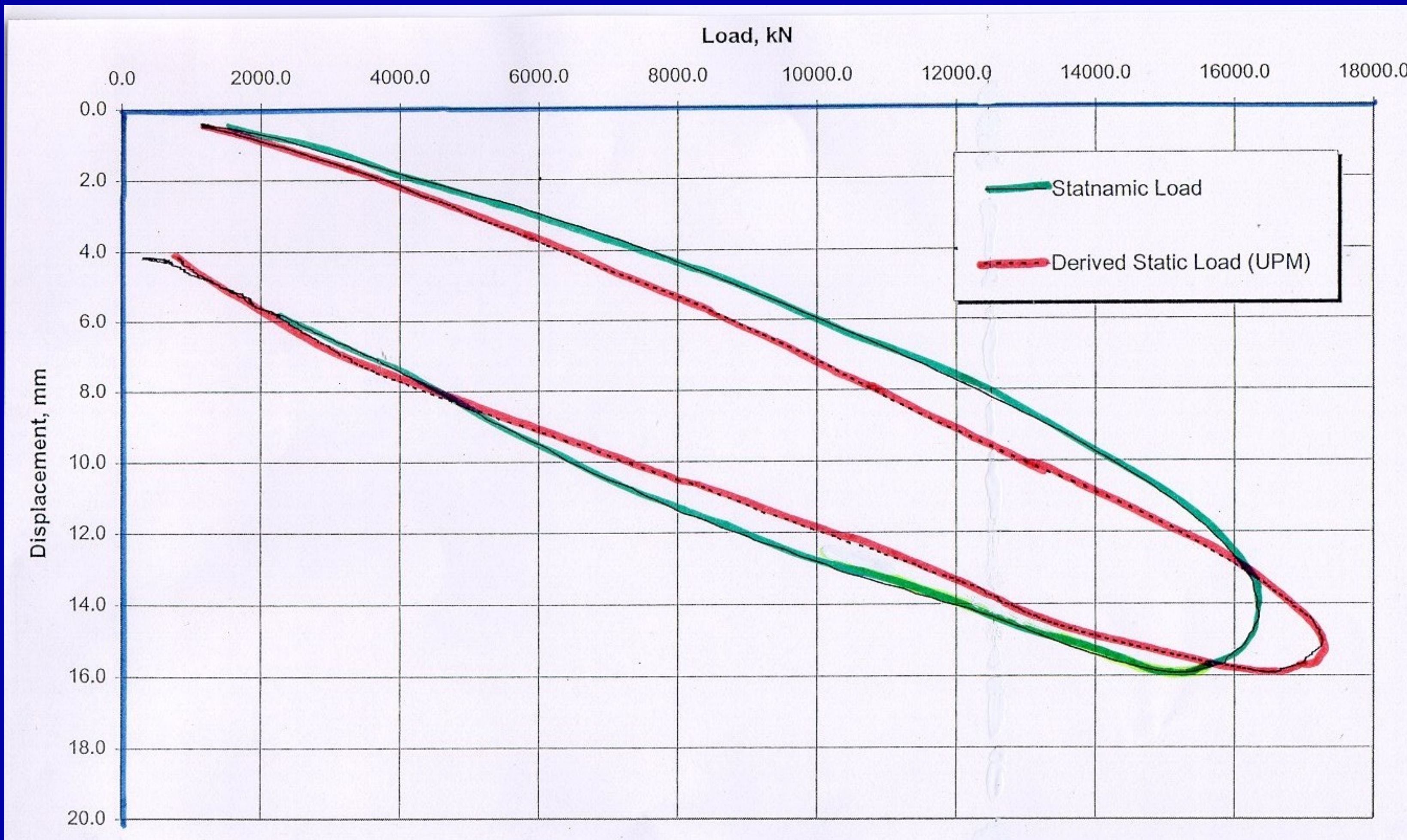
Data Capture



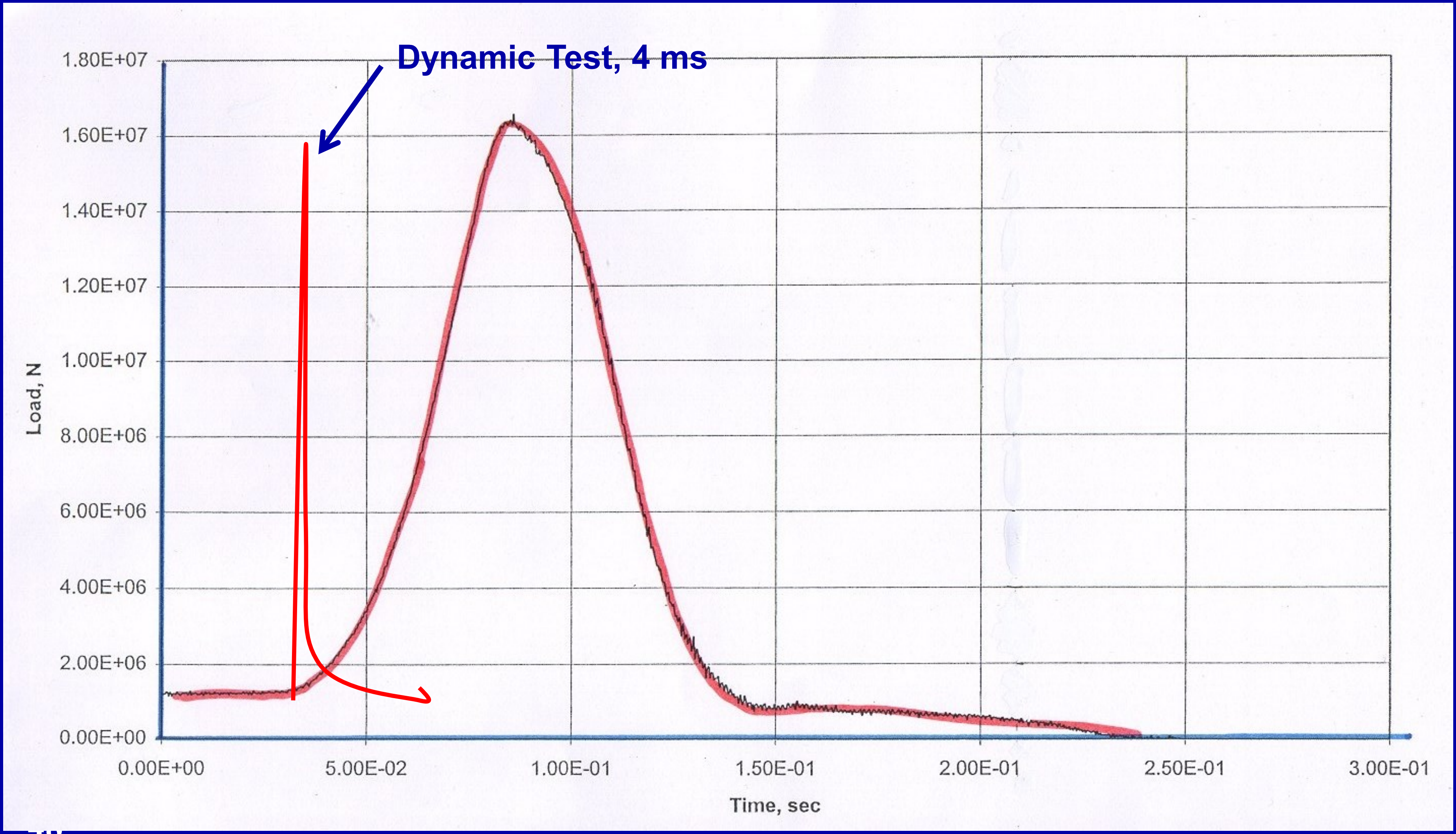
Statnamic Test
The Firing!

Statnamic Test
The gravel works, dust settles

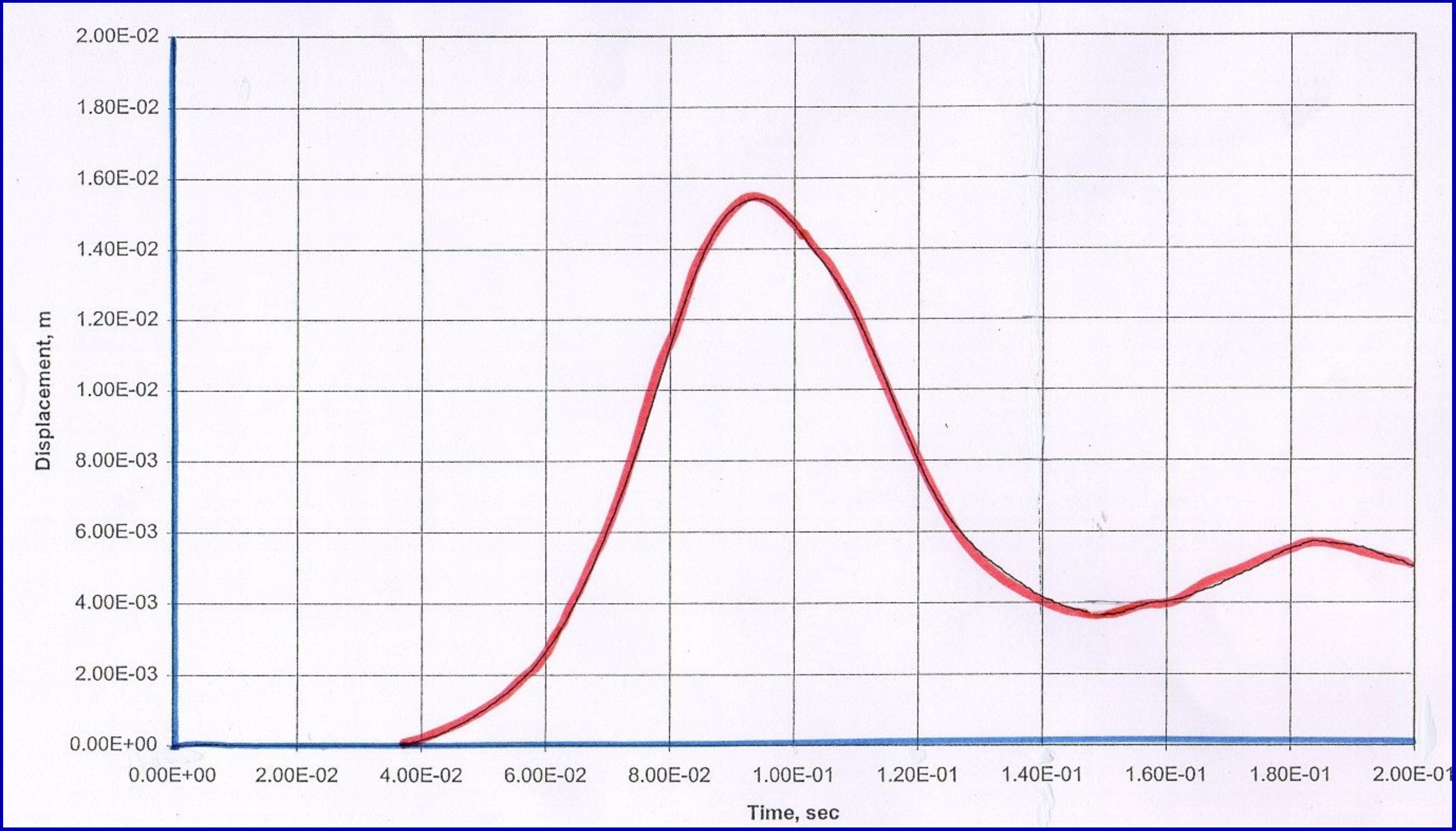
Statnamic Test
Load - Displacement:- Pile No 1



Statnamic Test
Load - Time



Statnamic Test
Displacement- Time



Eureka Tower
Statnamic Tests

	Pile 1	Pile 2
Construction	Just touching rock	Refusal on rock
Peak Static Force (MN)	17.3	16.9
Peak Displacement (mm)	15.5	12.3
Residual Displacement (mm)	4.0	2.0
Reaction mass (MN)	0.9	0.9
Dynamic Capacity (MN) (20 tonne drop hammer)	18 @ 3.0 m drop 21 @ 3.5 m drop	15.8 @ 1.4 m drop

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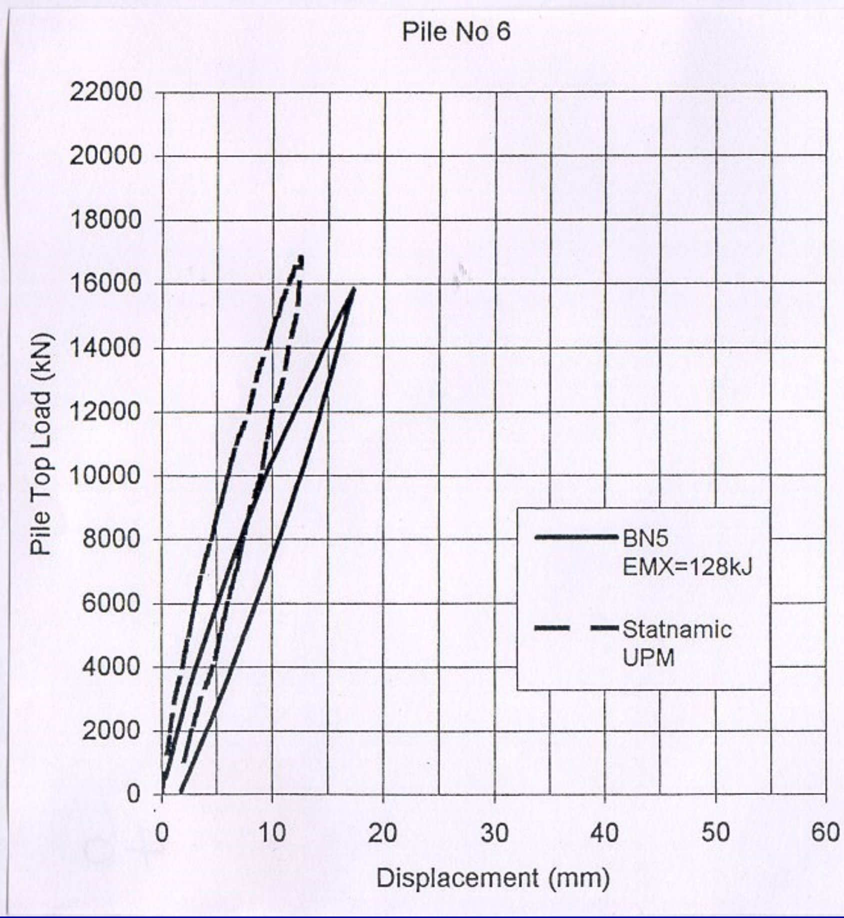
Dynamic Load Test

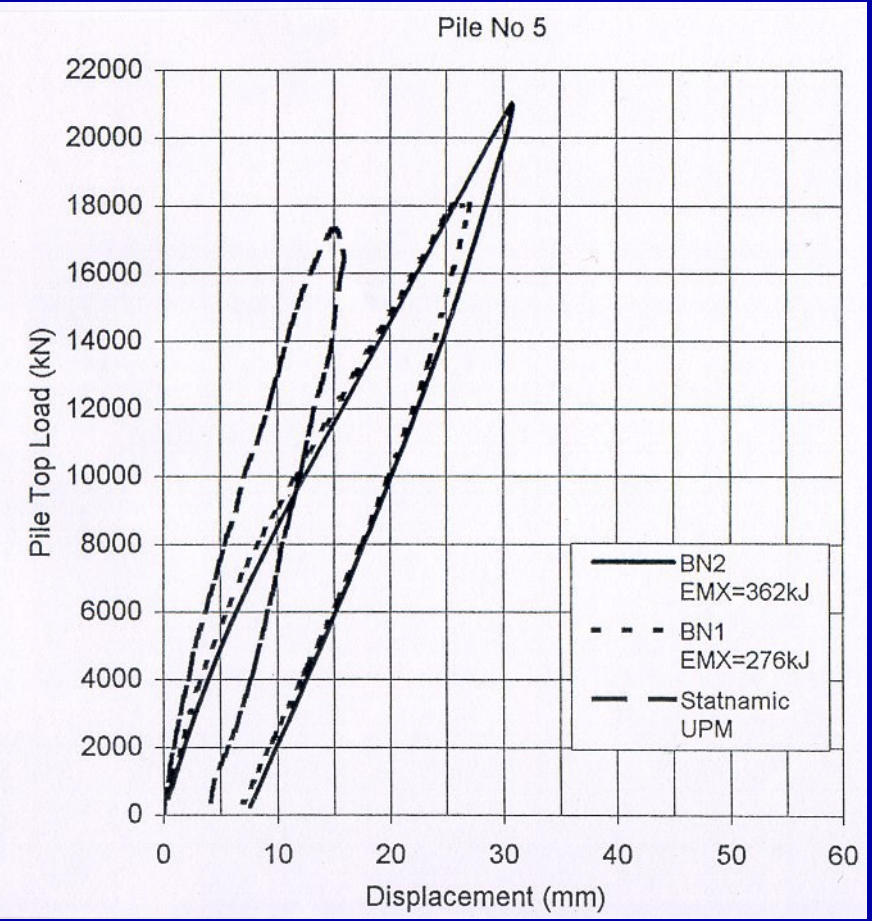
20 tonne hammer assembly

Dynamic Load Test
20 tonne hammer

Dynamic Load Test
20 tonne hammer assembly

CFA Test Piles
CAPWAP vs Statnamic





Eureka Tower
Dynamic Testing of Production Piles

- 20 tonne hammer, dropping 1.4 to 1.5 m
- Drop restricted due to noise and vibration
- 12 piles tested
- Shaft resistance mobilised 8.5 to 13.5 MN
- Base resistance mobilised:- 4.2 to 8.4 MN
- Total resistance mobilised:- 14 to 19 MN
- Measured permanent set:- 0.5 to 3.7 mm
- Considered to have satisfactorily proof tested these piles

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Eureka Tower
CFA Piling

CFA Piling Rig

CFA Piling:- Auger tip

CFA Piling:- drilling in clay

CFA Piling:- drilling in clay

CFA Piling:- Auger Change

CFA Piling:- 70 MPa concrete

Eureka Tower
Bored Pile Construction

- Large crane mounted rigs needed
- Excavated under bentonite fluid, tremie poured
- Tungsten carbide tipped core barrels needed in rock, sometimes in combination with chisels
- Base cleanliness a priority
- Base check with SID inconclusive, refined tools and methods
- Sockets roughened prior to final cleaning (needed special tools due to overlying basalt)
- All rock recovered logged to confirm design assumptions, and cleaning and roughening observed

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Eureka Tower
Bored Pile Construction

Bored Pile Construction

Congested Site

Soil and weak rock drilling bucket

1200 dia. core barrel

Rock core recovered

Core Removal

Success! - not so easy in basalt

Siltstone core:- note grouted borehole!

Rock Chisel

Base mill and cleaning pot tool

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Socket roughening tool

Final mechanical cleaning tool

Submersible Pump for Final Clean & Preliminary Desand

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Final Base Clean

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A Good Day's Work!

Eureka Tower
Concluding Remarks

- Possibly most complex building site in Melbourne
- High strength of both lower basalt and siltstone required the development of special drilling tools, and cleaning methods
- Upper basalt simply a complicating nuisance
- The earlier projects and the Eureka Tower project demonstrated the benefits of thorough investigation
- Contractor innovation with CFA saved time and cost
- All piles completed in 5 months

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Construction almost complete (Jan 2006)

Eureka Tower
The Foundations!

Thank you for your attention

Golder Associates