The UofA Geotechnical Centre

"Performance in Geotechnical Practice - An Update"

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Three Sources of Uncertainty

i) Parameter of Uncertainty

ii) Model Uncertainty

iii)Human Uncertainty

Objectives

While the objective of science is to provide explanations, that of engineering is to provide performance. Performance of engineering systems cannot be provided independent of human involvement and the functioning of social organizations.

Human error can obviously overwhelm an otherwise effectively operating system and risk analysis that ignores or understates human involvement in geotechnical practice borders on naivety. Even corruption is not unknown.

Value Added Component

The value added component of geotechnical engineering is closely linked to performance assurance.

When it goes wrong the penalties are severe for all involved. The fundamental premise of this lecture is that the complexity of performance assurance has been underestimated. This requires broad recognition. The application of comprehensive risk management tools provide the only way forward and deserve appropriate rewards when applied correctly. Risk management can only be successful if critical sources of uncertainty are understood.

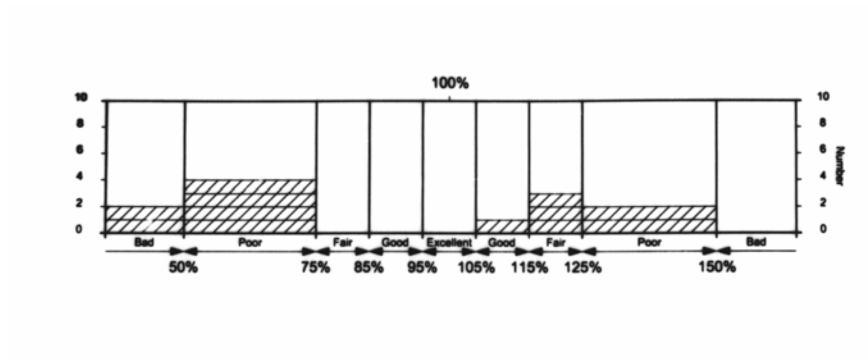
Classification of Prediction (Lambe, 1973)

Prediction Type	When Made	Results at Time of Prediction
A	Before Event	--------------
B	During Event	May be known or unknown
C	After Event	May be known or unknown

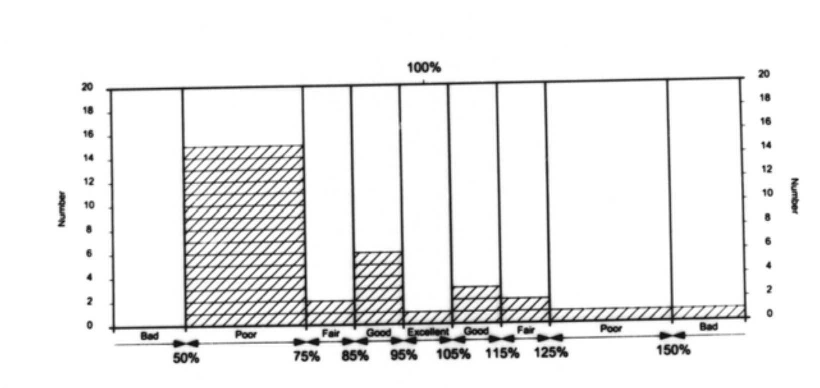
Prediction Quality Classes

Accuracy of Prediction (% actual)	Quality Class
95 – 105% (within ± 5%)	Excellent
85-95% or 105-115% (within ± 15%)	Good
75-85% or 115-125% (within ± 25%)	Fair
50-75% or 125-150% (within ± 50%)	Poor
<50° or > 105%	Bad

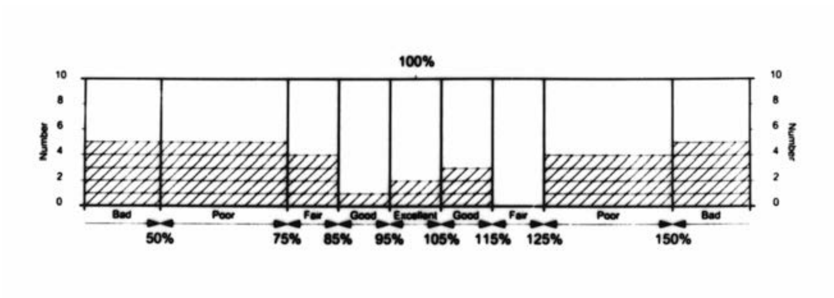
Prediction Quality Classification, MIT Embankment Prediction Competition (10 predictors)



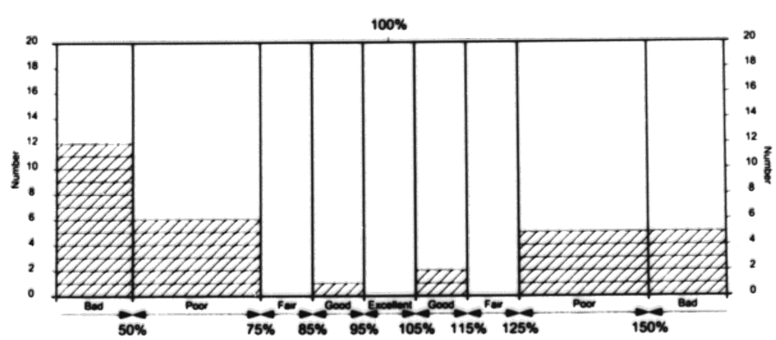
Prediction Quality Classification, Muar Embankment Prediction Competition (31 Predictors)



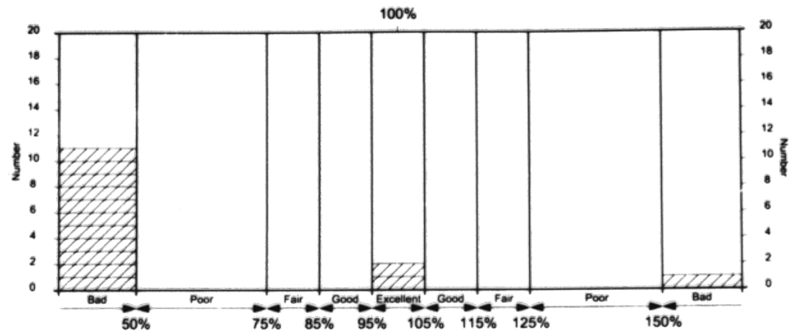
Prediction Quality Classification, Spread Footings on Sand. Maximum Bearing Capacity (30 Predictors)



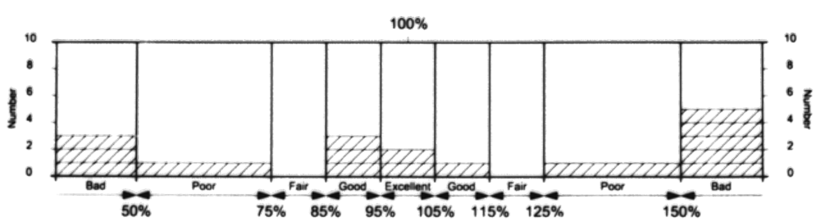
Prediction Quality Classification, Spread Footings on Sand. Settlement Under Design Load (31 Predictors)



Prediction Quality Classification, Driven Pile, Maximum Shaft Resistance (16 Predictors)



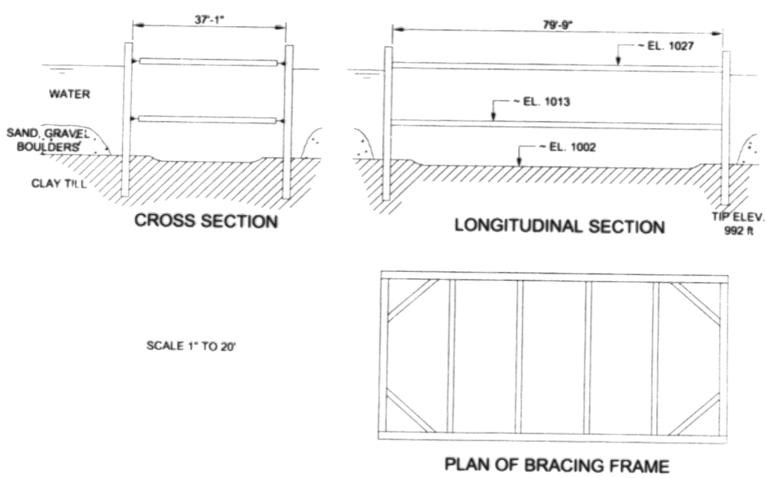
Prediction Quality Classification, Driven Pile, Maximum Base Resistance (16 Predictors)

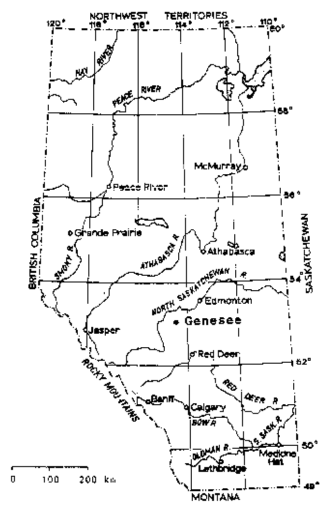


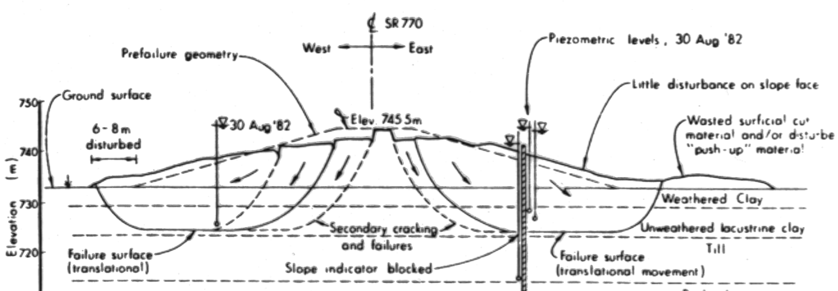
In the face of intrinsic uncertainty associated with geotechnical engineering, it is wise to remember Southwood's caution (1985).

"The things that we would like to know may be unknowable".

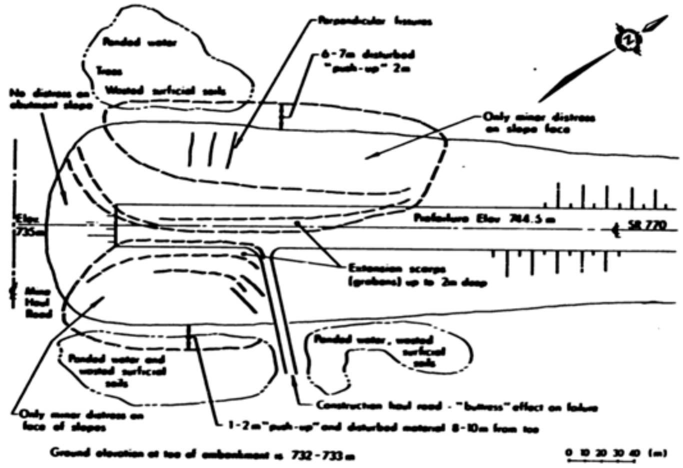
Failure of a Cofferdam, Plan and Sections



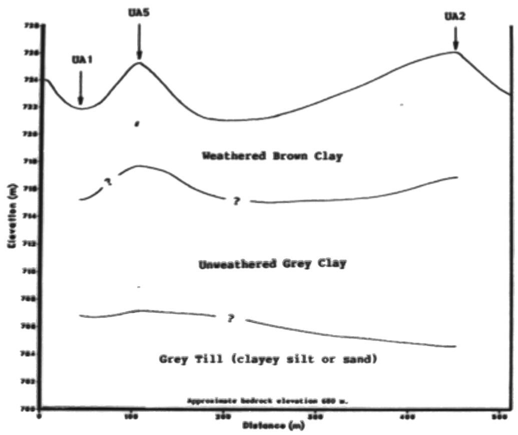




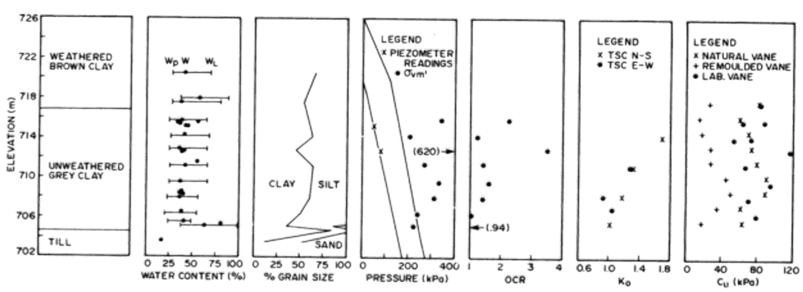
(after Crooks et al, 1985)

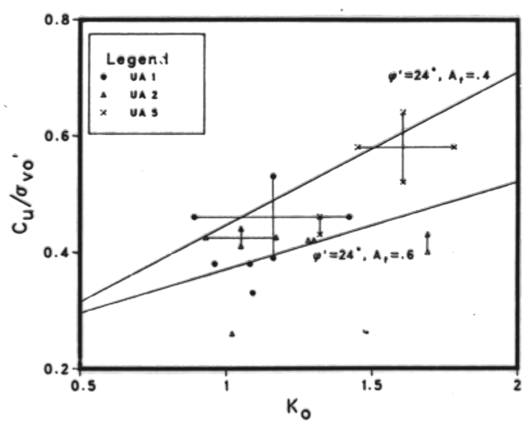


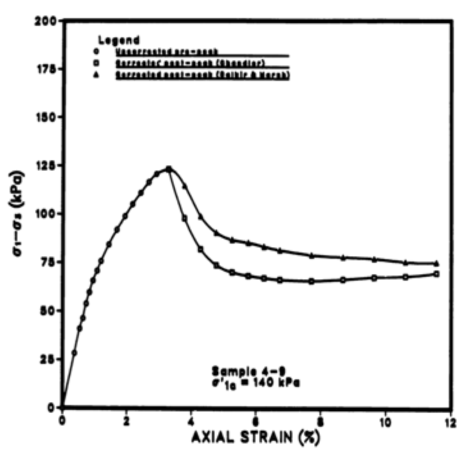
(after Crooks et al, 1985)



Geotechnical Properties of Genesee Clay (Test Location UA2)




0.8
0.6
0.4
0.2
0.5
1
1.5
2
C_u/σ_{vo}'
K_o
Legend
UA 1
UA 2
UA 5
$\varphi'=24°, A_f=.4$
$\varphi'=24°, A_f=.6$


200
175
150
125
100
75
50
25
0
0
2
4
6
8
10
12
$\sigma_1-\sigma_3$ (kPa)
AXIAL STRAIN (%)
Legend
Sample 4-9
σ'_{1c} = 140 kPa

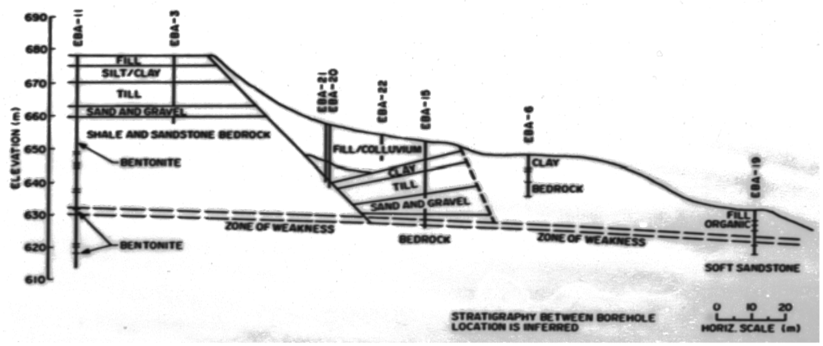
Structured Soils

Fissures and joints offer exercise an overwhelming influence on the geotechnical behaviour of a soil mass. They are commonly associated with stiff to hard clays and soft rocks.

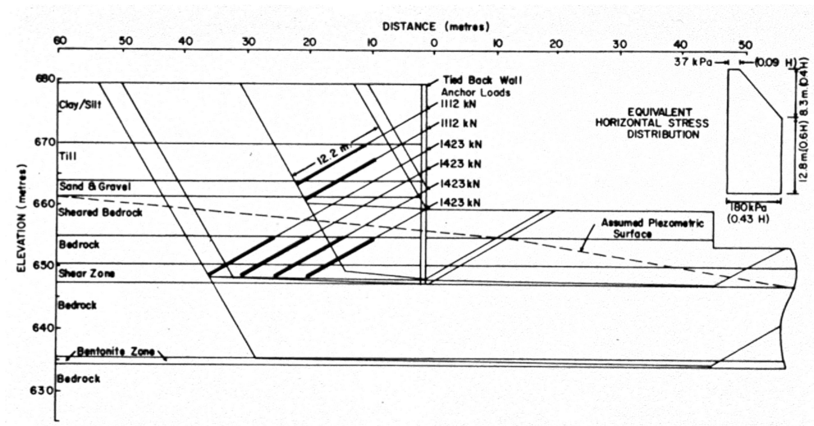
Indeed, they are so common in these deposits that the burden on site investigation should be to prove their absence if they are to be ignored.

Moreover soft fissured clays also exist. Fissuring can also be aggravated by construction processes.

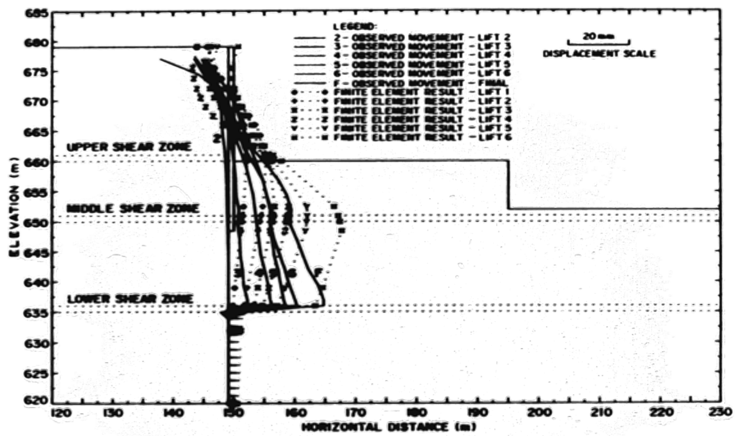
Soil Stratigraphy of Section A-A (from Balanko et al., 1980)



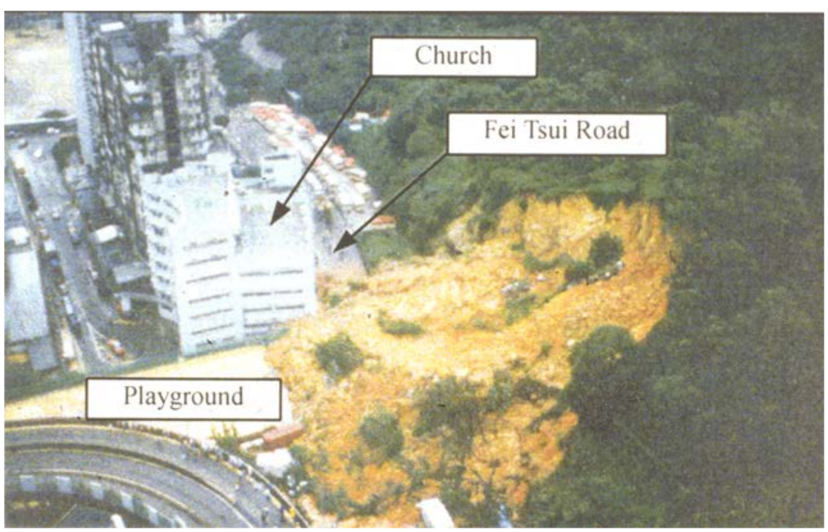
Overall Stability Analysis, Edmonton Convention Centre



Movement of Soil Behind Tangent Pile Wall

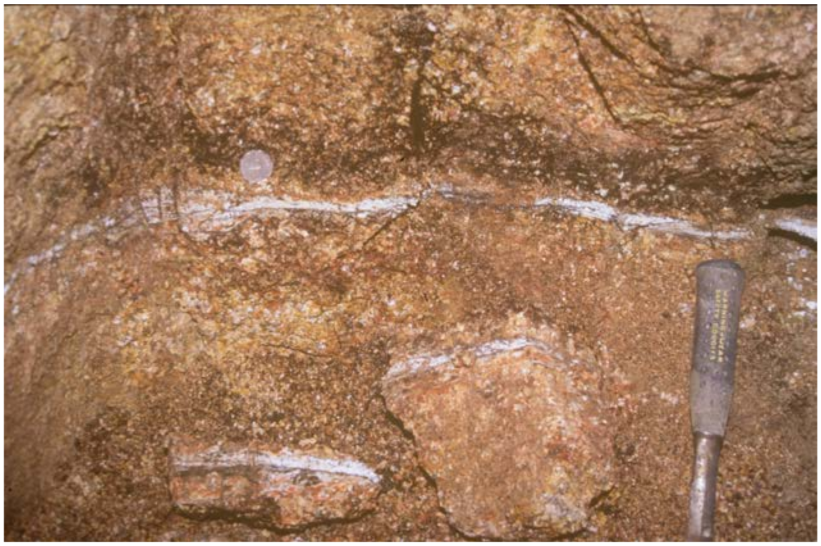


The 13 August 1995 Landslide at Fei Tsui Road, Hong Kong




Nikon


KODAK Color Control Patches



Commentary

Many geotechnical environments involve clay seams. The two examples here represent diverse origins, from deposition of volcanic ash in Upper Cretaceous marine sediments to secondary accumulation at rock head in saprolites.

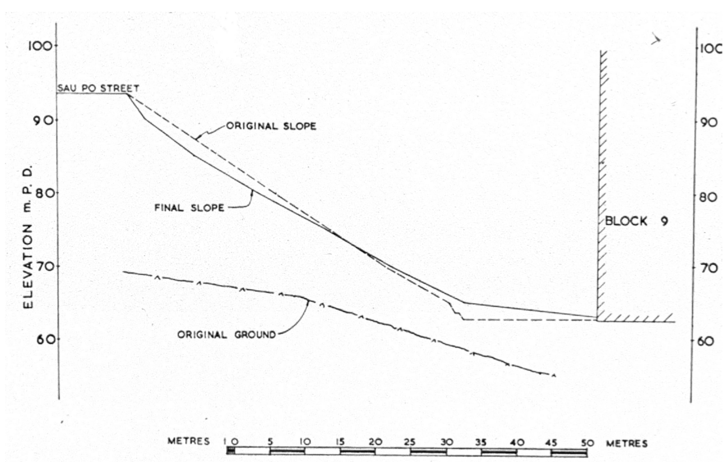
Clay seams affect all geotechnical properties and when they are reduced to residual strength, they dominate stability.

Unsuccessful performance on a number of projects can be attributed to inadequate understanding of the presence of clay seams, inadequate site investigation and logging techniques and inadequate geomechanical characterization.

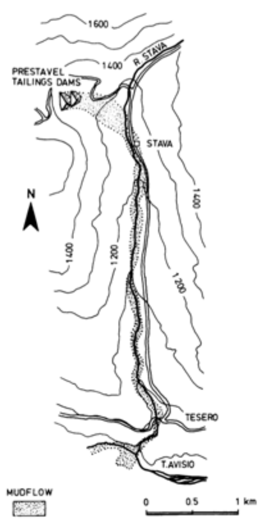
Rear of Block 9, looking towards Block 15, at about 11:00 am on 25th August 1976

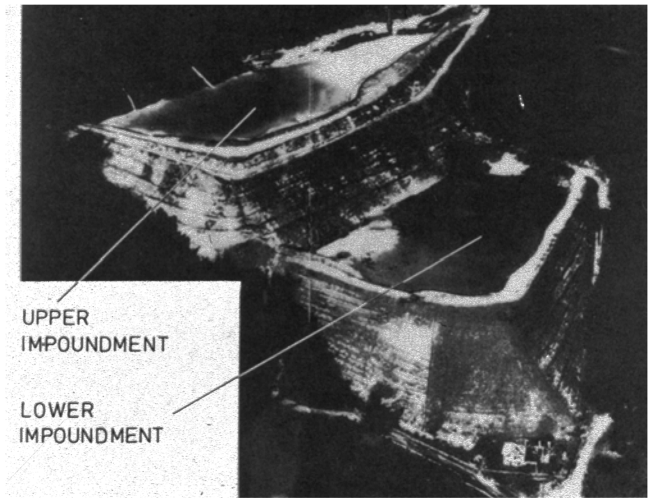
Photo courtesy of Housing Authority

Landslide III showing shallow depth of slide and layering parallel to slope



Position of Tailings Dams and the Mud Flow’s Course

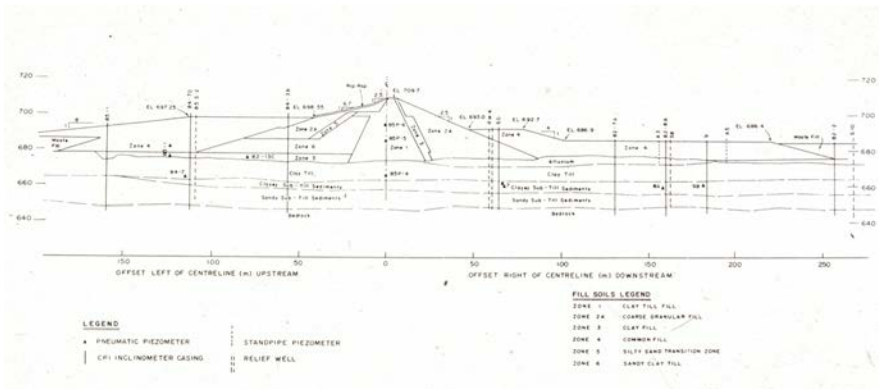



UPPER
IMPOUNDMENT
LOWER
IMPOUNDMENT

Commentary

A large number of materials are disposed to flow liquefaction. They range from quick-clays, recent marine silts, loose sandy gravels, poorly compacted decomposed granite fill and other loose fills, to loose sands, both natural and mine tailings. It has been known for along time that flow liquefaction can be triggered by both undrained and drained processes. However, a basic understanding of this initiation is more recent.

The observational method is limited in its capacity to eliminate flow liquefaction. Warning of the onset is often minimal and the phenomenon is brittle. As emphasized by Martin and McRoberts (1999), reliance on traditional effective stress approaches to design can be dangerous.

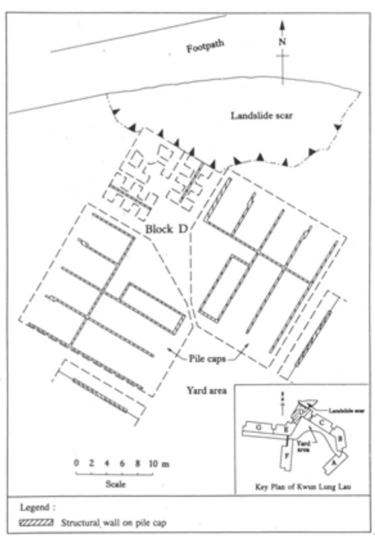


Commentary

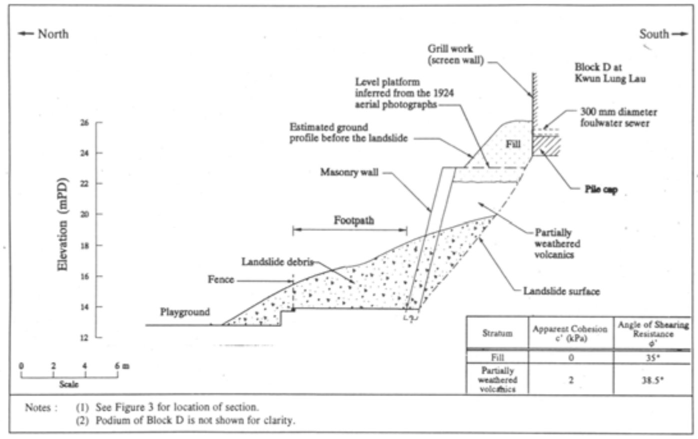
Assurance of geotechnical performance does not end with site investigation and design. While the observational method can be successful in detecting conditions that depart from the design basis, it alone is not sufficient to control the construction process to ensure that performance is as intended.

This is dealt with by construction specifications and quality assurance programmes. It is important that the potential problems that may arise in geotechnically sensitive construction be analyzed with care to ensure that specifications and quality assurance are properly focused.

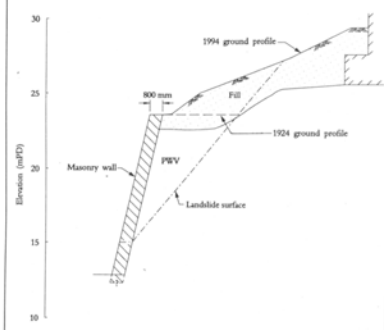
Legends of Pile Caps under Block D



Section 1-1 Through the Landslide



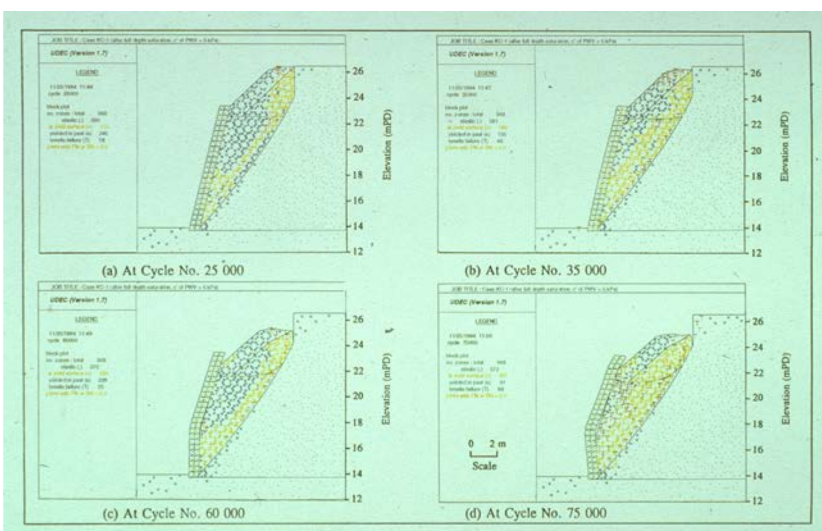
Section A-A for Slope Stability Analyses

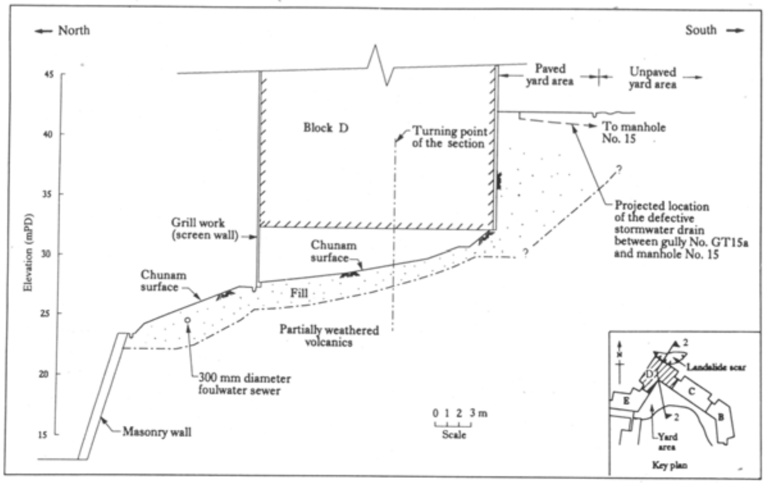


Material	Parameters		
	Apparent Cohesion c' (kPa)	Angle of Shearing Resistance ϕ'	Unit Weight (kN/m³)
Fill	0	35°	18
PWV	Varies	38.5°	19
Wall mortar joints	Varies	45° (case 1) 40° (case 2)	22 (wall)

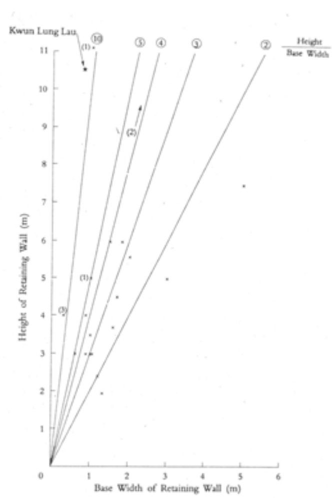
Notes : (1) For location of the section, see Figure L1.
(2) PWV denotes the partially weathered volcanics stratum comprising CDV and C/HDV.

Results of UDEC Analyses (Wall Condition and Stress State of Case KC-1 during Bulging Failure)





Dimensions of Masonry Retaining Walls Determined from GCB Inspection Records

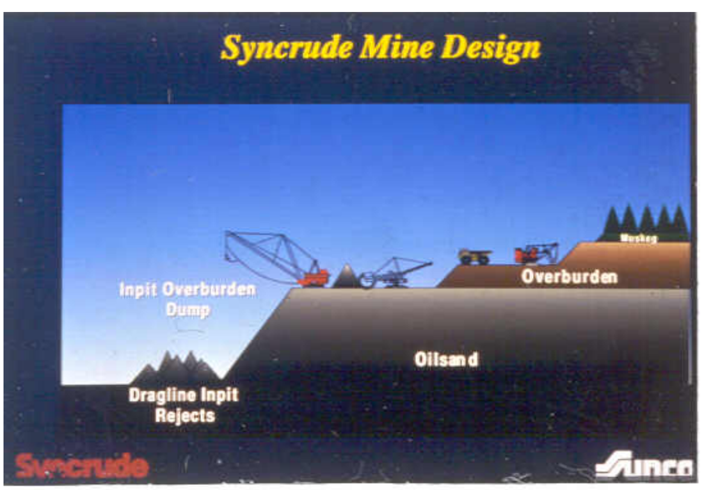


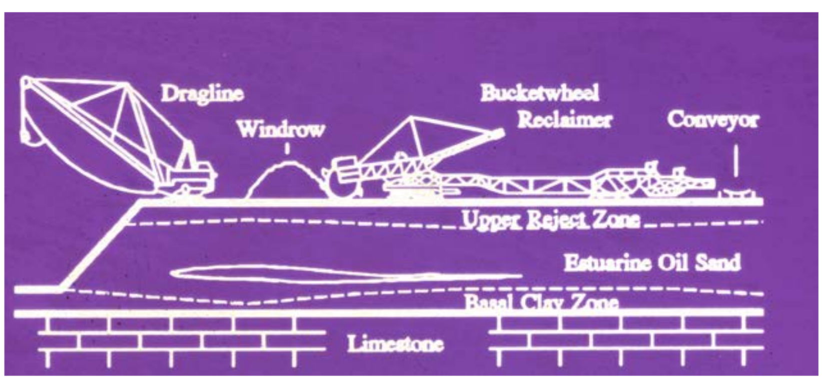
Notes : (1) Tied face walls.
(2) Height of wall = 15 m, base width of wall = 3.6 m.
(3) Stone-pitching wall on a 65° slope.

Commentary

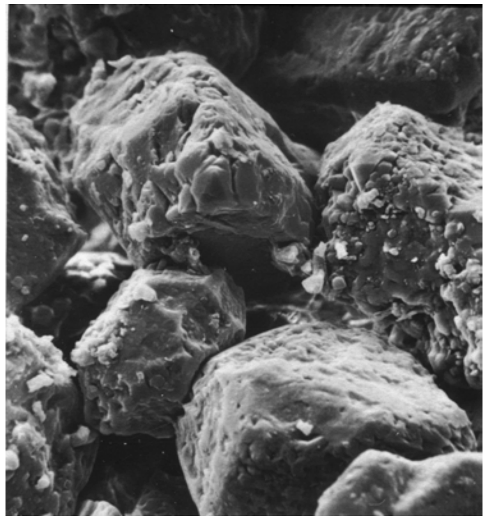
Human factors as a major cause of geotechnical failure have been discussed, among others, by Peck (1973) and Sowers (1991). Li and Lee (1991) provide an extended discussion noting that human error, inadequate supervision, lack of communication between project parties during construction, and ignorance of or failure to use prevailing knowledge have all been encountered.

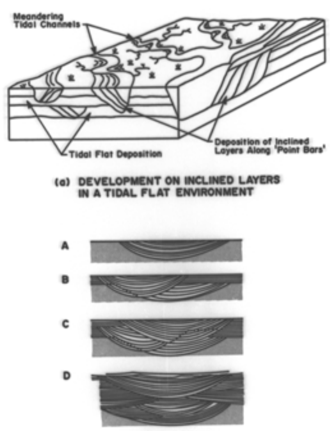
Performance in geotechnical practice cannot be assured without invoking appropriate risk management practice to minimize the detrimental effects of human uncertainty.




Dragline
Windrow
Bucketwheel
Reclaimer
Conveyor
Upper Reject Zone
Estuarine Oil Sand
Basal Clay Zone
Limestone

Locked Sand Fabric

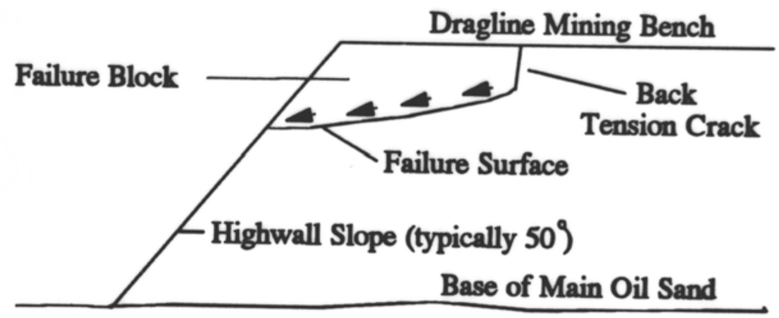




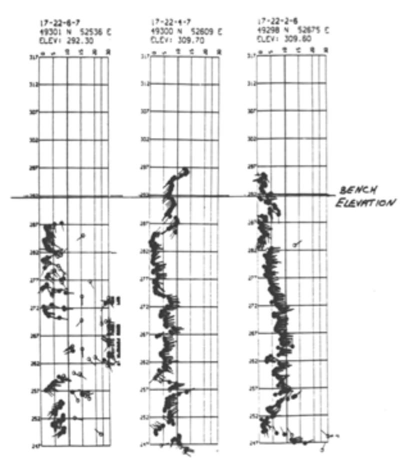
(a) DEVELOPMENT ON INCLINED LAYERS IN A TIDAL FLAT ENVIRONMENT

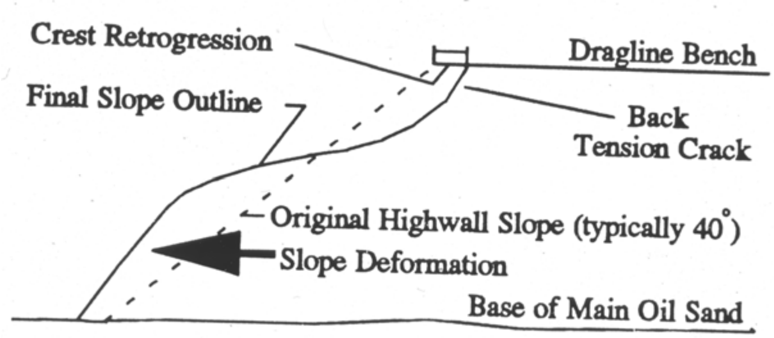
(b) DEVELOPMENT OF TIDAL CHANNEL-FILL CROSS-BEDDING

Typical Block Slide

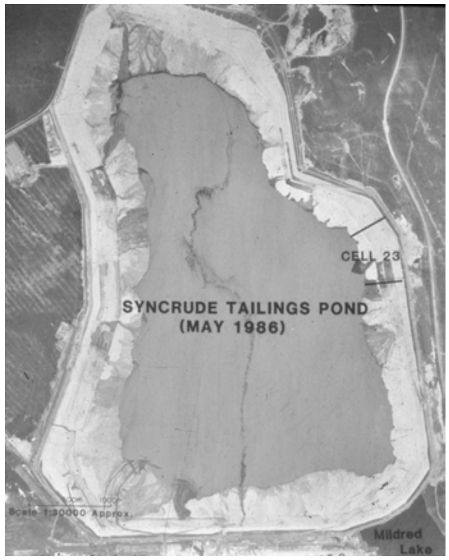


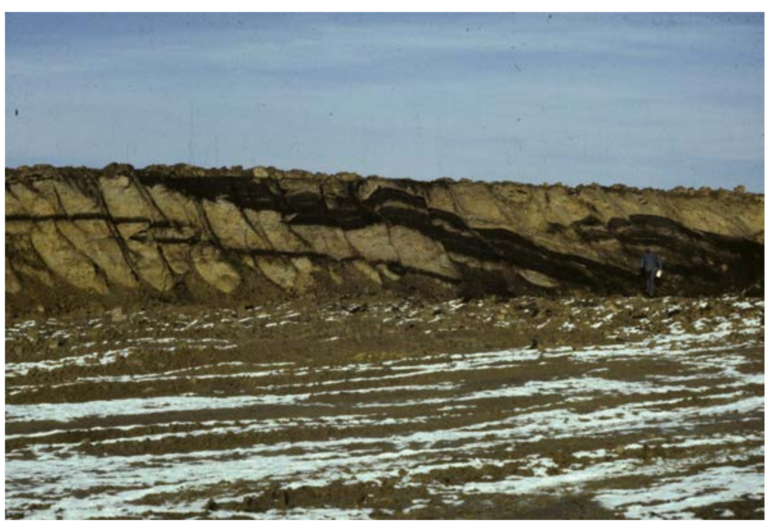
GEODIP PLOTS – 49300N



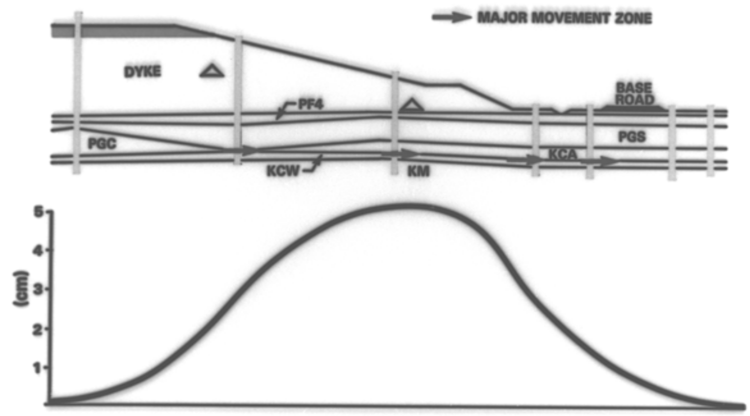


Crest Retrogression
Dragline Bench
Final Slope Outline
Back
Tension Crack
Original Highwall Slope (typically 40°)
Slope Deformation
Base of Main Oil Sand

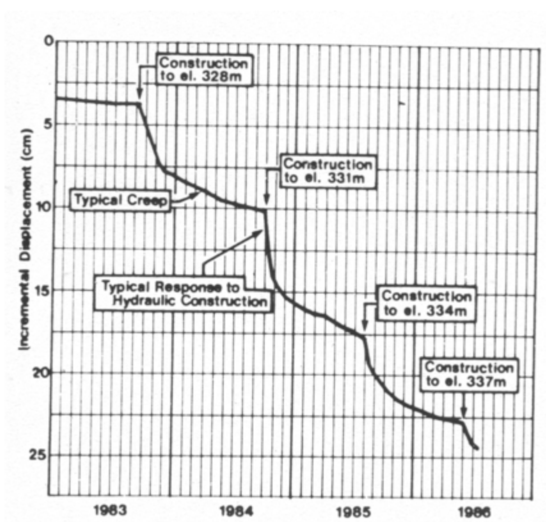

CELL 23
SYNCRUDE TAILINGS POND
(MAY 1986)
Mildred
Lake



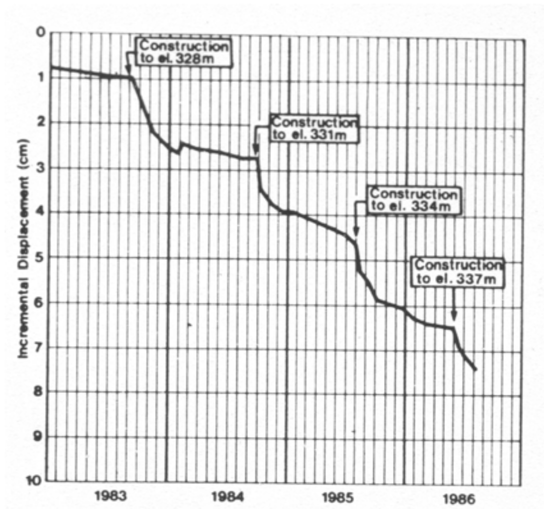
Incremental Displacement 1985



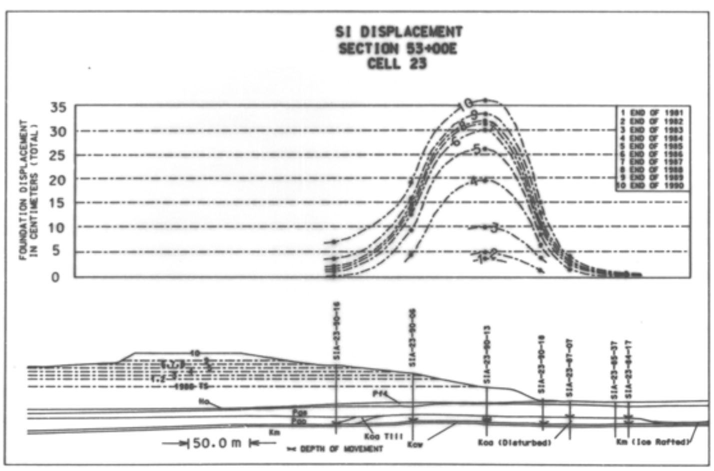
Performance History 319 Berm



Performance History Dyke Toe



SI Displacement



Commentary

The successful application of geotechnical engineering to the oil sands industry has relied on a number of contributions including:

1) Basic soil property studies
2) Advanced analytical studies
3) Geophysics
4) Instrumentation

But above all, there has been an intimate interaction between the analysis of the geological environment and geotechnical behaviour, with on-going application of the observational method.

- Reliability based

vs

- Robustness based

Risk Management

- Probabilistic risk analysis

vs

- Consequential risk analysis

Judgment is essential to assure successful geotechnical performance. This has been emphasized by many commentators. The need to apply the observational method is also recognized, but its limitations are sometimes underestimated. This lecture advocates the systematic application of qualitative and consequential risk analysis to the design and control of geotechnical projects. Such application would provide structure to the judgment process, make it more transparent and facilitate risk management. This part of a project development requires the highest level of experience. It should be recognized as adding the highest value and rewarded accordingly.

He concluded with the observations:

……"Engineering judgment dominates design in soil engineering, but it is tremendously difficult to transfer a sense of judgment from the experienced to the inexperienced".

He went on to say:

……"In the soil engineering world it is all to easy to spend time on calculating what can be calculated rather than on what should be calculated, to giving an over precise answer to the wrong question…".

…"It depends on our ability to bring the best engineering judgment to bear on problems that are essentially non-quantitative, having solutions that are non-numerical. To develop this judgment and to bring it to bear require a reordering of our present views of what constitutes the highest form of engineering.

Without detracting from the necessity for reasonable and meaningful engineering calculations and from the rewards to those who can carry them out, at least equal professional prestige and responsibility should be accorded men of judgment, even when that judgment is not expressed in numerical form…".

This lecture builds on the advice of Lumb and Peck to emphasize the role and judgment.

However it goes further in advocating that the application of judgment should be structured within a framework of qualitative and consequential risk analysis, without precluding any other quantitative studies currently used in practice.

The assurance of geotechnical performance would be enhanced if geotechnical engineering shifted from the promise of certainty to the analysis of uncertainty.