SI Planning & Laboratory Testing for Hill-Site Development

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IEM Penang

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Cameron Highlands, 1961

Horror in the Highlands

1961

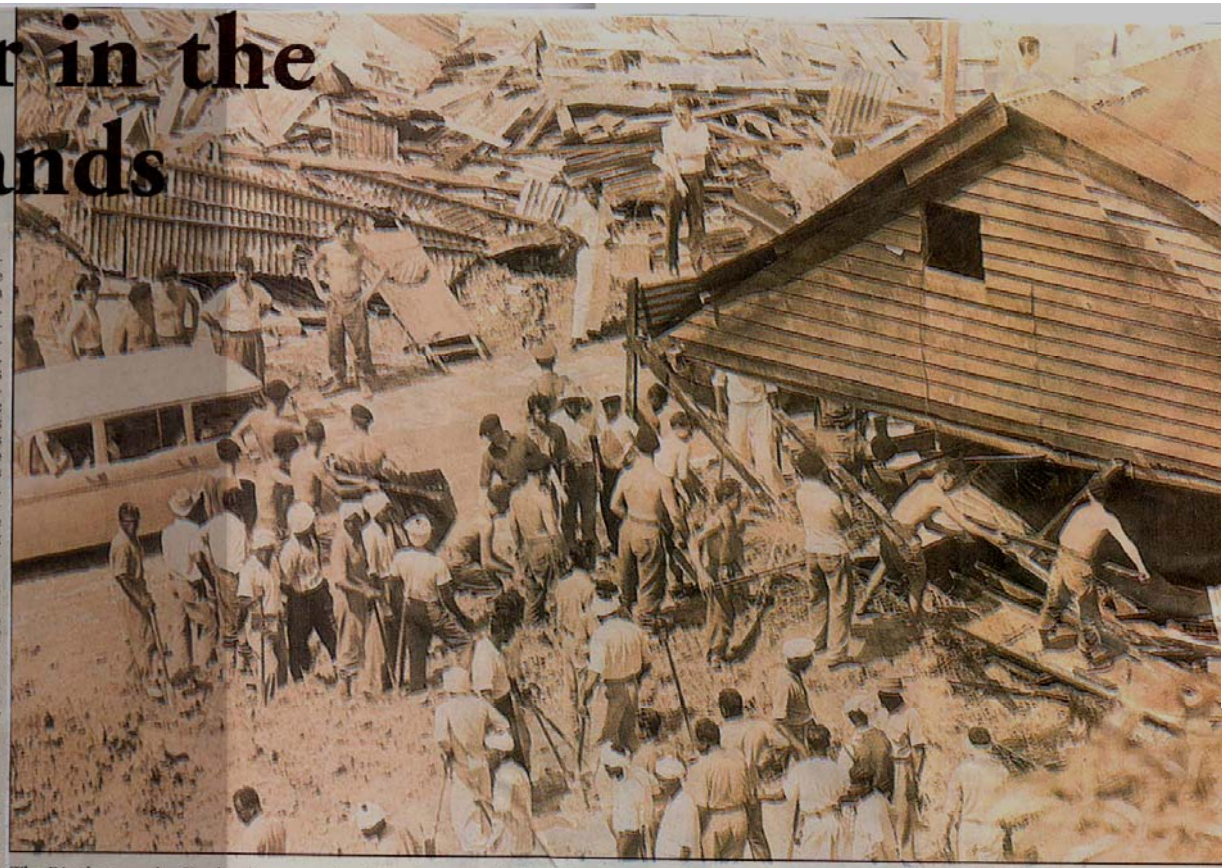
May 11

An avalanche of earth buries six shophouses in a row of eight in Ringlet, in the Cameron Highlands. A great fall of earth spills onto the main road for 50 yards. Immediately after the 10-second, 4pm landslide, hastily-organised parties from nearby houses and farms begin rescue work. Within minutes, the number of rescuers swells to 700. Hundreds from projects connected with the Highlands hydroelectric scheme hasten to give aid. Rescue workers labour frantically to clear away thousands of tonnes of earth to reach those entombed. Civilian and medical teams from Tanah Rata rush to render first aid. Minister of Finance Tan Siew Sin, holidaying in the Highlands, takes personal charge of rescue operations. A mobile generating plant is set up to provide electricity as rescue operations continue after nightfall.

Commander of the visiting US 7th Fleet in the Pacific, Vice-Admiral Charles D. Griffin, offers to postpone his departure from Port Swettenham if his men can be of use. This gracious gesture is declined by a "very touched" Tunku Abdul Rahman, who feels the Vice-Admiral "could not do very much just now". The Prime Minister travels by air and by road to the scene of the tragedy; men of the *Saint Paul*, flagship of the 7th Fleet, make a collection on board. In the 10 minutes before their departure, they collect $631.

The township of Ringlet consists of this ill-fated row of shophouses and another of 20, surrounded by bungalows, farms, and the Lubok Temang New Village. Customers in coffee-shops, playing mahjong and cards, have been caught unawares by the landslip.

Four hours after rescue operations begin, a boy of six is dug out alive, but in severe shock. Others are trapped under 25 feet of earth with little or no chance of survival. At dusk the following day, mud-besplattered rescue workers overcome with fatigue lie in their vehicles, and on desktops and the floor of a nearby school. The death toll is 17.



The Ringlet tragedy: Six shophouses are buried under an avalanche of earth. The death toll is 17

Genting

Plate 8 : Landslide L6 on a cut slope which measured about 16 metres high.

Highland Tower 1993

Bukit Antarabangsa, 1999

Landslide at Hillview (2002) = claimed *8* lives

Kampung Pasir, Ulu Klang (2006)

claimed *4* lives

ULU KLANG was struck by landslide again, the fifth major tragedy since 1993.

Two women died and two toddlers were listed missing yesterday when thousands of tonnes of earth flattened an Indonesian settlement of 160 homes near Taman Zooview, less than 2km from Highland Towers.

Sixteen Taman Zooview houses atop the slope that gave way have been deemed dangerous and the residents told to move out.

■ Stories and pictures in Pages 4, 35, 36 & 37

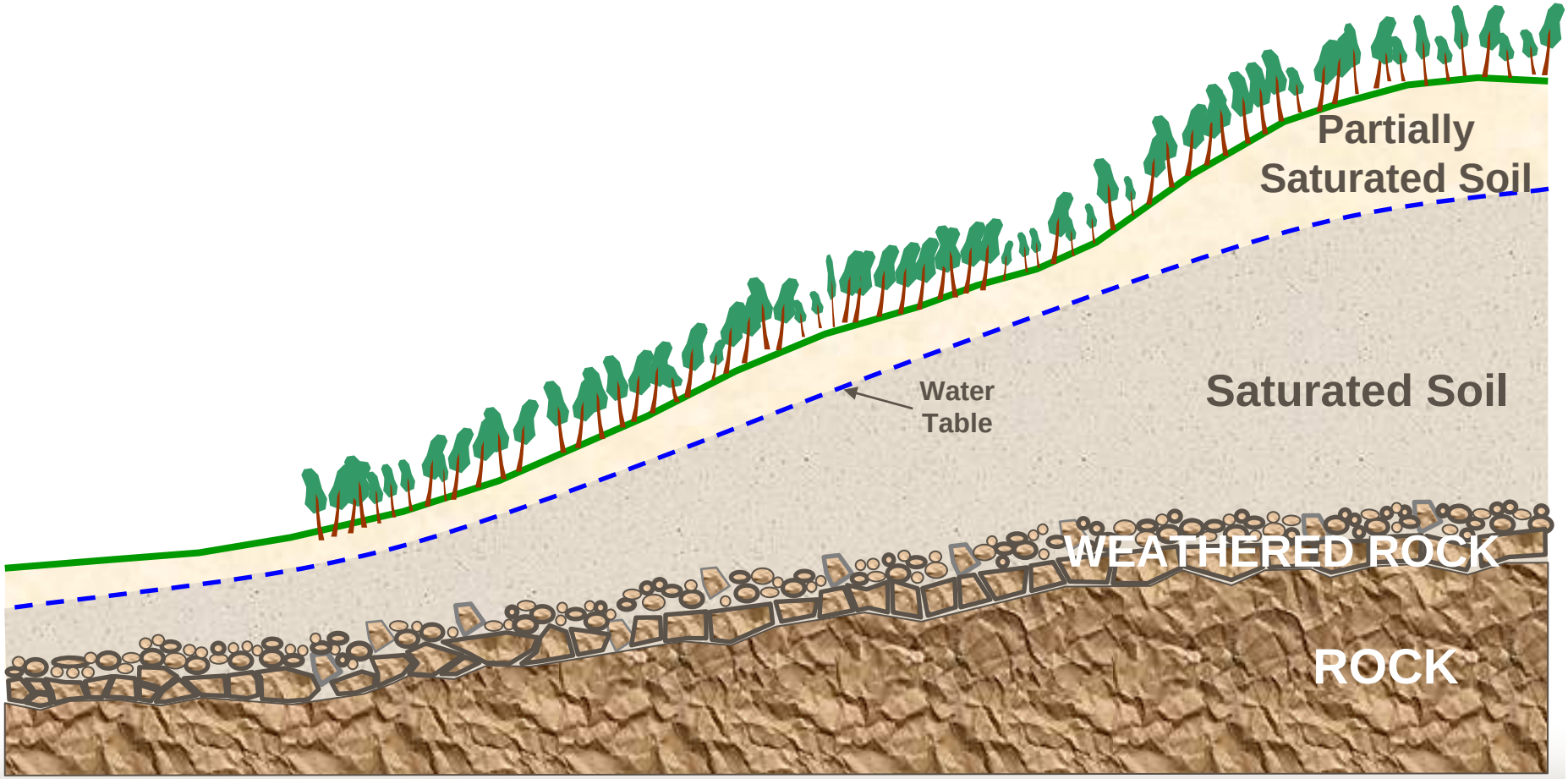
Landslide at Bukit Antarabangsa Dec 2008

claimed *4* lives

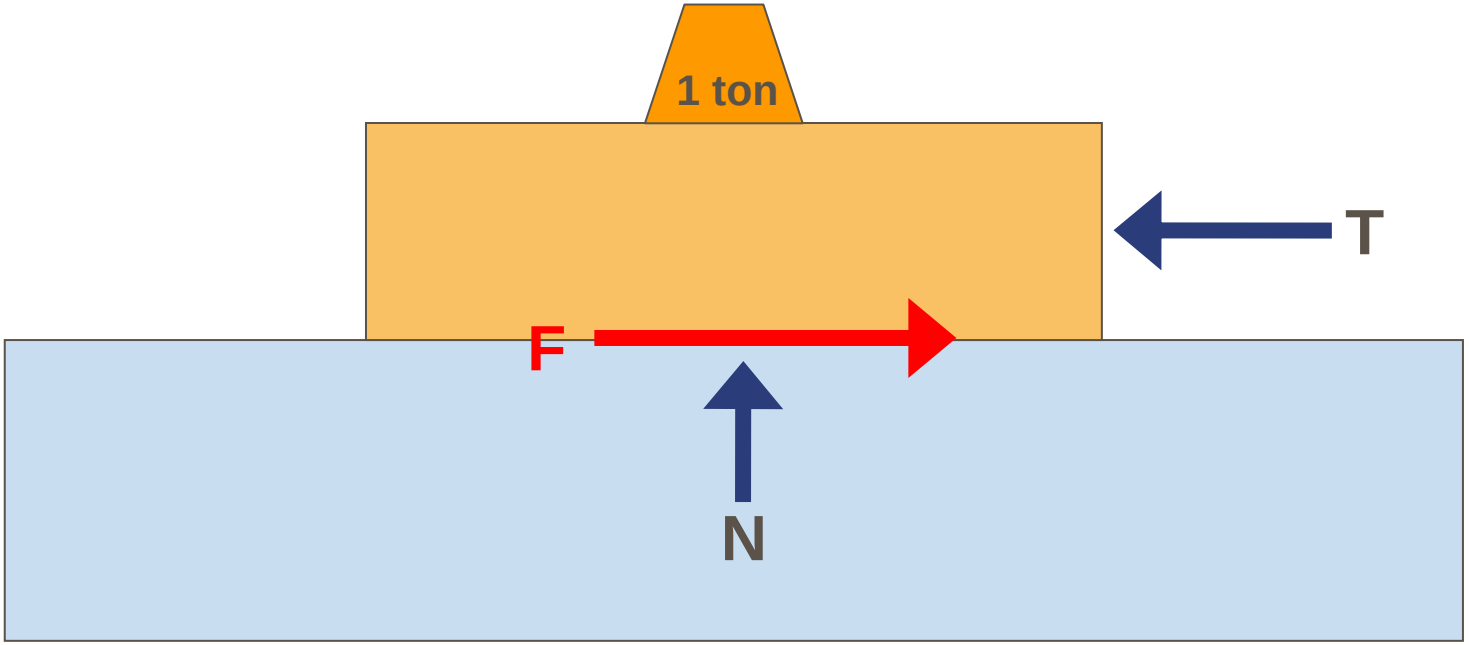
Understand Engineering Aspects of Hill-Site Development

(Simple Terms)

Anatomy Of A Slope



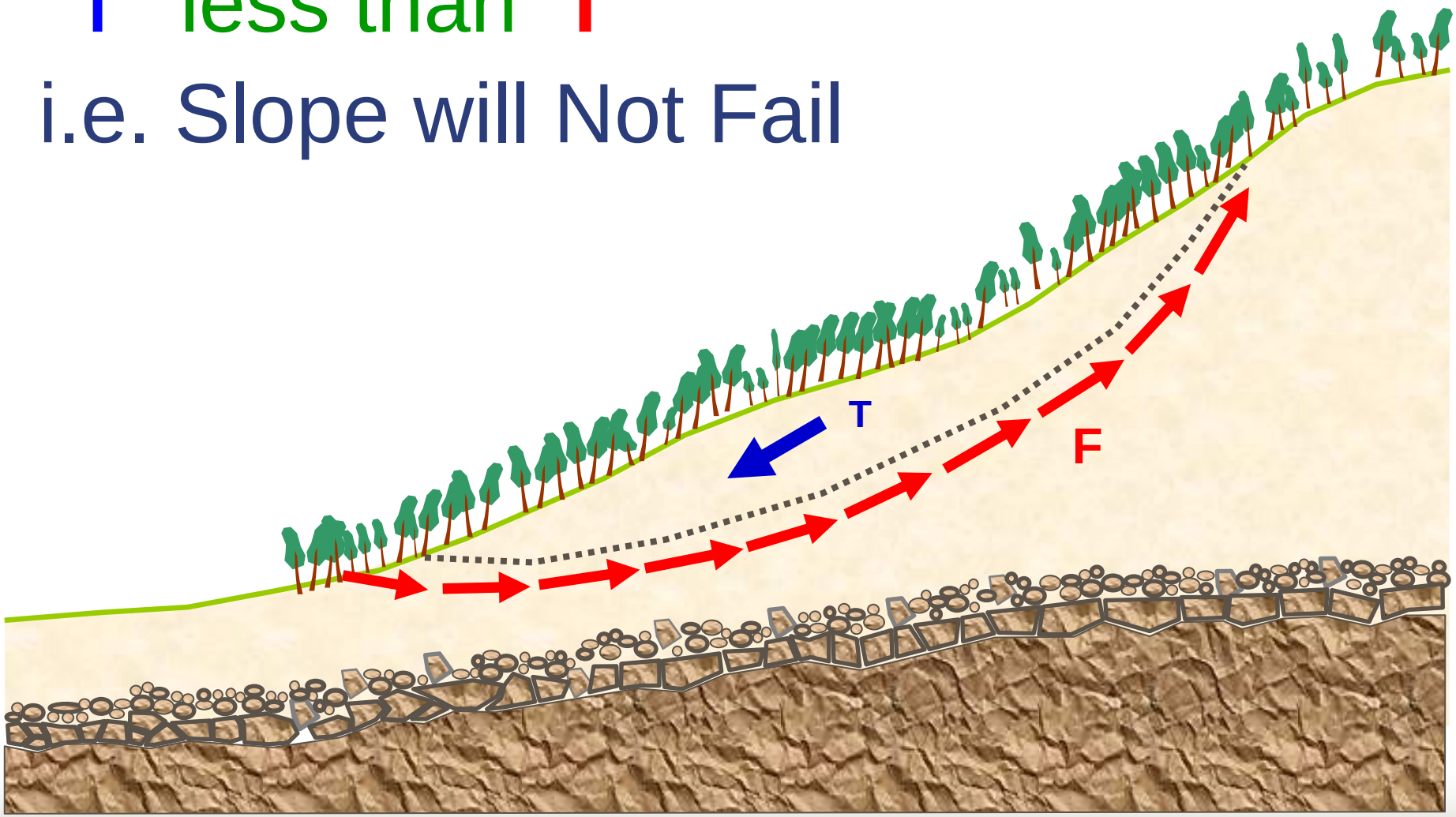
FRICTION CONCEPT



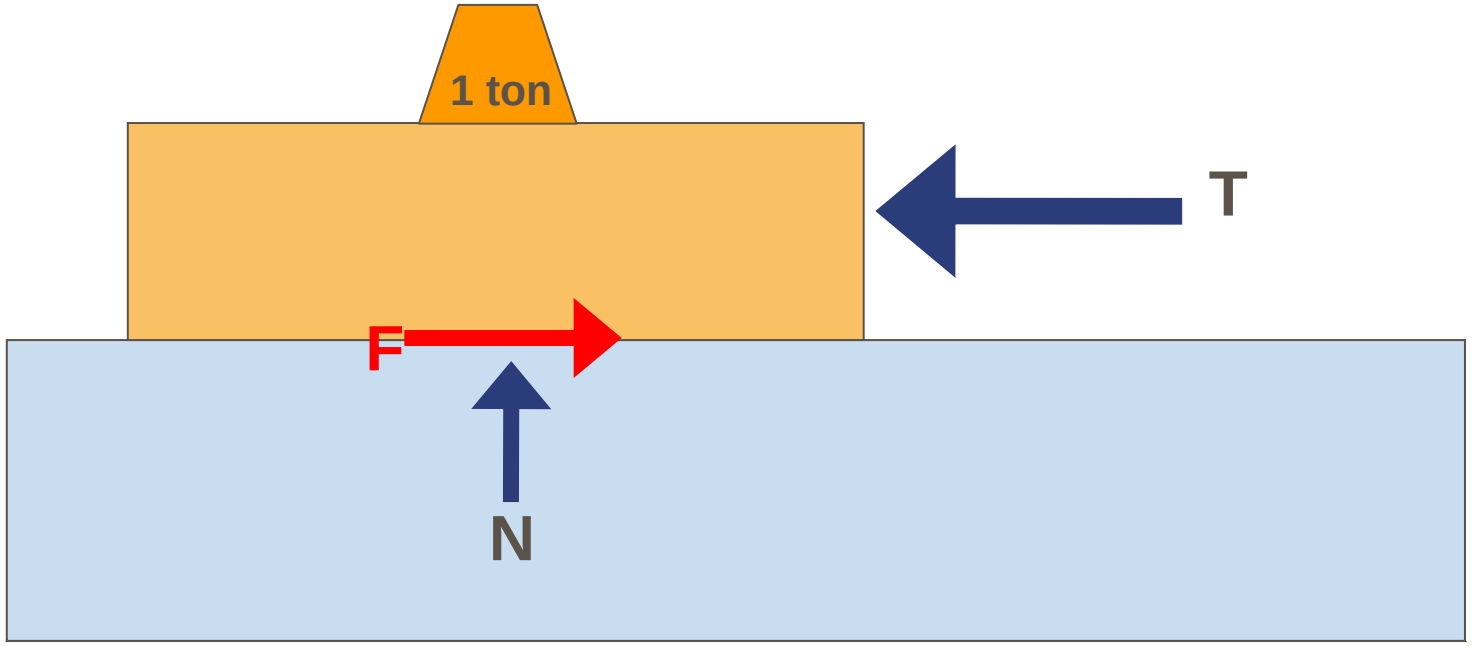
- Box Will Not Slide when F > T

“T” less than “F”

i.e. Slope will Not Fail



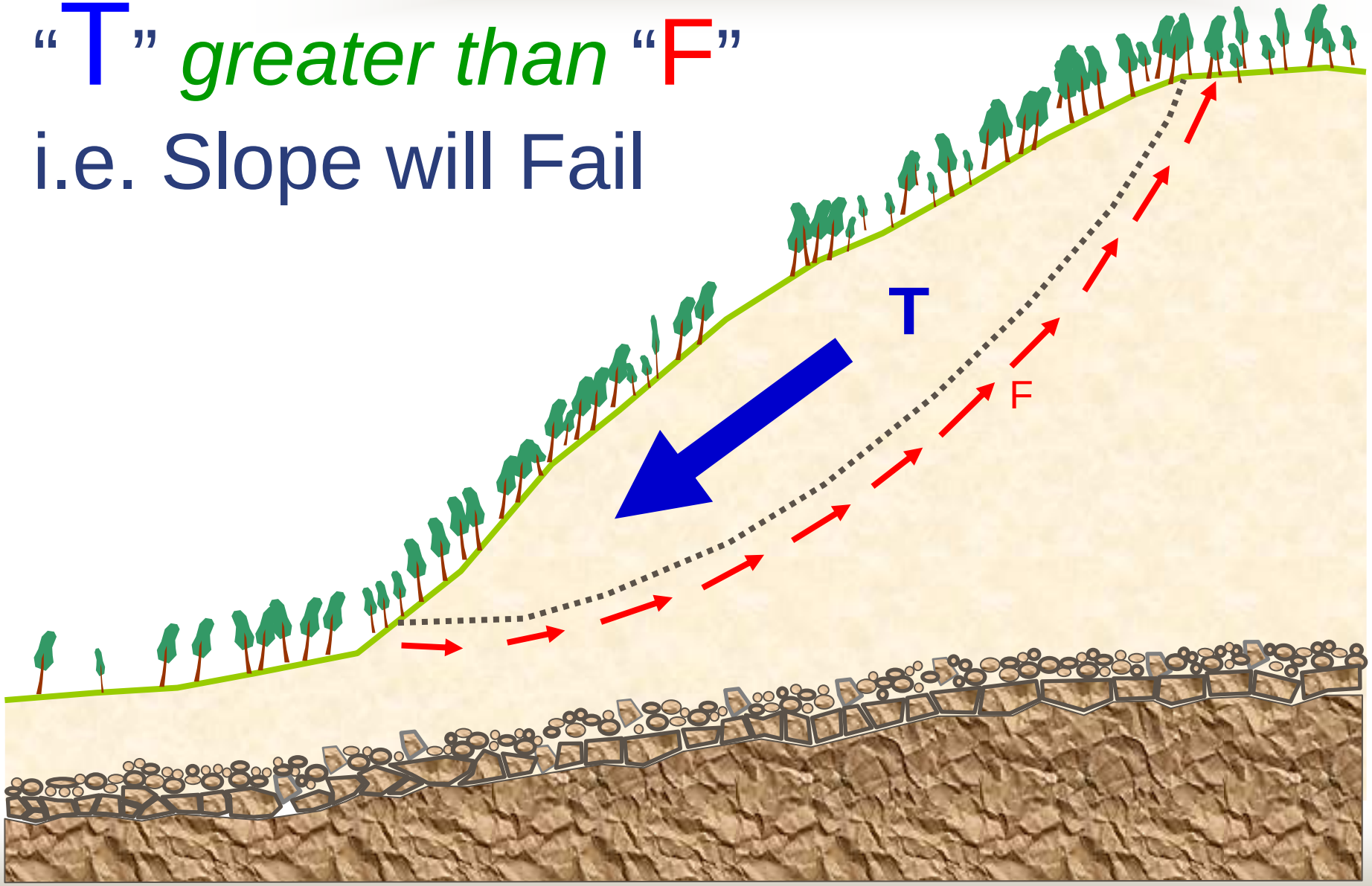
SLIDING



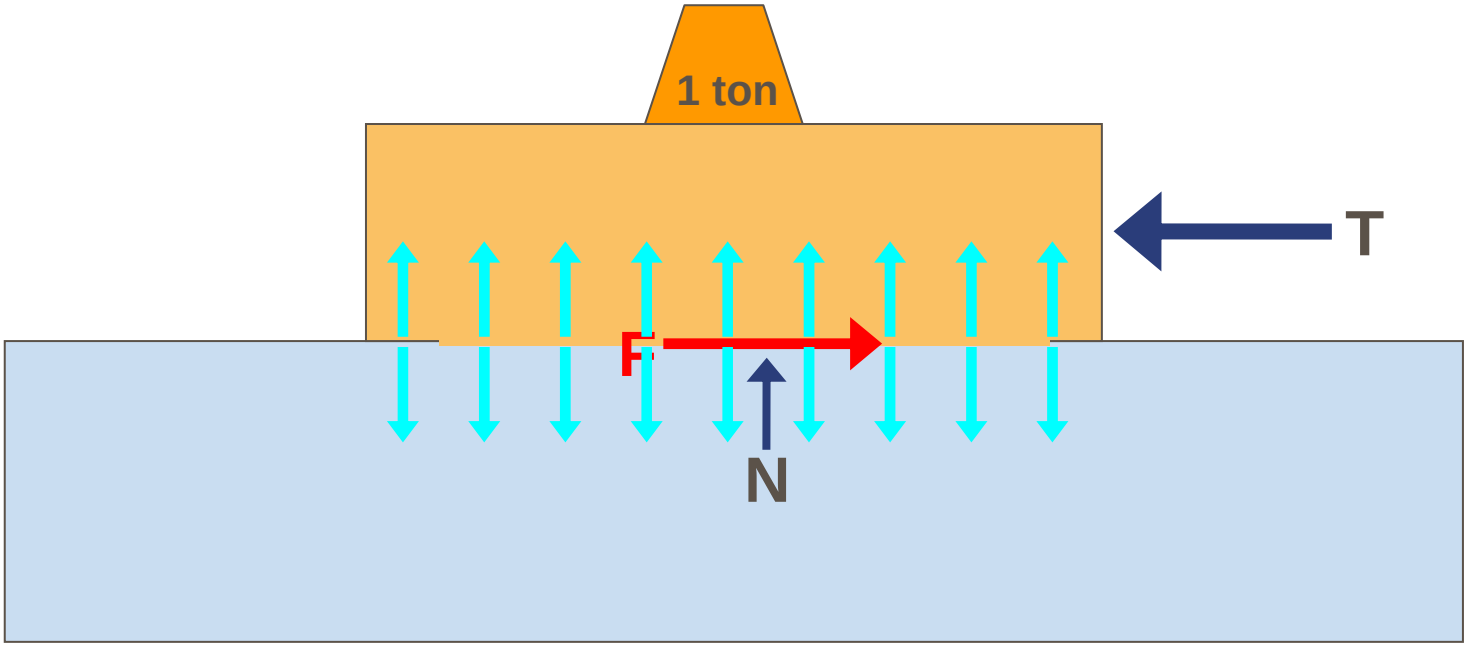
- Sliding Occurs when T>F

“T” *greater than* “F”

i.e. Slope will Fail

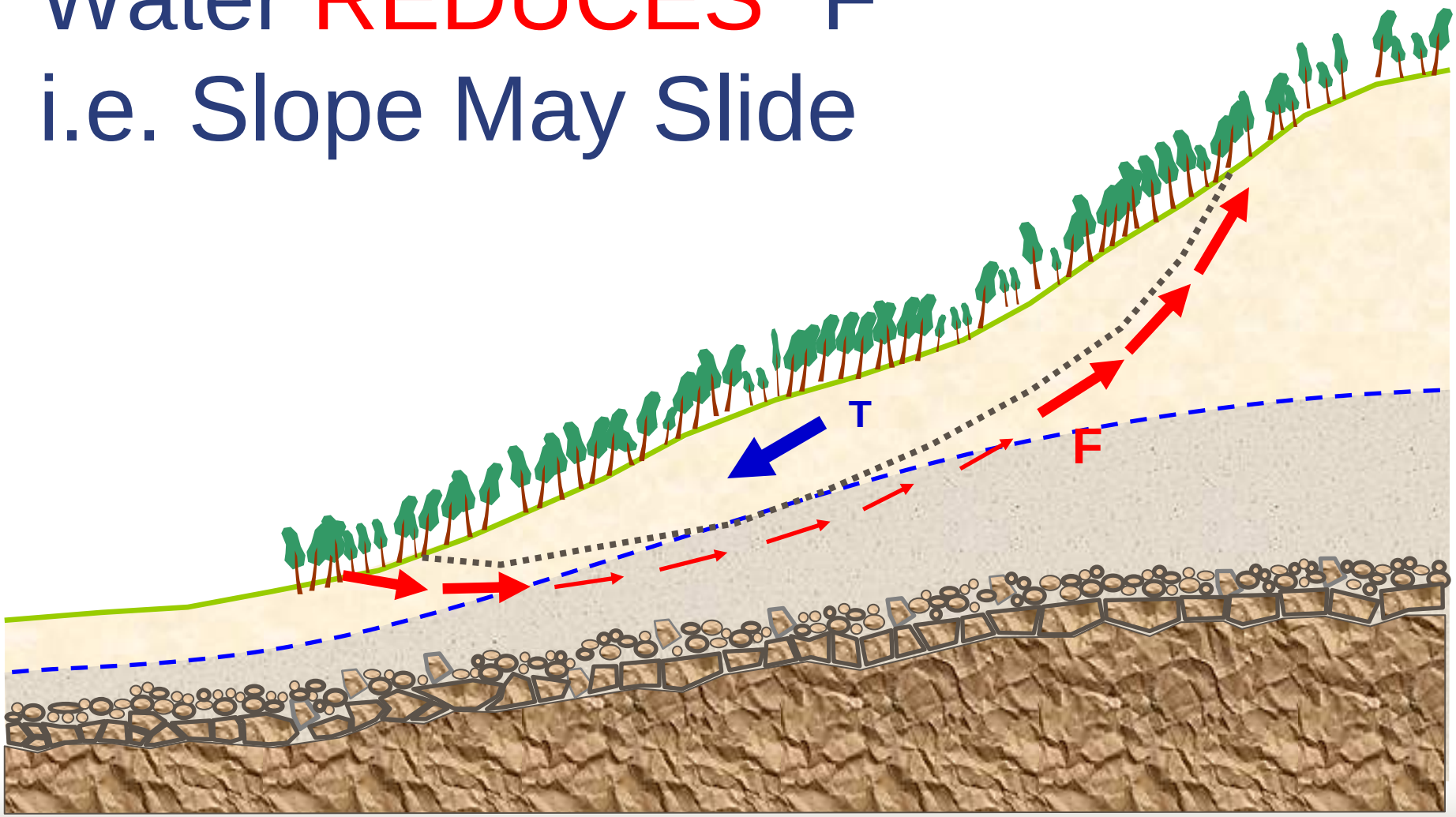


WATER PRESSURE

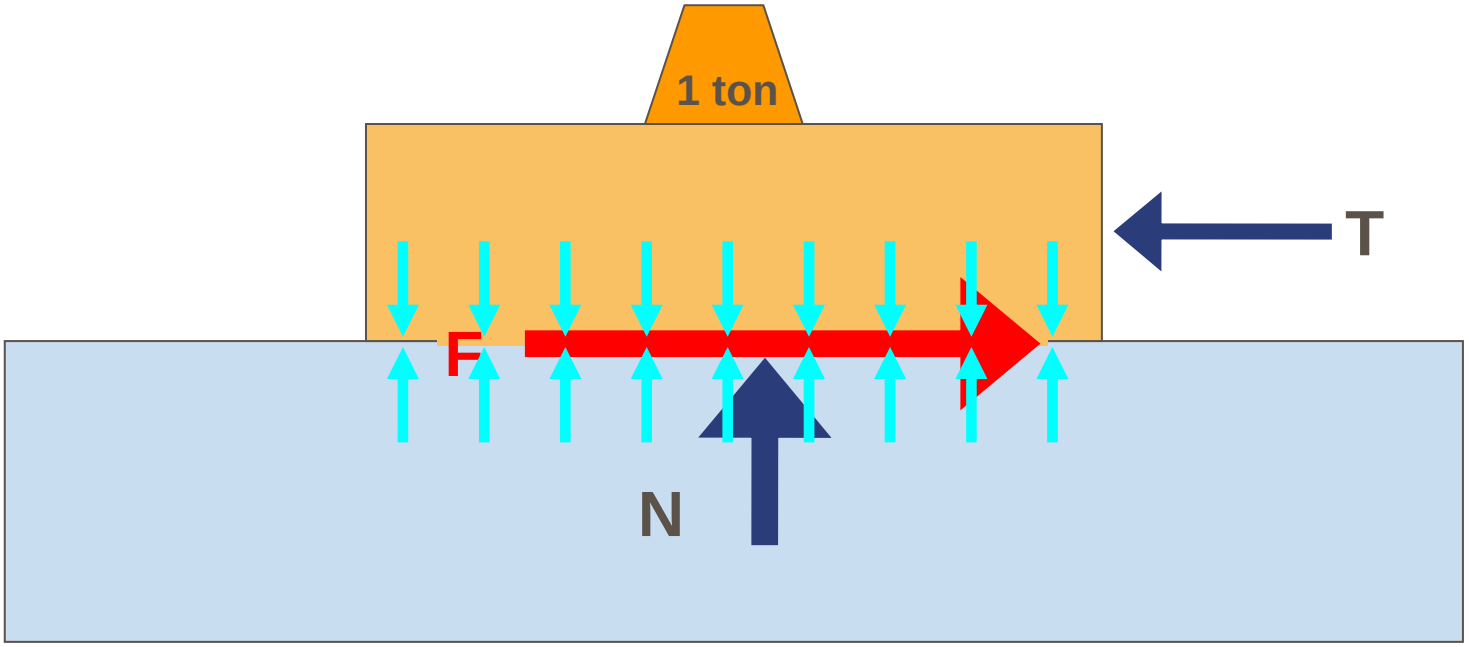


- Water Pressure Reduces N $\Rightarrow$ Reduces F

Water REDUCES “F”
i.e. Slope May Slide



SUCTION

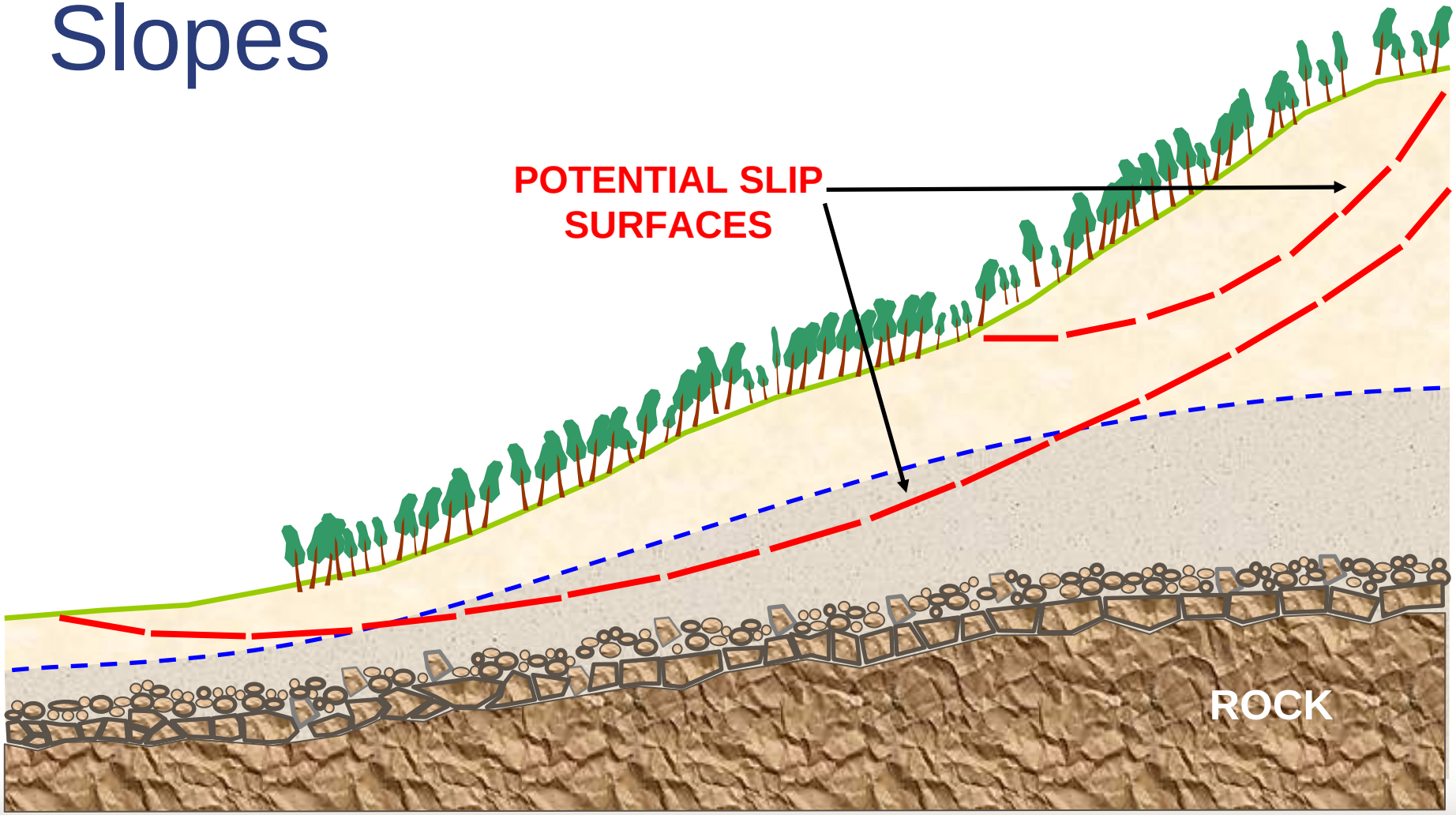


- Suction Increases N $\Rightarrow$ Increases F

Temporary Cut Slope

Permanent Graded Slope

Engineering Analyses of Slopes



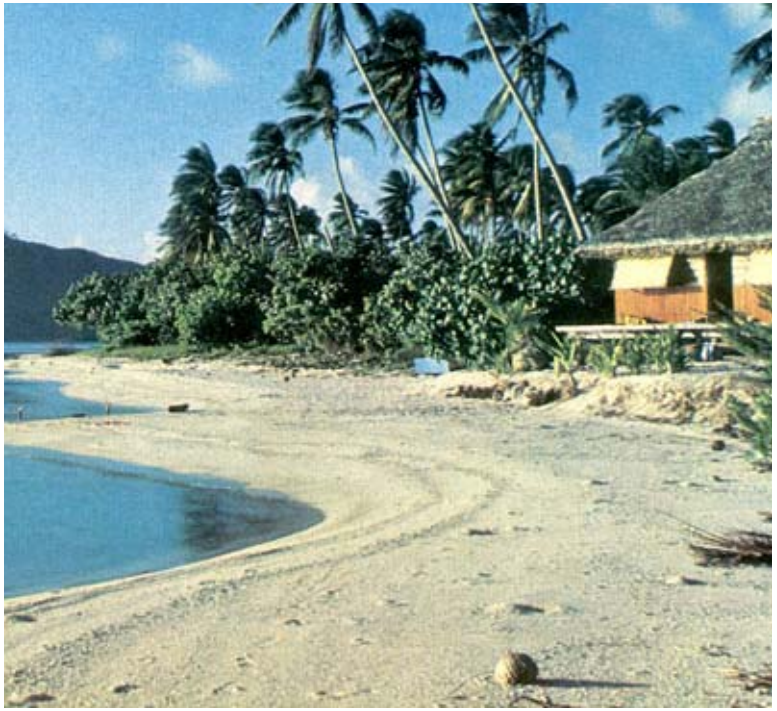
IMPORTANT

Slope Stability Factors

- **Soil Properties**

Soil Properties

Steep Rockface



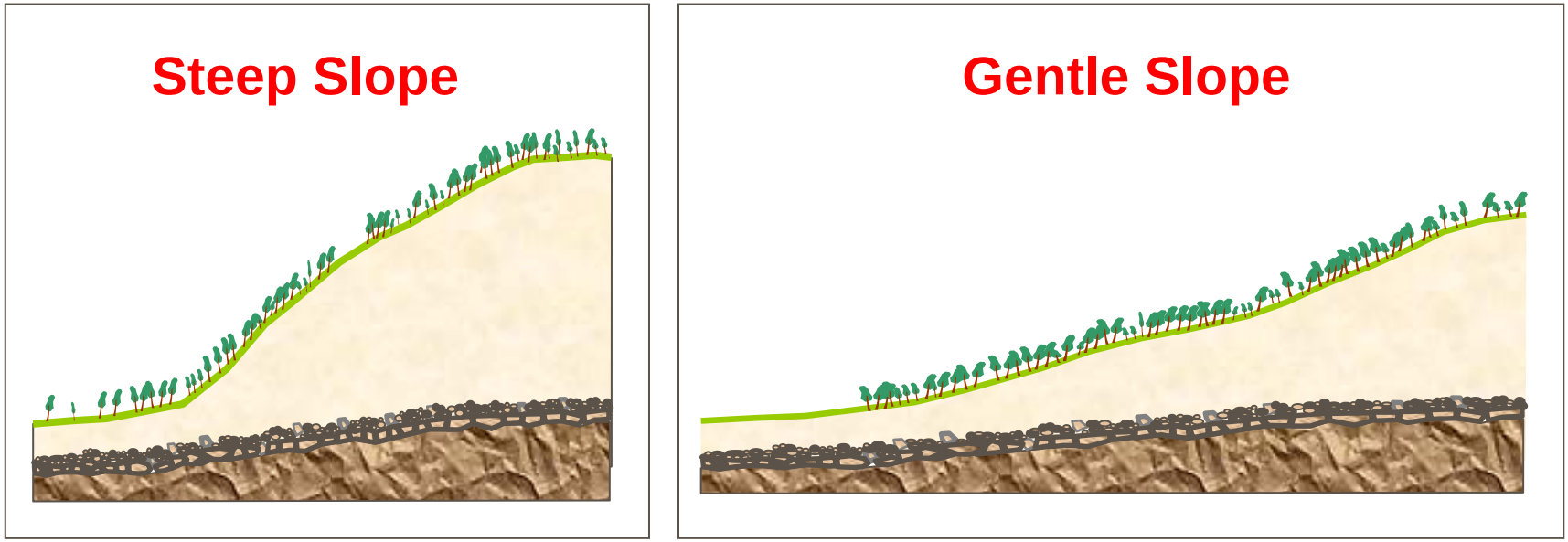
Gentle Beach

IMPORTANT

Slope Stability Factors

- **Soil Properties**
- **Slope Geometry**

Slope Geometry

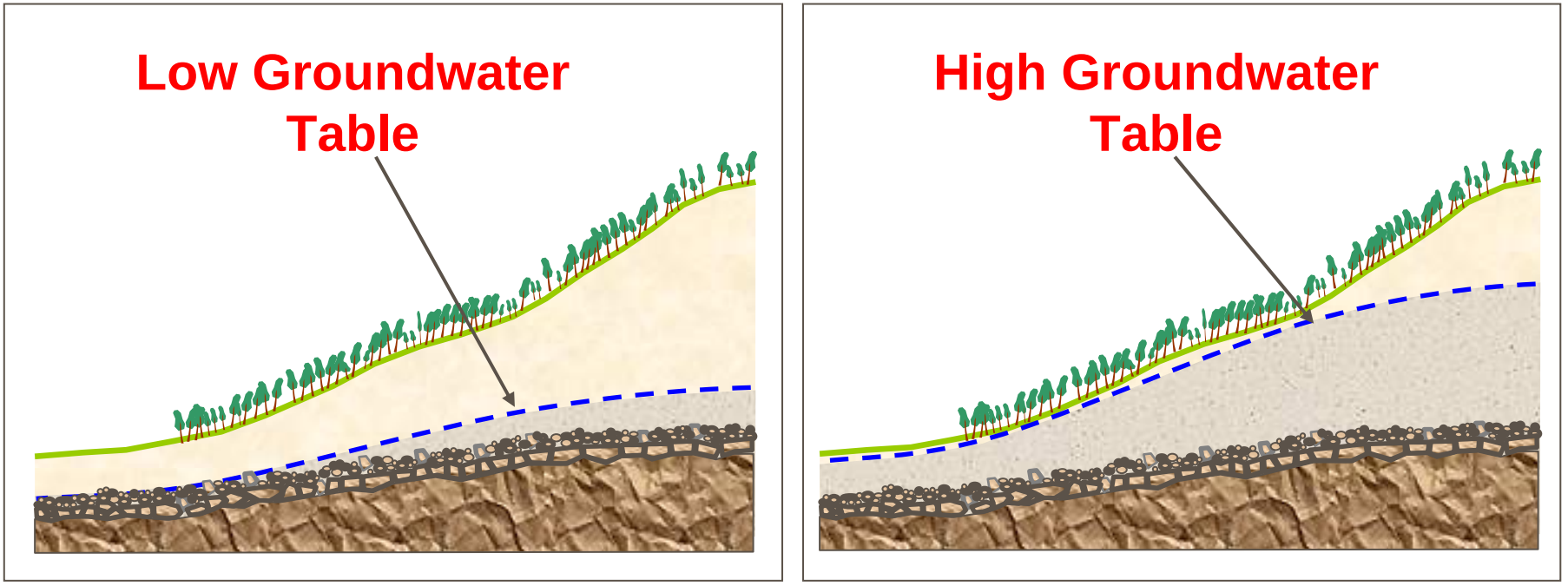


- Steep Slopes Has Higher Risk of Failing

IMPORTANT
Slope Stability Factors

- **Soil Properties**
- **Slope Geometry**
- **Groundwater**

Groundwater Effect



- High Groundwater Increases Risk of Failure

IMPORTANT

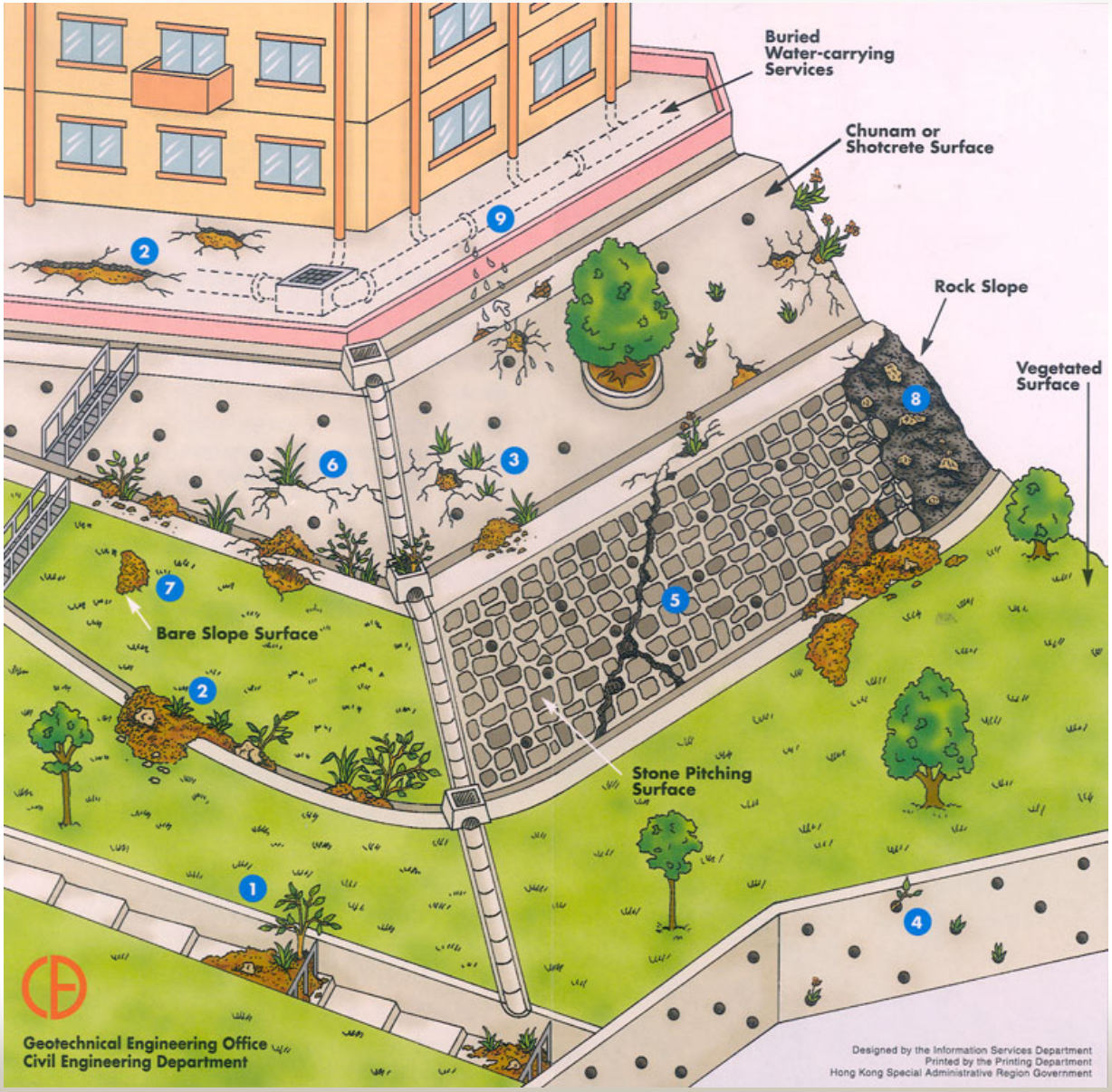
Slope Stability Factors

- **Soil Properties**
- **Slope Geometry**
- **Groundwater table profile**
- **Slope Maintenance**

No Slope Maintenance (Damaged Drains)

No Slope Maintenance (Erosion)

Slope Maintenance



Planning of SI

INTRODUCTION

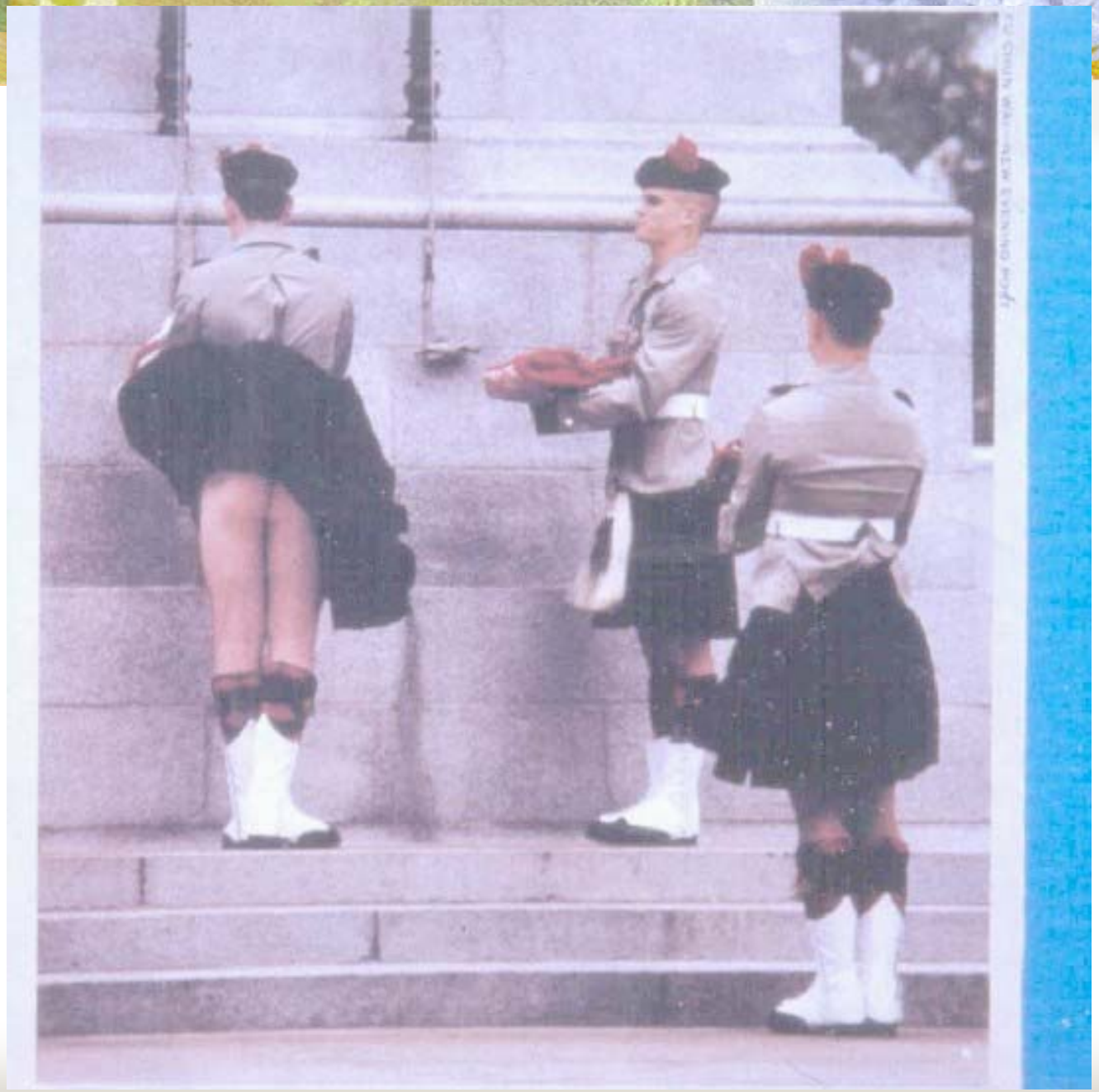
To provide guidance notes to design engineers on practical aspect of :

- **Subsurface Investigation (S.I.) and**
- **Specifying of Laboratory Tests**

For Geotechnical Design of Hill-Site Development or Cut Slopes:

Planning of Subsurface Investigation

1. Introduction
2. Desk Study
3. Site Reconnaissance
4. Extent of S.I.
5. Selection of Types of Field Tests & Sampling Methods. + Determining of Groundwater



Planning of Subsurface Investigation

Usually Two(2) Stages S.I. :

(1) Preliminary S.I.

- To obtain general subsoil profile.
- Preliminary planning of layout or formation level.
- Preliminary soil parameters & water levels
- Preliminary design & (cost + time) estimates.

(2) Detailed S.I.

- Plan for critical areas of concern (e.g. major fill or cut, valley which has soft materials)
- Refine soil parameters for detailed design.
- Locations with structures (e.g. walls, foundations)

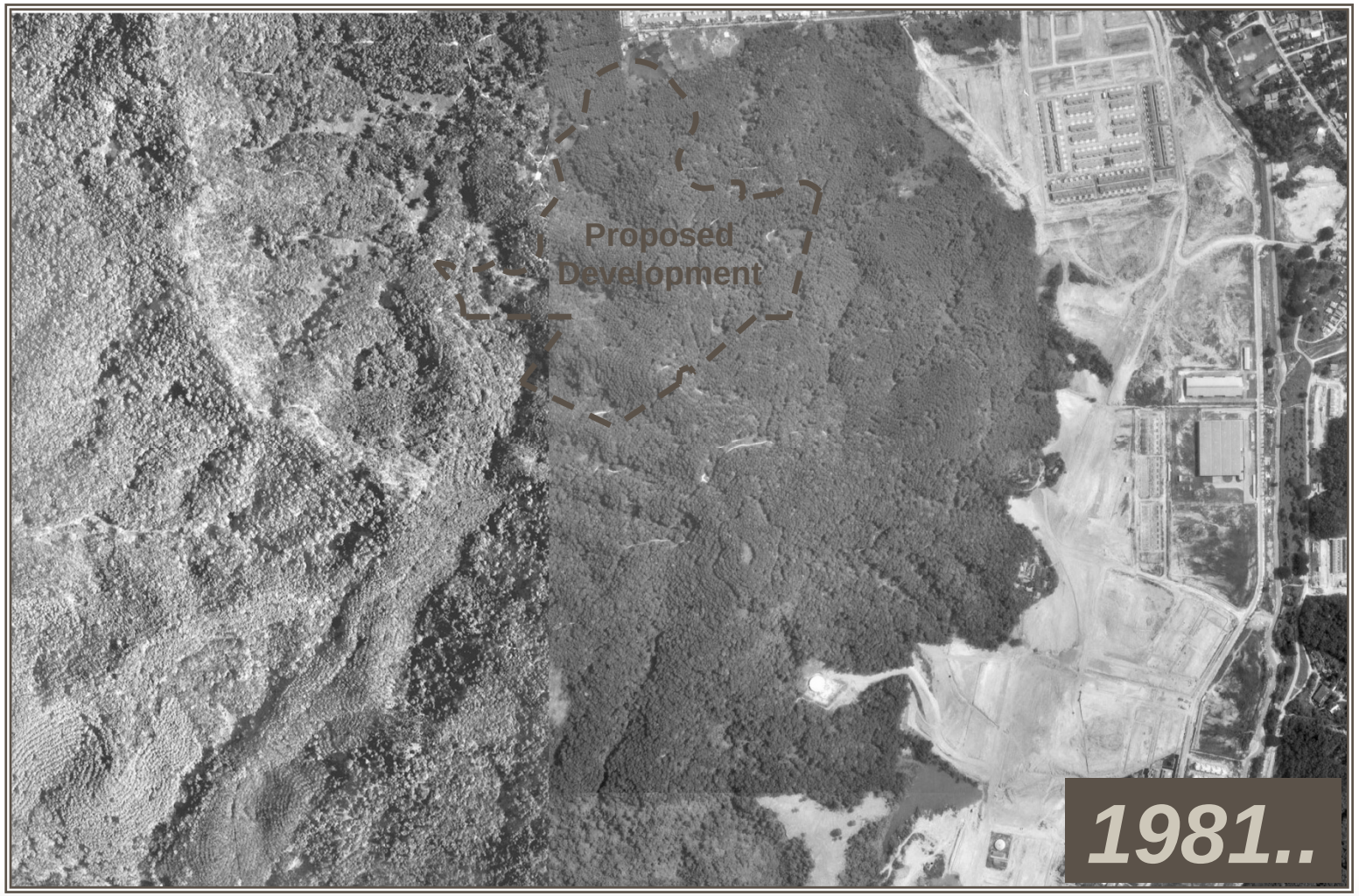
DESK STUDY

- Geological Maps & Memoirs
- Topographic Map
- Aerial Photographs
- Site Histories
- Details of Adjacent Development
- Requirements of the Proposed Structures or Foundations

Aerial Photographs

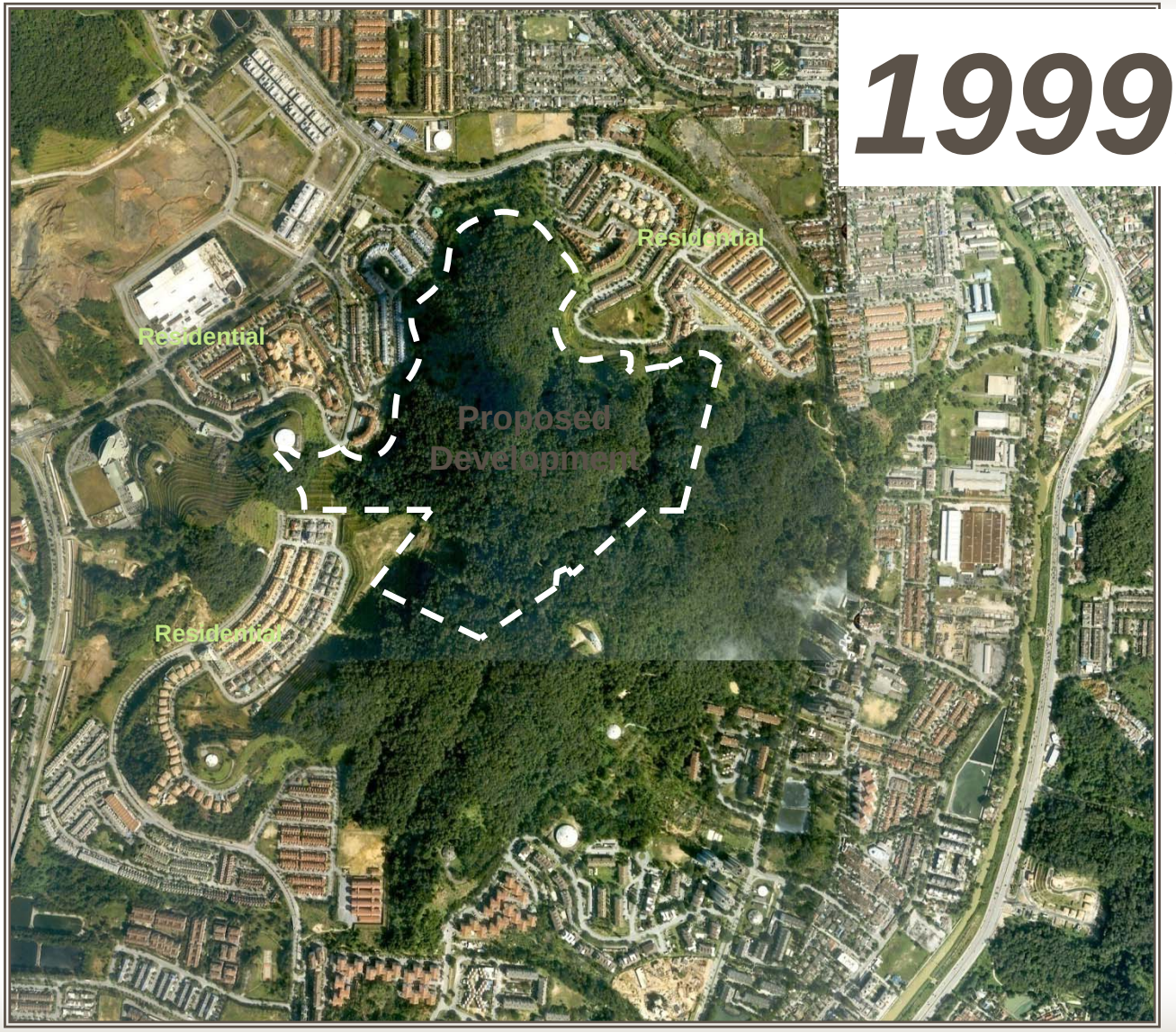
Development History of Site…

Aerial Photograph (22 years ago)



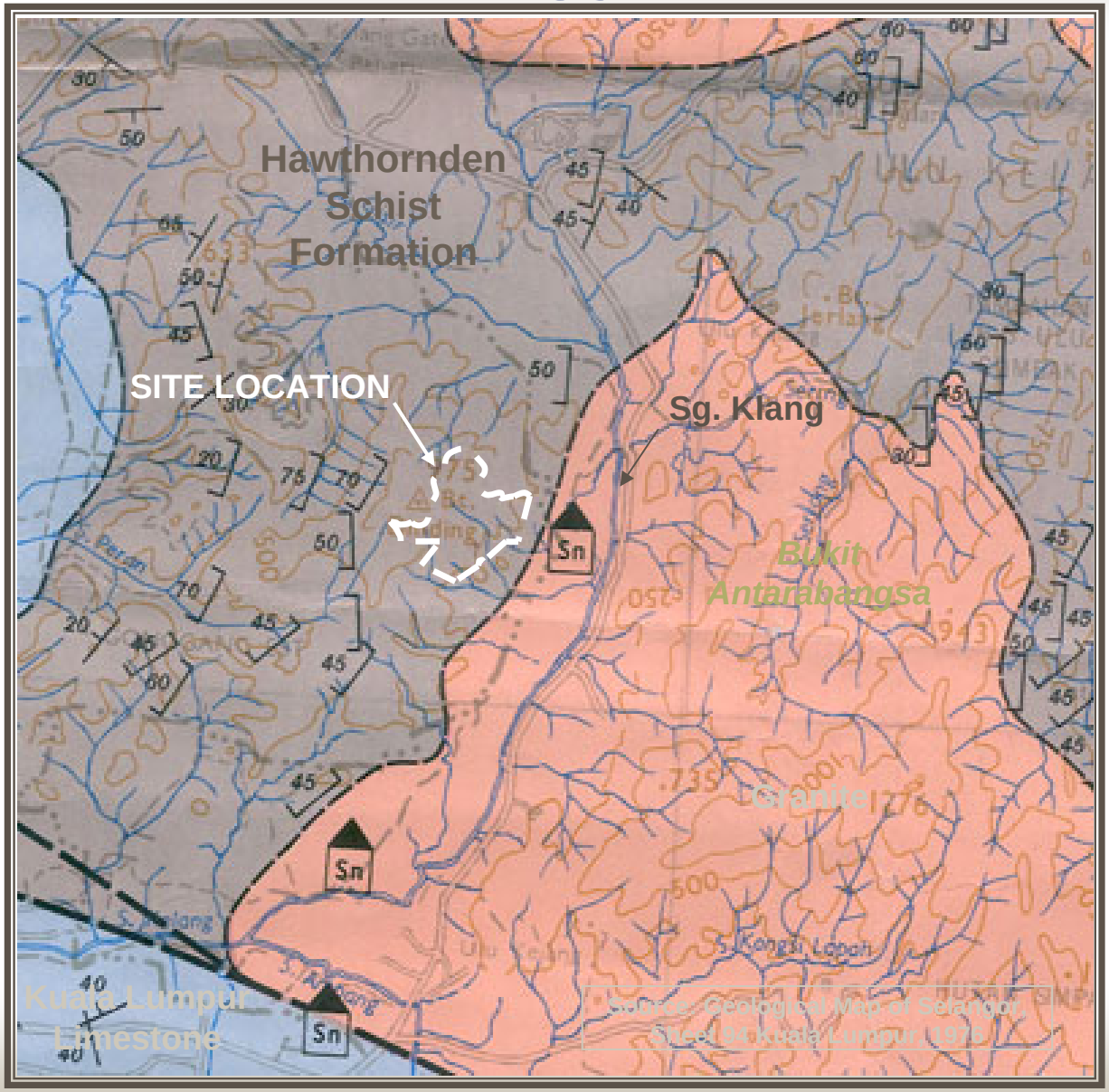
Aerial Photograph (18 years ago)

Aerial Photograph (4 years ago)



1999..

General Geology



SITE RECONNAISSANCE

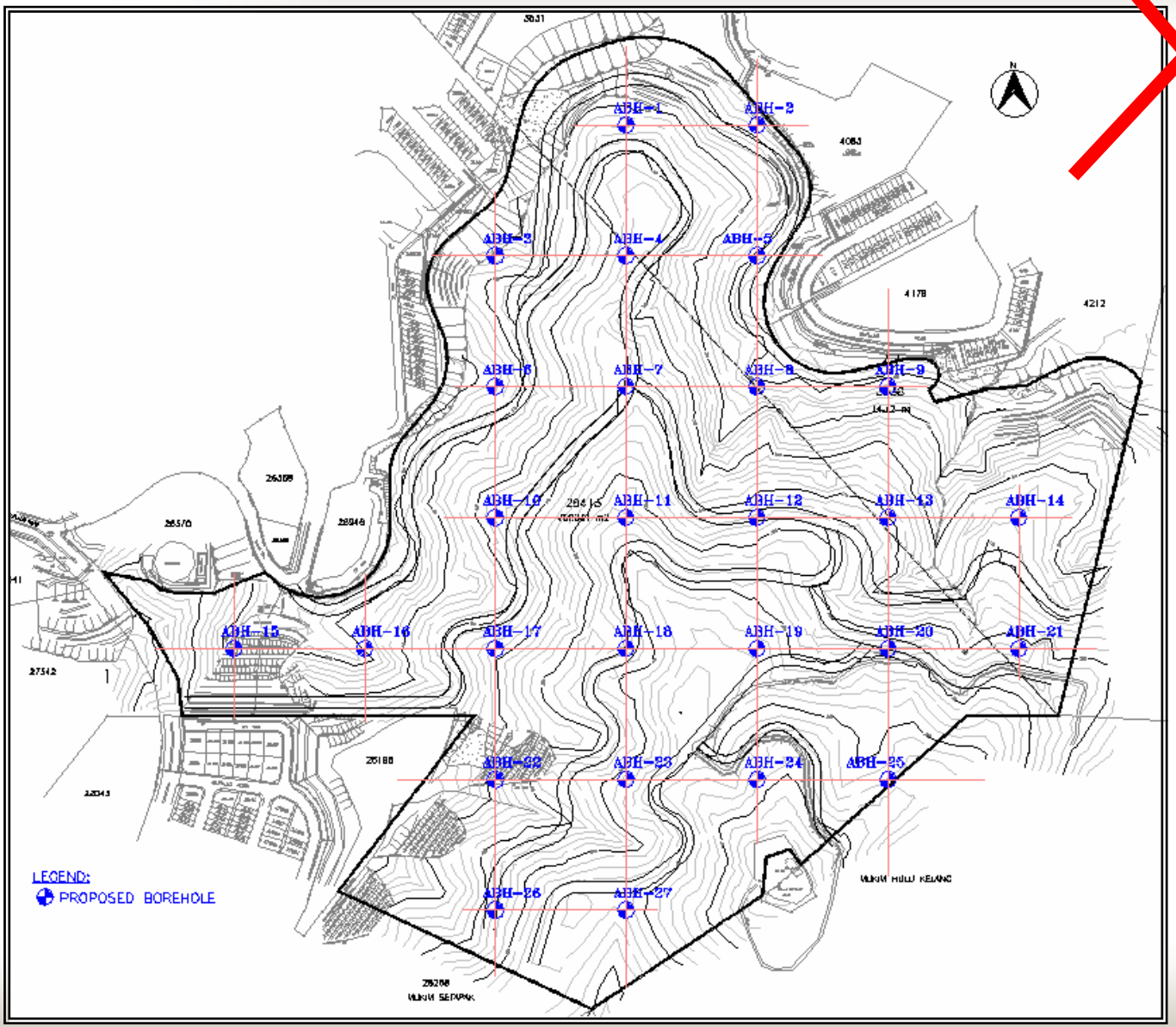
- Confirm & obtain additional information of site
- Examine adjacent and nearby development
- Compare surface features and topography with data obtained from desk study (e.g. Vegetation)
- Locate & study the outcrops, previous slips

EXTENT of S.I.

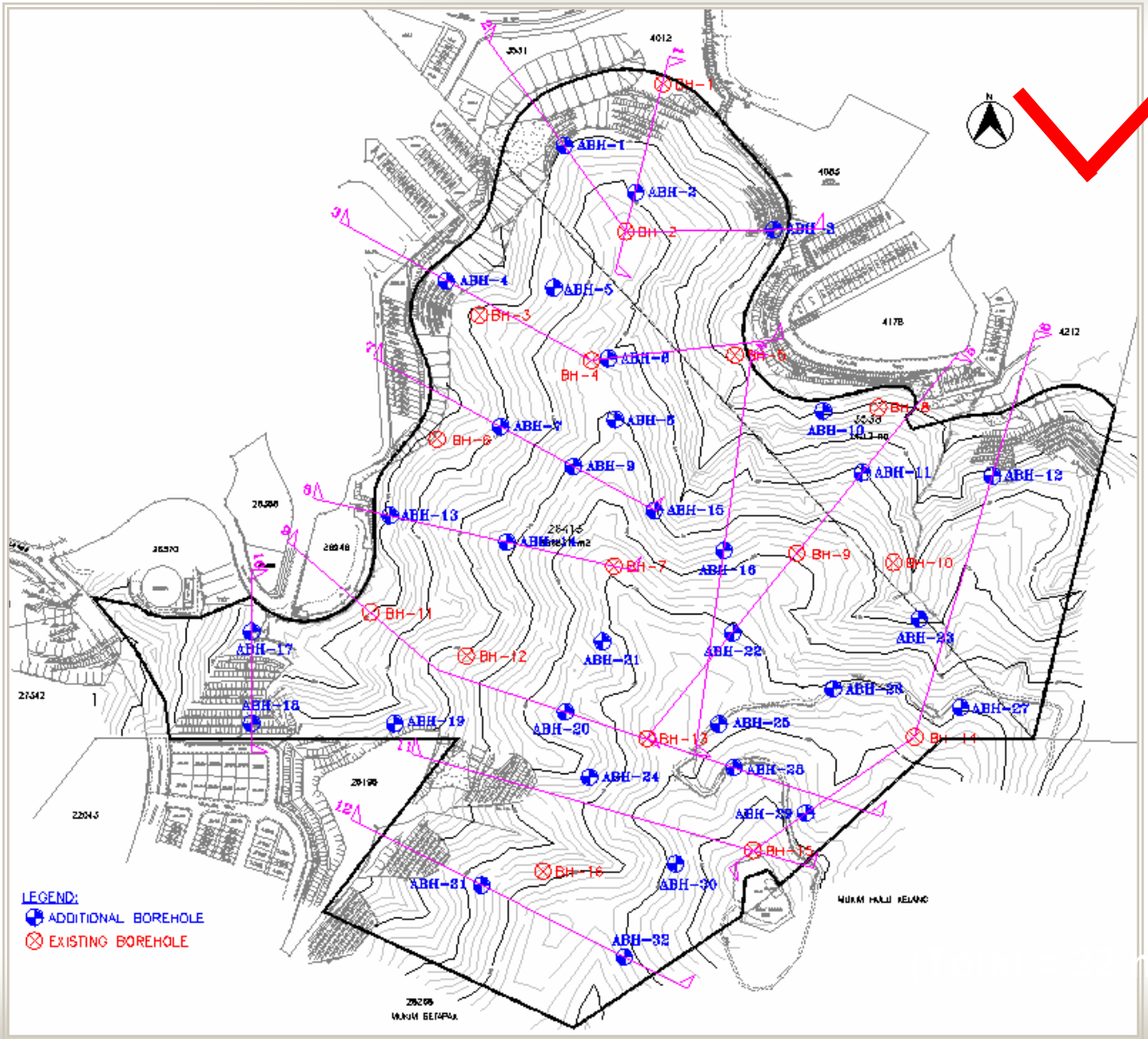
Depends on :

- Available Information
- Geological Formation & Features
- Variability of Subsoil & Groundwater
- Proposed Structures & Foundations

S.I. In Grid Pattern (Wrong !!)



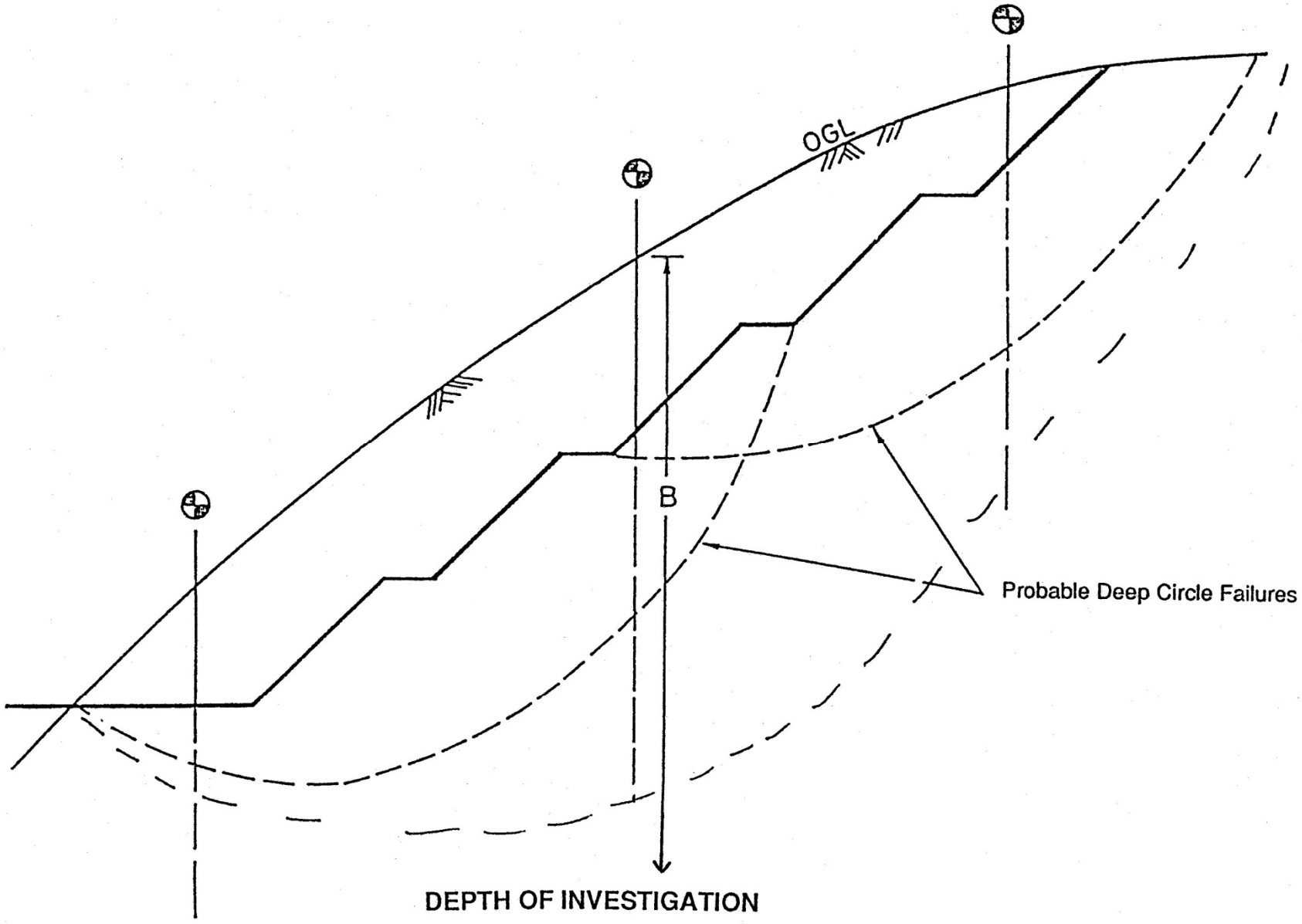
Proposed SI (Correct Way)



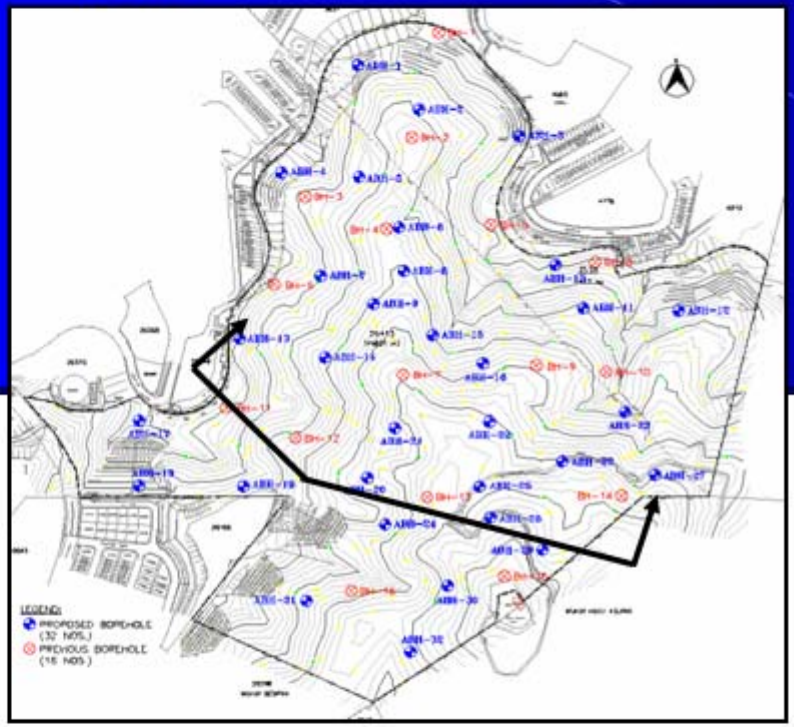
To Place boreholes across the slopes cross - sections.

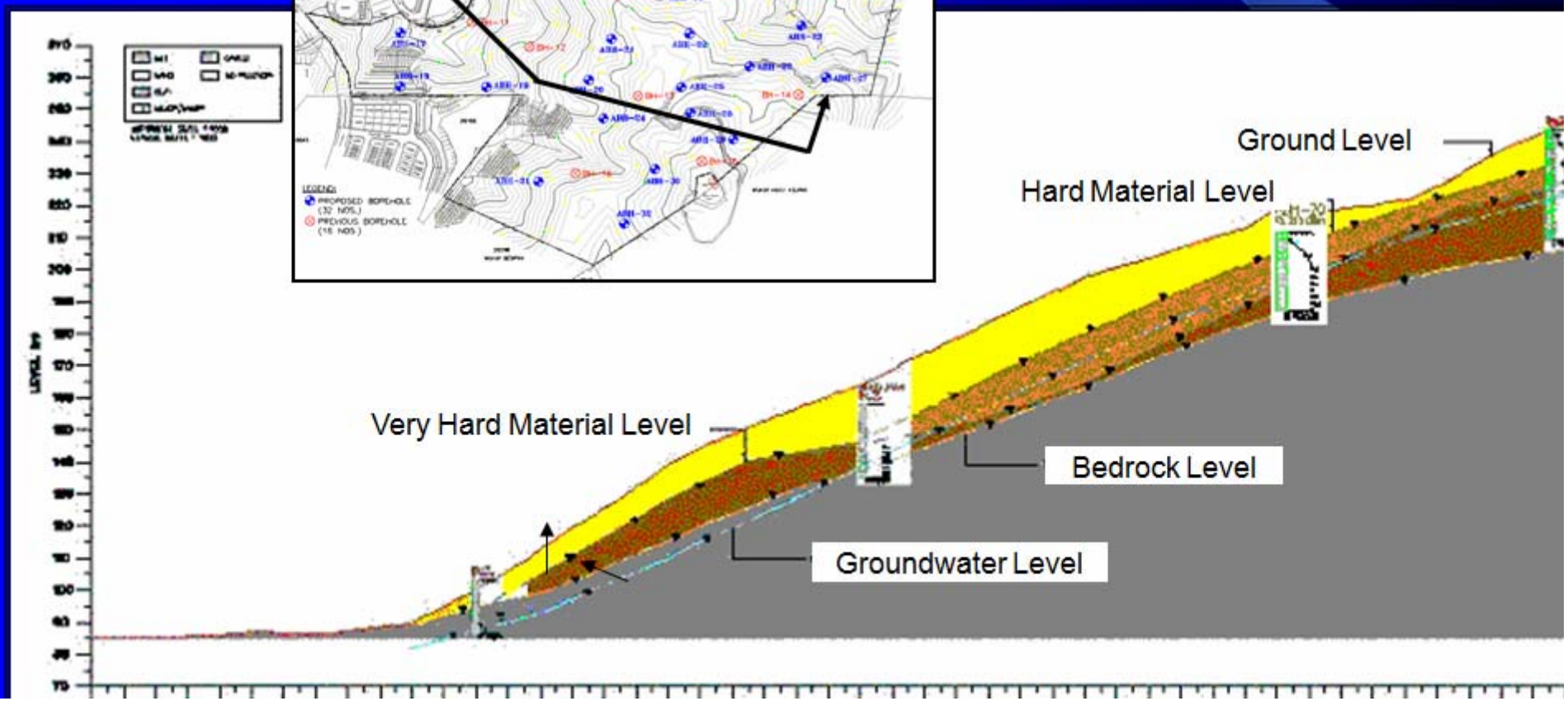
To get subsoil profile for analysis and design

Depth of Field Tests for Slopes Design

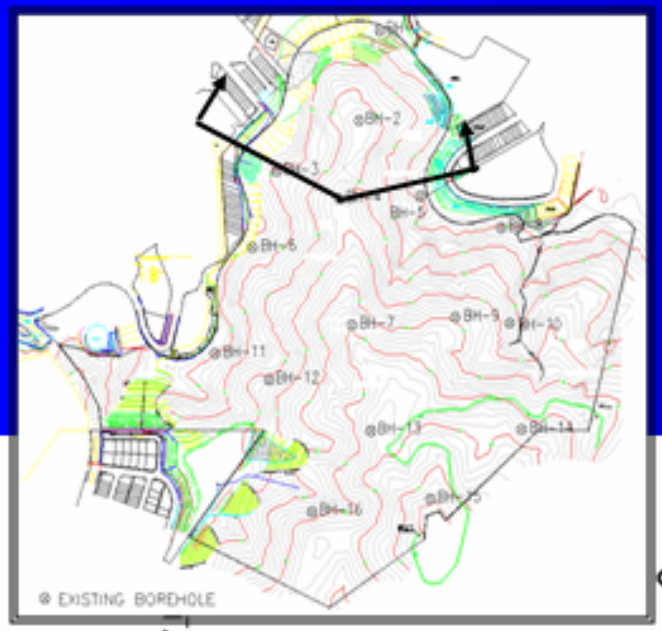


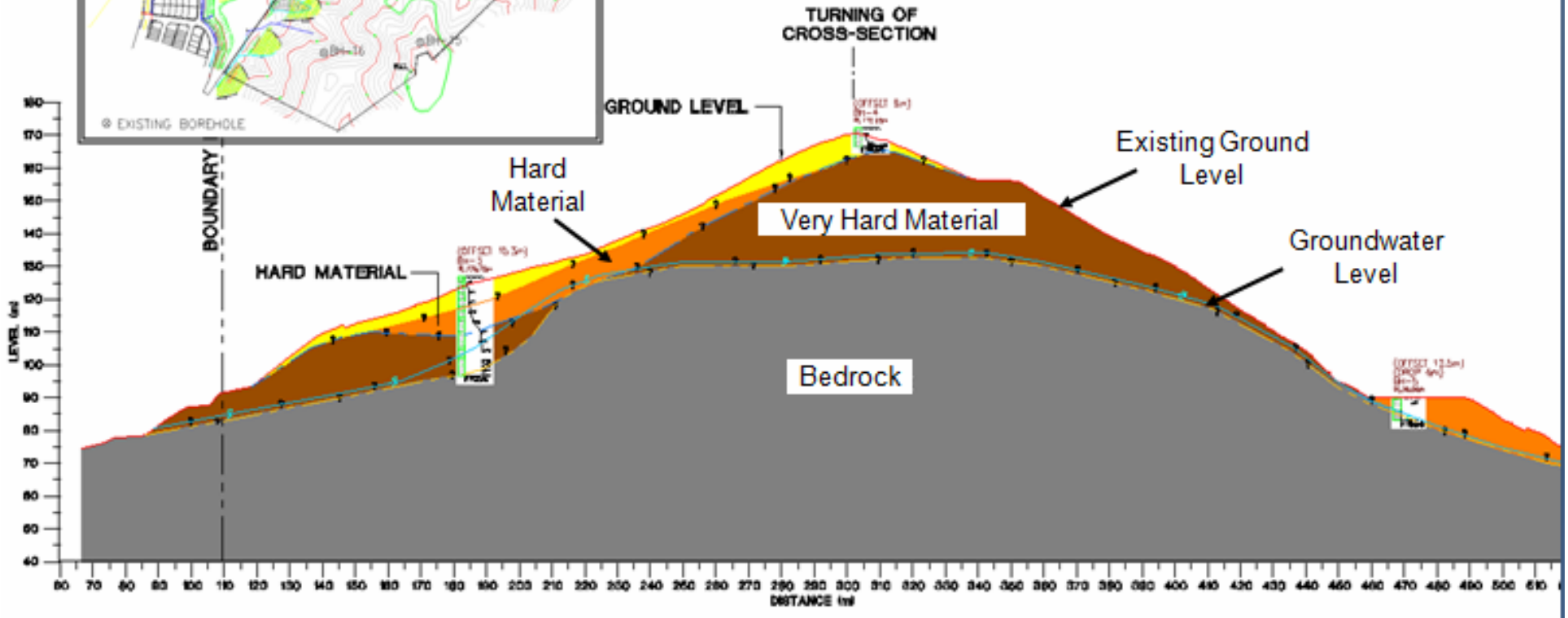
Typical Cross-Section



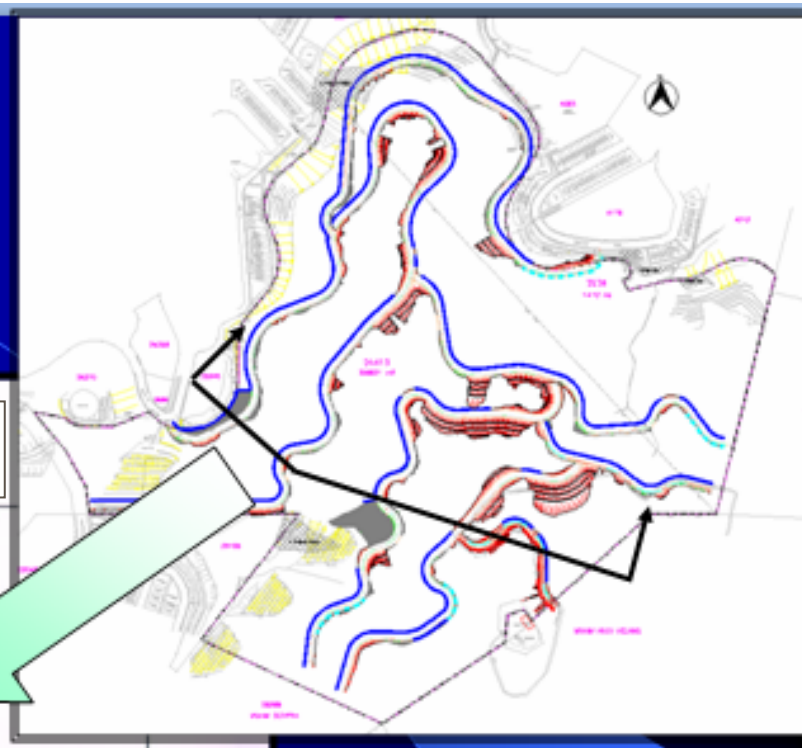


Typical Cross-Section





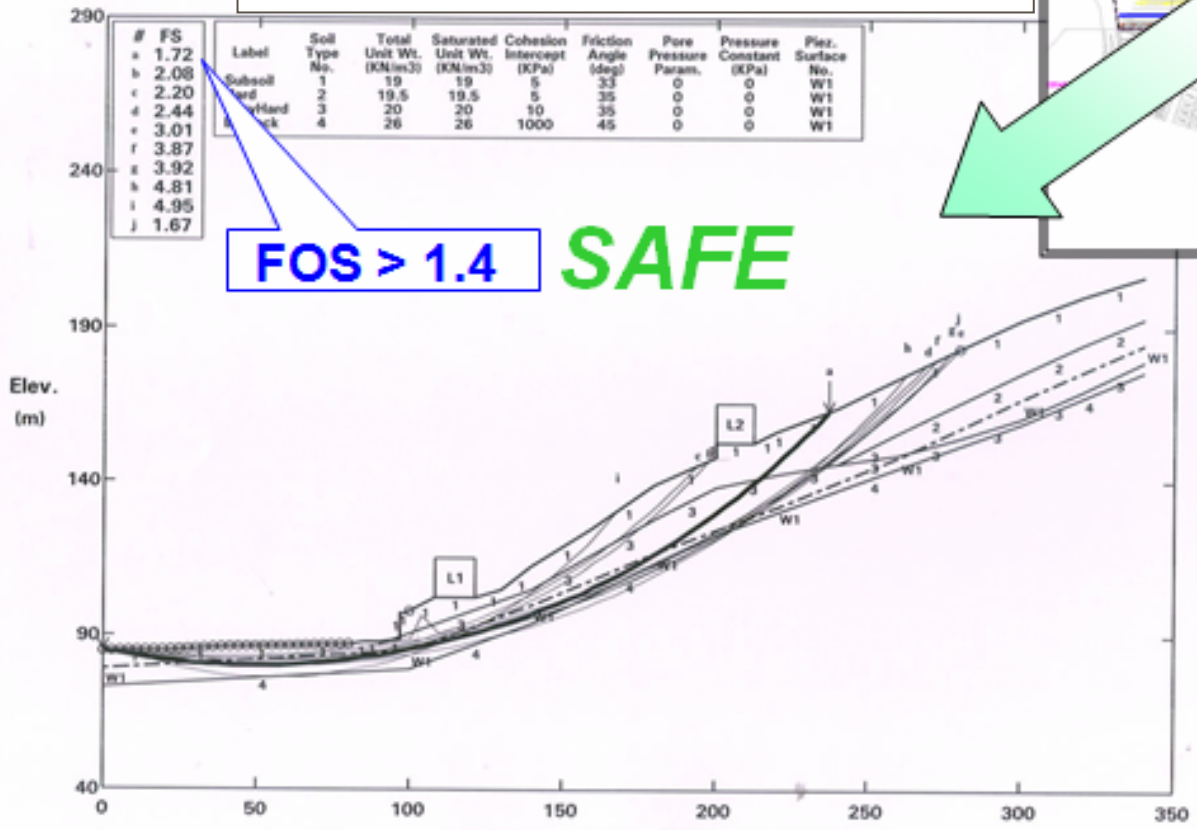
Sample of Slope Stability Analysis



#	FS
a	1.72
b	2.08
c	2.20
d	2.44
e	3.01
f	3.87
g	3.92
h	4.81
i	4.95
j	1.67

Label	Soil Type No.	Total Unit Wt. (KN/m3)	Saturated Unit Wt. (KN/m3)	Cohesion Intercept (KPa)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (KPa)	Piez. Surface No.
Subsoil	1	19	19	5	33	0	0	W1
[illegible]	2	19.5	19.5	5	35	0	0	W1
[illegible]Hard	3	20	20	10	35	0	0	W1
[illegible]	4	26	26	1000	45	0	0	W1

FOS > 1.4 ***SAFE***



STABL6H FSmin = 1.72 X-Axis (m)
Factors Of Safety Calculated By The Modified Bishop Method

Selection of Types of Field Tests & Sampling Methods.

+ Determining of Groundwater

Selection of Types of Field Tests & Sampling Methods

Commonly used Field Testing for Hill-Site development :

* **Boreholes**
  - Standard Penetration Test (SPT)
  - Collection of disturbed & undisturbed soil samples.
  - Collect rock Samples
  - Used in long term as Standpipe (Groundwater Monitoring)

(A) Light Dynamic Penetrometer

(JKR or Mackintosh Probes) - determine soft layer or shallow rock

Boreholes

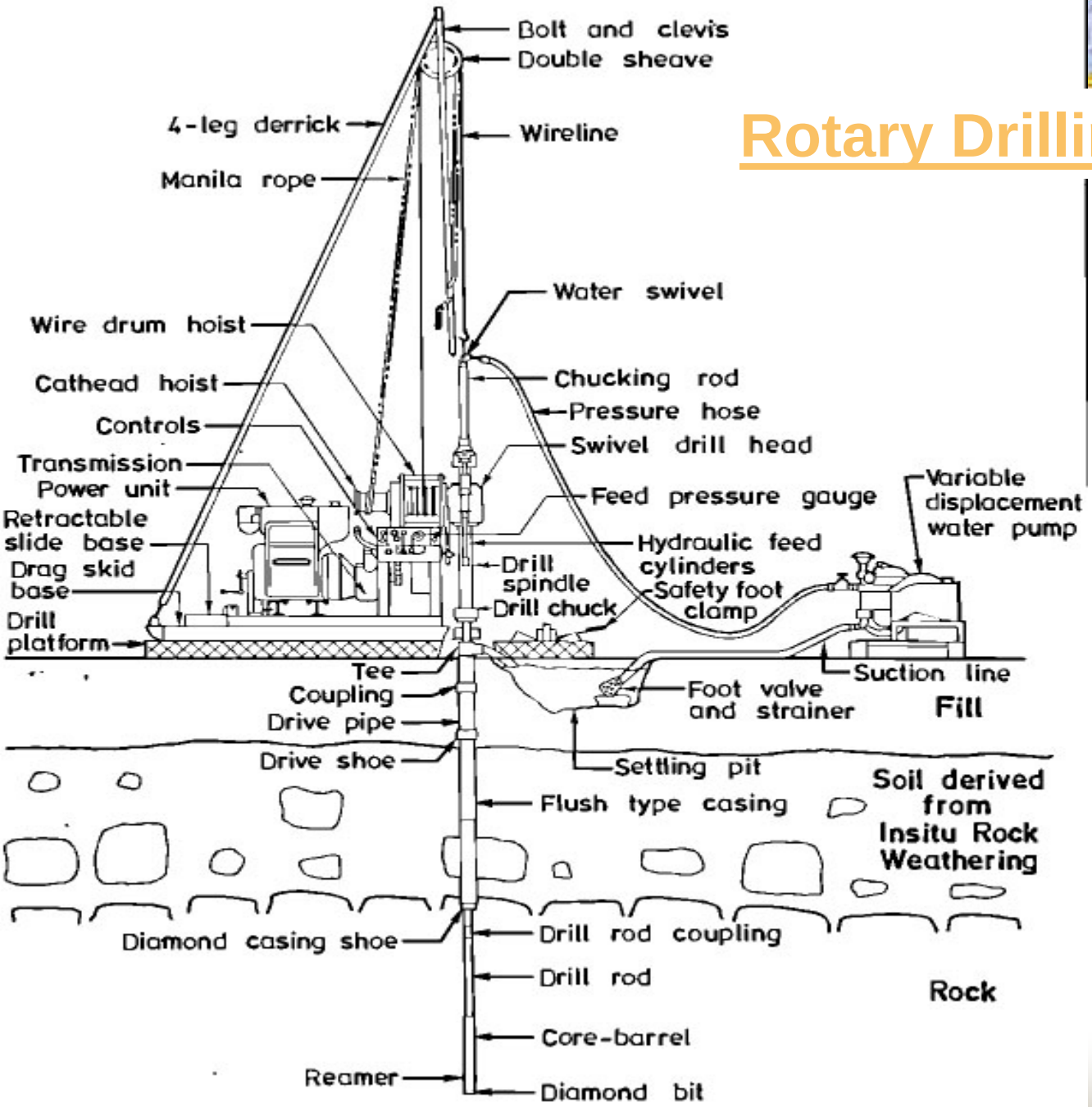
Described in BH5930:1981:

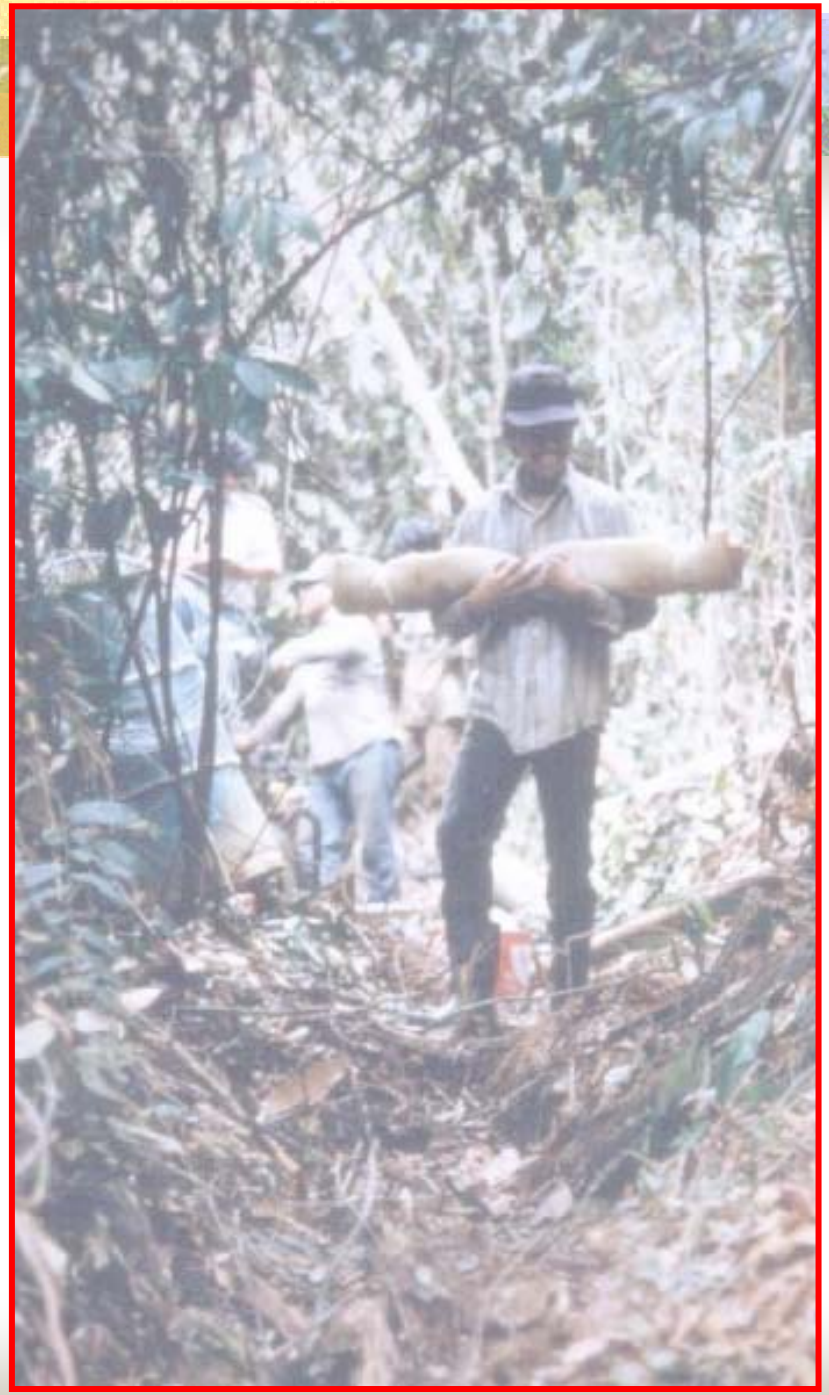
- Borehole includes : boring, sampling, in-situ testing and indicative water table observation.
- Depth usually < 100m
- Drill through all soils & core through rocks

Type of Drilling :

- Rotary drilling by circulating fluid (water or bentonite or air foam) is most common.
- Wash boring percussive action (chisel) – Lots of disturbances

Rotary Drilling Rig





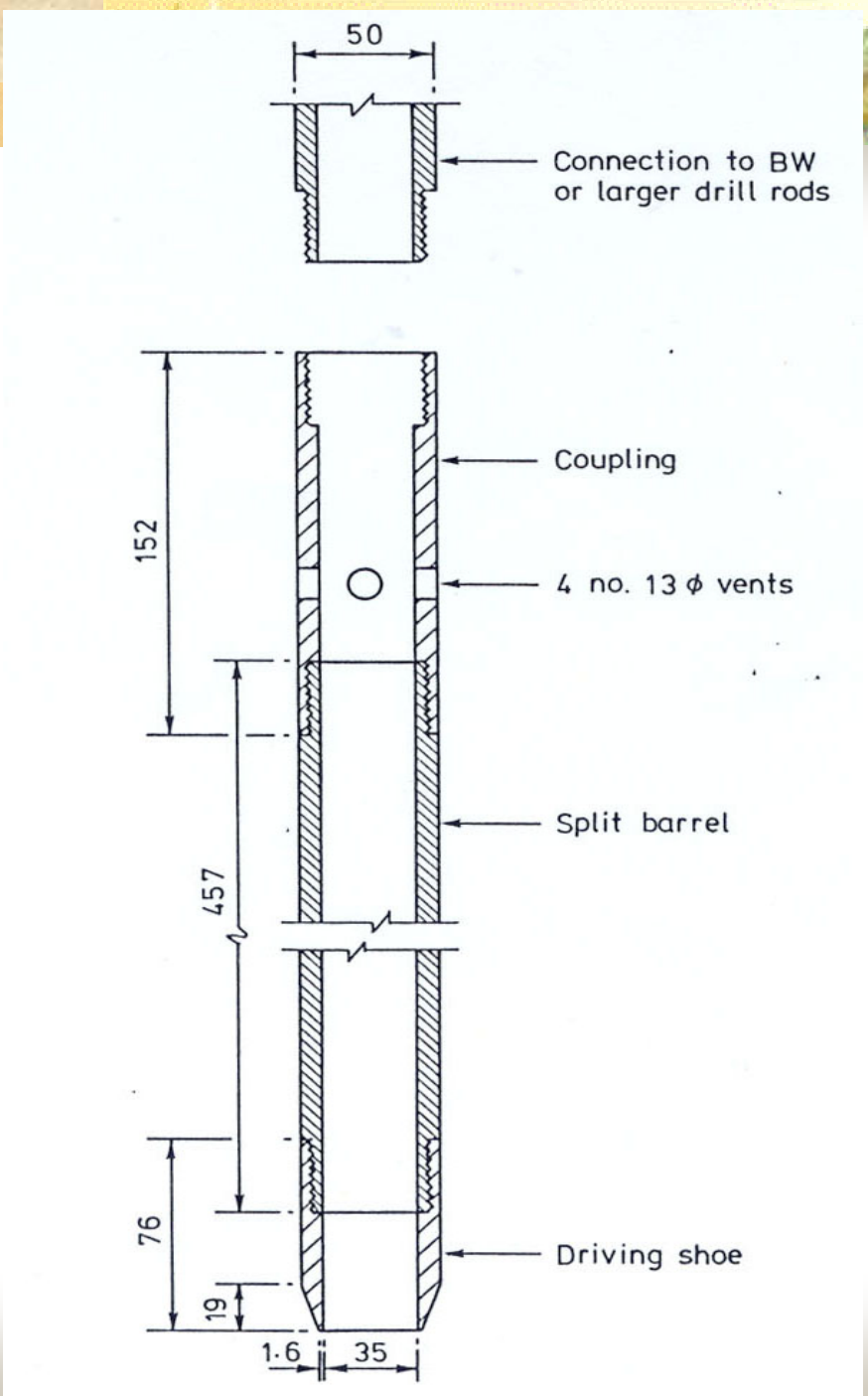
Standard Penetration Test

Standard Penetration Tests (SPT) →

BS 1377

- Obtained SPT'N' values (blowcounts per 300mm)
- Usually carried out at 1.5m depth interval.
- At greater depth can use larger interval.
- Obtained disturbed soil samples from split spoon sampler.

Split Spoon Sampler of SPT



Collection of Soil Samples from Borehole

Types of Soil Samples :

- **Wash Samples** :- from soil washed out from the borehole for soil strata description.

- **Disturbed Soil Samples** :- from split spoon samplers after SPT.

- **Undisturbed Soil Samples** :-

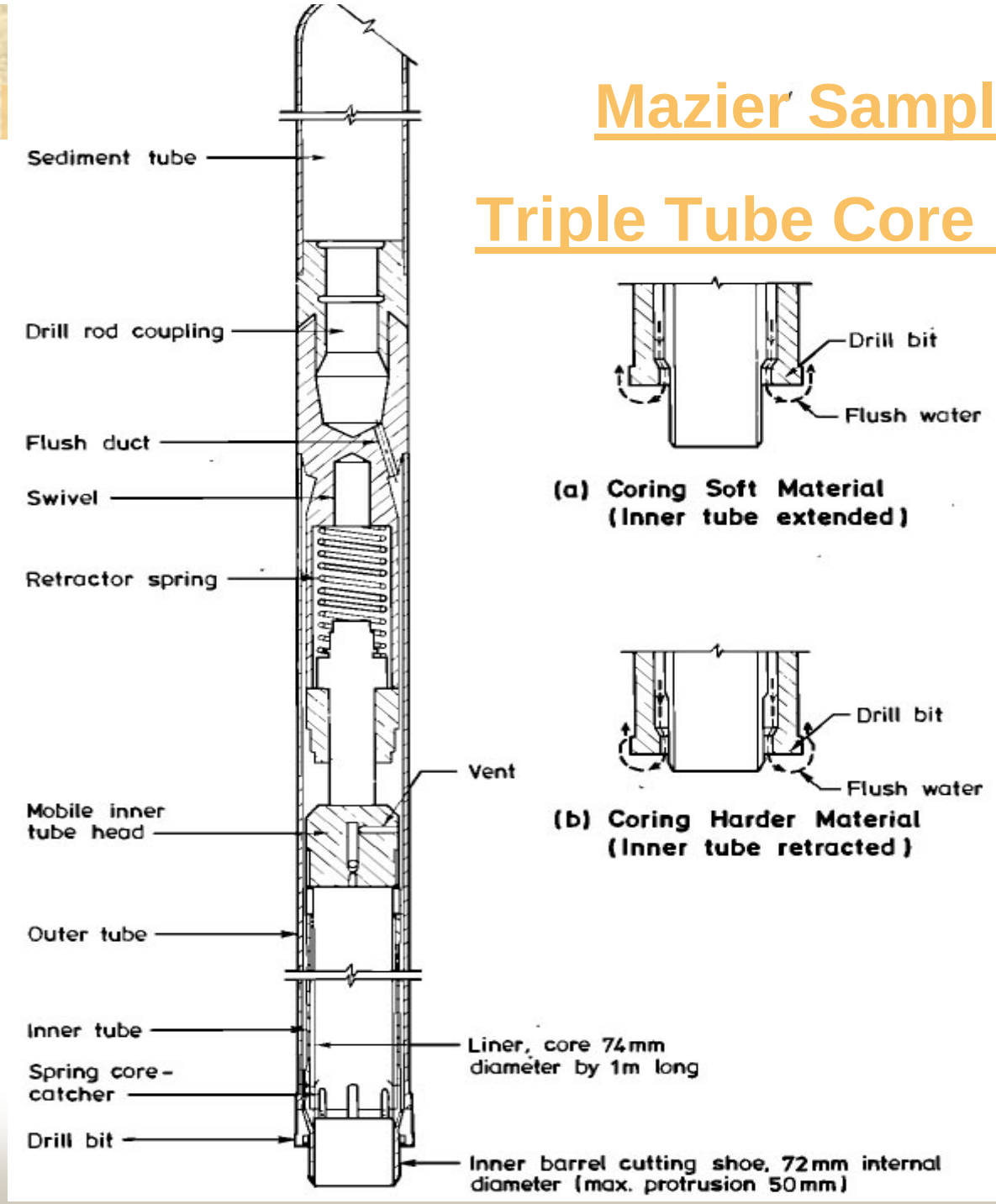
  (a) Piston Sampler (very soft clay)

  (b) Thin Wall Sampler (soft soils)

  (c) **Mazier Sampler** (Commonly used for SI in Hill-Site as can collect UD soil samples in residual soils or stiff soils)

Note : Require STABLE PLATFORM

Mazier Sampler / Triple Tube Core Barrels



(a) Coring Soft Material (Inner tube extended)

(b) Coring Harder Material (Inner tube retracted)

-Contain detachable liners within the inner barrel.

-Ideal for triaxial test as the diameter of core is 74mm.

-To sample undisturbed soil samples from Stiffer soil stratum.

Determination of Groundwater

Groundwater affect Effective Stress of the Soil

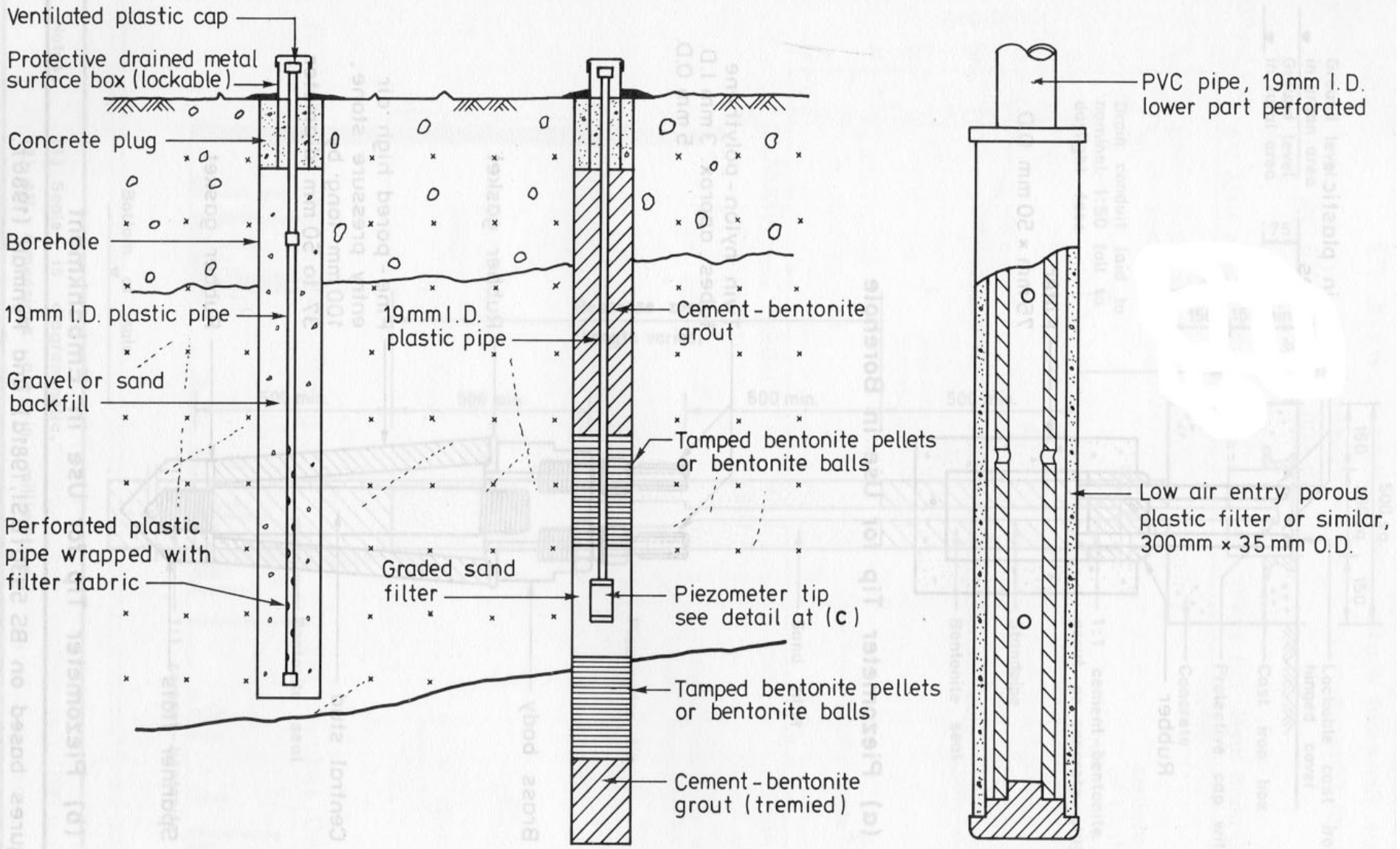
(a) Borehole (temporary & indicative)

- Daily observation of water level in the borehole. (indicative only).
- Prevent surface water flowing into the borehole.

(b) Standpipe or Piezometer (long term & representative)

- Porous elements must be fully saturated & filled with deaired water or glycerine fluid.
- For quick response

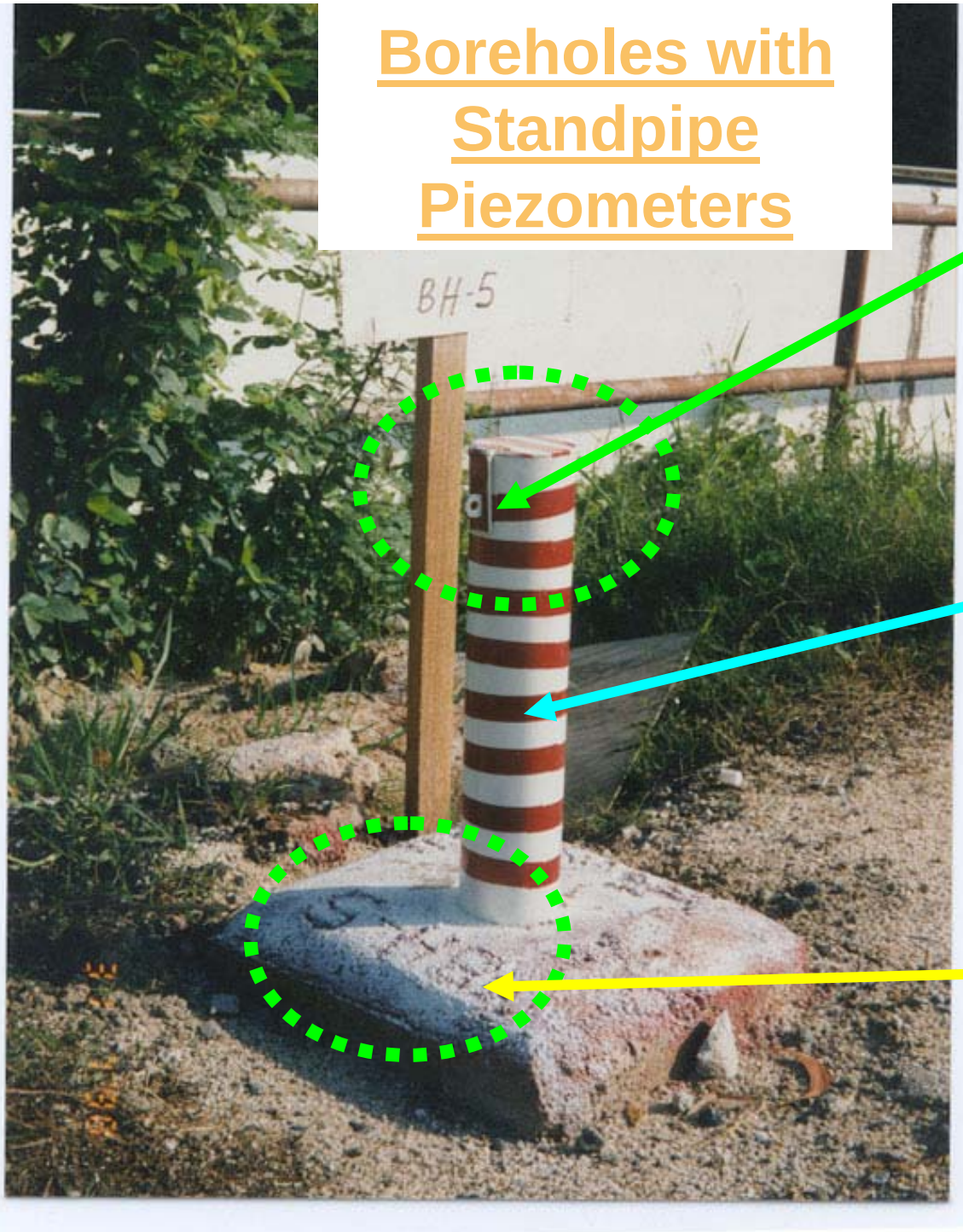
→ use Vibrating wire piezometer



(a) Standpipe (b) Open-hydraulic Piezometer (c) Casagrande-type Open-hydraulic Piezometer

Boreholes with Standpipe Piezometers

Lockable Cap to prevent vandalism



Bright Color

(Red + White) to prevent vehicle knocking into it.

Borehole Number Clearly Marked on Concrete

Interpretation of Laboratory Tests

TWO Major Categories :

(1) Strength Parameters :

- Stability Analyses of Slopes & Embankment.
- Bearing Capacity Analyses for Foundation.

(2) Stiffness & Deformation Parameters :

Prediction & evaluation of :-

Settlement, Heave, Lateral deformation,

Volume Change.

Strength Parameters

TWO Conditions :

(A) Total Stress :

- For Short Term Conditions in Cohesive Soils.
- Little of no drainage.

(B) Effective Stress :

(Commonly used for Cut Slopes Analysis)

- For Long Term & Permanent Conditions.
- Fully “Drained” Conditions.

Effective Stress Strength

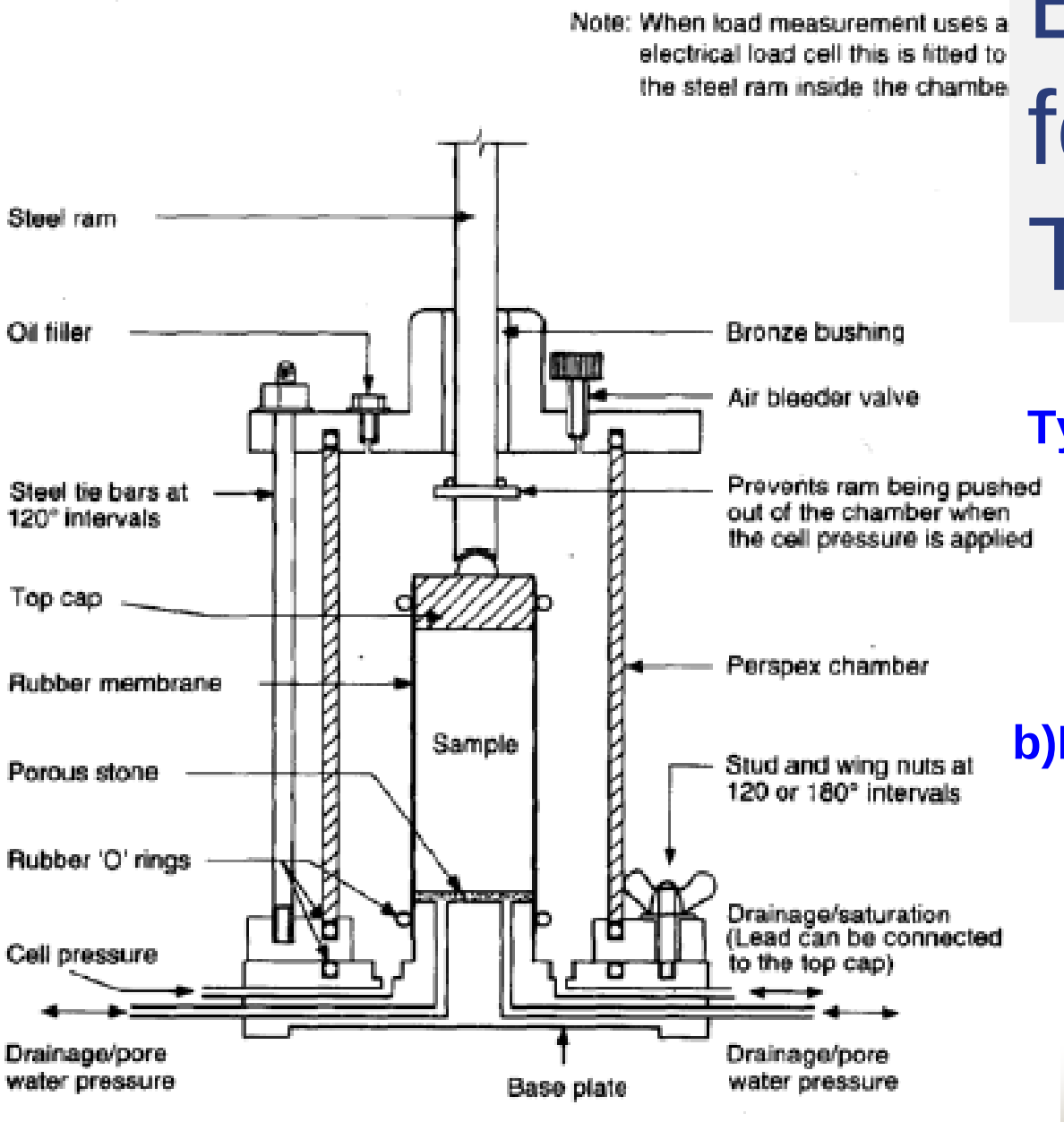
Parameters c' & ϕ' → Interpretation from

(i) Isotropic Consolidated Undrained Triaxial Test, CIU + ΔU

(ii) Isotropic Consolidated Drained Triaxial Test, CID

(iii) Laboratory Shear Box Test (at very. slow rate)

Equipment for Triaxial Test



Typical Set-up of Triaxial Test

a)Base

b)Removable cylinder and top cap

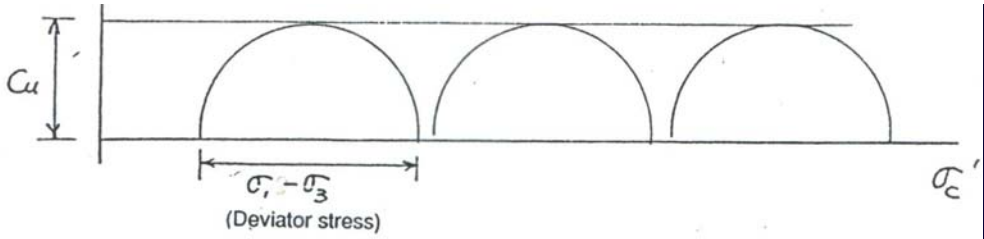
c)Loading ram

d)Rubber membrane

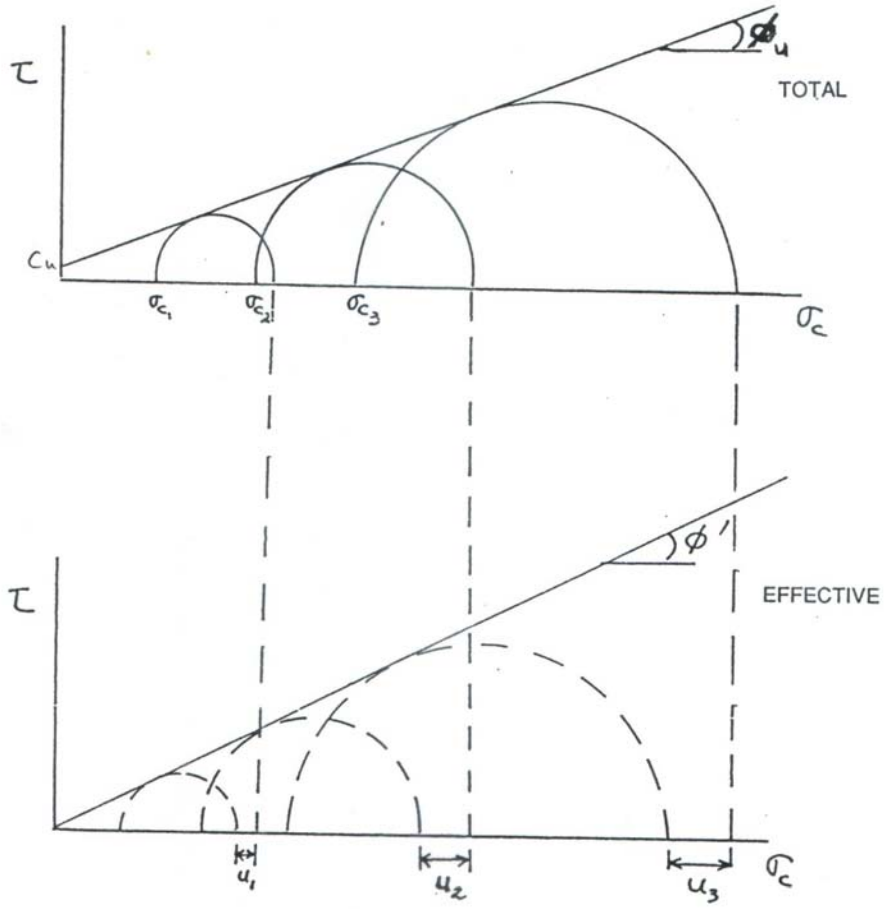
Mohr Columb

To get

c’ & ϕ’



UNCONSOLIDATED UNDRAINED TEST



CONSOLIDATED UNDRAINED TEST

Stress Path Interpretation

Two types of Plot

(i) MIT Stress Path Plot (T.W. Lambe of MIT, 1967)

The vertical axis :

$t = (\sigma_1 - \sigma_3)/2 \quad = (\sigma'_1 - \sigma'_3)/2$

The horizontal axis :

$s = (\sigma_1 + \sigma_3)/2 \qquad \&$ $s' = (\sigma'_1 + \sigma'_3)/2$

(ii) Cambridge Stress Path Plot

(Roscoe, Schofield and Wroth (1958) at the Cambridge, England)

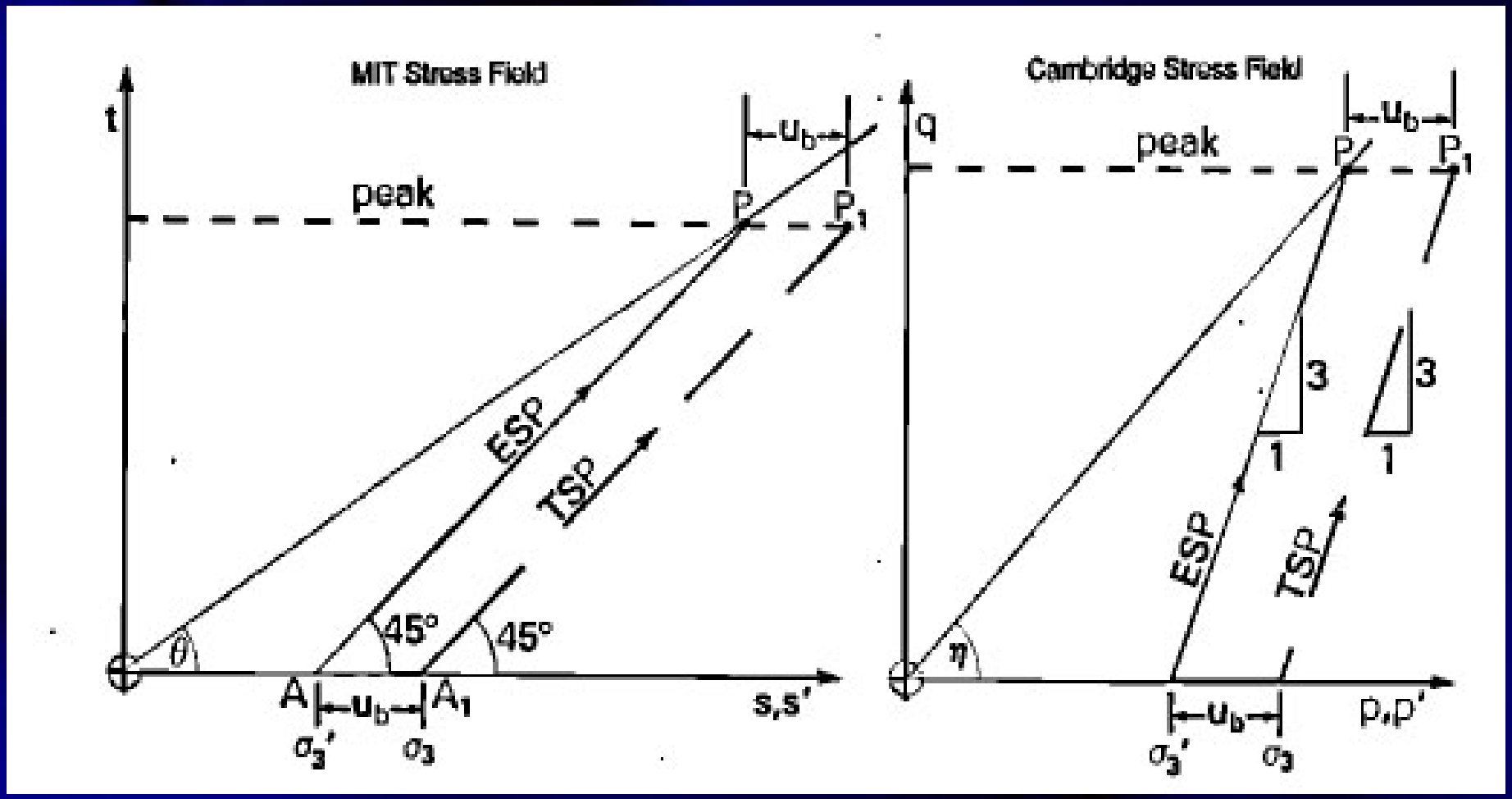
The vertical axis :

$q = \sigma_1 - \sigma_3 \qquad = \sigma'_1 - \sigma'_3$

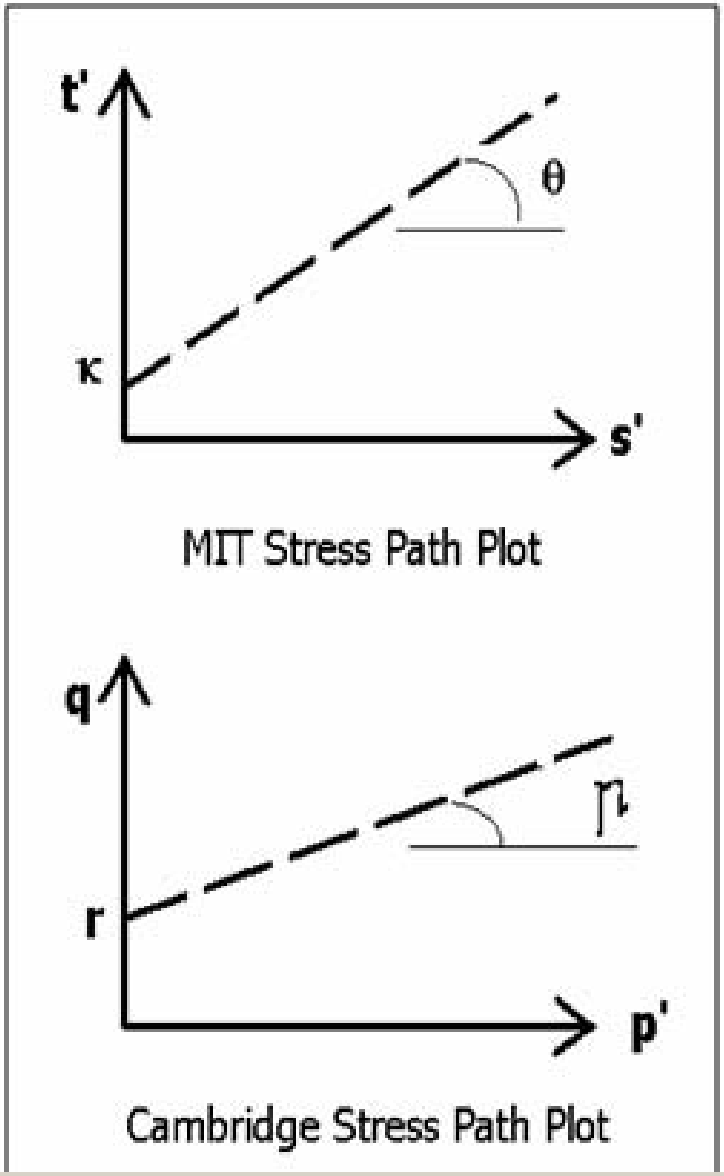
The horizontal axis :

$p = (\sigma_1 + \sigma_2 + \sigma_3)/3 \qquad \&$ $p' = (\sigma'_1 + \sigma'_2 + \sigma'_3)/3$

MIT & Cambridge Stress Path Plot



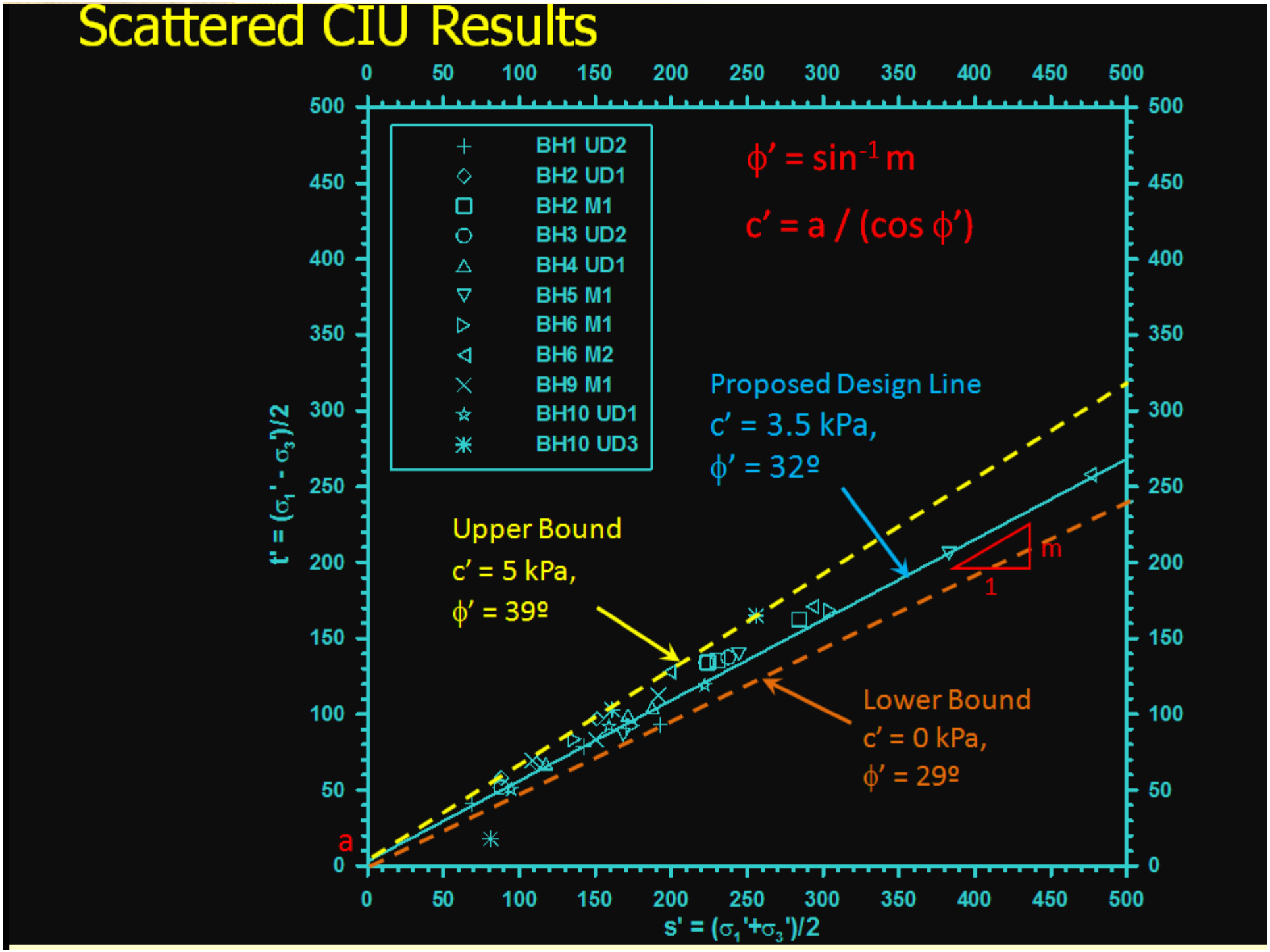
MIT & Cambridge Stress Path Plot

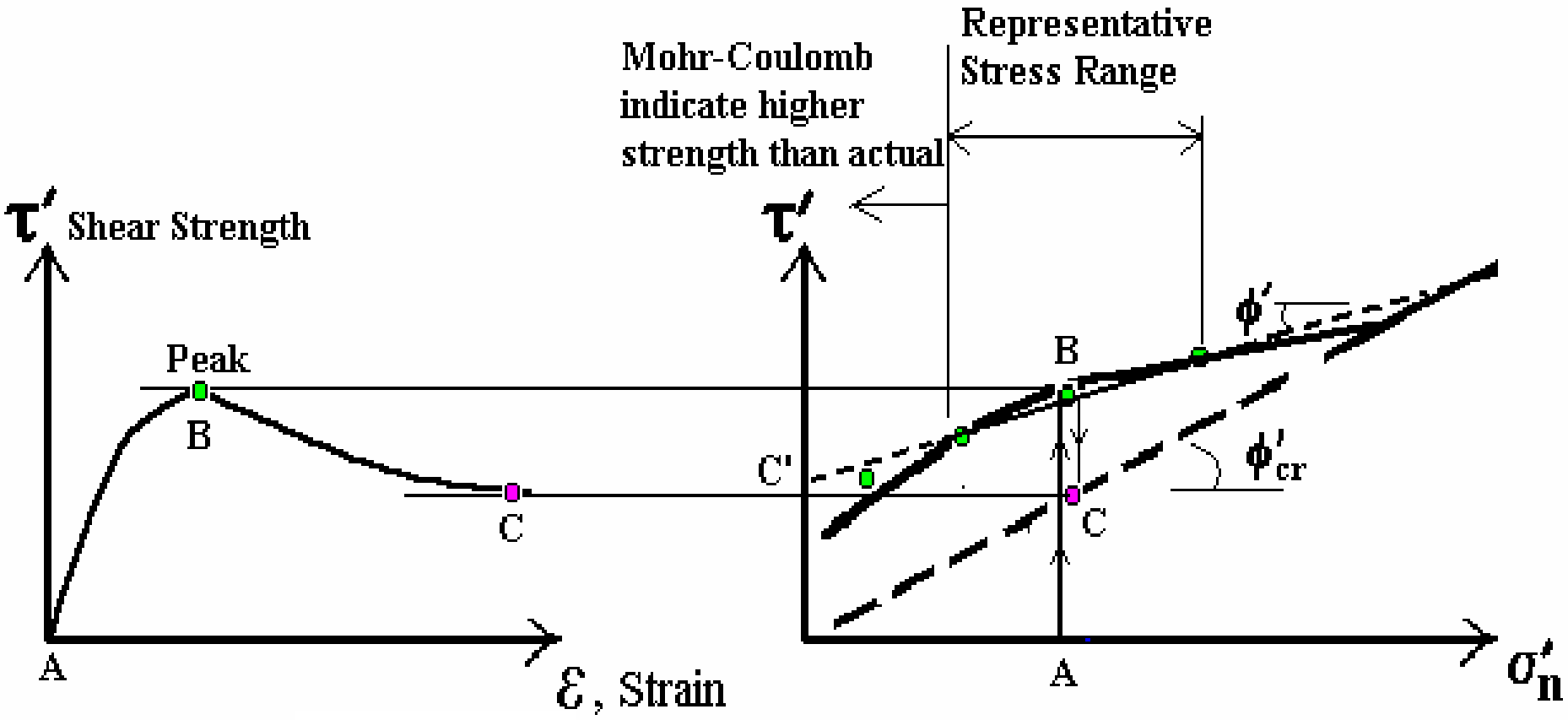


$$\text{Tan}\,\theta = t' / s$$
$$\text{Tan}\,\theta = \text{Sin}\,\phi'$$
$$K = c' \,\text{Cos}\,\phi'$$
$$C' = \frac{K}{\text{Cos}\,\phi'}$$

$$\text{Tan}\,\eta = q / p'$$
$$\text{Sin}\,\phi' = (3\,\eta) / (6 + \eta)$$
$$r = c' (6\,\text{Cos}\,\phi') / (3 - \text{Sin}\,\phi')$$
$$C' = \frac{r\,(3 - \text{Sin}\,\phi')}{6\,\text{Cos}\,\phi'}$$

Scattered CIU Results

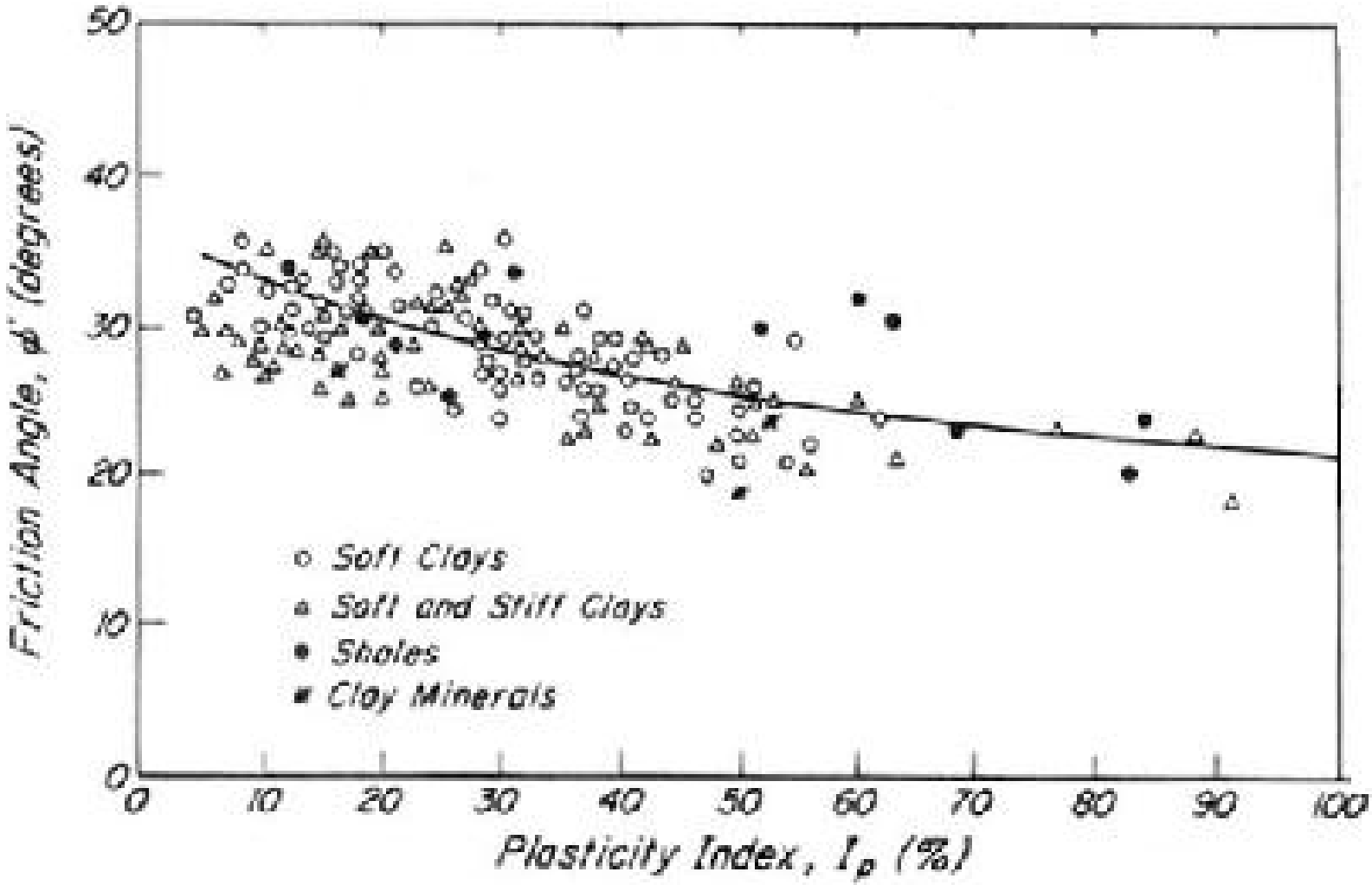




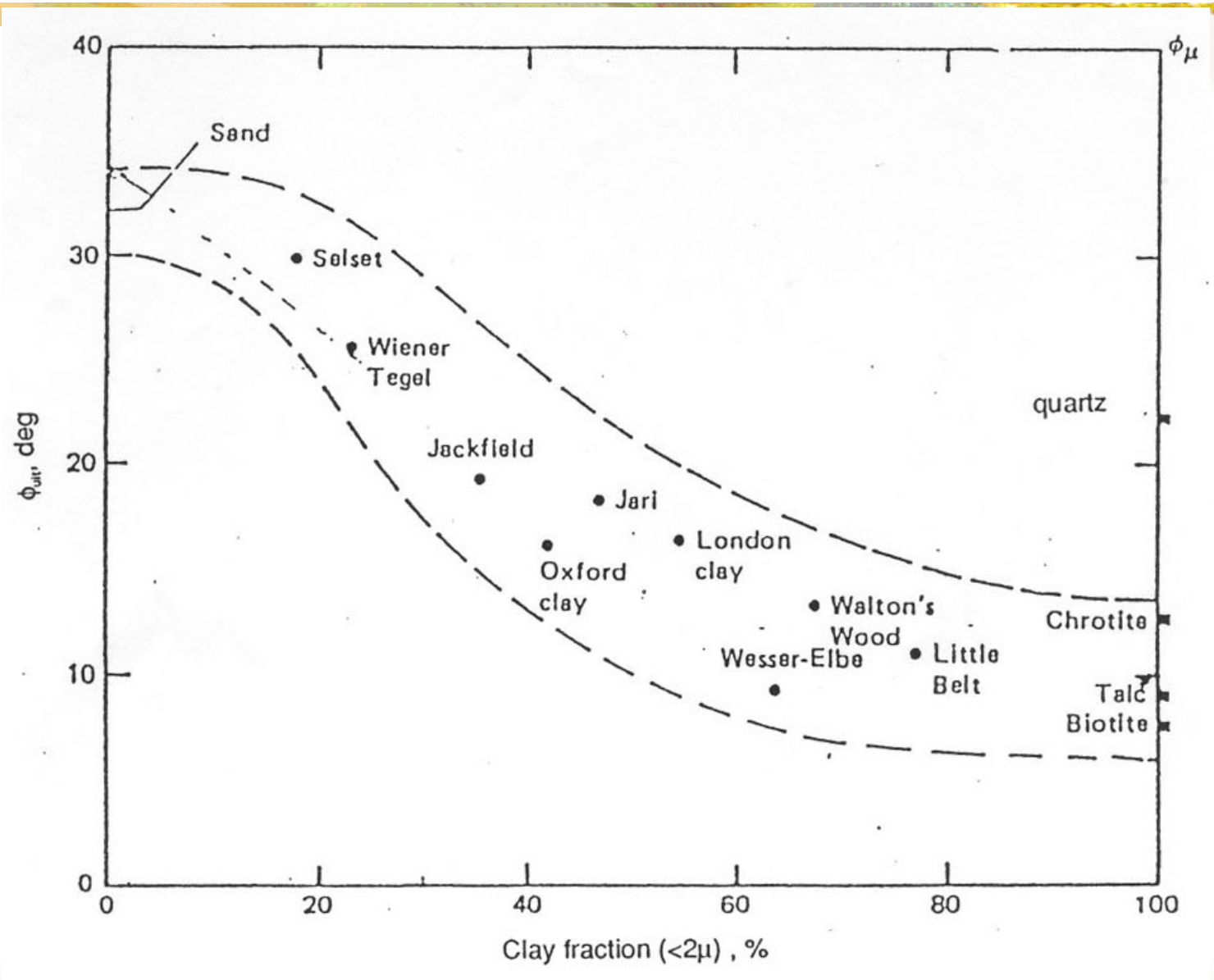
Stress path from Point A (consolidation pressure) to Point B (Peak Strength) to Point C (Critical State).

Correlations for Preliminary Assessment of ϕ'

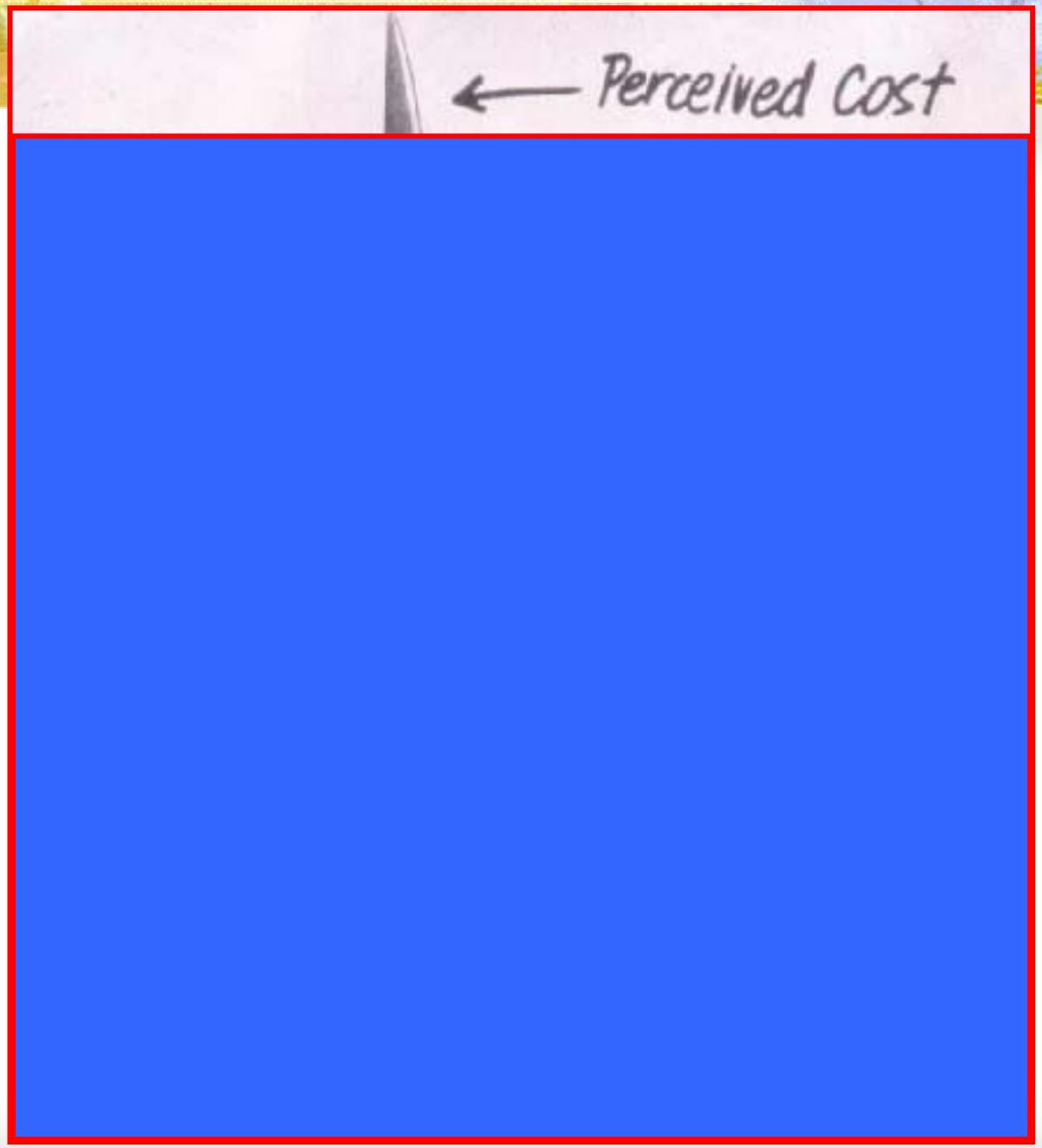
Φ' Values vs Plasticity Index (after Terzaghi)

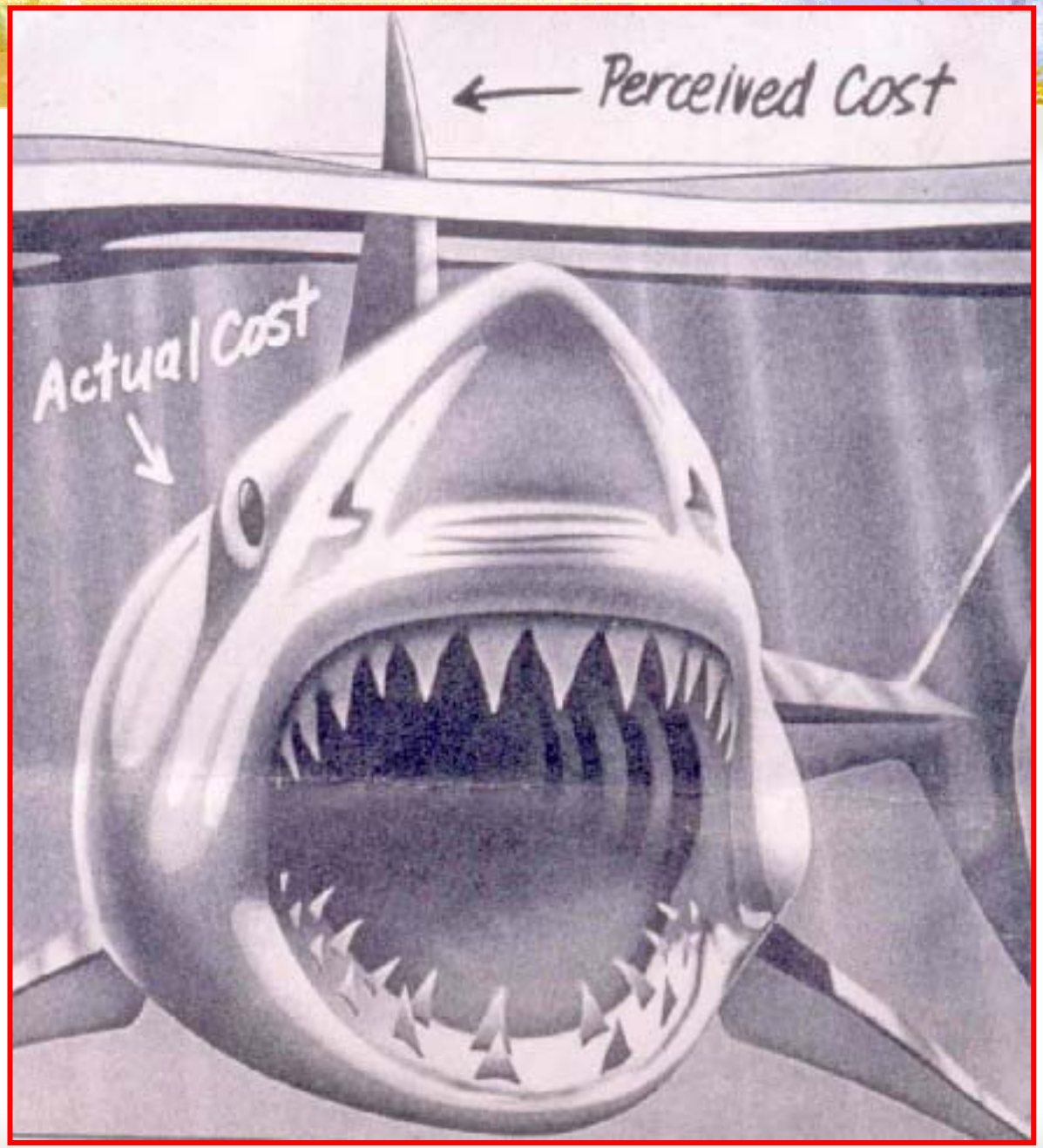


Φ' Values vs Clay Content (Skempton, 1964)



When the lecture reach here →


Perceived Cost


Perceived Cost
Actual Cost

THANK YOU

Ir. Tan Yean Chin
G&P Geotechnics Sdn Bhd