


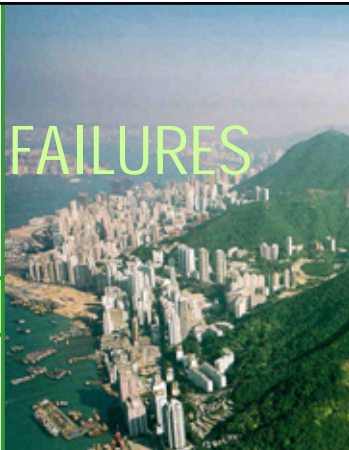
CPD Course on  
Some Old Geotechnical  
Failure Incidents in Hong Kong



**SLOPE FAILURES**

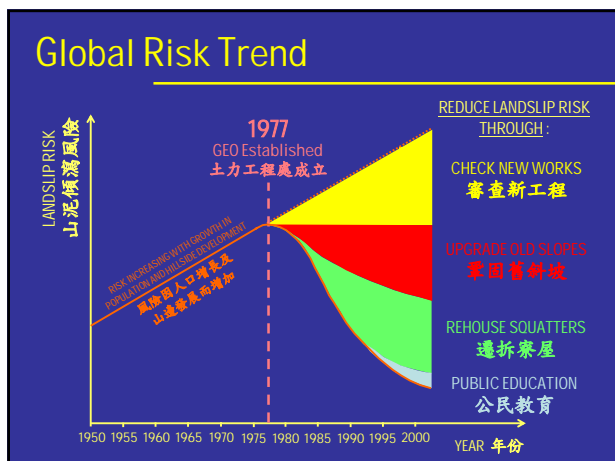
Ir Ken Ho  
Chief Geotechnical Engineer  
Geotechnical Engineering Office  
Civil Engineering and Development Dept

10 MARCH 2007



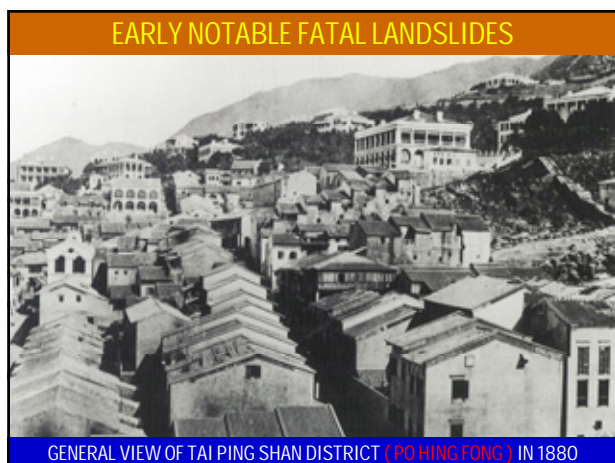
## Objectives

- To remind practitioners of :
  - observations from selected notable landslides up to about the **mid-1990s**
  - impact of landslides on the evolution of the **Slope safety system** in Hong Kong

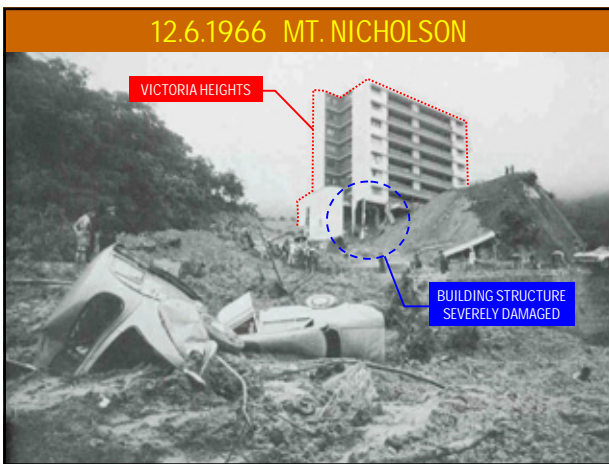
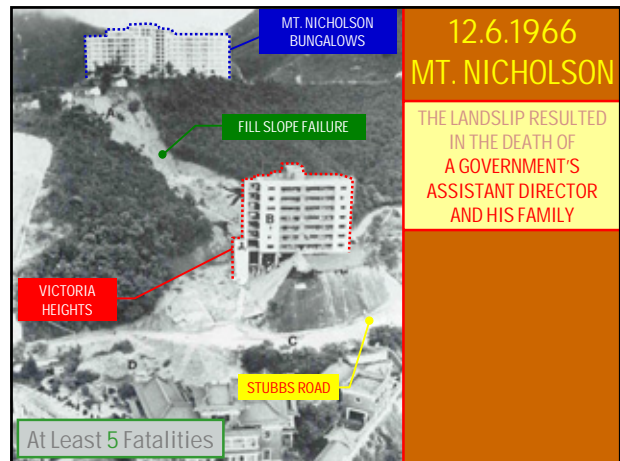
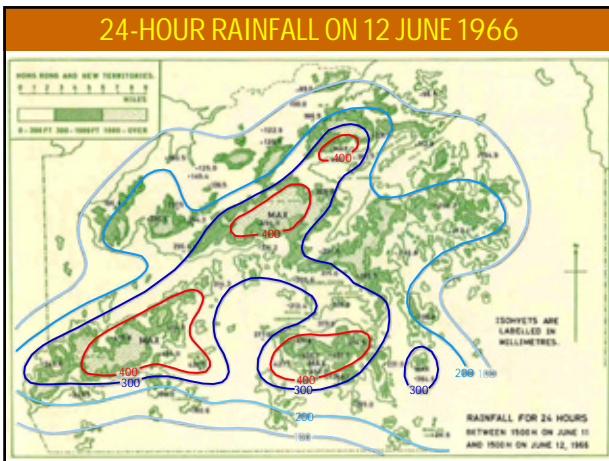


## Slope Safety System

- **SEVEN** Key Results Areas ( KRAs ) :
  1. Improve slope safety standards, technology, and administrative and regulatory frameworks
  2. Ensure safety standards of new slopes
  3. Rectify substandard Government slopes
  4. Maintain all Government man-made slopes
  5. Ensure that owners take responsibility for slope safety
  6. Promote public awareness and response in slope safety through public education, publicity, information services and public warnings
  7. Enhance the appearance and aesthetics of engineered slopes







**12.6.1966 MT. NICHOLSON**

**Body Of Man Recovered**

The body of a man, believed to be that of Mr C. K. Law, missing Assistant Director of Education who was reported trapped in his car near the garage of his Stubbs Road home on Sunday, was dug out from the debris last night.

Official confirmation was not available last night pending identification by the victim's family at the public mortuary.

Clearing operations continued throughout the night, while digging for two others also missing, believed to be Mr Law's sons, aged 11 and 13, will resume today.

The family was reported to have been leaving for bowling games when the tragedy occurred.

The landslide, which struck shortly after noon on Sunday, swept the lower part of the seven-storey Victoria Heights over the road and into the compound of a building below.

- ▣ The landslide occurred at about 11:15 a.m. on Sunday
- ▣ Part of the garage of Victoria Heights collapsed
- ▣ The Assistant Director of Education and his family, together with some 15 cars, were buried under "tons of earth"

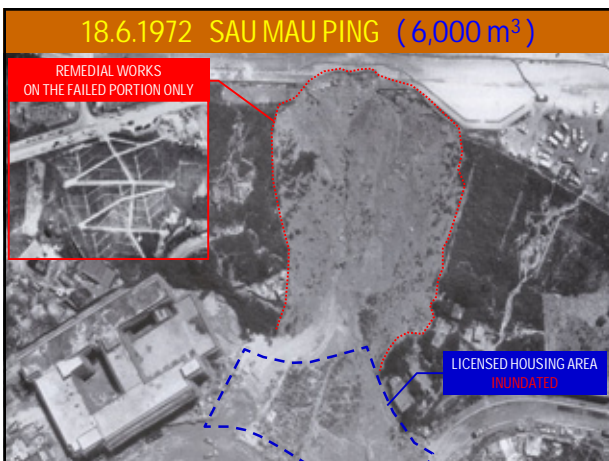
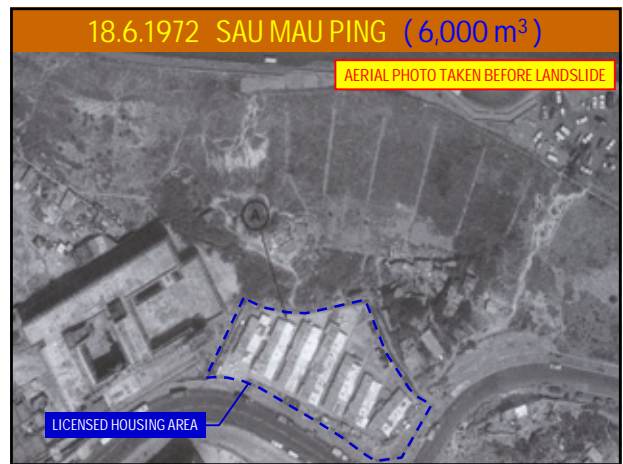
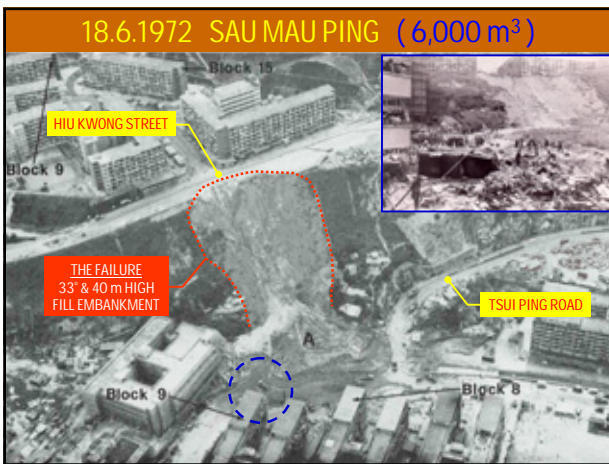
**THE DAMAGING POWER OF JUNE 1966 RAINSTORM**

- ▣ Return period about 1 in 500 years
- ▣ Extensive Flooding + Some 500 Landslides
- ▣ Many roads were blocked or damaged
  - ▣ Disrupted communications and isolated a number of areas, including the Peak District
- ▣ Resulted in 64 fatalities and 29 injuries

**FOLLOW-UP INSTITUTIONAL CHANGES**

- ▣ Public Works Department (PWD) was charged with the responsibility to act on complaints concerning possible dangers in the squatter areas
- ▣ Established the Landslip and Rainstorm Damage Committee
  - ▣ To make decisions on landslip cases that might constitute damage to life or properties re. liability for carrying out remedial works
- ▣ But, NO significant improvement to both the design standards for earthworks and related building control procedures

# 1970s

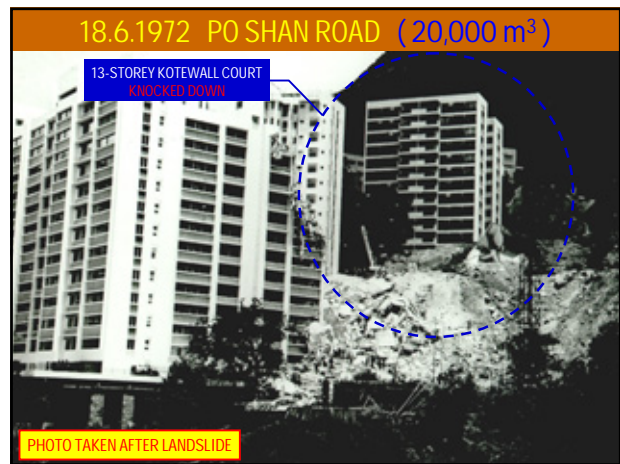
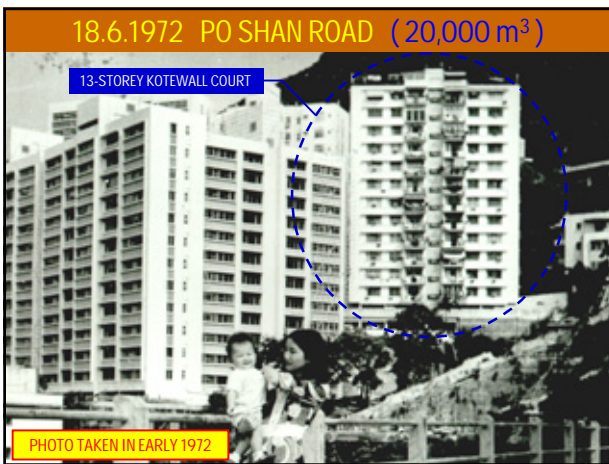
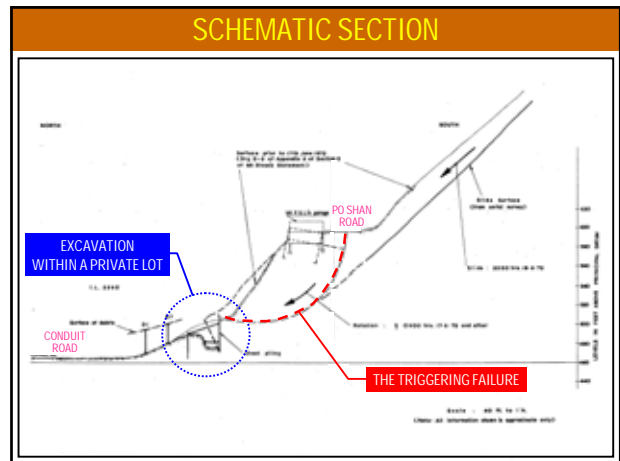


THE COMMISSION OF INQUIRY

RAINSTORM DISASTERS 1972

- ▣ The fill embankment was built in 1964
  - ▣ Decomposed granitic fill, from adjoining site formation works, to be compacted in 3 ft. layers (Specification not fully followed - Why?)
- ▣ The landslide was .....
  - “ due primarily to softening of fill material caused by infiltration of rain-water mainly through the sloping face, as a result of an exceptional long and intense rainstorm. ”

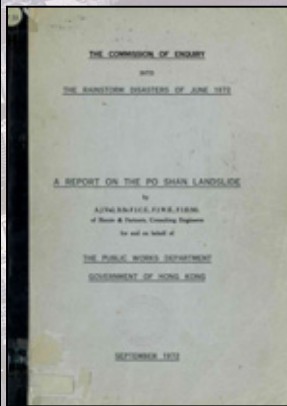
INTERIM REPORT OF THE COMMISSION OF INQUIRY



### THE COMMISSION OF INQUIRY

- Government appointed a Commission of Inquiry
  - Mr. Yang Ti-liang
  - Prof. Sean Mackey
  - Mr. Eric Cumine
- The Po Shan Landslip was initiated by the collapse of a steep and high cutting within a private development lot that had been left to stand for more than 8 years

### CONSULTANT'S TECHNICAL REPORT



- ▣ Binnie & Partners provided expert advice on the **technical aspects** of the Po Shan Road Landslide for the Commission of Inquiry

### FOLLOW-UP ACTIONS

- ▣ **Soil Engineering Division** set up in **Buildings Ordinance Office (BOO)** of PWD to assist in checking geotechnical aspects of private development submissions
- ▣ **Permissible angle rules** (i.e. 50° for cutting and 35° for filling) no longer acceptable by Government; major earthworks required justification by means of **soil mechanics analyses**
- ▣ In 1973, Government engaged consultants to commence **systematic slope stability studies** in selected areas in phases
- ▣ **A Guide to Site Investigation and Earthworks** published in 1973 in the form of a Circular Letter

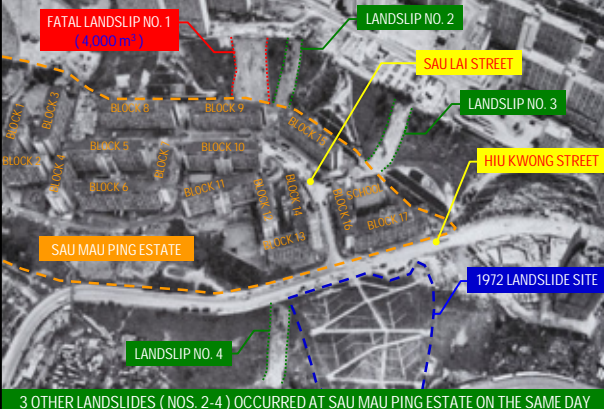
### 25.8.1976 SAU MAU PING (4,000 m<sup>3</sup>)



**FAILURE MECHANISM**  
LIQUEFACTION OF LOOSE FILL  
(SUDDEN & MOBILE)

**18 Fatalities & 24 Injuries**

### 25.8.1976 SAU MAU PING (4,000 m<sup>3</sup>)



**FATAL LANDSLIP NO. 1** (BLOCK 9)

**LANDSLIP NO. 2**


**LANDSLIP NO. 3**

**LANDSLIP NO. 4**

**1972 LANDSLIDE SITE**

**3 OTHER LANDSLIDES (NOS. 2-4) OCCURRED AT SAU MAU PING ESTATE ON THE SAME DAY**

### 25.8.1976 SAU MAU PING (4,000 m<sup>3</sup>)



**BLOCK 15**

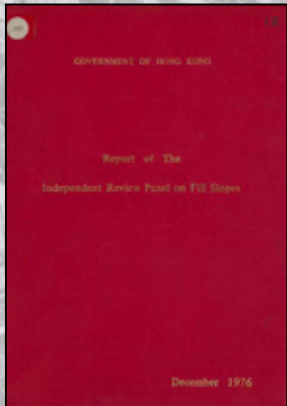
**BLOCK 9**

### 25.8.1976 SAU MAU PING (4,000 m<sup>3</sup>)



### INDEPENDENT REVIEW PANEL ON FILL SLOPES

- ▣ 4 landslides at Sau Mau Pau Resettlement Estate on 33° fill embankments formed by Government in the 1960s
- ▣ Government engaged an **Independent Review Panel** comprising 6 international geotechnical experts
- ▣ **Conclusion** : Mobile failure was due to **liquefaction of the loose fill with inadequate compaction (end-tipping)**



### INDEPENDENT REVIEW PANEL ON FILL SLOPES

- ▣ The method of construction (**End-tipping**) for fill slopes was commonly adopted and widely accepted throughout the early 1960s
- ▣ **Independent Review Panel recommended** :
  - ▣ establishment of a **geotechnical control organization** within the Government
  - ▣ recompaction of the **top 3 m of loose fill slopes** as a prescriptive treatment to retrofit the substandard works
  - ▣ .....
- ▣ The then Governor accepted the recommendations. The **Geotechnical Control Office** was set up in Engineering Development Department (EDD) and the **Geotechnical Control Branch** established in B00 in July 1977

### EVOLUTION OF SLOPE SAFETY SYSTEM

**JULY 1977**

- ▣ The Geotechnical Control Organization was established ( 524 posts created ), consisting of two bodies :
  - ▣ **Geotechnical Control Office** ( within EDD )
  - ▣ **Geotechnical Control Branch** ( within B00 )

**LATE 1977**

- ▣ Commenced staged studies for both private and public existing slopes (**LPM Programme**)
- ▣ Launched a **Landslip Warning System**, primarily for squatters

### EVOLUTION OF SLOPE SAFETY SYSTEM

**1977 - EARLY 1980's**

- ▣ Geotechnical checking of both **private and government earthworks** was mostly carried out by consultants until there was sufficient in-house staff strength

**1977 - 1979**

- ▣ **Administrative Instruction** issued to allocate the responsibility for **routine maintenance** of Government slopes to user departments

**1977 - 1978**

- ▣ Compiled the **Catalogue of Slopes** ( about 10,000 sizeable man-made slopes in the urban areas ), and a **risk-based priority ranking system** for LPM action

### EVOLUTION OF SLOPE SAFETY SYSTEM



**1976 - 1983**

- ▣ Consultants engaged to carry out **systematic studies and slope upgrading works** ( Initially on fill slopes, later expanded to cover cut slopes also )

**November 1979**

- ▣ **Geotechnical Manual for Slopes ( First Edition )** published

### EVOLUTION OF SLOPE SAFETY SYSTEM

**1980**

- ▣ **Buildings Ordinance** amended to include specific geotechnical provisions to tighten up private geotechnical control

**May 1979 - 1982**

- ▣ **Temporary ban** imposed on developments in **Mid-Levels Area and Mid-Levels Study**, including investigation of past landslides, undertaken by consultants



# 1980s



### THE JUNE 1981 BOULDER FALL AT KING'S ROAD

- **TWO** boulders fell from natural terrain above cut face
  - One (260 kg) of the boulders fell down first and landed at about 3 m from the slope toe, which killed a pedestrian
  - Another boulder (530 kg) followed and struck a tubular steel railing along the pedestrian footpath and shattered into pieces
- **Findings of the Investigation :**  
 A week of heavy rainfall preceding the incident might have softened the soil supporting the 260 kg boulder that was eventually dislodged
  - The dislodgement of the smaller boulder removed the support to a larger boulder (530 kg) behind, causing it to roll down the slope
- Resulted in 1 fatality and 2 injuries.

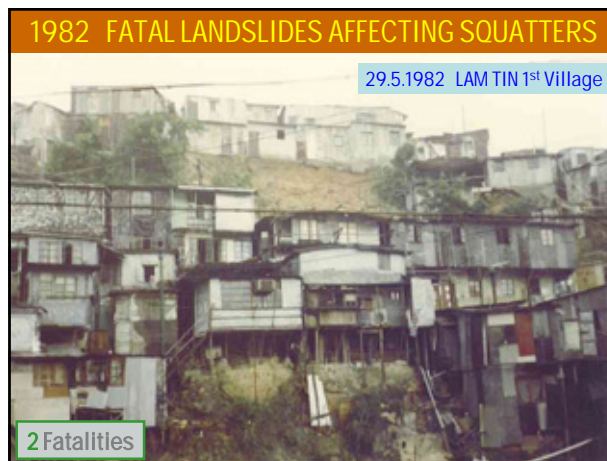
### GOVERNMENT'S BOULDER POLICY

- The Government's Boulder Policy was endorsed by the then Secretary of Works in 1988
  - **Boulders Affecting Existing Developments**
    - Undertake preventive actions to tackle immediate and obvious danger
    - Evaluate boulder stability only where there have been persistent boulder falls or the situation is liable to become dangerous and undertake preventive action when considered necessary
  - **Boulders Affecting Proposed Developments**
    - Undertake preventive actions to tackle immediate and obvious danger
    - Evaluate boulder stability only where there is a significant perceived risk and undertake preventive action when considered PRUDENT
- Carried out a review of the stability of selected boulder fields (e.g. Mid-Levels Area)

### BOULDER FIELD PREVENTIVE WORKS

- Constructed a boulder fence and carried out in-situ stabilization of boulders in the Mid-Levels Area in the mid-1980s (Mid-Levels Boulder Field Preventive Works Pilot Scheme)

BOULDER FENCE






**NATURAL TERRAIN LANDSLIDES IN 1982**

- ▣ There were > 1,400 natural terrain landslides recorded in the **Natural Terrain Landslide Inventory (NTLI)** as a result of the two severe rainstorms in May & August 1982
- ▣ Consequences
  - ▣ Caused **9** fatalities and many injuries
  - ▣ Permanent evacuation of squatter huts
  - ▣ Blocked many roads
  - ▣ .....

**LANDSLIDE RISK TO SQUATTERS**

- ▣ More than **700** landslides were reported to have occurred in squatter areas in May & August 1982, resulting in **23** squatter fatalities in total - prompted the **review of squatter policy**
- ▣ Housing Department (HD) conducted **Squatter Structure Survey** in 1982
- ▣ In 1984, the Government initiated a systematic programme to reduce the vulnerability of squatters to landslide hazards:
  - ▣ **Non-development Clearance (NDC)** (based solely on **slope safety grounds**) programme by HD based on GCO's geotechnical advice (**Method Statement approach**, based largely on judgment)
  - ▣ Re-housing of eligible squatters

### TEN LANDSLIDE STUDIES IN 1982




- ▣ List of **Ten Major Landslides** studied in 1982 :
  - ▣ Chai Wan Road
  - ▣ Junk Bay Road
  - ▣ Chung Hom Kok Road
  - ▣ South Bay Close
  - ▣ Tuen Mun Highway
  - ▣ Dragon Beach
  - ▣ Lai Shum Villa
  - ▣ PEPCO Power Station, Tsing Yi
  - ▣ Tsing Yi Trunk Road
  - ▣ Ching Cheung Road

### TEN LANDSLIDE STUDIES IN 1982

- ▣ The project was initiated in **June 1982** and these studies were led by the Special Projects Division of the GCO
- ▣ **NO** post-failure subsurface investigation was carried out as part of these studies
- ▣ **Key Findings** :
  - ▣ Majority of the failures were attributed to **complex geological conditions** and / or **unanticipated groundwater conditions**
  - ▣ "Lack of (ground) investigation data cannot be compensated by a higher factor of safety, as the **major problem appears to be in investigation and interpretation** rather than in numerical analyses"
  - ▣ Key findings incorporated into subsequent revision of **Geotechnical Manual for Slopes** (2<sup>nd</sup> Edition issued in 1984)

### 30.7.1987 CHO YIU ESTATE (1,200 m<sup>3</sup>)



**THE FAILURE**  
15 m HIGH & 20 m WIDE

**SOIL & ROCK CUT**  
11NW-A/C140

LIM CHO STREET

### 30.7.1987 CHO YIU ESTATE (1,200 m<sup>3</sup>)



**BLOCK 4**

**PART OF THE SPREAD FOOTING WAS EXPOSED**

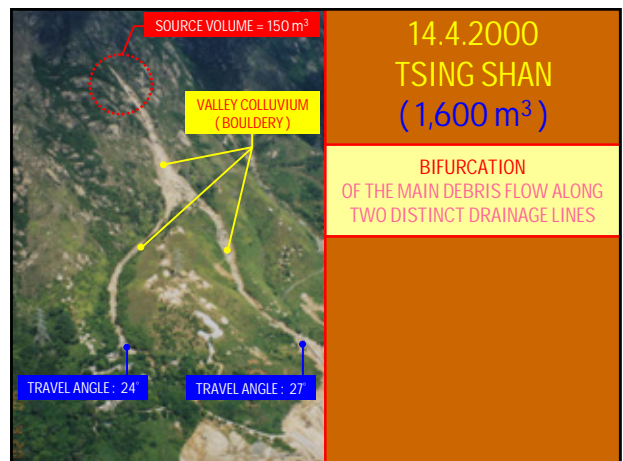
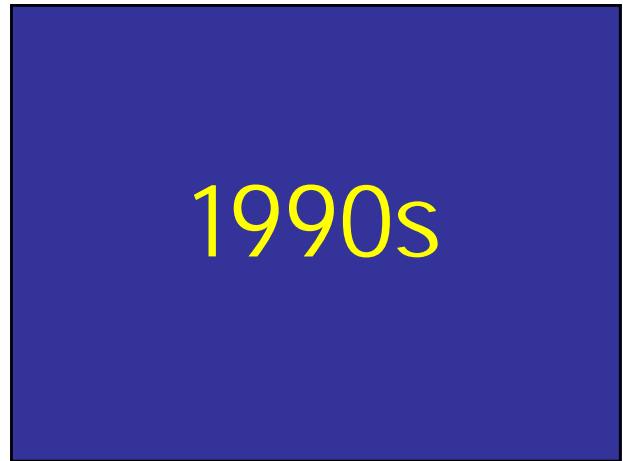
### 30.7.1987 CHO YIU ESTATE (1,200 m<sup>3</sup>)



**FAILURE SURFACE ALONG ADVERSELY ORIENTATED RELICT JOINTS WITH KAOLIN INFILL**

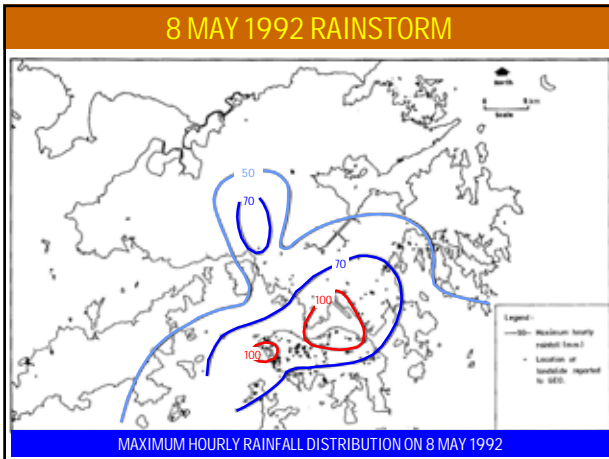
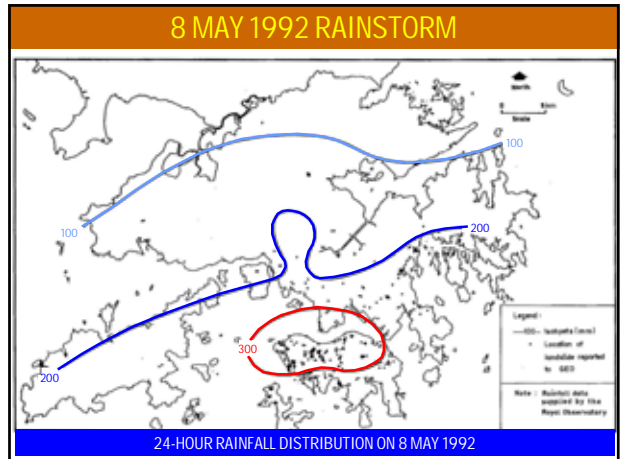
### LESSONS LEARNT

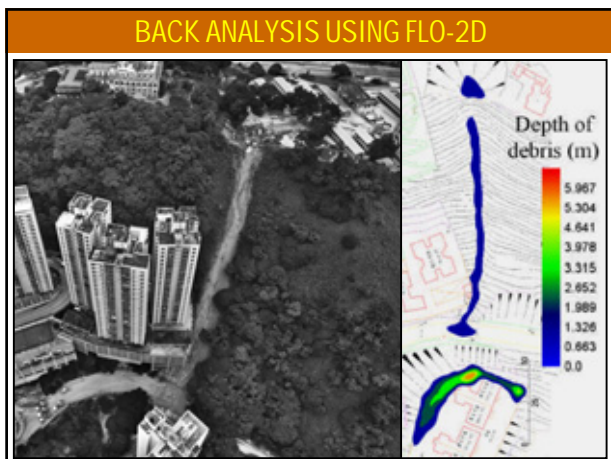
- ▣ Failure of an **ENGINEERED SLOPE**, principally caused by :
  - ▣ Adversely orientated relict joint with weak **kaolin-infill**
  - ▣ **Direct infiltration** during heavy rain
  - ▣ **Blockage** of drainage system
- ▣ Previous investigations / stability studies in late 1970s and 1980s were "carried out in accordance with the **requirements and conventional practices** of the time", but :
  - ▣ Inadequate allowance for the influence of **major relict joints**
  - ▣ "A detailed study, including the determination of the existence of weak relict joint planes, may have indicated a much lower value of factor of safety, and **the failure may have been predicted.**"



### LANDSLIDE RISK OF NATURAL HILLSIDES

- The 1990 Tsing Shan debris flow highlighted landslide hazards associated with **natural terrain**. It prompted the commencement of a R&D programme on **NATURAL TERRAIN LANDSLIDE HAZARDS**, with key components such as :
  - Compilation of **Natural Terrain Landslide Inventory (NTLI)** based on high-altitude aerial photos ( **Some 30,000 Landslides** ) ( **Enhanced NTLI** using low-altitude aerial photos to be completed in 2007 ( **About 105,000 Landslides** ) )
  - Guidelines on Natural Terrain Hazard Study
- Detailed study of 1990 Tsing Shan debris flow with a view to identifying **other similar vulnerable areas** in Hong Kong





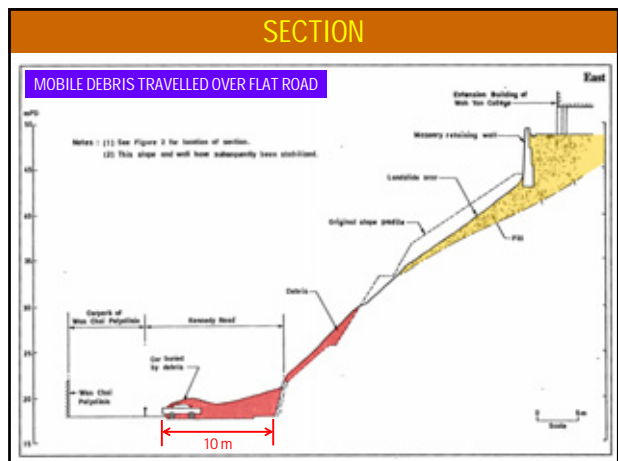
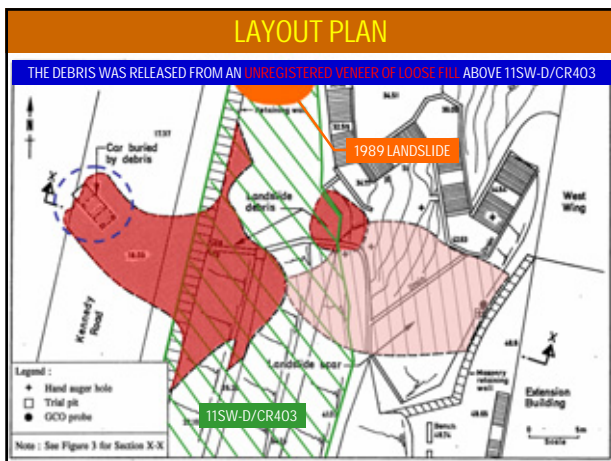
### MATTERS OF CONCERN ARISING

- ▣ The 1992 Baguio Villas landslide highlighted two matters of concern :
  - ▣ Some sizeable slopes were not registered in the 1977/78 Catalogue of Slopes  
Some uncatalogued slopes can pose a significant hazard to the community
  - ▣ Private Owners not aware of their Maintenance Responsibility  
Many private owners were genuinely unaware of their obligations to inspect and maintain slopes under their responsibility

### FOLLOW-UP ACTIONS

- ▣ Initiated the Systematic Inspection of Features in the Territory (SIFT) project, and later the Systematic Identification and Registration of Slopes in the Territory (SIRST) project
- ▣ Enhanced public awareness and public education programmes on the importance of slope maintenance and private owners' maintenance responsibility
- ▣ Injected all SIFT 'Class A' Features ( i.e. Baguio Villas Type fill features ) into the LPM Programme for detailed studies





### LESSONS LEARNT

- ▣ LPM Programme was largely focused on slopes affecting occupied buildings such as schools, hospitals, residential buildings, etc. since 1976
- ▣ The 1992 Kennedy Road fatal incident highlighted that the risk posed to busy roads could also be significant

### LESSONS LEARNT FROM 8 MAY 1992 RAINSTORM

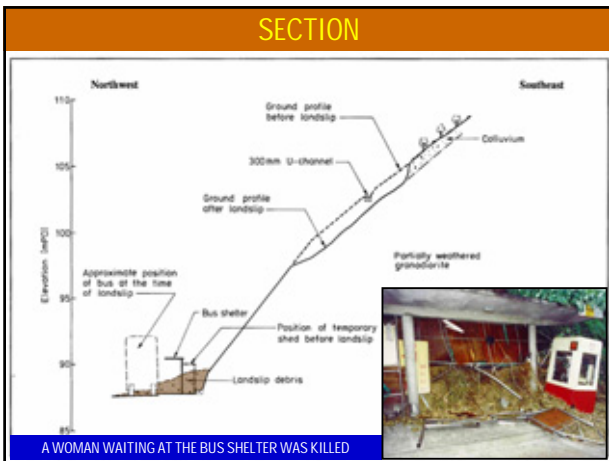
- ▣ Some 350 landslides were reported to GEO as a result of the severe rainstorm hitting the urban areas of HK, many resulted in blockage and closure of roads
- ▣ Lack of slope maintenance was considered to be one of the contributory factors to 42 of the reported landslides
- ▣ Highlighted the consequences associated with lack of maintenance
  - ▣ Efforts on slope maintenance stepped up by departments
  - ▣ Shotcreting of many roadside slopes as a quick measure of slope protection
  - ▣ However, extensive shotcreting provoked public concern on slope appearance
  - ▣ Led to NEW INITIATIVE OF SLOPE GREENING subsequently

### FOLLOW-UP ACTION

- ▣ Landslip warning signs were erected on BRIL Roads (Busy Roads with a History of Landslides)

### 16.6.1993 CHEUNG SHAN ESTATE (50 m<sup>3</sup>)

1 Fatality & 5 Injuries



### BRIEF SITE DEVELOPMENT HISTORY

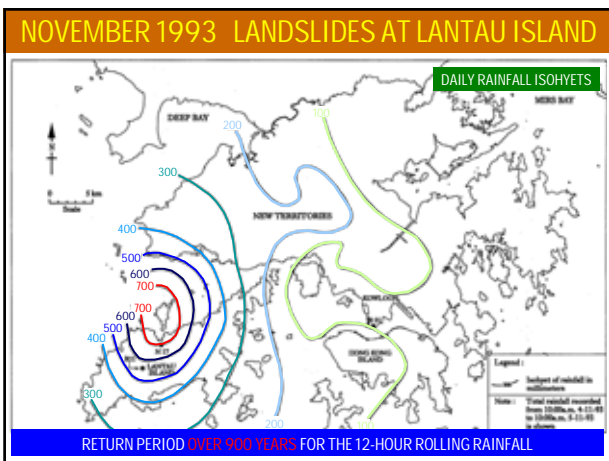
- ▣ The bus terminus was formed and the slope was modified to the configuration at the time of 1993 landslide during the construction of **Wo Yi Hop Interchange of Route 5** in late 1980s
- ▣ A consultant was engaged to undertake geotechnical assessment of both the proposed and existing slopes

### GEOTECHNICAL ASSESSMENT

- ▣ The consultant submitted the design in March 1987
- ▣ April 1987 - GCO commented that " it is noted that the possibility of **perched water table** forming between fill / colluvium and decomposed rock was **not** taken into account. This needs clarification "
- ▣ May 1987 - consultant replied that " perched water tables are **unlikely** to occur at the base of the colluvium because the test results indicate that underlying completely / highly decomposed rock is coarser and hence more permeable. **It will provide underdrainage to the colluvium**", and added that " inspection would be made during excavation for the cut slopes above **Wo Yi Hop Interchange**. If any significant signs of perch tables are encountered, **appropriate drainage measures** would be installed at the colluvium / decomposed rock interface. "

### REVISED CONSEQUENCE-TO-LIFE CATEGORIES

- ▣ New guidance on the consequence-to-life categories for **bus shelters and other public sheltered waiting areas ( viz . Cat . 1 )** was subsequently issued (**Later incorporated into WBTC NO. 13/99**)




### NOVEMBER 1993 LANDSLIDES AT LANTAU ISLAND

- > 300 MAN-MADE SLOPE FAILURES (GEO INSPECTED 281 CASES)
- > 800 NATURAL HILLSIDE FAILURES (GEO INSPECTED 56 CASES)

**GENERAL REPORT ON MAN-MADE SLOPE FAILURES**

- ▣ Systematic study of characteristics of man-made slope failures
- ▣ Also, a good chance to :
  - ▣ Assess the effectiveness of design and construction of surface protection and drainage measures
  - ▣ Assess the effectiveness of routine slope maintenance
  - ▣ Explore the possible use and effectiveness of prescriptive measures



**NOVEMBER 1993 LANDSLIDES AT LANTAU ISLAND**

FAILURE OF MAN-MADE FEATURES



BUILD-UP OF PERCHED WATER TABLE

**NOVEMBER 1993 LANDSLIDES AT LANTAU ISLAND**

FAILURE OF MAN-MADE FEATURES



RISE IN MAIN GROUNDWATER TABLE

**NOVEMBER 1993 LANDSLIDES AT LANTAU ISLAND**

FAILURE OF MAN-MADE FEATURES



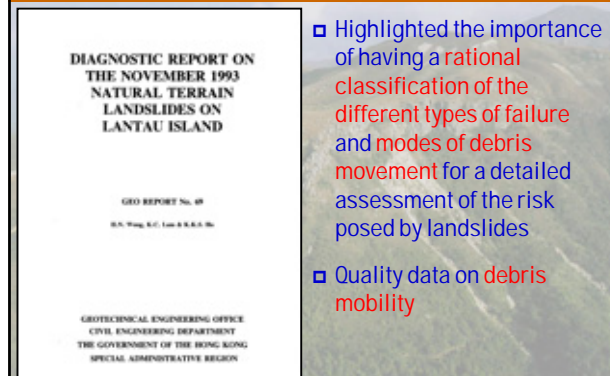
WASH-OUT

**NOVEMBER 1993 LANDSLIDES AT LANTAU ISLAND**

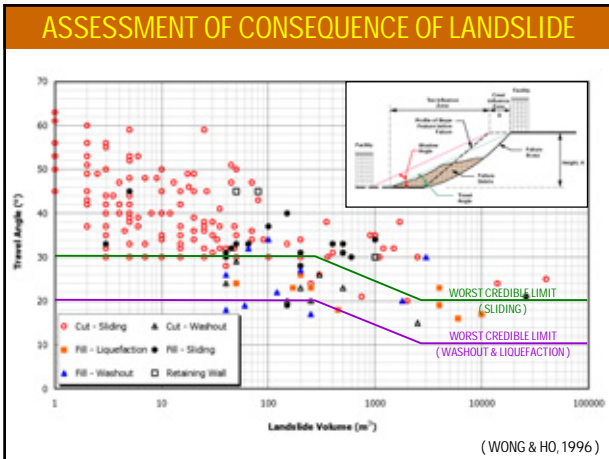


NATURAL TERRAIN LANDSLIDES

**DIAGNOSTIC REPORT**



- ▣ Highlighted the importance of having a rational classification of the different types of failure and modes of debris movement for a detailed assessment of the risk posed by landslides
- ▣ Quality data on debris mobility



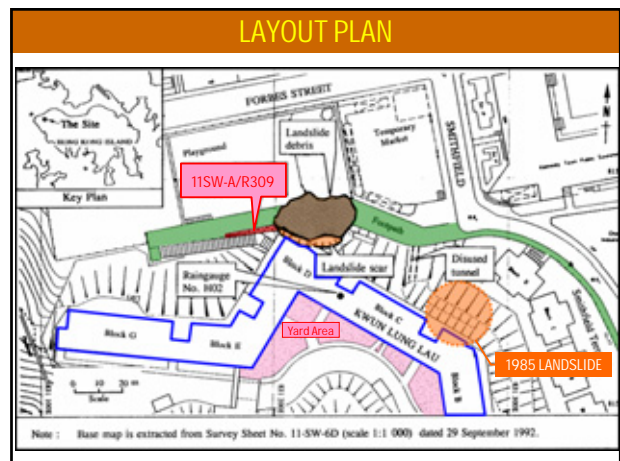
### FOLLOW-UP ACTIONS

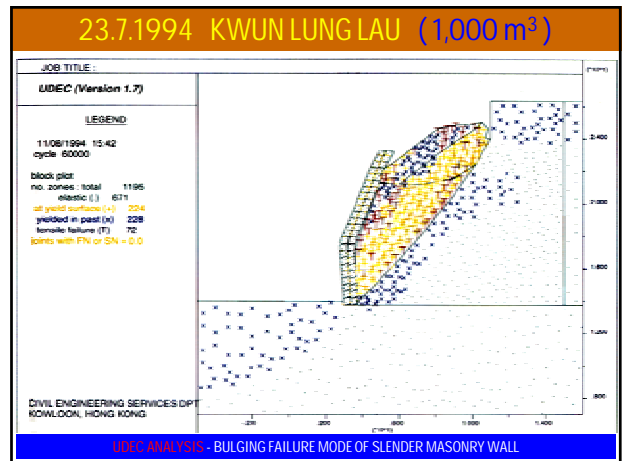
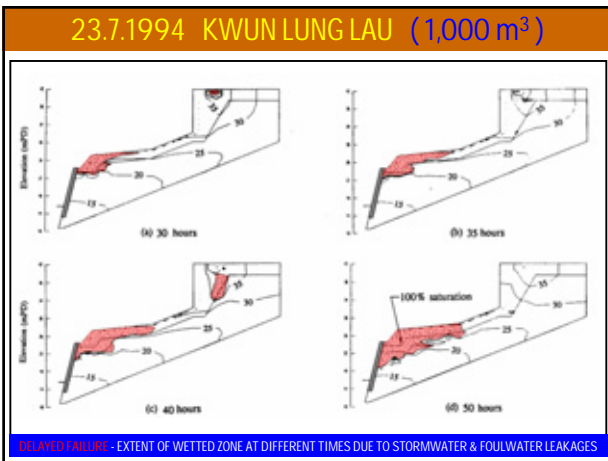
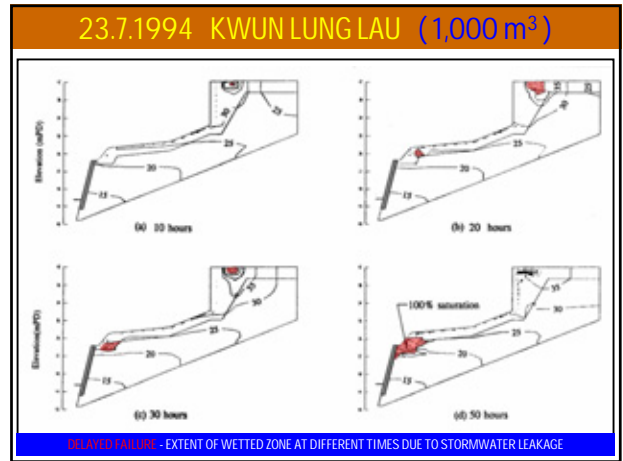
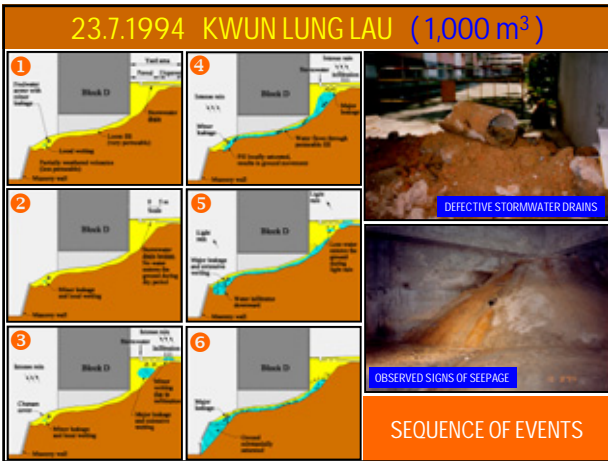
APPLICATION OF PRESCRIPTIVE MEASURES TO SLOPES AND RETAINING WALLS

GEO REPORT No. 56 (Second Edition)

Geotechnical Engineering Office  
Civil Engineering Department  
The Government of the Hong Kong Special Administrative Region


- ▣ Led to the development of prescriptive measures (GEO Report No. 56)
- ▣ Enhanced understanding of slope performance under extreme rainfall scenario (Emergency preparedness)
- ▣ Advocated the application of quantitative risk assessment (QRA)





### INDEPENDENT TECHNICAL REVIEW

- ❑ 2,500 residents were temporarily evacuated overnight
- ❑ Forensic investigation by GEO
- ❑ Independent technical review by Prof. Norbert Morgenstern, who also carried out a review of the adequacy of the Government's slope safety practice



### INDEPENDENT TECHNICAL REVIEW

- ❑ FIVE Recommendations :
  - ❑ To implement a programme of measuring masonry wall thickness
  - ❑ To develop a programme for direct monitoring and repair of buried services at housing estates or other developments
  - ❑ To introduce a more integrated approach into the slope stability assessment process
  - ❑ To undertake and support research into improved means of site characterization focused on the factors that affect slope stability
  - ❑ To appoint an external Slope Safety Technical Review Board



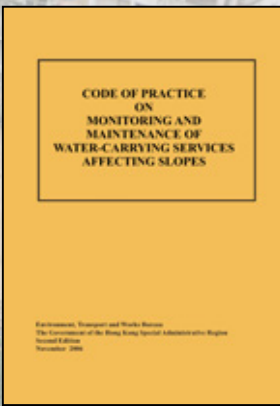
### SELECT COMMITTEE OF LEGISLATIVE COUNCIL



- ❑ Recommendations :
  - ❑ There should be a thorough, and then regular, review of the landslip preventive measures and the related systems
  - ❑ It is necessary to establish, review and enforce standards of good practice for slope stability assessment and maintenance
  - ❑ There should be stepped-up measures to promote public awareness and responsibility

### LESSONS LEARNT & FOLLOW-UP ACTIONS

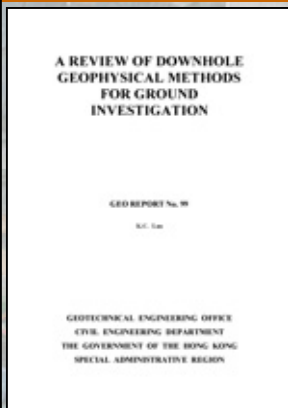
- ❑ Highlighted the adverse effects of leakage from buried water-carrying services on slope stability
  - ❑ Issued the Code of Practice on Inspection of Water-Carrying Services Affecting Slopes in 1996 (Second Edition in 2006)
  - ❑ Systematic programme for leakage testing of water-carrying services



### LESSONS LEARNT & FOLLOW-UP ACTIONS

- ❑ Advanced understanding of the failure mechanism of slender masonry wall
  - ❑ Revised GEO Circular on assessment of masonry walls
  - ❑ Slender masonry walls (height / thickness > 5) are liable to fail in a brittle manner
- ❑ Engaged consultants to carry out a systematic gauging programme to verify the thickness of masonry wall by weephole probing
- ❑ Initiated systematic landslide investigation
  - ❑ Trial implementation (1997 to 1999) & then became part of LPM
- ❑ Established the Slope Safety Technical Review Board (SSTRB)


### LESSONS LEARNT & FOLLOW-UP ACTIONS



- ❑ Initiated a R&D programme on the use of geophysics on slopes
  - ❑ Non-invasive surface techniques
    - ❑ Potentially useful for identifying the geometry of existing masonry wall
  - ❑ Downhole geophysical methods
    - ❑ Potentially suitable for identifying weak clay-rich layers with thickness of the order of 30 mm or above


### REPORT ON THE SLOPE SAFETY REVIEW

- ❑ **EIGHT** Recommendations :
  - ❑ To fast-track the LPM Programme (5-year accelerated LPM Programme)
  - ❑ To review the risk categorization system
  - ❑ To include low consequence-to-life slopes, such as those affecting busy roads and footpaths into the LPM Programme
  - ❑ To improve statutory geotechnical control of private slopes and developments



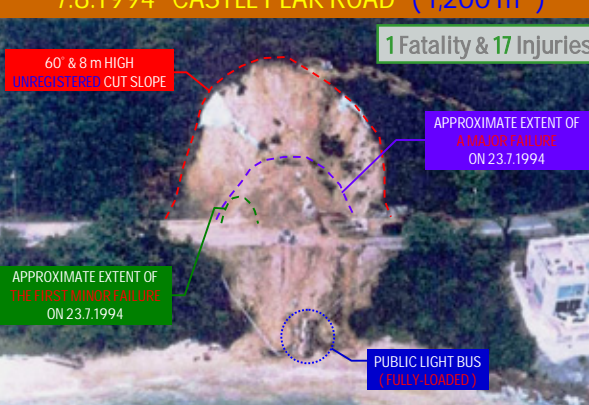
### REPORT ON THE SLOPE SAFETY REVIEW

- ❑ **EIGHT** Recommendations :
  - ❑ To step up public education campaign on slope maintenance
  - ❑ To clearly identify the maintenance responsibilities for all registered slopes
  - ❑ To reduce the response time of the Works Department in attending landslide incidents
  - ❑ To follow up as soon as possible the five recommendations made in the Independent Technical Review by Prof. Morgenstern



### 7.8.1994 CASTLE PEAK ROAD (1,200 m<sup>3</sup>)

1 Fatality & 17 Injuries



60° & 8 m HIGH UNREGISTERED CUT SLOPE


APPROXIMATE EXTENT OF MAJOR FAILURE ON 23.7.1994

APPROXIMATE EXTENT OF THE FIRST MINOR FAILURE ON 23.7.1994

PUBLIC LIGHT BUS (PLB) (MORNING)

TWO FAILURES OCCURRED ON THIS UNREGISTERED SLOPE ON 23.7.1994


### 7.8.1994 CASTLE PEAK ROAD (1,200 m<sup>3</sup>)



THE FULLY-LOADED PUBLIC LIGHT BUS WAS PUSHED DOWN THE EMBANKMENT ONTO THE BEACH

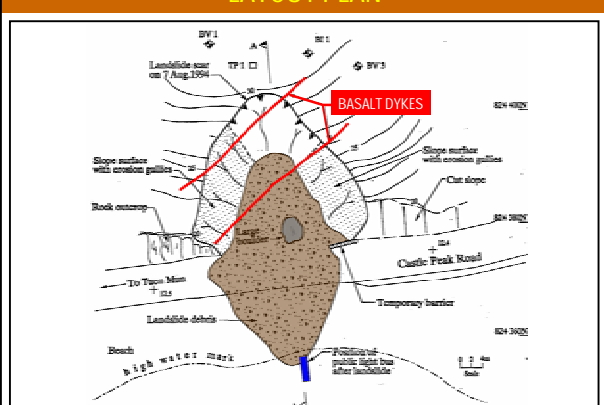
### 23.7.1994 CASTLE PEAK ROAD (700 m<sup>3</sup>)

A MAJOR FAILURE OCCURRED AT 3:30 p.m.

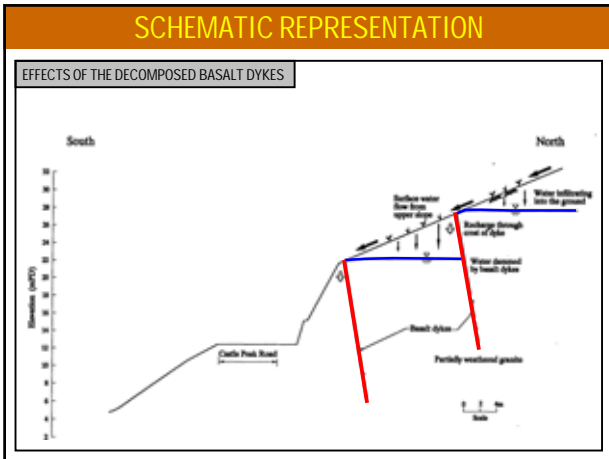


A MINOR FAILURE (20 m<sup>3</sup>) OCCURRED IN THE MORNING OF 23.7.1994

### LAYOUT PLAN



BASALT DYKES

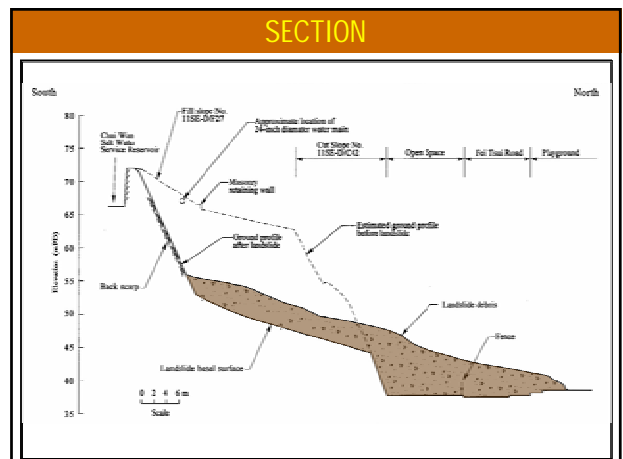
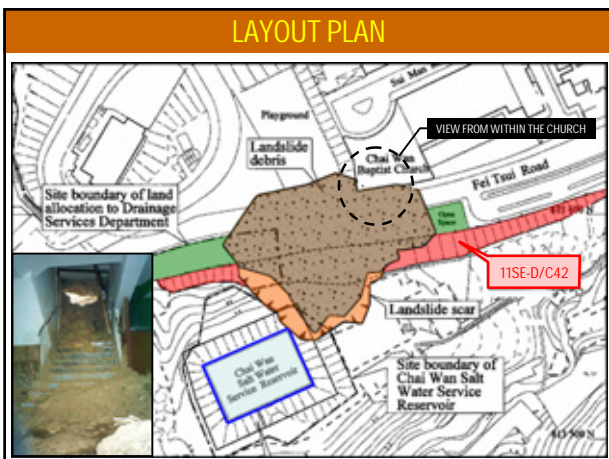


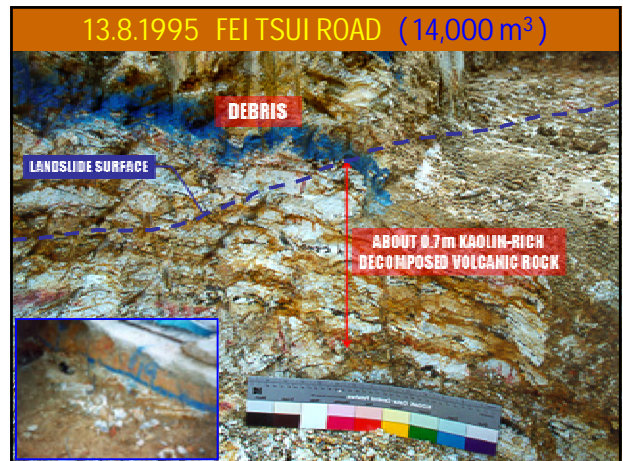
### LESSONS LEARNT & FOLLOW-UP ACTION

**GEO EMERGENCY MANUAL**

- SECTION 1: PURPOSE AND SCOPE OF THE GEO EMERGENCY MANUAL
- SECTION 2: RESPONSIBILITY OF THE GEO EMERGENCY MANUAL
- SECTION 3: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 4: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 5: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 6: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 7: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 8: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 9: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 10: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 11: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 12: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 13: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 14: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 15: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 16: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 17: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 18: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 19: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK
- SECTION 20: THE GEO EMERGENCY MANUAL'S SCOPE OF WORK

- Promulgation of elaborated guidance on emergency landslide inspections





INDEPENDENT TECHNICAL REVIEW

- Forensic investigation by GEO
- Independent technical review by Sir John Knill
- Slope had previous geotechnical input from three consultants and GCO

REPORT ON THE FEI TSUI ROAD LANDSLIDE OF 13 AUGUST 1995

Volume 1

INDEPENDENT REVIEW OF THE INVESTIGATION BY THE GEOTECHNICAL ENGINEERING OFFICE

Sir John Knill  
 Berkshire, the United Kingdom

February 1996

### LESSONS LEARNT

- Highlighted the importance of **engineering geological input** in slope design and understanding of the properties of **weak persistent clay seams** in weathered rocks
- Highlighted the **potential hazard** of leakage from service reservoir and effects of slope failures on reservoirs

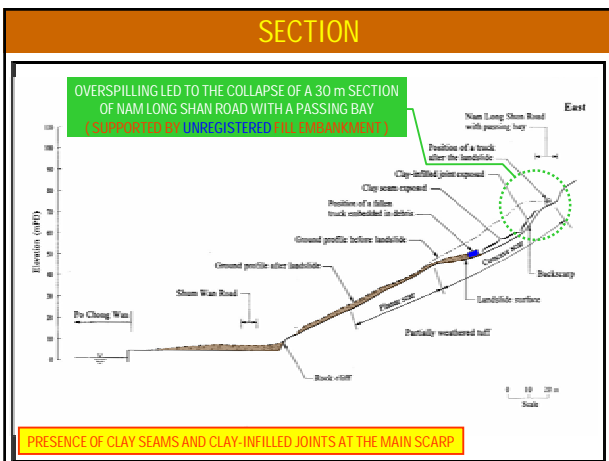
### 13.8.1995 SHUM WAN ROAD (26,000 m<sup>3</sup>)



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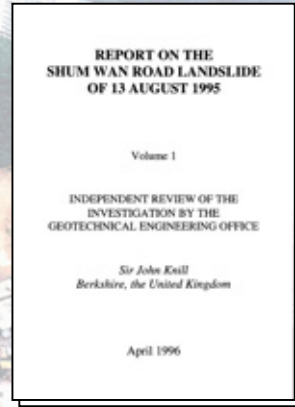


### SECTION



### INDEPENDENT TECHNICAL REVIEW

- Forensic investigation by GEO**
- Independent technical review by Sir John Knill**
- The landslide killed two people in the illegally constructed shipyard**

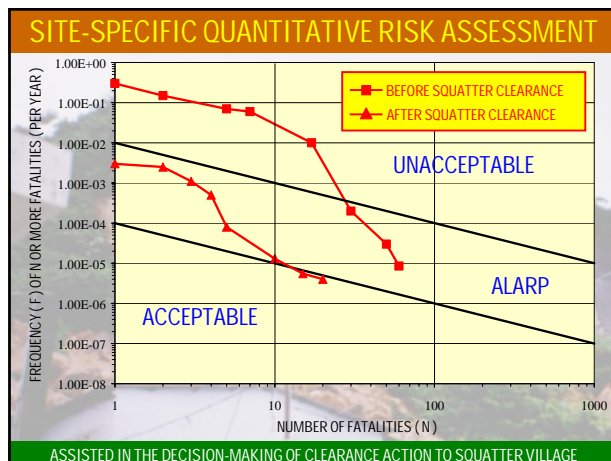
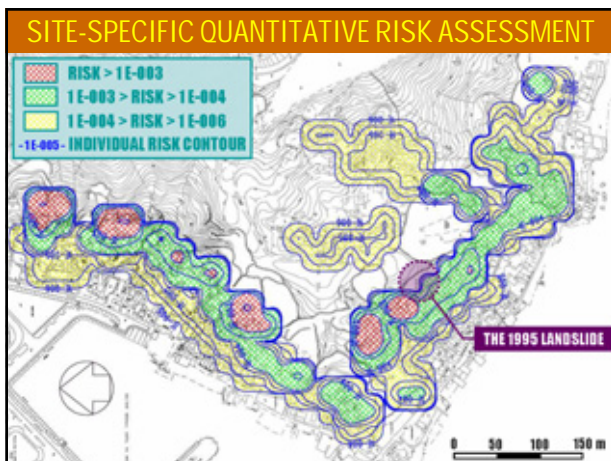
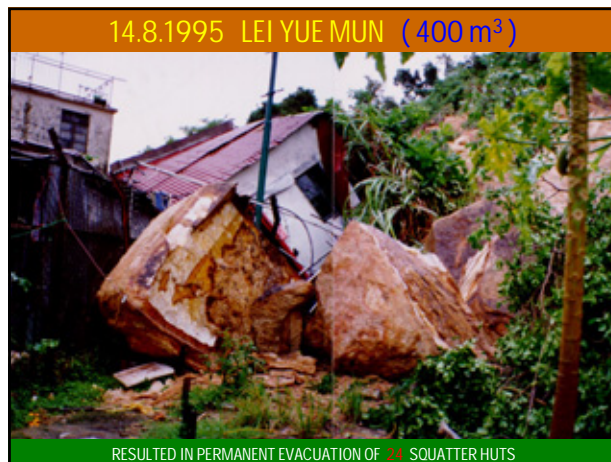


### LESSONS LEARNT & FOLLOW-UP

- ▣ Revealed the importance of adequacy and regular maintenance of road drainage provisions
  - ▣ Highways Department (HyD) conducted a follow-up study to inspect vulnerable road sections and formulate schemes to prevent overspilling of stormwater from carriageways to vulnerable downhill slopes
- ▣ Need to consider environmental factors, such as the possibility and effects of overflow of stormwater running along road, in slope stability assessments and detailing
- ▣ Publication of Highway Slope Manual by GEO
- ▣ Vulnerability of marginally stable, old coastal slopes is highlighted

### OTHER FOLLOW-UP ACTIONS

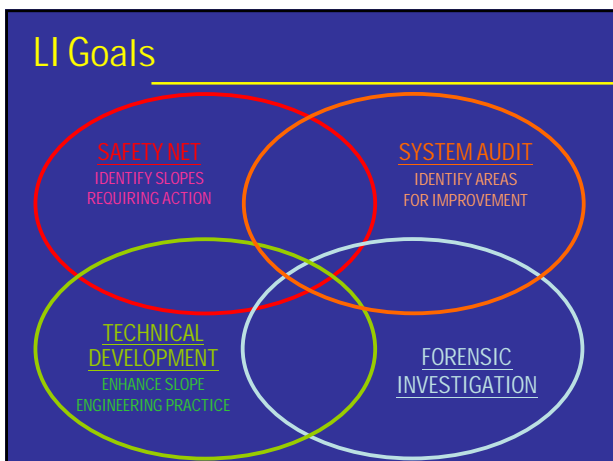
- ▣ Issued guidance on recognition of geological features with clay-rich layers in slopes (GEO TGN 4)
- ▣ Initiated engineering geology area studies :
  - ▣ SEVEN area studies of cut slopes and natural terrain
  - ▣ Identified areas vulnerable to adverse geological structures
  - ▣ Thematic maps published
- ▣ Initiated a study on mineralogy and fabric of weathered igneous rocks
- ▣ Initiated mineralogical studies of kaolin :
  - ▣ Provided new insights into the mode and occurrence of kaolin infills



### SITE-SPECIFIC QUANTITATIVE RISK ASSESSMENT

- ▣ This was the first application of site-specific quantitative risk assessment (QRA)
- ▣ Successful application of QRA to **supplement and calibrate engineering judgment** in the delineation of extent for squatter clearance
- ▣ Changes in NDC policy

### Systematic LI Programme Since 1997



### Some Recent Notable Landslides

YEAR	LOCATION	VOLUME (m <sup>3</sup> )	REMARKS
1997	KAU WAH KENG UPPER VILLAGE	360	1 Fatality
1997	TEN THOUSAND BUDDHAS' MONASTERY	1,500	1 Fatality
1997	CHING CHEUNG ROAD	5,200	Failure of soil cut slope upgraded under LPM Programme
1999	SHEK KIP MEI	6,000	Permanent evacuation of 3 housing blocks
1999	SHAM TSENG SAN TSUEN	600	1 Fatality
2001	HILLSIDE ABOVE LEI PUI STREET	750	Channelized debris flow
2005	FU YUNG SHAN TSUEN	400	1 Fatality

### Conclusions

- ▣ Landslides have played a key role in the evolution and continual refinement of the slope safety system and slope engineering practice in Hong Kong
- ▣ It is important to have a good appreciation of the rationale underlying the current practices
- ▣ There is much to learn from studying landslides to appreciate how best to prevent failures

