

Ground Investigation for Natural Terrain Hazards

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Contents

- Extent of Ground Investigation and determining the extent and type of work
 - How much is enough?
 - Focused GI to Define Hazard Models
 - GI for Mitigation Design
- Typical GI techniques
- Logging

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Extent of Ground Investigation Works

- What questions need answering after the API and Field Mapping has been carried out :
 - What parts of the geological or ground model need to be verified?
 - What previous landslide events do I need to prove / justify / gather data from ?
 - What hazards models need to be better defined ?
 - Are my source area assumptions correct ?
 - Are the entrainment assumptions correct ?
 - Where are the deposition areas ?

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Extent of Ground Investigation Works

- What questions need answering:
 - What will the Checker / Regulator / Client accept ???
 - Mitigation measures designs what do I need to know to do the design ?
 - How much of this can be obtained from existing data?
 - Where do I not have enough data ?
 - What type of investigation techniques will best achieve the desired goal ?
 - What will the budget allow ?

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How much existing data do you already have?

- Carefully review the Desk Study Information
- Consider mapping and nearby slope record information
- Where and what are the existing GI records ?
 - Are they useful and relevant ?
 - Are they detailed enough ?
 - Are they too old and possibly unreliable ?

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Extent of Ground Investigation Works

How can I obtain the information I need?

- Field Mapping
- Boreholes
- Trial Pits / Trenches
- In-situ Field Testing
- Sampling & Laboratory Testing
- Geophysical Methods
- The amount and type of work will typically controlled by the allowable budget and timeframe for the project

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Field Mapping

- Walkover the study area
- Identify and inspect exposures
- Accurately record location and details



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Field Mapping – Hazard Models Objectives

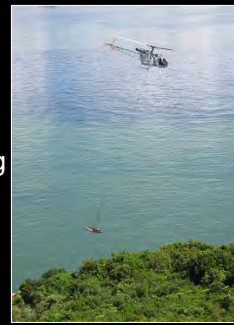
- Should provide the most information to validate the Hazard Models
- Develop GI Strategy based upon the Field Mapping and API
- All other GI for the Hazard Models should be supplementary or validate the Ground and Geological models



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Boreholes

- Provide deeper profile of geological conditions
- Facilitate sample collection and groundwater monitoring
- Definition of deeper rockhead
- Important for Mitigation Designs such as Soil nails, ground anchors, minipile designs, mitigation foundations etc



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Boreholes for Landslide Hazard Models

- Objectives / Requirements
 - Appropriate for deep seated landslide hazards
 - Appropriate for areas of distressed hillside
 - Instrumentation installation if required (inclinometers, piezometers ?)
 - If area distressed then continuous monitoring useful to find reasons for distress (must split and log accurately)
 - Soil and Rock properties at depth
 - Rockhead definition
 - Groundwater definition
 - Refine and develop ground model for better Hazard Definition
- Should not need many Boreholes / rely more on TP and Mapping

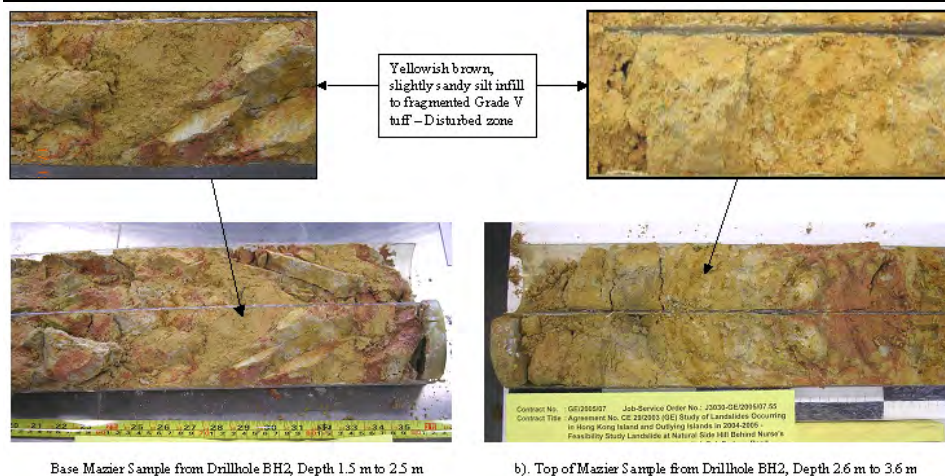
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Boreholes for Mitigation Designs

- Objectives / Requirements
 - Targeted at actual and likely mitigation locations
 - Soil and Rock Properties at all depths
 - In-situ testing and samples for Lab Testing
 - Rockhead definition
 - Groundwater definition
 - Refine and develop ground model for Mitigation Design
- More Boreholes to ensure compliance with Design Criteria and ensure cost effective mitigation designs.

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Boreholes – Example from Distressed Ground



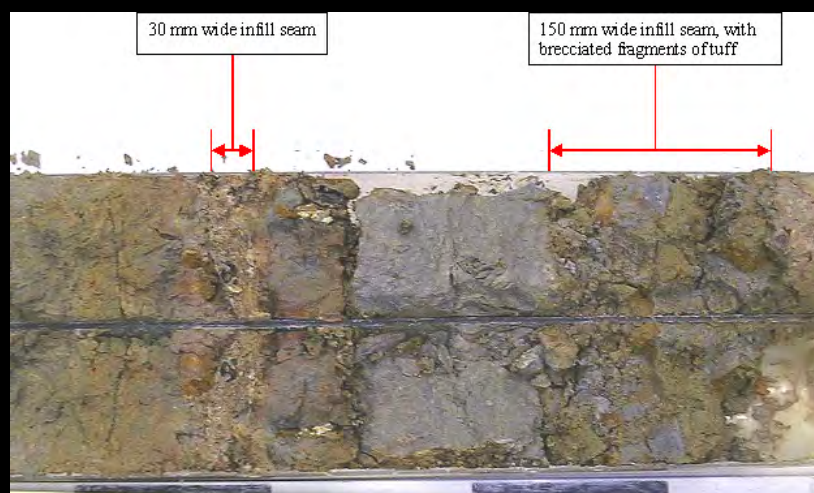
FSW, LIC Study into Queen Mary Hospital Landslide

Boreholes – Example from Distressed Ground



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Boreholes – Example from Distressed Ground



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Trial Pits / Trenches

- Allow detailed inspection of near surface soils



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Trial Pits / Trenches for Hazard Models

- Objectives / Requirements
 - Soil layering (recent landslide debris, colluvium etc)
 - Observations of distressed ground (old and recent)
 - Observations of geological features leading to distress
 - Identification of similar geological features that may lead to redefining Hazard models
 - Depositional environment and possible age dating
 - Undisturbed samples (block samples) of near surface soils
 - Entrainment assessment and channel definition
 - Refine and develop ground model for Hazard Model

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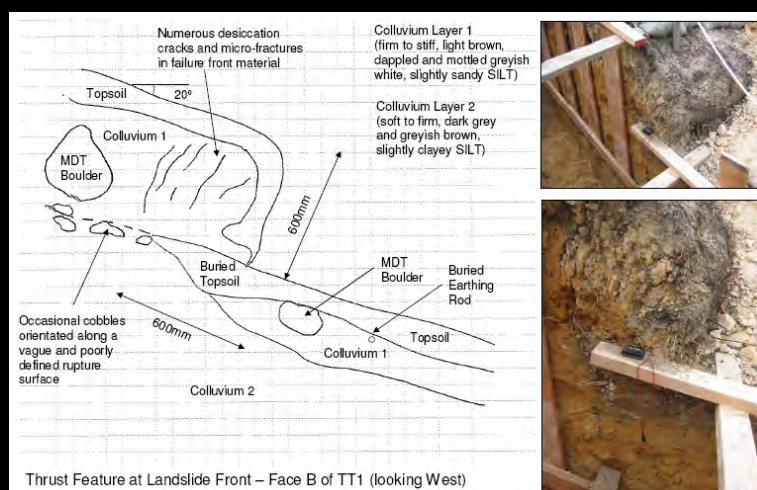
Trial Pits / Trenches for Mitigation Design

- Objectives / Requirements
 - Targeted at actual and likely mitigation locations
 - Soil and Rock Properties
 - Site formation information (grading, recompaction etc)
 - Rockhead definition (maybe if shallow)
 - Groundwater definition (maybe if shallow)
 - Refine and develop ground model for Mitigation Design

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Trial Pits / Trenches

- Ground Movement Features – Compression / Thrusting



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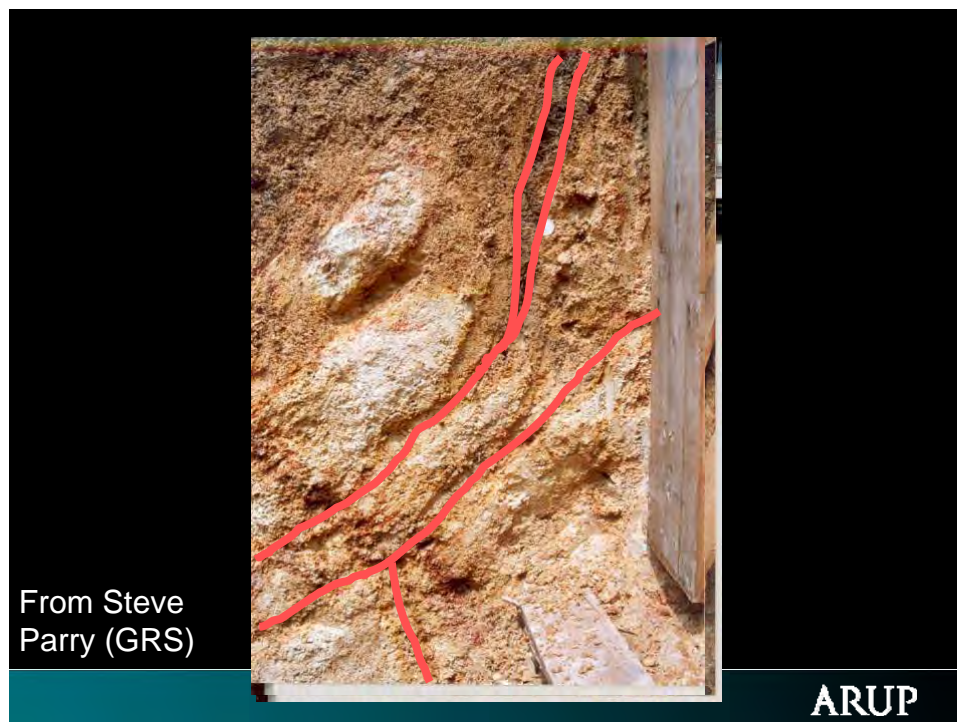
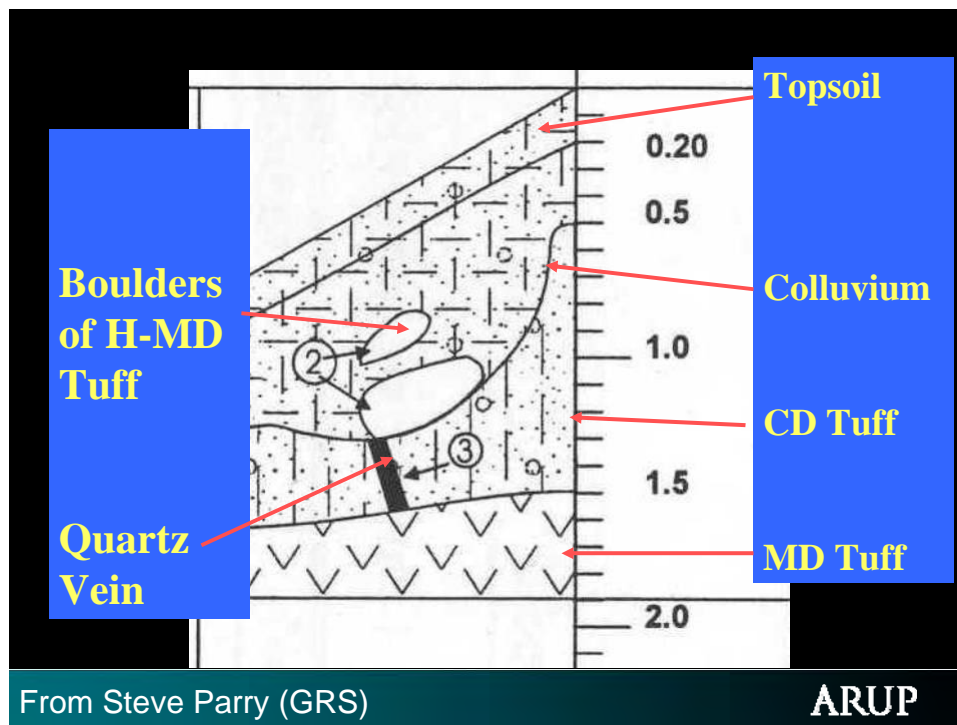


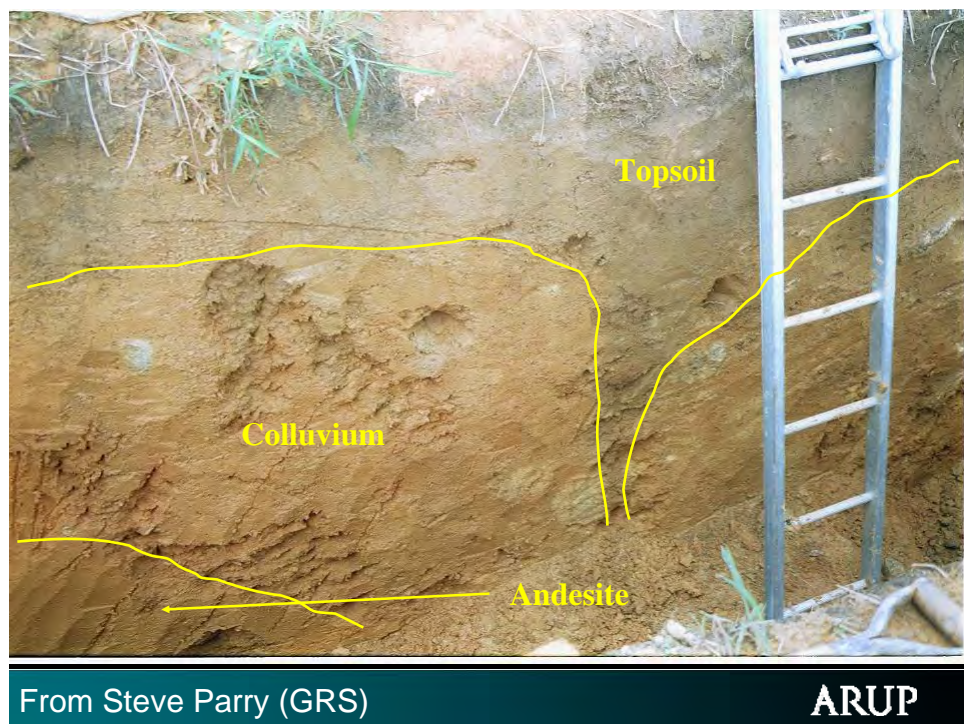
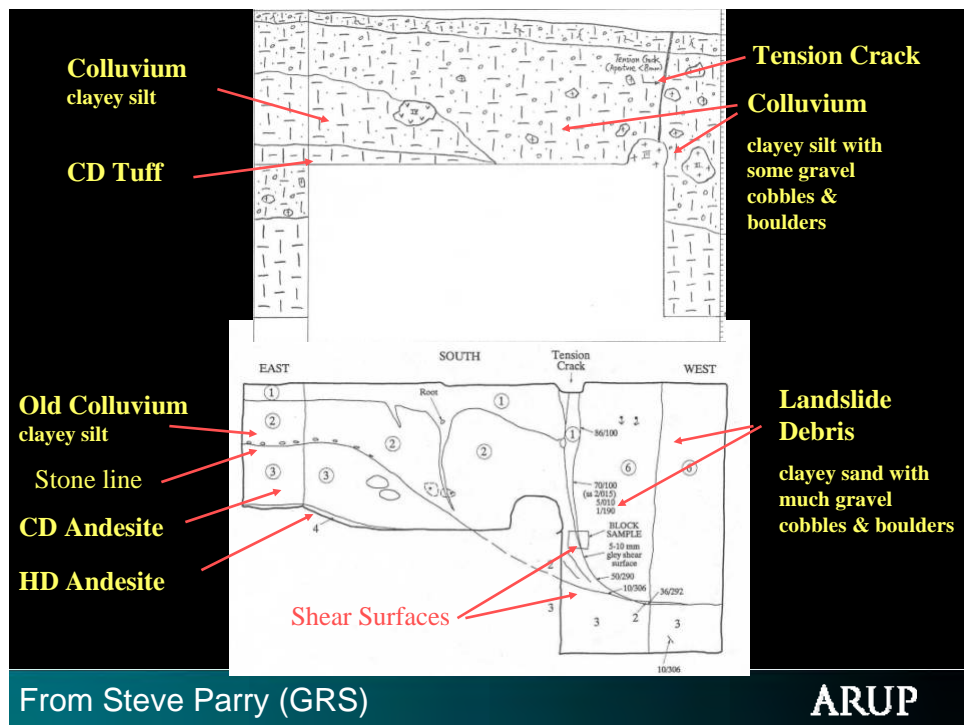
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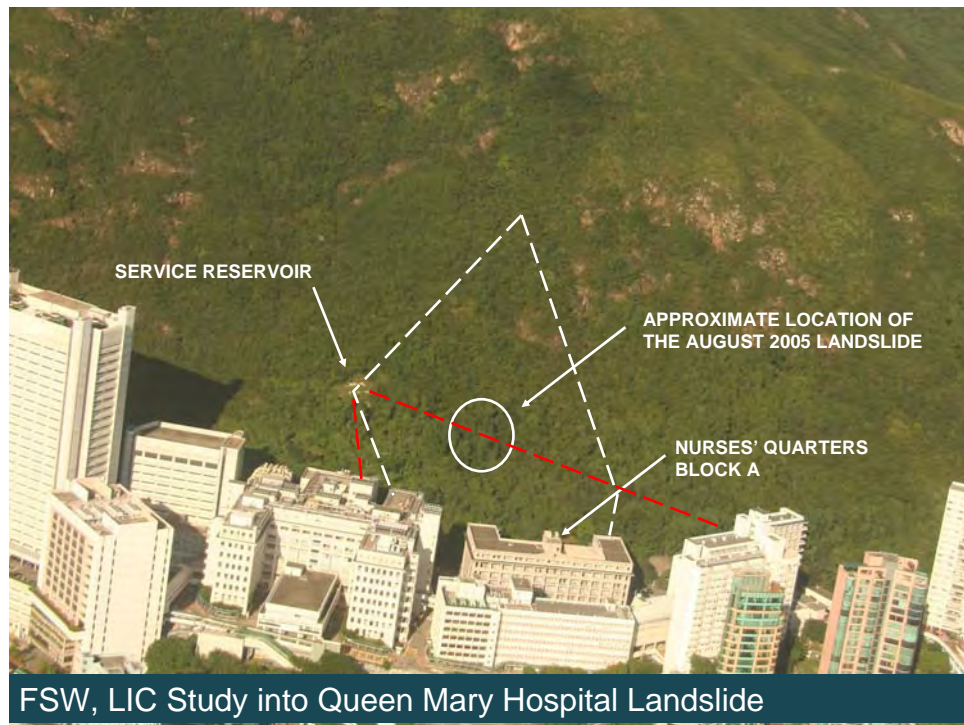


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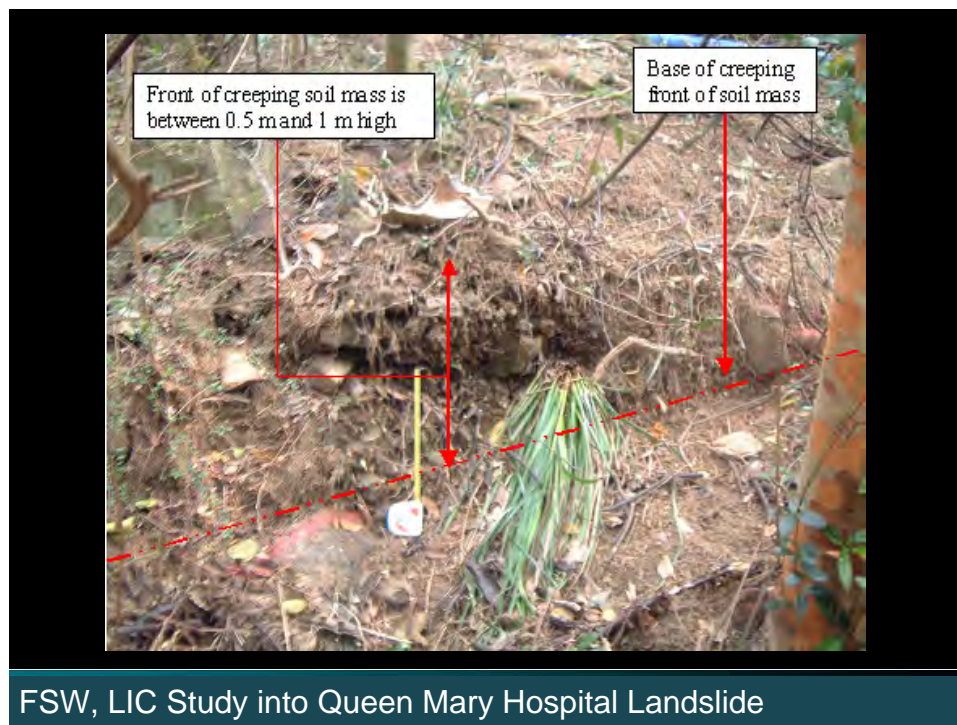




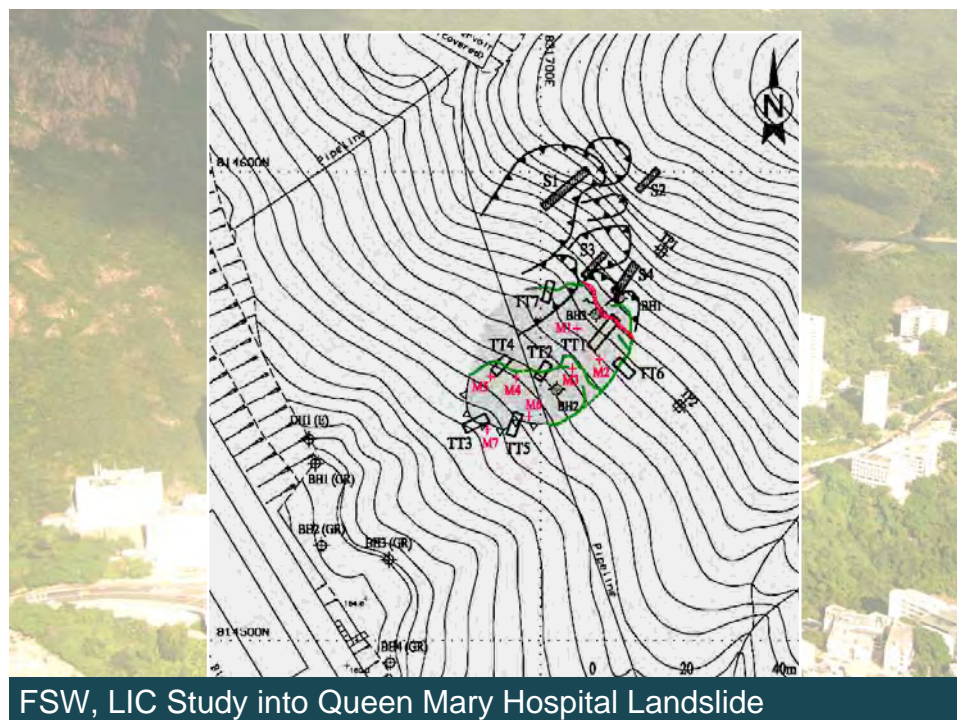
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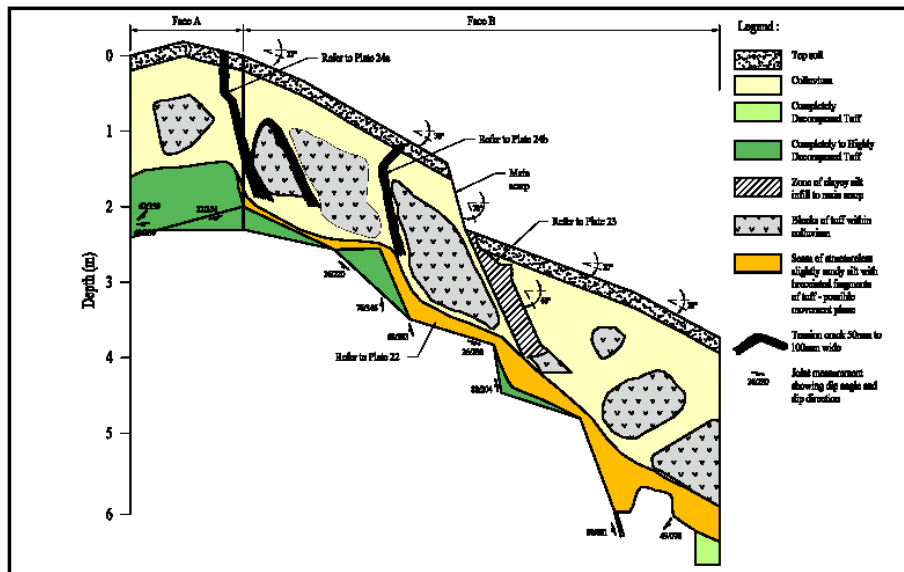
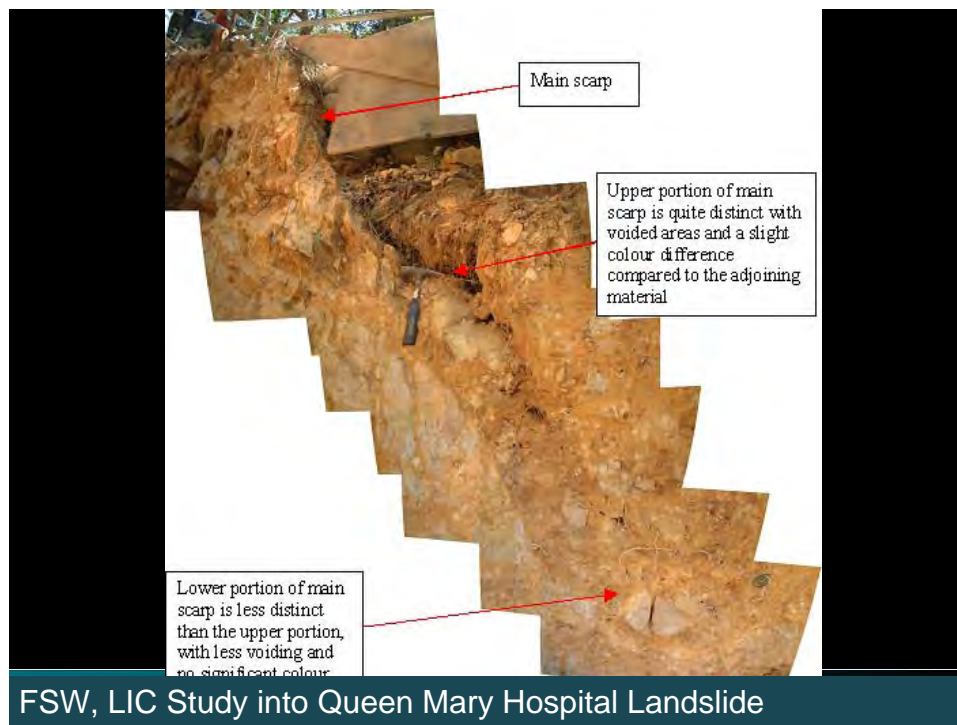


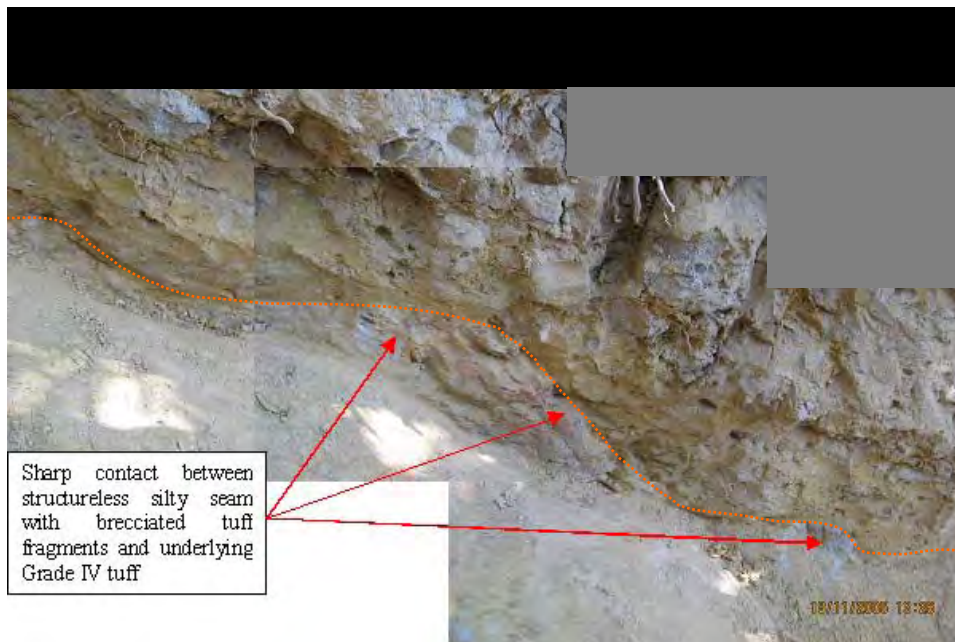
Figure 7 - Trial Trench TT1 (Face A and B)

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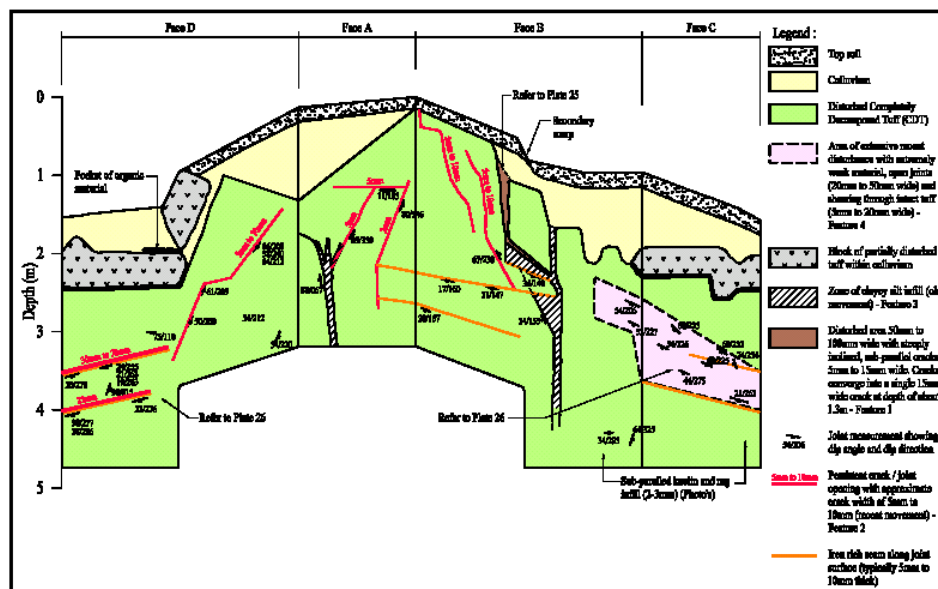
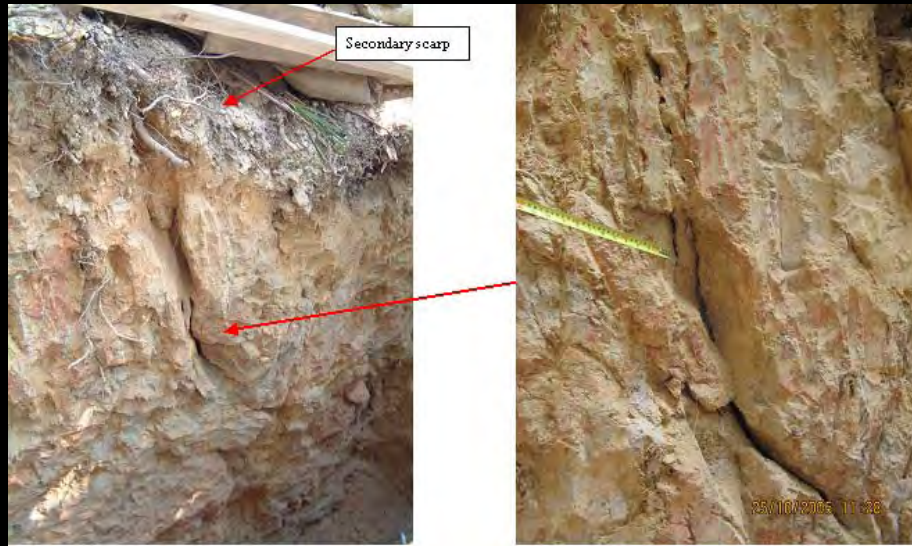
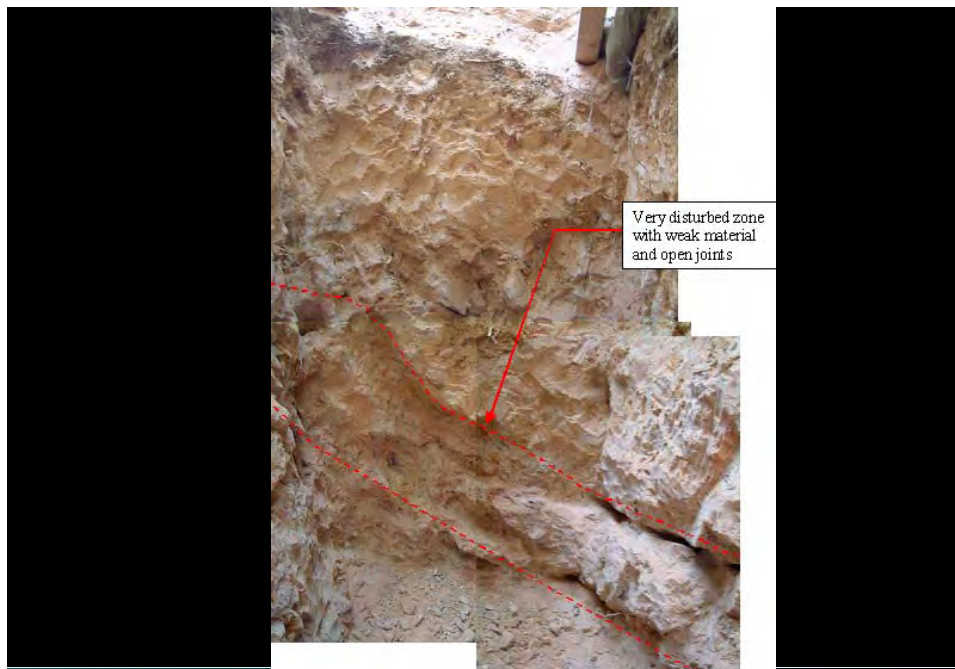


Figure 8 - Trial Trench TT2

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Vegetation / Slope Strips for Hazard Models

- Objectives / Requirements
 - Identify surface evidence of distress
 - Ridges
 - Tension cracks
 - Ground creep
 - Check slope angles and surface soil types
 - Check boulder embedment
- Also observe trees for bending (soil creep)
- Vegetation type for near surface water seepage

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Ground Investigation Logging

- Logging of boreholes, trial pits and vegetation / soil strips etc should be independently logged by an Engineering Geologist or Geologist from the Consultant
- “The Detail” needs to be included in the logs
- Persons undertaking the Field Mapping should really do the GI logging
- Borehole maziars should always be opened and logged if not needed for Lab Testing

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In-situ Testing

- Permeability Tests
 - Falling Head / Rising Head / Constant Head
- Density Tests
 - typically Sand Replacement Tests
- Discontinuity Surveys
 - Acoustic Televiewer Survey
 - Impression Packer Tests
- SPT etc...



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Sampling

- Disturbed or Undisturbed?
 - Disturbed = characterisation testing only
 - Undisturbed = detailed geotechnical testing & In Trial Pits or Trenches = identification of feature of interest
- How Frequent and Why?
 - Depends on the degree of detail and objectives required, consult the Engineering Geologist for the Hazard Definition and the Geotechnical Design Engineer for the Mitigation Designs.
- Handling & Storage
 - Samples cost considerable amounts of money to obtain and should be treated with great care.
 - Maziers should be opened and logged.



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Laboratory Testing (mostly for Mitigation Design)

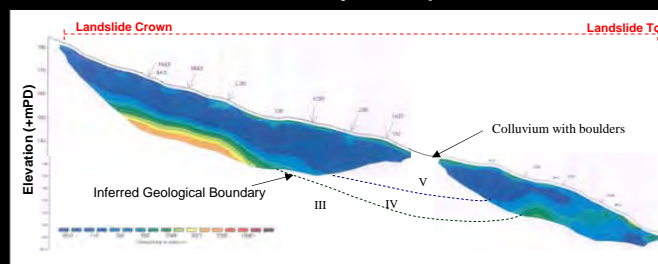
- Soil and Rock Strengths (undisturbed)
- Normal index tests
- Superficial soils grading and compaction properties
- Chemical Testing for Soil Aggressivity and Concrete Durability etc
- Age Dating ??



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Geophysical Methods

- Potentially good ways of investigating large areas or cross sections and identifying areas of interest for Borehole or trial pit construction
- Needs some trial pits or Boreholes to act as a 'control' for the results
- Seek specialist advice to ensure appropriate techniques are used and results correctly interpreted



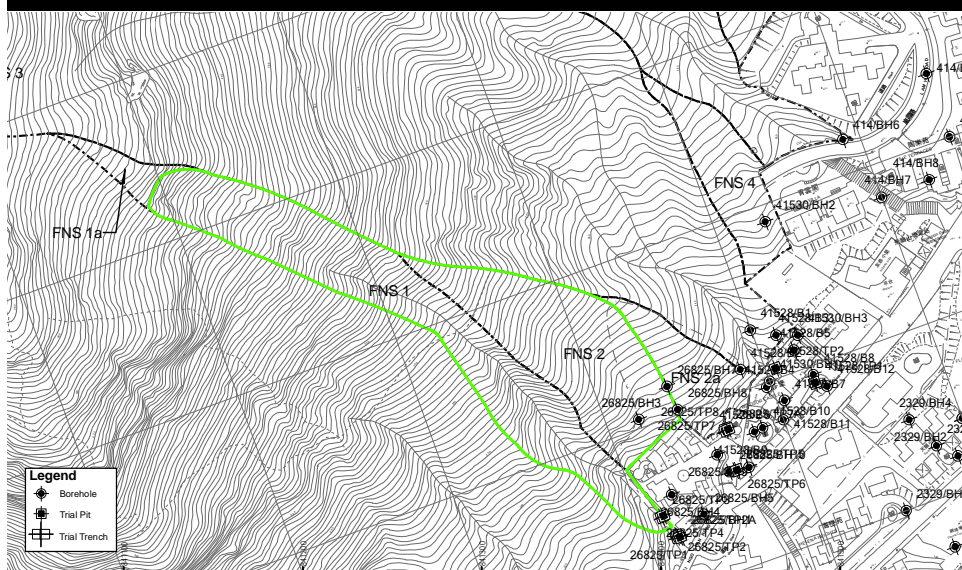
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Geophysical Methods

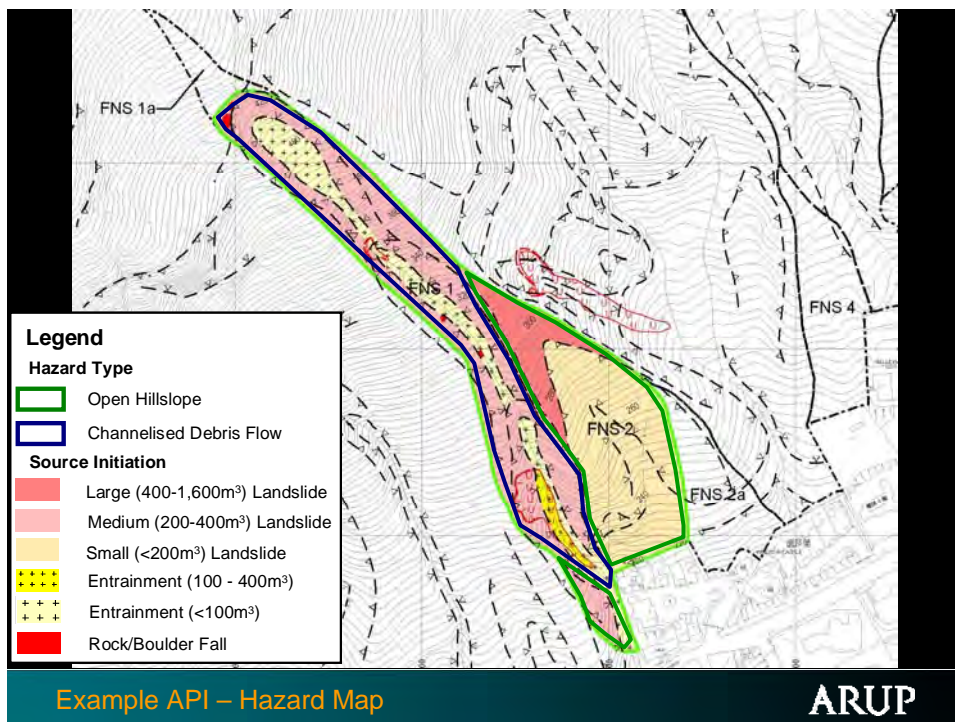
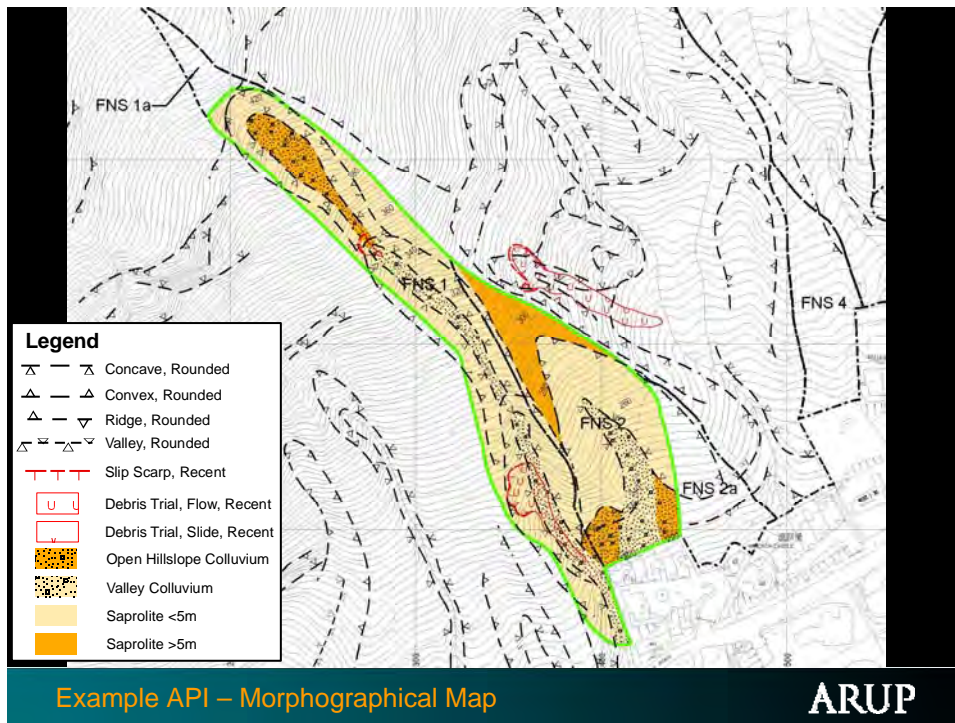
- Possible Techniques
 - Resistivity (Gradient Array / Schlumberger)
 - Tension Cracks and Fissures
 - Soil profiles / Rockhead maybe
 - Depositional zones and soil layering
 - Groundwater
 - Microgravity
 - Rockhead definition / contours
 - Shallow Seismics
 - Refraction
 - Reflection
 - Soil layering (maybe only for thicker deposits)
 - Others (Ground Penetrating Radar, Electromagnetics ??????)

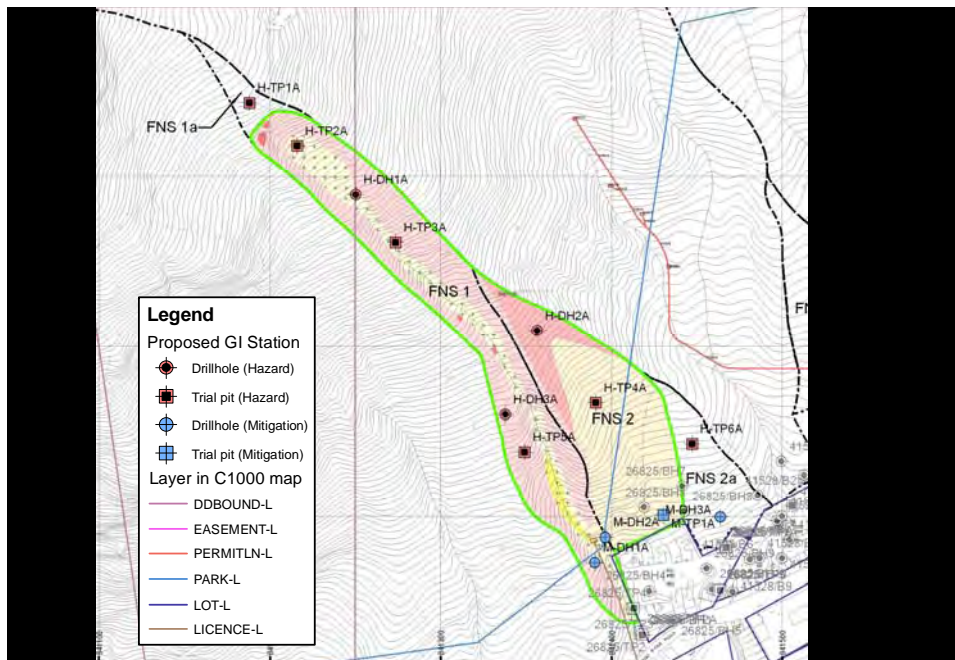
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Example - Existing Ground Investigation Records



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Example API – Proposed GI Plan

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Thank You

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