Methods

For studying & assessing a karst area

1: Planning & Preliminary Work
2: Field Mapping & Inventory
3: Specific tasks
4: Analysis & Consolidation
5: Reporting
6: Local Feedback

METHODS - overview

Methods:

Overview of the 6 steps...
We will work through these. But discuss only some aspects in detail

1: Preliminary Stage

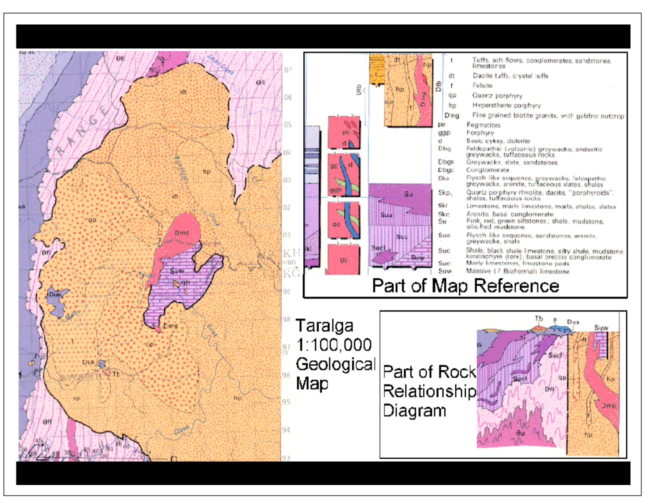
- Identify the purpose
- Identify the area (boundaries)
- Literature review
  - Reports & Maps
  - Cave info
  - Climate, geology, soils, vegetation etc...
  - Land usage & ownership
  - Existing Management Plans

1:Preliminary stage

Literature Review:

* **How accurate** are the maps & other data

* **How to use a geol Map** .... (next slide)



Geol map

Geol Map
(NB it might be better to put up the OHP version !!)

Discuss how to identify units and move between the different parts of the map.

Note use of screen patterns & letter-codes.

1: Preliminary Stage

- Air-photo interpretation, etc
- Initial Site reconnaissance
  - Access, Local contacts
  - Check accuracy of existing reports
- Plan the Main study
  - Requirements, methods & funding
  - Impacts ?
- Computer Database, GIS, etc
- Specialist Personnel ?

Air photo interpretation

1: Prelim Stage:

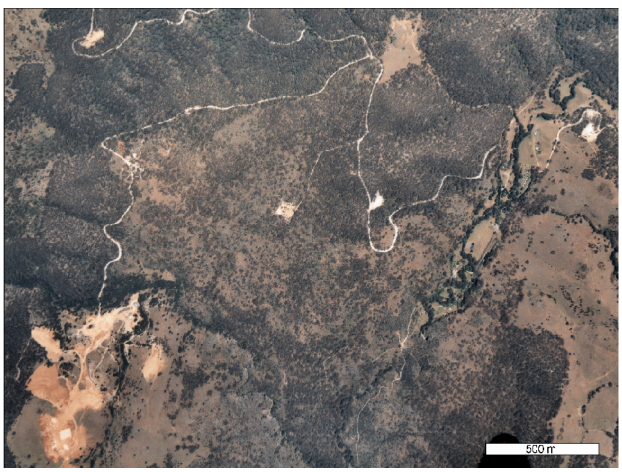
*** Air Photo Interpretation**

See separate handout on use of stereoscopes, and this afternoon's exercises.
Show an Air-photo and its annotations etc. How to work out the scale.
Lineaments = photo-linears = fracture traces = ???

*** Beware Lineaments !!!**
* Other peoples lineaments.
Be sceptical untill ground-checked
Do they distinguish strong from weak lineaments?

* Your own lineaments.
Beware bias to your preconceptions
Beware bias to faint features that match obvious tends
Beware artifacts (old roads, fencelines, bushfire scars, vegetation effects that are unrelated to geology, ...
If you are not sure what caused the lineament be careful.
If in doubt leave it off.

Fracture Zones = lineaments by another name !

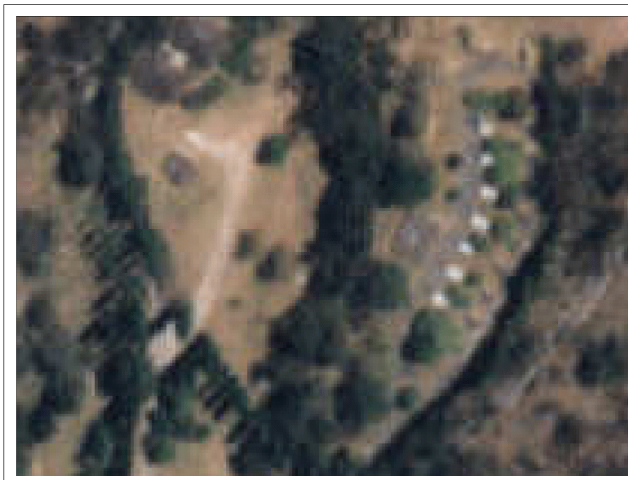


Air Photos:

Example of an air photo of the Wombeyan area.

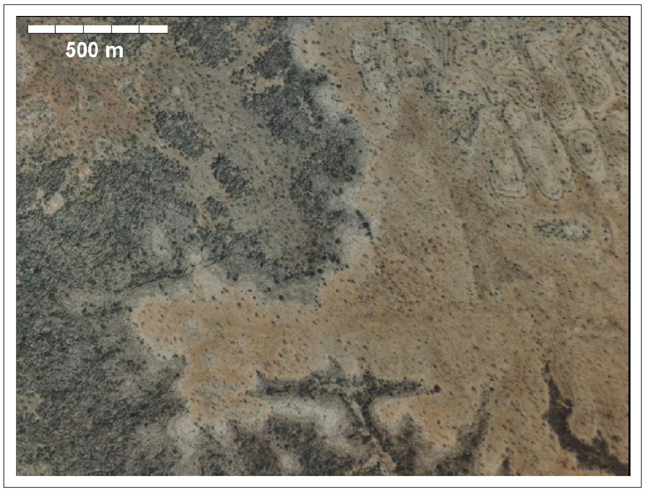
Note obvious features:
Vegetation, major streams, roads, quarries, ...

For more details examine the original this afternoon.



Pixels:

Detail from a scanned version of the Wombeyan 1:25,000 air photo. Scanned at 600 dpi. So pixel resolution is about one metre.
This image is blown up so the indiidual pixels can be seen.
Note that a 1m pixel size does NOT mean you can recognise things 1 m in size !

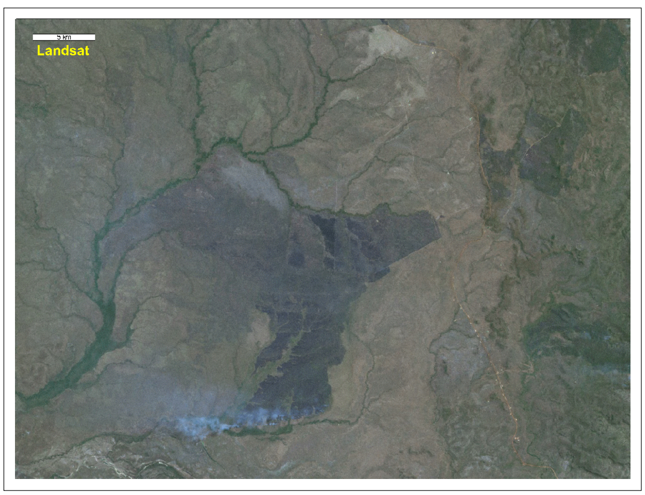


Gregory karst: geology &lineaments

Looking for (real) lineaments.

Air photo from Gregory Karst NT.
* dark grey belt = Flat-lying bed of dolomite with strong karren field - including joint-conrolled grikes (small black lines) - see afternoon exercise for a more detailed photo of these.
* Pale brown = overlying mud and dolomite unit.
* circular and curly lines at top-right = "layer-cake" geology of flat-lying beds (dark = thin dolomite outcrops).

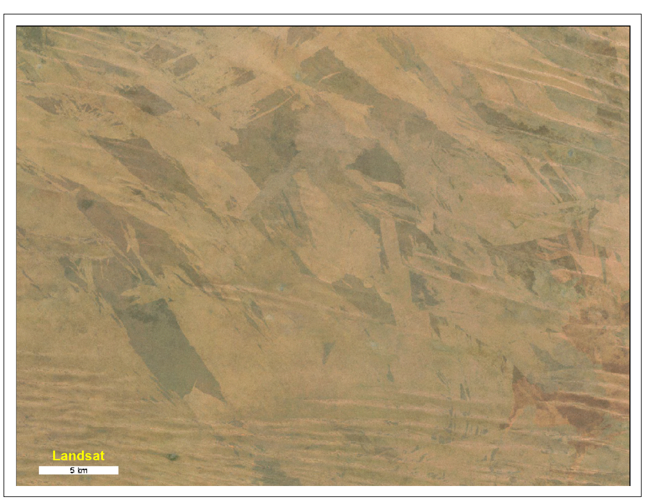
Lineaments =.
GOOD: NNW trends in top-right (show up in 3-D also) - probably major joints?
T-valley in lower-middle (faults?)
FAIR: show them   (long E-W and NNW trends crossing near middle)
POOR: show them (creek to NW, ...)



Bushfires

Lineaments (continued)

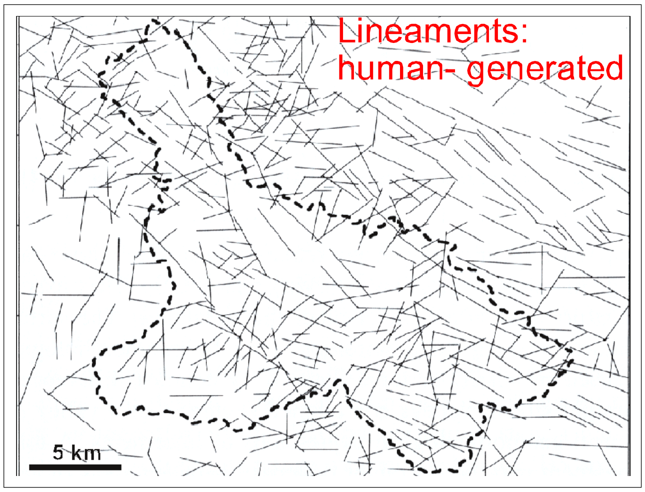
Artifacts: Bush-fire scars, roads, fences, vegetation patterns



Lineaments (continued)

More fire scars (multiple generations).

Also linear dune ridges.



Lineaments (human)

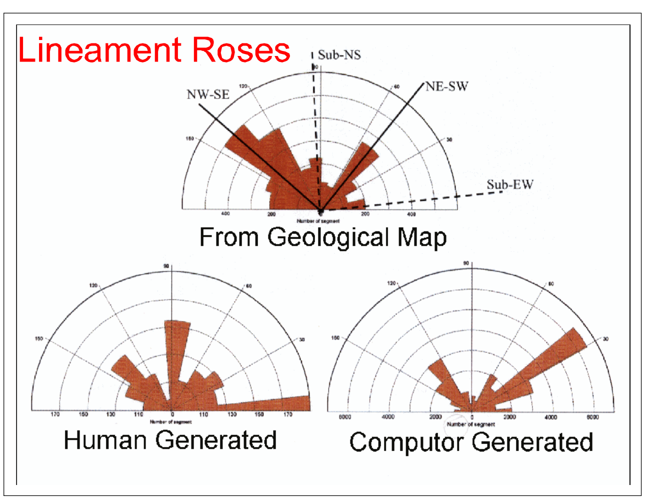
Example of human-generated lineament map
(from Landsat @ 15m pixel = fused 30m multispectral & 15m panchromatic)

* Some are realisitic (based on quick look at its accompanying geol map - which was presumably done from airphotos at ~1.5m pixel + field data)
* No indication of strength of individuals
* Confusing !!

Lineaments (computer)

Example of computer generated lineaments (same area as previous)

* total confusion !
* A 'lineament' if it is longer than 6 pixels !!
* Authors admit that many are artifacts (roads, shadow effects)
** But they have not attempted to eliminate those for the purpose of their exercise.



Rose diagrams of lineaments

Comparison of lineaments generated by different methods
(these refer to the previous two lineament maps)

"Rose" diagrams = circular histograms of directional data.

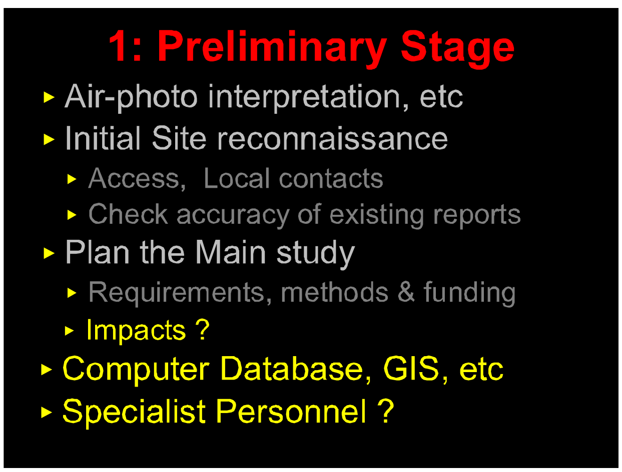
1: based on Geol Map (faults, joints, bedding)
We are assuming that the map is well done (air-photo + ground data) and that this is the 'real' situation.
2: Human generated: from landsat (15m pixel)
detects some geol trends, but with different emphasis
3: Computer generated: from same landsat.
detects a different set (including artifacts) Text says the main NE & NW tends are due to shadows!!

Discuss bias from shadow directions.
Both positive (right angles) & negative (parallel)
Tree shadow "grain"
Dolines and 'pseudo-dolines' (movement of shadow)

Fine ENE pattern visible on air-photo

This is caused by the shadows cast by trees!!

A computer might mistake these for lineaments?



Impacts

Prelim Stage (continued):

* **Impacts of the study** (see reedings on the ACKMA-CD)
Access to and within Caves
Sampling,
Do NOT trust the 'scientists'
Spreading of location information.
Pollution within caves and on surface.

see following slides for example of insensitive sampling ...

5U-1 Victoria Fossil Cave, Naracoorte. Starburst Chamber (Spring Ch). NB drill holes!
(c) Peter & Ann Bosted, 2000

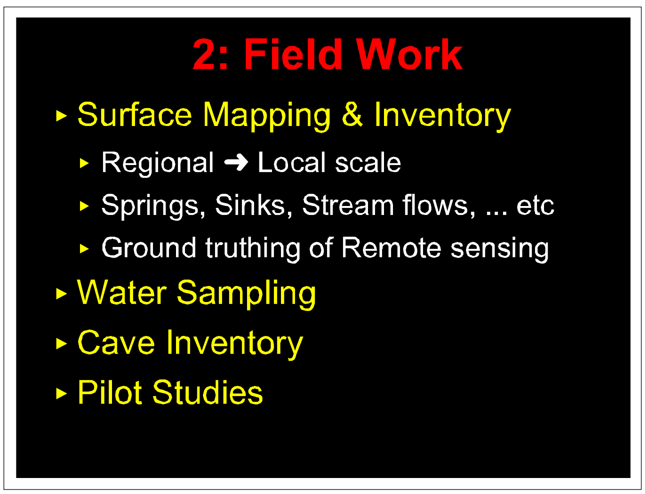
Starburst chamber

Photo was taken from a marked trail, just out of view in foreground.

Permission was given for sampling of speleothems for dating...

Sampling damage:

The drill holes are in full view of the track!
The scientists need only have taken two more steps and drilled into the back of each stalagmite, out of sight.



Fieldwork

2 Field Work:

... Discuss: Springs, sinks etc...

Sinks

Stream Sink. (PNG)

Not all sinks (or springs) are this obvious.

Can sink into bed of creek, or into alluvial banks, or into bottom of a pool. ... etc ...

For this one - note that flood flows obviously continue downstream.

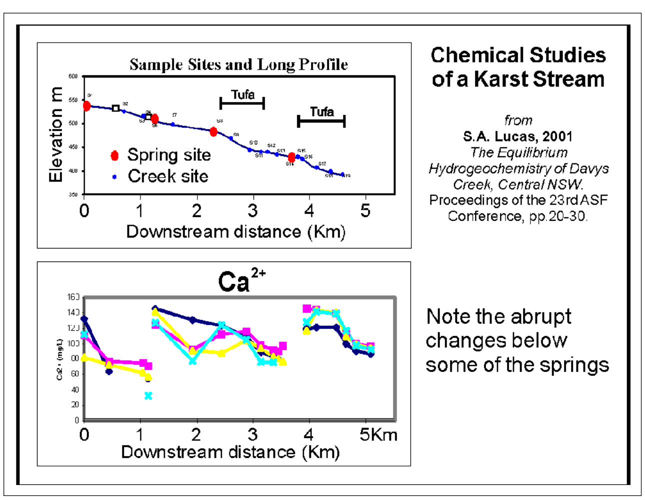
Stream sink (Drik Drik)

The obvious sink is into the cave entrance, but at low flows the water does not quite get there, it sinks into the gravel bed in foreground.

Springs

Springs can also be hidden offshore or in bottom of pools etc.

Tools for detecting them = ...
Infra-red (thermal variations)
Changes in discharge along a stream,
Changes in EC (or other chemistry) of stream waters
...

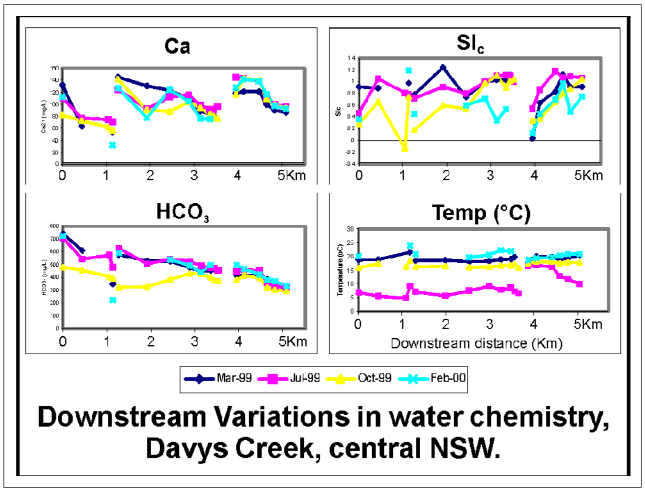


Finding springs with stream chem etc

Stream Chemistry (Davey Ck NSW)

Note how the springs can be identified by sudden changes on the chemistry of the surface water.

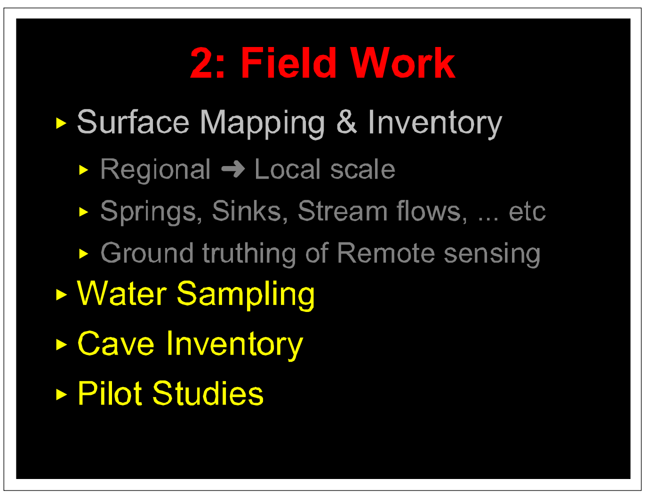
Colours = different seasons



Stream Chemistry (Davey Ck NSW) part 2

4 different chemistrys.

Note that for temperature the best contrast is in winter (purple line) or summer, rather than the equinoxes. Underground waters generally remain same throughout year - surface waters vary.



Water sampling

2: Field Work (continued)...

Discuss Water sampling ...
Need to know what sort of info you are looking for.

Water sampling.

Check with the laboratory wrt any on-site treatments or tests that should be done.

He has collected seperate samples for anions & cations and is adding HNO3 to his cation (metals) sample to stabilise the carbonate.

3: Special Jobs (examples)

- Indirect Subsurface
  - Geophysics etc (costs ?)
- Direct Subsurface
  - Drilling,
  - Cave studies
- Water Tracing
  - Conduit & diffuse flows

Geophysics & Drilling

3: Special Jobs...

Geophysics & Drllling ...

Both are expensive. Normally only used for engineering sites etc where the expense is justified.
Both have problems in detecting small cavities at depth.
BUT geophysics techniques are improving all the time.
... so watch this space !

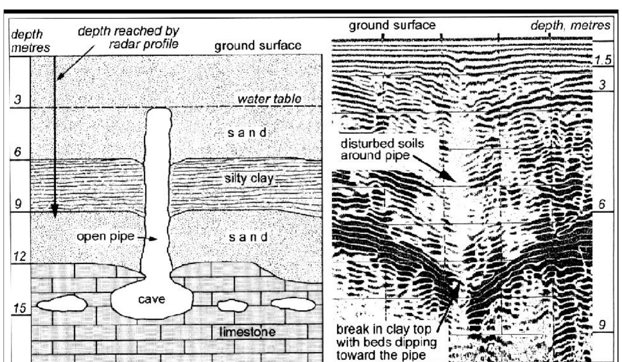


Figure 9.3. Profiles of pipes developing through soil over limestone in North Carolina; on the left, a conceptual geological section; on the right, an image from ground probing radar that could not reach below the clay; note that the ground section reaches deeper than the radar profile, on which the vertical scale is not linear, as it is time-dependant.
After Benson and Yuhr (1987).

G.P. Radar

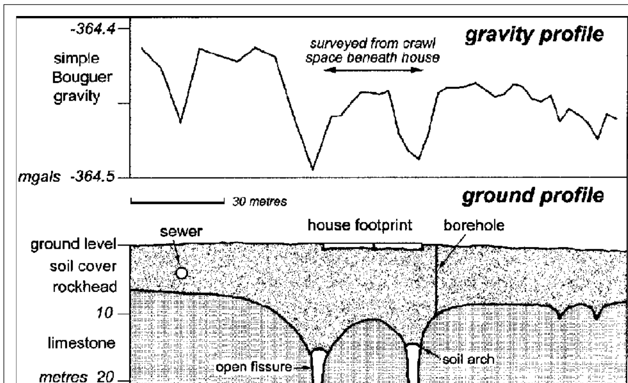
Examples ...

GPR = Ground Penetrating Radar.

Limited depth penetration:
Reasonable in dry sediments (max 30m in dry sand)
Poor in clay or wet sediments - ie useless below the WT.

Trade-off between depth and detail.

Mainly used for foundation studies (road & building)



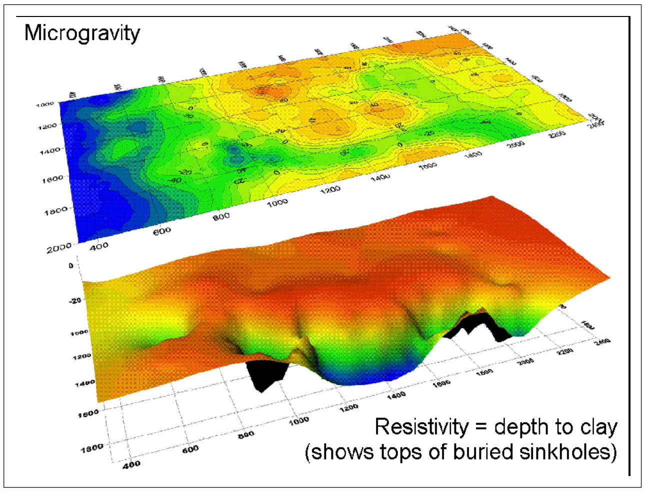
Micro-gravity study of foundation problems
(c) Waltham et al, 2005 - after Crawford et al, 1999

Examples ...

Micro-gravity
= high precision at close spacings.

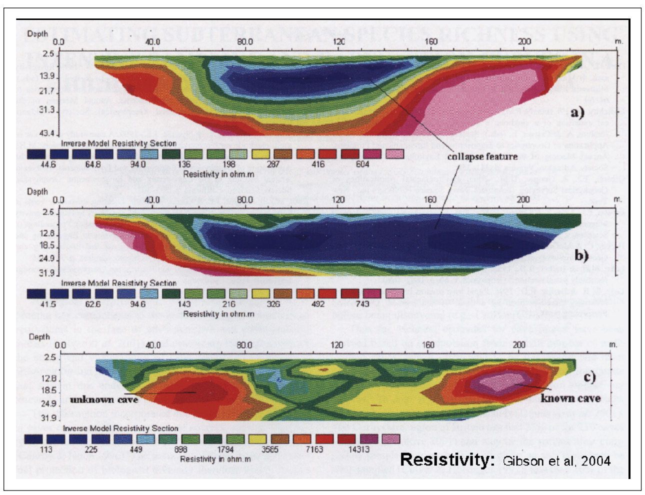
Small shallow cavities or big deep ones.

Interpretation needed.



Top = Microgravity contours (from a grid)
Bottom = Resisitivity depth probe - detected a clay "marker horizon" which has pronounced hollows. = buried sinkholes ?
Drilling confirmed this.

From Technos (2005)

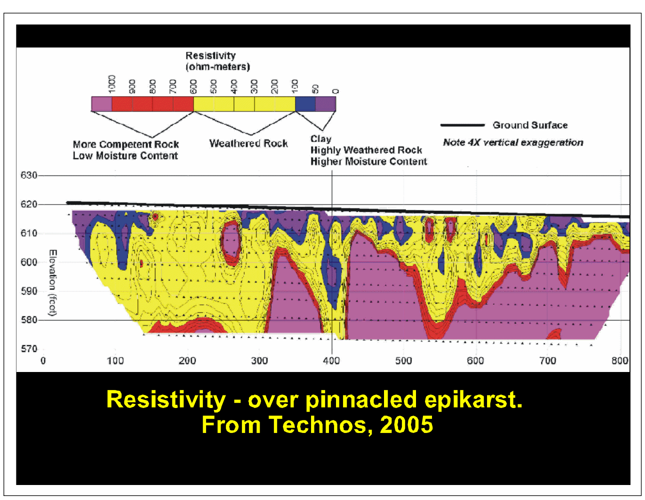


Resistivity example.

2D profile of karst features beneath glacial regolith

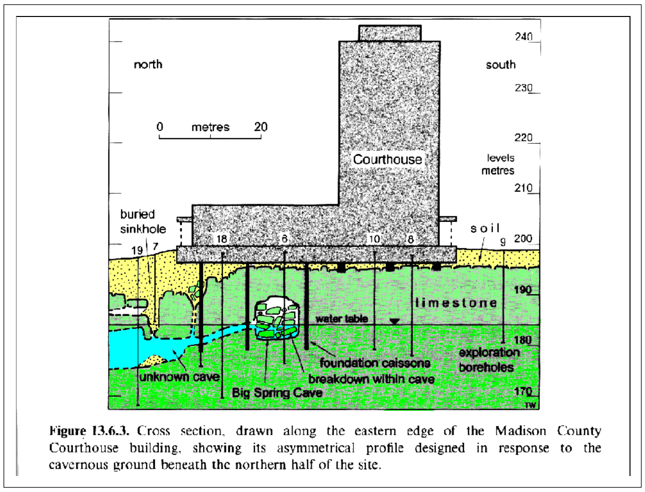
Top pair = 2 multi-electrode 'pseudo-sections' across a sed-filled doline -
blue = low res = sediments (damp?)
red = med res = limestone

Bottom = same across cavities (NB different colour scale).
green = med res = limestone.
red = v-hi res = air.



Resisitivity Example

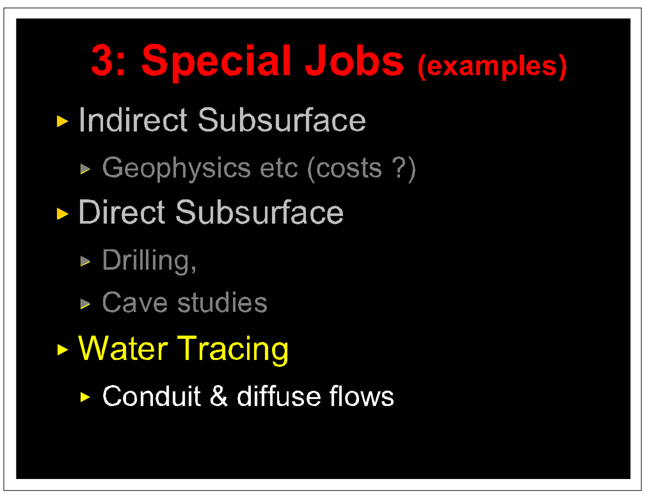
Mapping a Pinnacled Epikarst under soil (for a foundation study)



example ...
Foundation study - using drilling etc.

High costs means that geophysics and drilling are really only options in major Engineering works such as this.

An exception might be if a student with access to university equipment wants to do a thesis study.



Water Tracing

3: Special Jobs (continued) ...

Water Tracing ...

NB impacts and landowner relations (don't colour their washing water)

Permits etc

Estimating the optimum amount of dye is tricky!!

Water Tracing.

No longer able to just chuck in a bucket of dye and go looking for green water!

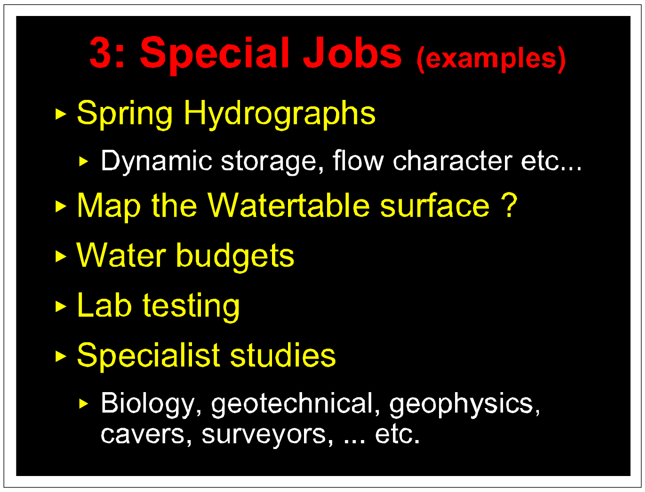
NB impacts and landowner relations (don't colour their washing water)

Permits etc (CMA...)

Estimating the optimum amount of dye is tricky!!

Modern detectors are very sensitive - but also expensive and complicated.

Serious water tracing is becoming a specialist task.



Hydrographs

Special Jobs (continued)

Spring Hydrographs

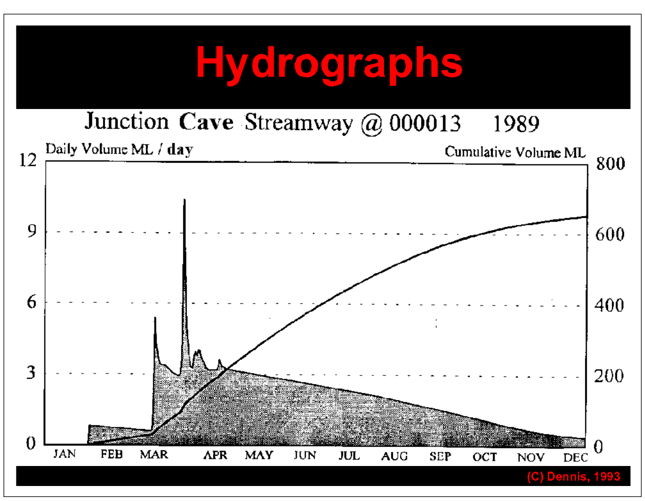
Give a variey of useful info - especially if combined with chemistry monitoring.

See next slide for typical setup ...

V-Notch Weir

For measuring water discharge.
  90 degree V-notch is traditional, but other shapes can be used in special conditions.

Note the stilling tube - enclosing the depth sensor, which dampens any ripples.
Note the sign explaining what is going on.



Hydrograph:

Example from Wombeyan (Junction cave streamway - Dennis, 1993)

Typical response is a sharp jump after a storm event, followed by a declining tail.

Hight of jump and length and slope of tail give info on relative size of conduit versus diffuse flow and/or storage effects.

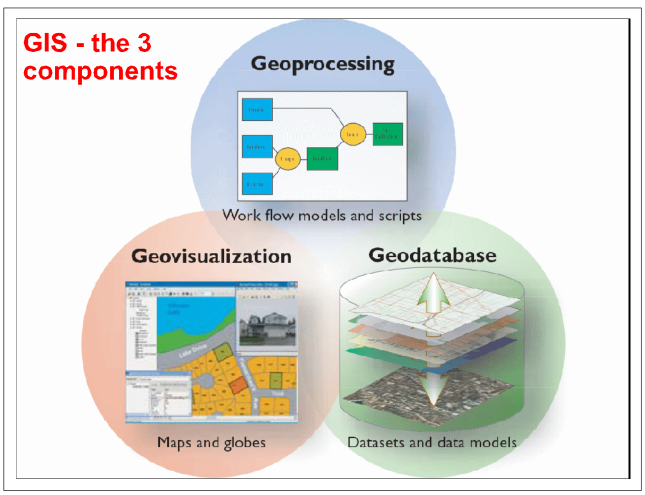
3: Special Jobs (examples)

- Lab testing
- Specialist studies
  - Biology, geotechnical, geophysics, cavers, surveyors, ... etc.
- Models
- Data Entry (GIS etc)

GIS Systems

Special Jobs (cont) ...

GIS systems.

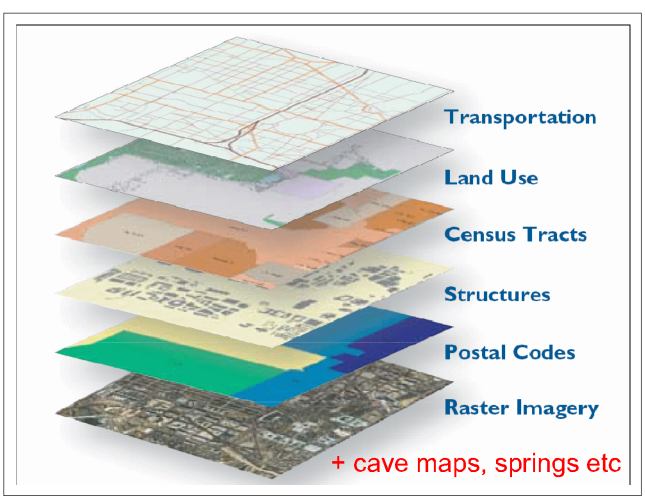


GIS:

The components and functions of a GIS system.

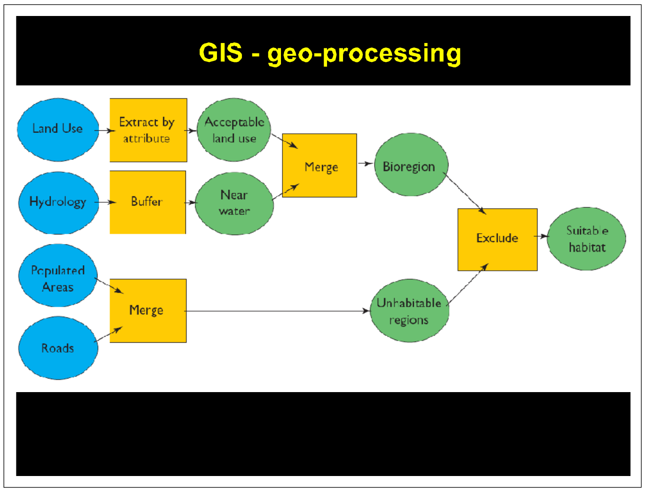
* The actual Data (attributes of points, lines, areas, + rastor images)
* The Processing engine (create NEW data views)
* The visualisation tools (create maps)

Many people use it merely as a map display and do not use all its capabilities (lack of training).



GIS:

The Actual Data
Attributes of points, lines, areas, + rastor images

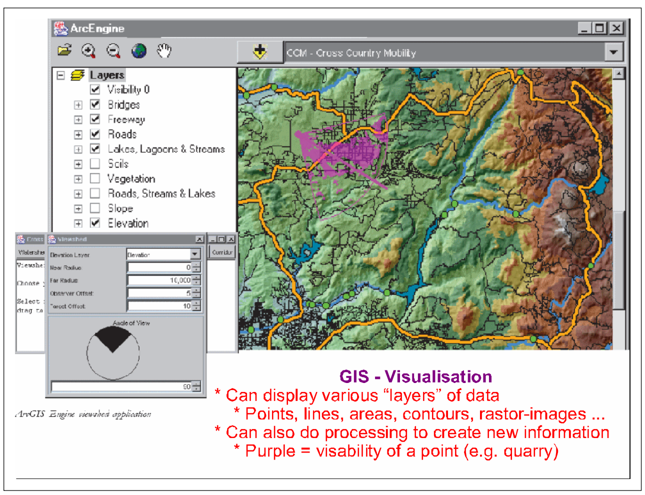


Geo-processing.

There is an array of powerfull tools for processing & combining data to create new views and answer questions.

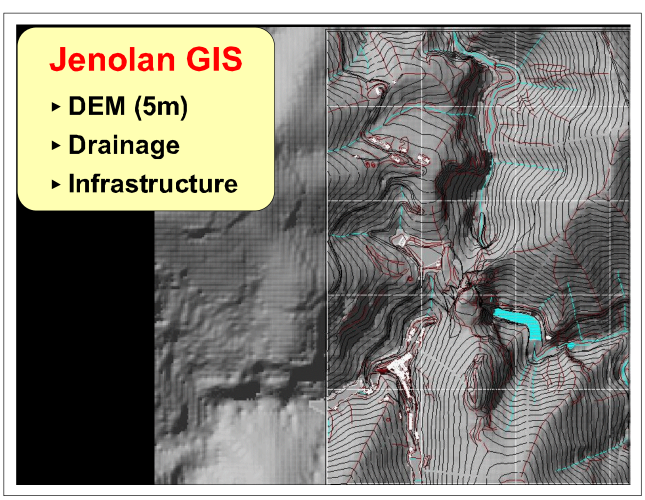
But training s needed to use this.

NB use of "Buffer" function.



GIS - visualisation

1: Example of multi-layer display ("Layers" = "Themes")
+
2: Example of a processing exercise - working out visibility of a point (eg a proposed quarry) by analysing the elevation data.



GIS: Jenolan

DEM (5m interval) combined with drainage , buildings, roads etc.

A "Visualisation" aid.

But can also use it to calculate slopes and aspects, and combine it with subsurface data to calculate overburden.

NB light is from NW (conventional) but experiment with other directions.

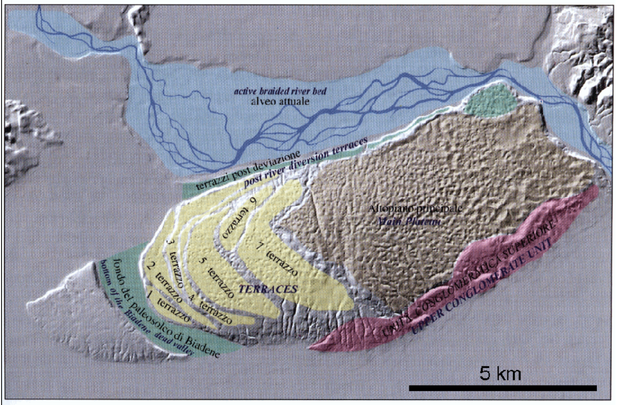
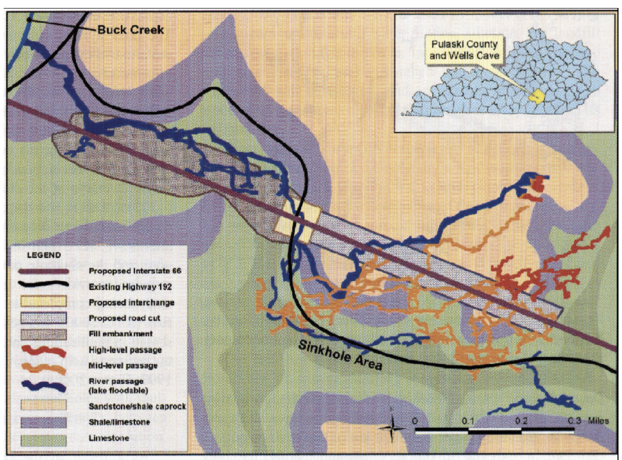


Fig. 2: Digital model of the Montello and of its main geomorphological units.
(c) Ferrarese et. al. 2005, *Acta Carsologica* **34(2)**

Another DEM (from Italy)

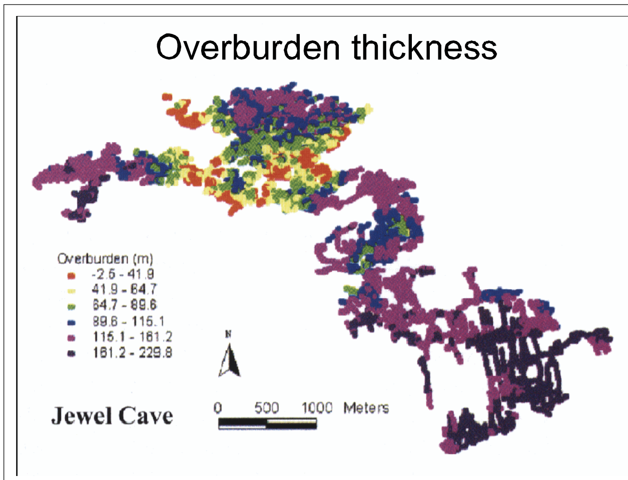
Colour overlay is geology (old valley terraces etc)



GIS: Kentucky USA. Proposed new Freeway route
* Geology
* Sinkhole areas
* Caves (coloured by depth class)

Visualisation aid.

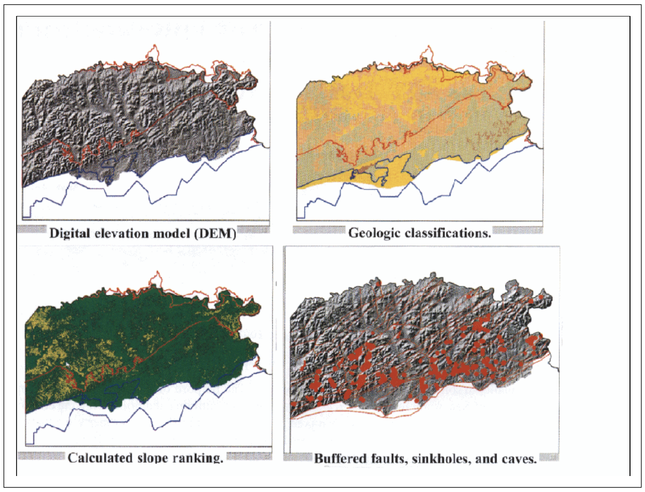
The lack of accurate depth data for the caves limits its usefullness (but that was all that was available at the time).



GIS: Jewel cave (USA)

* Overburden thickness above cave
* Was calculated by the GIS as a Combination of surface DEM elevations and Cave Survey elevations.

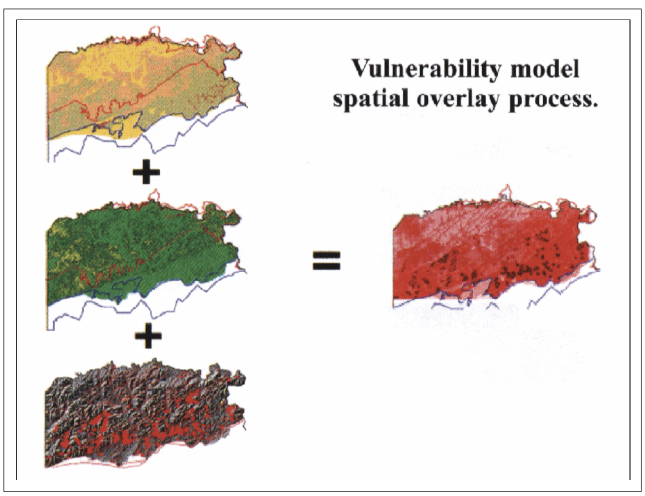
* Note shallowest range includes some passages calculated to be up to 2.5m above the surface!
* Always remember the likely errors in the data.



Part of Edwards Aquifer - Texas, USA

Maps are abt 10 km wide ??
Objective was to evaluate lands for purchase for management of aquifer intake zone. Wanted to identify areas with largest intake (i.e. vulnerable to pollution).

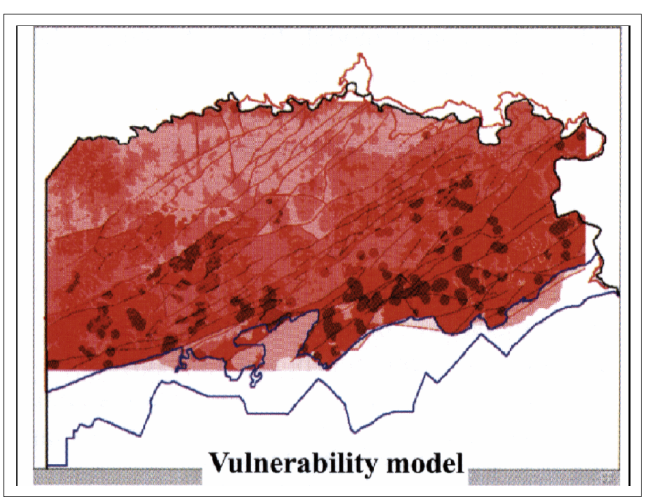
1: DEM elevation
2: Geology (classes) - classed according to porosity
3: Slope (calculated from the DEM) - low slopes have greater infiltration
4: Areas of likely enhanced recharge: Faults, sinkholes, caves. NB these are **Buffered** (25 & 50m buffers)



GIS - Combination of data-sets to generate a "vulnerability" index.

* Geology (a weight was assigned to each unit)
  Q: how good is the geol map? how realistic were the weights?
* Slope (weighted by inverse of slope)
* Input structures (buffered)

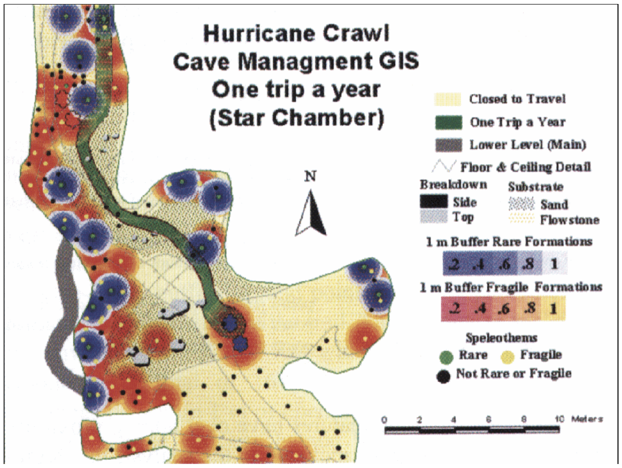
result = areas of maximum water input = areas that need best management.



GIS - Combination of data-sets to generate a "vulnerability" index.
larger view.

The combination indicates areas where purchese and management will be most effective.

A further step, involved biology and property boundaries
 * elimated properties less than 60 acres (too small to be useful)
 * enhanced values for properties that are adjacent to others of potential value
   (better to buy several adjoining prperties and manage jointly, than to buy isolated properties)



GIS: Cave management (sensitive areas)

Managing an extremely sensitive cave.
For most caves, This level would not be needed.

* Individual speleothems categoriesed as:
  * Rare types Folia, pendulites, ...
  * Fragile straws, frostwork, helictites ...
* Buffered (1m radius)

Used to check appropriatness of marked trails and decisions about frequency of visits.
* Existing trails were OK
* used as a tool to test proposed new tracks.
* High level (out of reach) formations were removed from analysis.

Q: How much damge during the detailed survey?
A: Much of the recording of formations was done in the intiial cave survey, augmented by later special visits.

4: Analysis & Consolidation

- What does it all mean?
  - 1 day in field = 1 week's office work
  - Create & test hypthesies
  - Produce preliminary maps & reports
- Tidy up field Work
  - Always allow time for this

4: Analysis & Consolidation

4: Analysis

5: Reporting

- **Work it all out**
- **Audience ?**
- **Text**
  - **Executive Summary**
  - **Introduction**
  - **The data**
  - **Interpretation**
  - **Conclusions**
  - **Recommendations**
  - **Bibliography**
  - **Acknowledgements**
  - **Appendixes**

5: Reporting

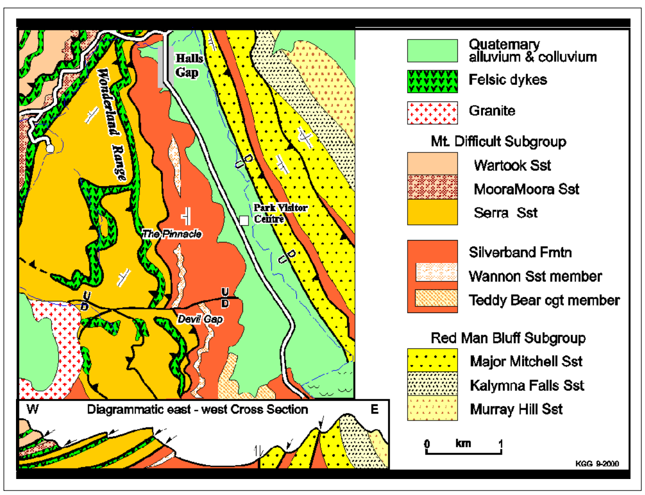
Reporting

Maps

Reporting:

Map & Diagrams.

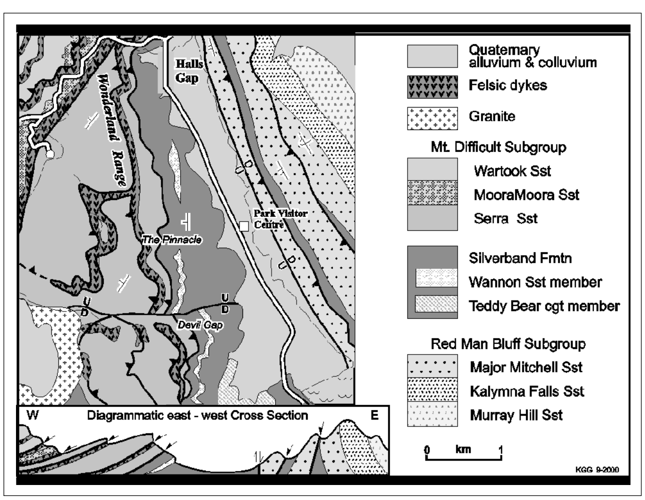
NB in paticular - use of colour and patterns.



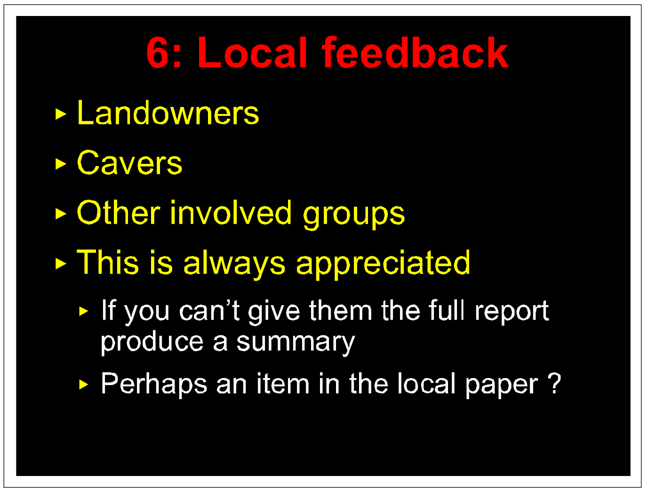
Use of Colour & patterns in maps & diagrams.

* Some people are colour blind.
* Many have difficulty distinguishing colour in thin lines (esp green : blue)
* many will be working with a grey-scale photocopy

SO - design with both patterns AND colour
TEST with a grey photocopy to see how it works.



Same map - in GREY !!!



Feedback to locals

6: Local feedback.