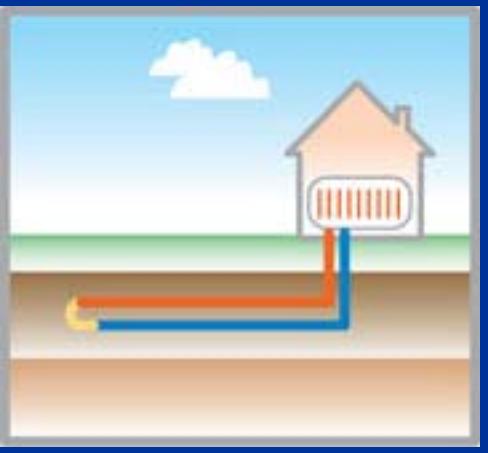
Thermal Needle Probe Conductivity Testing

For The Design of Horizontal Ground Loop Arrays

June 7th 2011



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SOIL HEAT

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Topics

- Horizontal array design – Problems & issues
- Case study – disaster!
- Borehole TRT and the Horizontal equivalent?
- The SoilHeat Technology
- Testing
- Case studies
- Conclusions & thoughts

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Problem, What Problem?

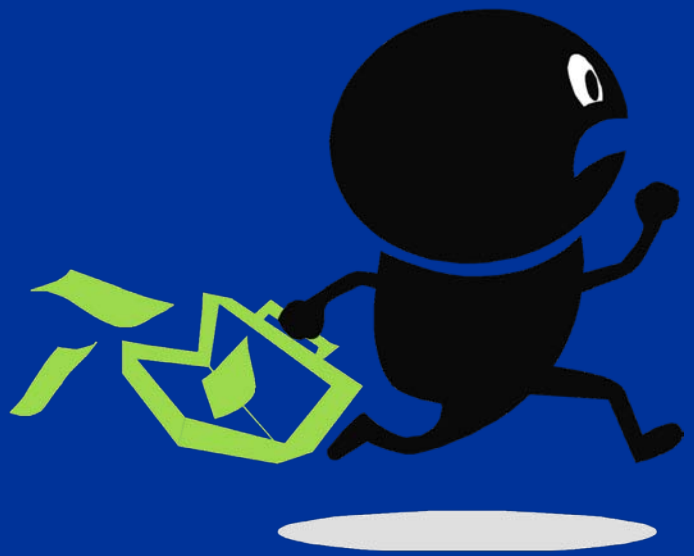
- Installers generally from one of the 'trades' with little training or understanding of thermal properties of soil. Why would they have?!
- Heat pump training courses pay lip service to ground source design and relevance of soil properties.
- Design packages have a few soil types;
  - Dry soil
  - Moist soil
  - Rocky soil
  - Normal Soil (!)
- Not representative – & does anybody check anyway?
- It takes years of training to recognise soil types

Problem, What Problem?

- There are no Soil conductivity maps
- Even an experienced geologist can't estimate soil thermal conductivity (λ) from looking at a sample
- Cheapest tender wins!
  - How does installer increase his chance of winning?
  - *Select the soil design option from drop down list that requires least pipe length for least cost.*
  - But … will it work long term?
- Lack of quality building specific data
  - Building heat loss and heating loads
  - Operational hours (domestic use 2400 hours or is it 3600 hours?)
  - Design temperatures & site temperature 'swing'
  - Distribution system

Outcome if design is wrong?

- Building not getting warm = angry homeowner
- Brine temperature too low
- Low system efficiency (at best)
- High running costs
- Nobody taking responsibility
- Who to blame or fix the system?
- Potential for a poor reputation – industry as a whole?
- Oh dear…



Case study – Poor practice

- 300m^2 barn conversion installed early 2010
- No site specific geological or soils review
- SAP report completed – but for a different barn! 10kW system selected
- Building contractor leading project using local plumber to install heat pump & array
- Manufacturer specified the heat pump and ground array using 'rules of thumb'
- Nobody considered heating load and operational hours
- Nobody sure how much ground array pipe installed

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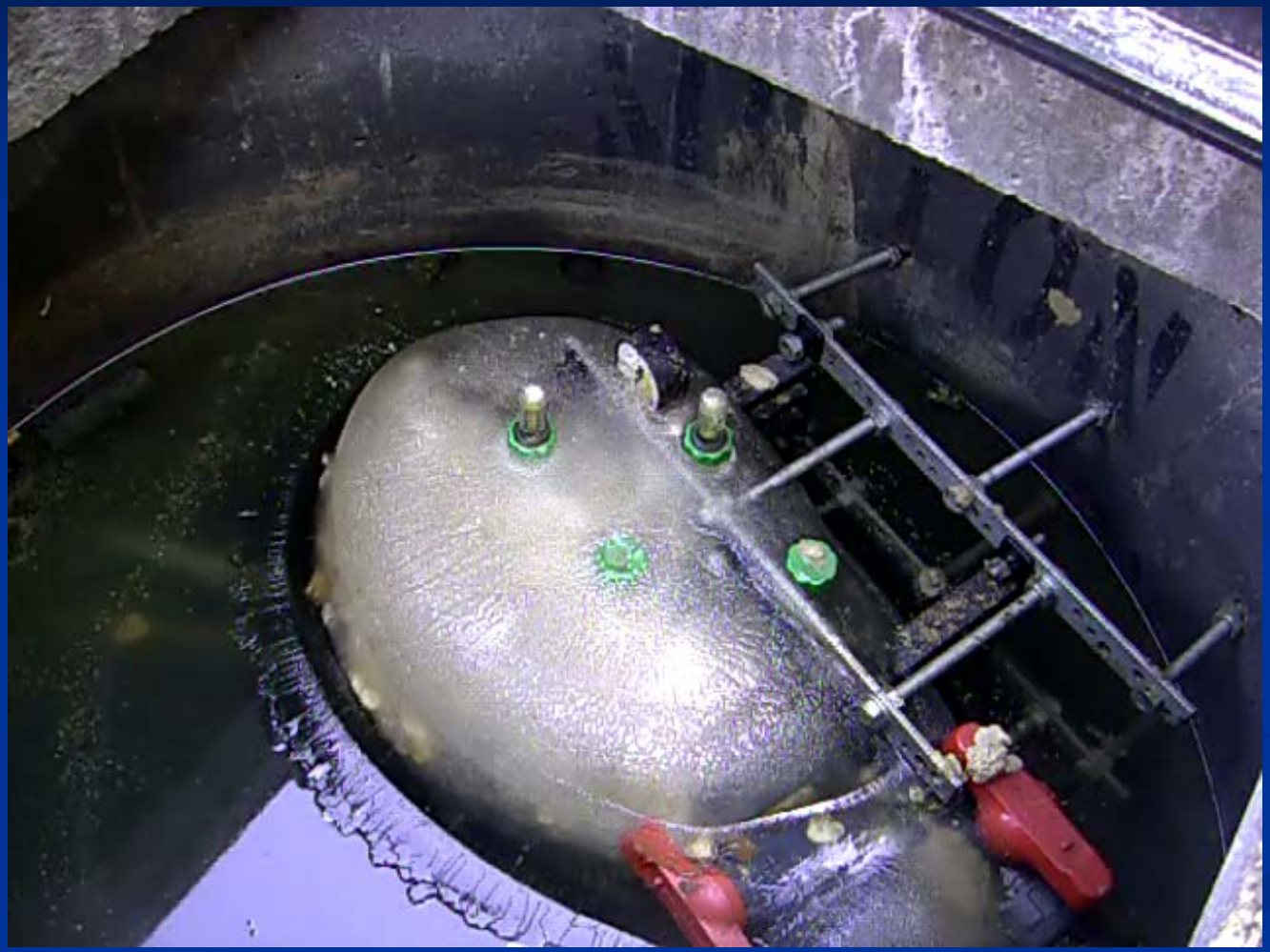
The Result?



An iceberg in the manifold, frozen pipe array, no heating or hot water and a very angry & bewildered home owner

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What Can we do about it?

- Borehole schemes have the option of a TRT to measure in-situ thermal conductivity (λ)
- Borehole λ is used in EED or GLD with Building load data to design a suitable array
- SAP assessment or other good quality building heat & cool data. VITAL.
- SoilHeat offers the potential to measure SOIL λ
- Not the only variable but it is VITAL

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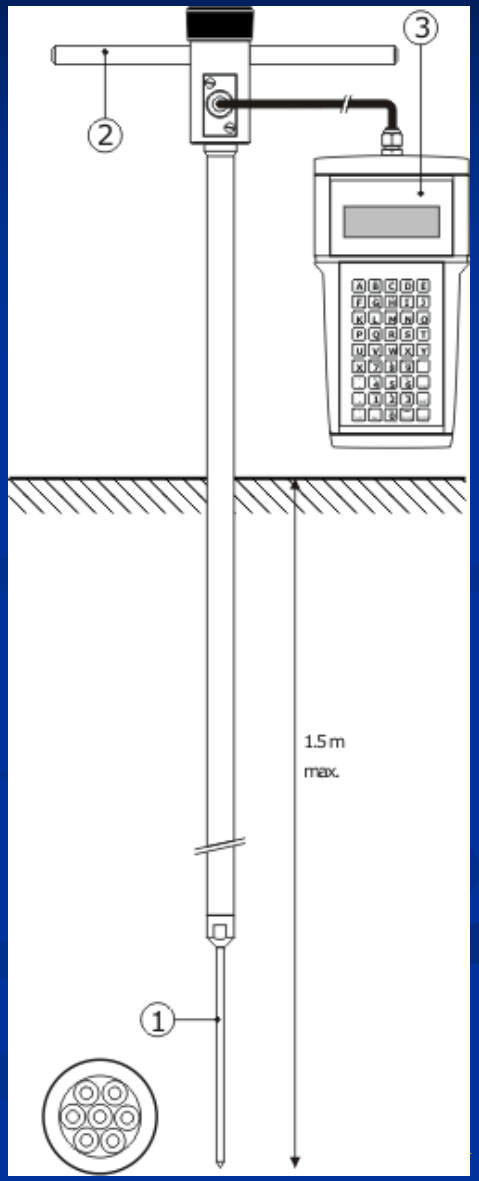
The Thermal Needle

- Thermal probe used for field work in the power cable industry
- One man operation
- Probe inserted into auger excavation or base of trial pits
- Control system provides power & data storage
- One survey day sufficient for most applications



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Technology

- voltage is applied to a resistance element in the probe causing it to heat up
- 2 power settings available
- System waits for temperature stability
- constant heat power propagates radially into the surrounding soil
- Temperature T of the probe increases with time monitored over 5 mins
- Radial heat conduction is assumed, T increases in proportion to the log of time, *t*, according to "line source" approximation

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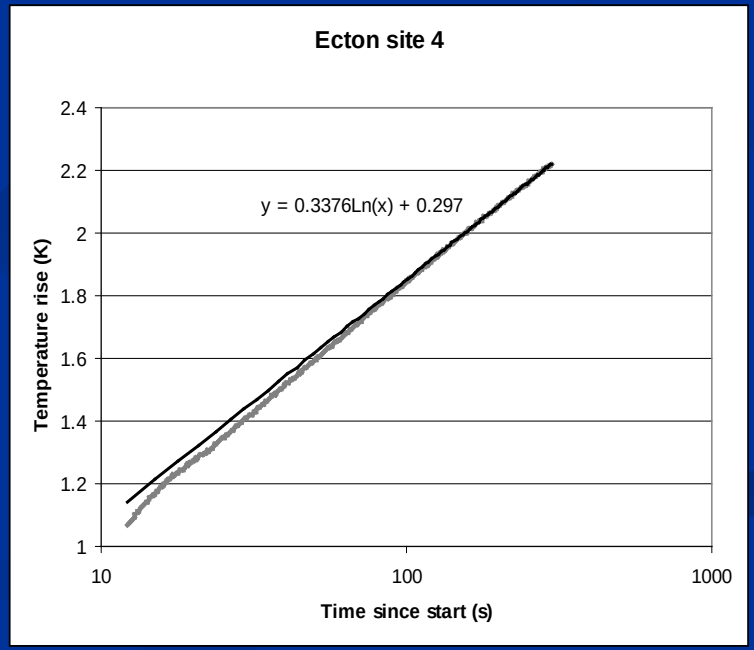
How is λ derived?

- ΔTemp is plotted against ln *time*,
  - In the same way as a TRT, a straight line can be drawn, with gradient P/4Πλ, where λ is soil thermal conductivity. Knowing the power P, λ can be calculated

A typical heating cycle has a duration (H) of 300 s. In the field, the probe's readout unit ignores the first half of the test data and automatically calculates the thermal conductivity for the intervals;

0.5*H* to *H*, 0.6*H* to *H*, 0.7*H* to *H* and 0.8*H* to *H*. An average of these results is calculated for each determination.



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Field measurements

- The thermal conductivity λ is representative of a small volume of soil around the probe: a cylinder of soil 100 – 300 mm diameter.
- A representative assessment of a site's "bulk" soil conductivity (i.e. a single value that can be used in design software) requires a significant number of individual determinations distributed across a site,
- careful consideration of the statistical distribution;
- Details of statistical treatment can be seen in;

"**Field Determination of Shallow Soil Thermal Conductivity Using a Short-Duration Needle Probe Test" Banks, Findlay & King.**

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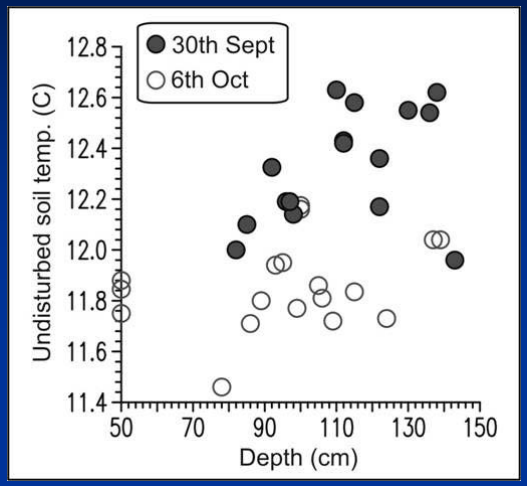
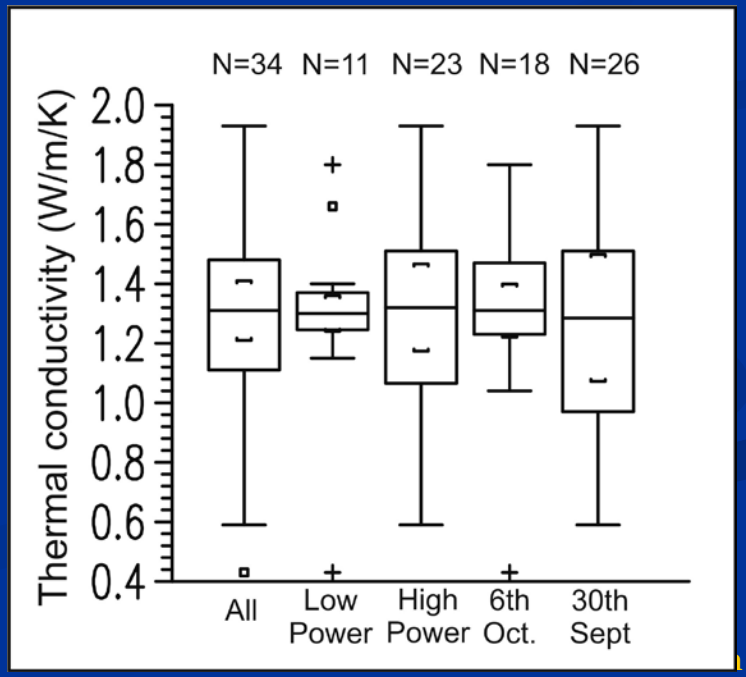
Case study 1 'Ecton'

- Distribution of soil temperature with depth measured on 2 days

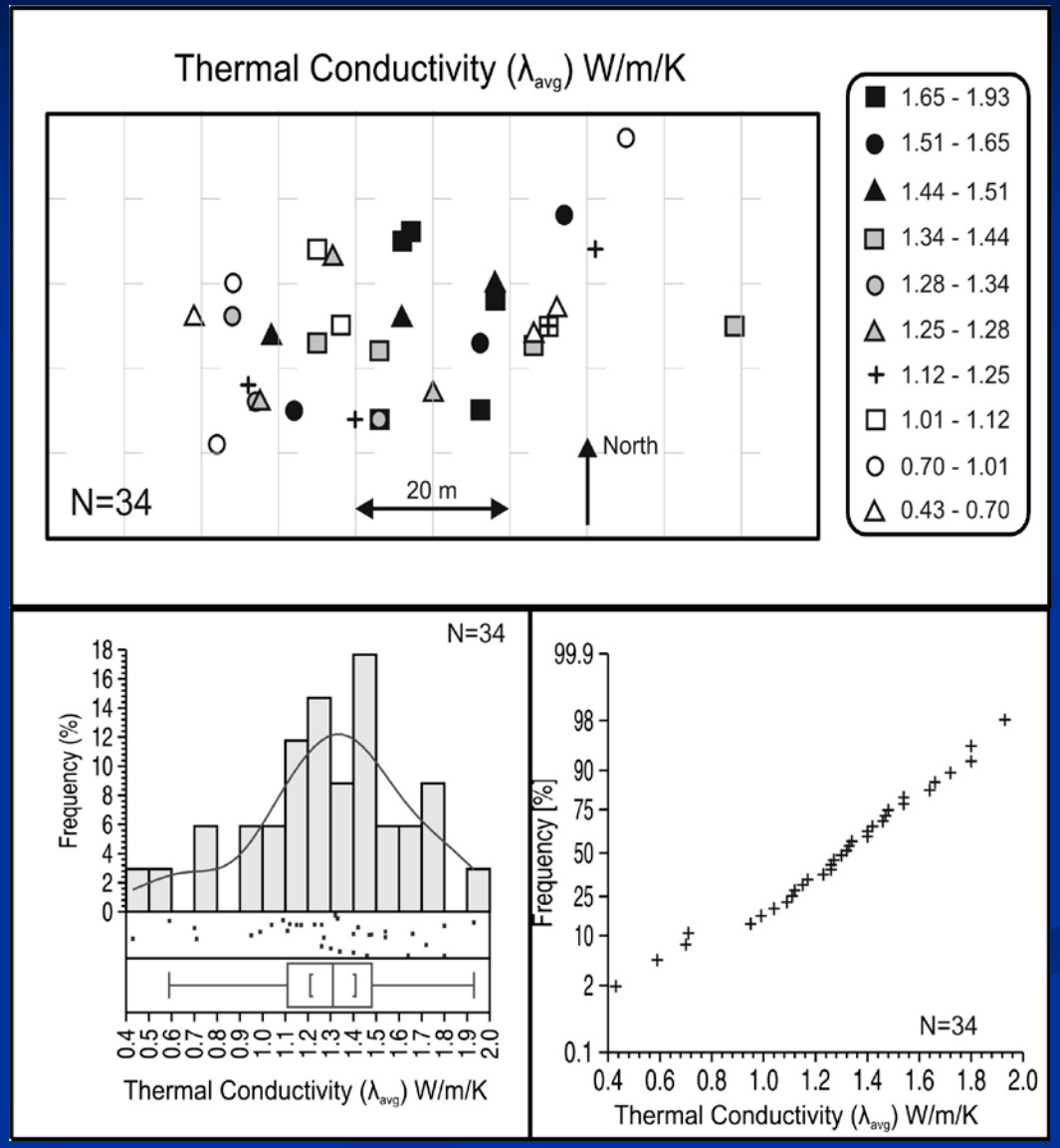


- Distributions of thermal conductivity values determined on 2 days. Values determined at high-power and low-power settings.
- Suggests power setting or starting soil temperature NOT factors on variation of λ



Case Study 1 Field Results

- Spatial distribution of thermal conductivity determinations; note high variance!
- No clear pattern. Variation likely due to soil composition & moisture
- Data set approximately 'normally' distributed
- Discard measurements >10% SD
- Bulk $\lambda = 1.22 \pm 0.12$ W/m/K



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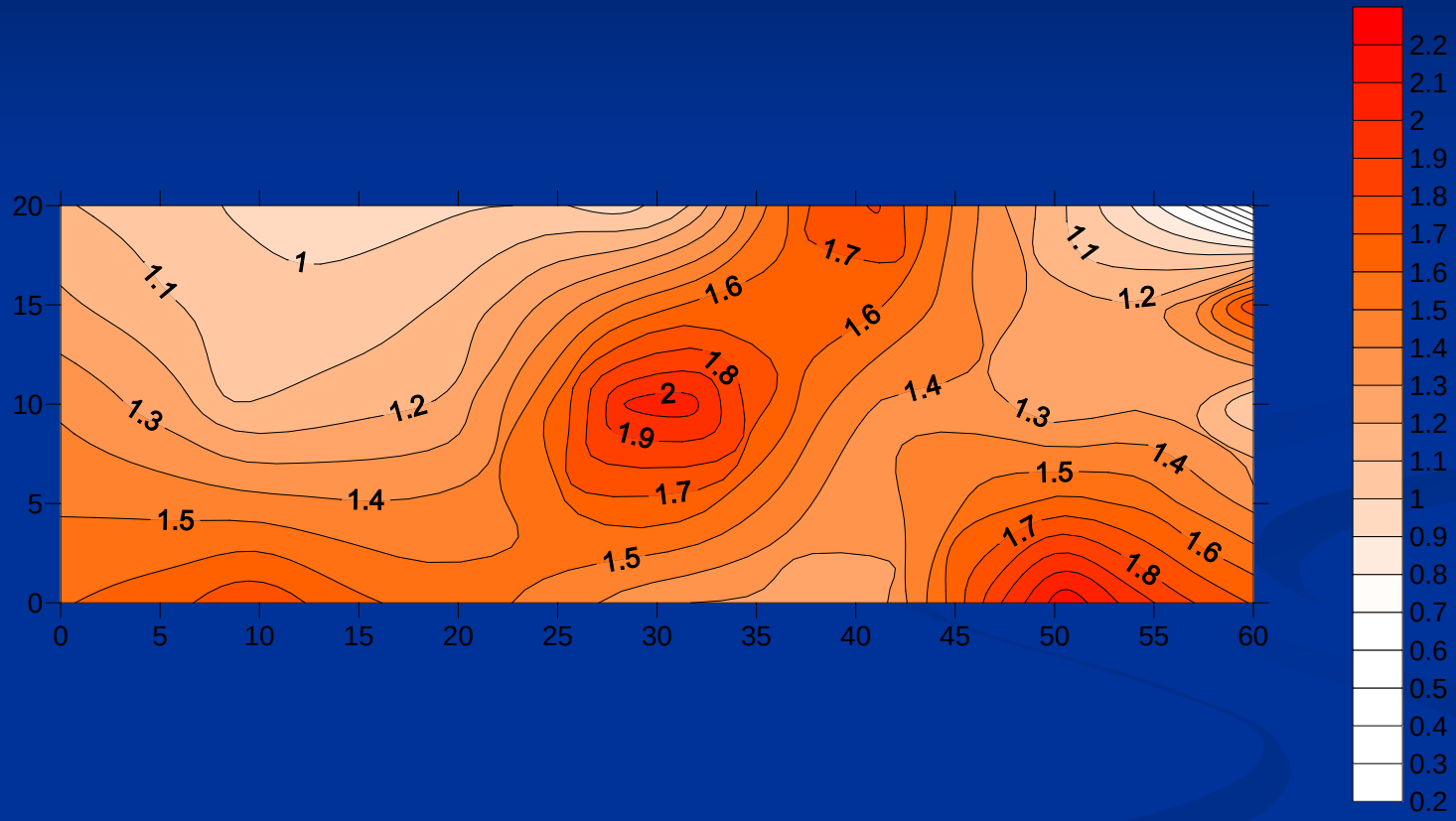
Typical distribution of Soil λ



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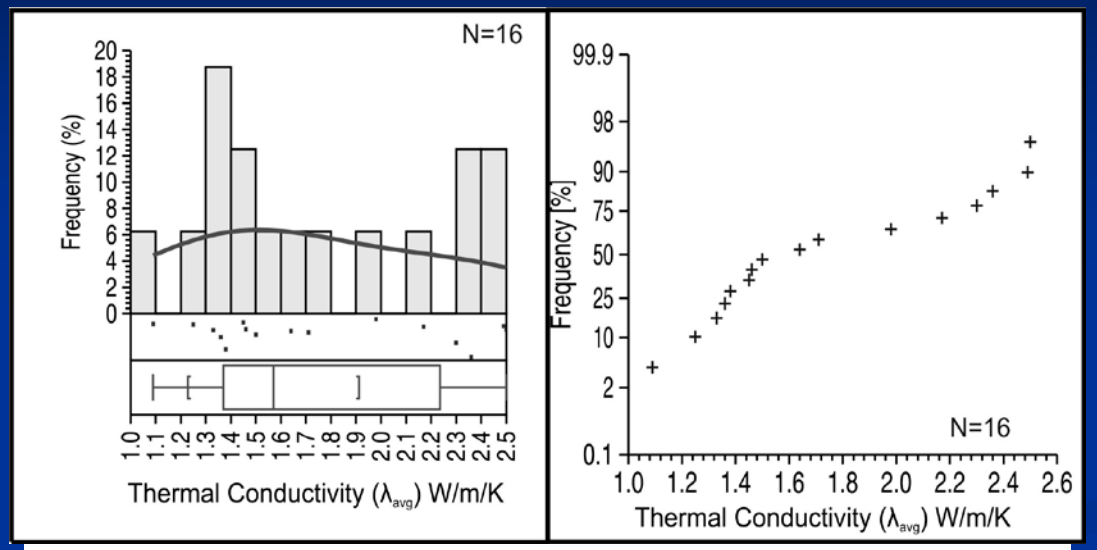
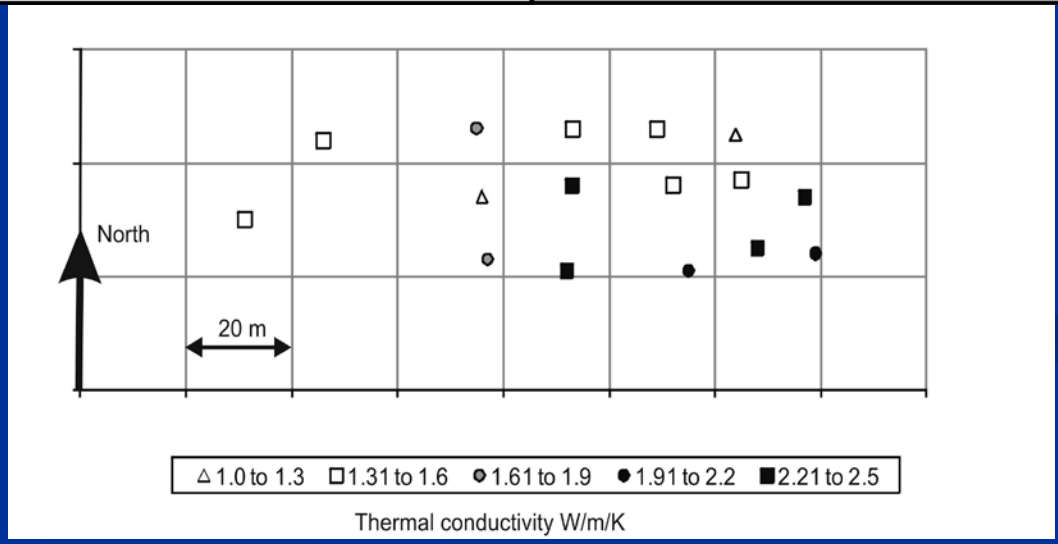
Case study 2 Whatstandwell

- Data set *not* normally distributed
- Bimodal soil distribution
- Where would you install your ground array?
- Discard 'outliers' and take geometric mean;
- Bulk λ =1.65 ± 0.23 W/m/K





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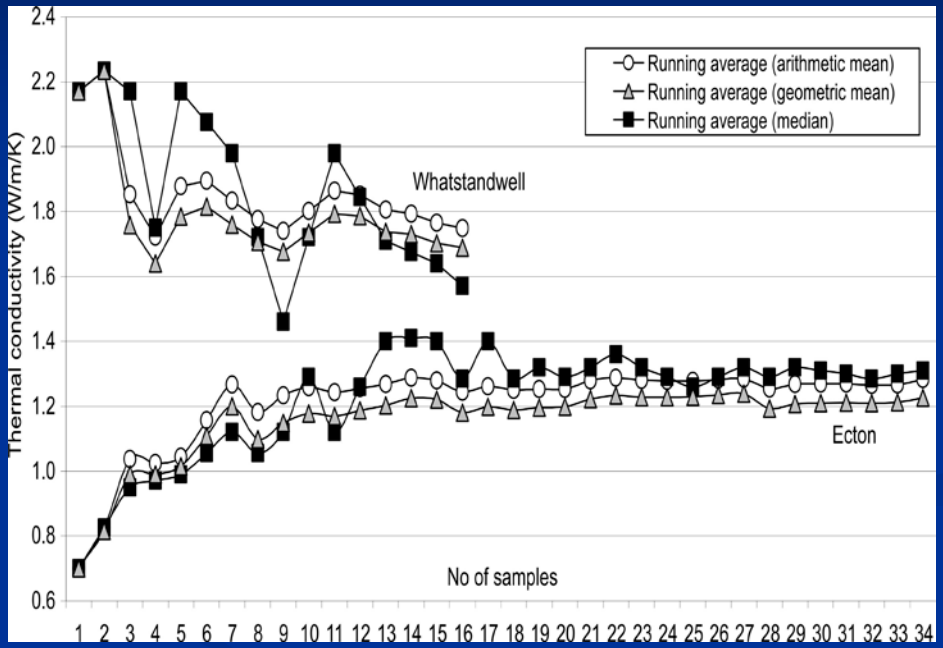
How many measurements ?

- Running averages suggest, no fewer than 12
- In some cases (Whatstandwell – mixed soil profile across the site) more would be needed
- Survey achievable in 1 day
- Geometric mean of measurements provides best estimate of bulk λ



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Conclusions

- Measured value of λ does not depend strongly on;
  - whether determinations are in trial pit or manually drilled auger hole.
  - undisturbed ground temperature.
  - Whether low or high power setting of the instrument is used.
- High variance of measured λ – even on small sites. Suggests current 'rules of thumb' have little relevance
- A minimum of 12, and preferably 16, measurements required across a site of about 100 x 40 m
- Each measurement takes about 20 minutes
- In a large area – locate area with most favourable λ?
- In a limited area; how much heat can I extract ?

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Points to ponder

- SoilHeat survey is a good step forward, but;
- Bulk λ not only important parameter, others include;
  - What is the system required to deliver?
  - Temperature swing at the site
  - Soil thermal diffusivity
  - Depth of loop burial
  - Type of pipe installation
  - Soil moisture
- Further testing & research in progress

SoilHeat surveys are now available commercially

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Any Questions?

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