



**A robust code for geothermal reserves
and resources estimation**

15 June 2007

Jim Lawles

(SKM)

**Chairman, International Geothermal Association
Committee on Reserves and Resources**

Acknowledgements

- > Geoscience Australia and SKM have provided funding
- > Technical contributions from:
 - o Tony Menzies
 - o Jim Randle
 - o Allan Clotworthy
 - o Graeme Beardsmore
 - o Fiona Holgate
 - o Greg Ussher
 - o Constructive comments from many others

Background

- > In Australia the AGEG is taking a lead role in defining a code for reporting of geothermal resources and reserves
- > An initial seminar has been held, a draft discussion paper produced, further discussion at HDR conference
- > Intention is to have a code in place by end 2007
- > Parallel activities:
 - o IGA committee - to produce agreed approach by April 2008
 - o TSX – forming working party now
 - o NZGA – supportive, want to apply agreed methodology to new national assessment
 - o USGS – doing national inventory, liaising with

Why: Having Sound Reserves Definitions is Increasingly Important For Geothermal

- > Lenders and stockmarket investors
 - o Traditional requirement for resource potential analysis
 - o Increasing numbers involved in geothermal financing
 - o Quantifying Resource and Project Value through the development cycle

- > New technologies and resources emerging
 - o HDR, HFR, EGS, low temperature



Scope

- > “Conventional” geothermal projects in other countries
- > Existing projects as well as green-fields
- > Need to allow for energy already extracted
- > Temperature range 100 to 370 °C in situ
- > Focus on electricity generation not direct use
- > But methodology readily adaptable to other situations

Types of Geothermal Resource

- > Can divide into “natural” and “EGS” types, or “magmatic” and “amagmatic”
- > More complex classifications possible
- > But to emphasise common factors concentrate on:
 - o Presence of fluid
 - o Temperature
 - o Permeability:
 - Convective
 - Conductive



Reporting vs. Guidelines

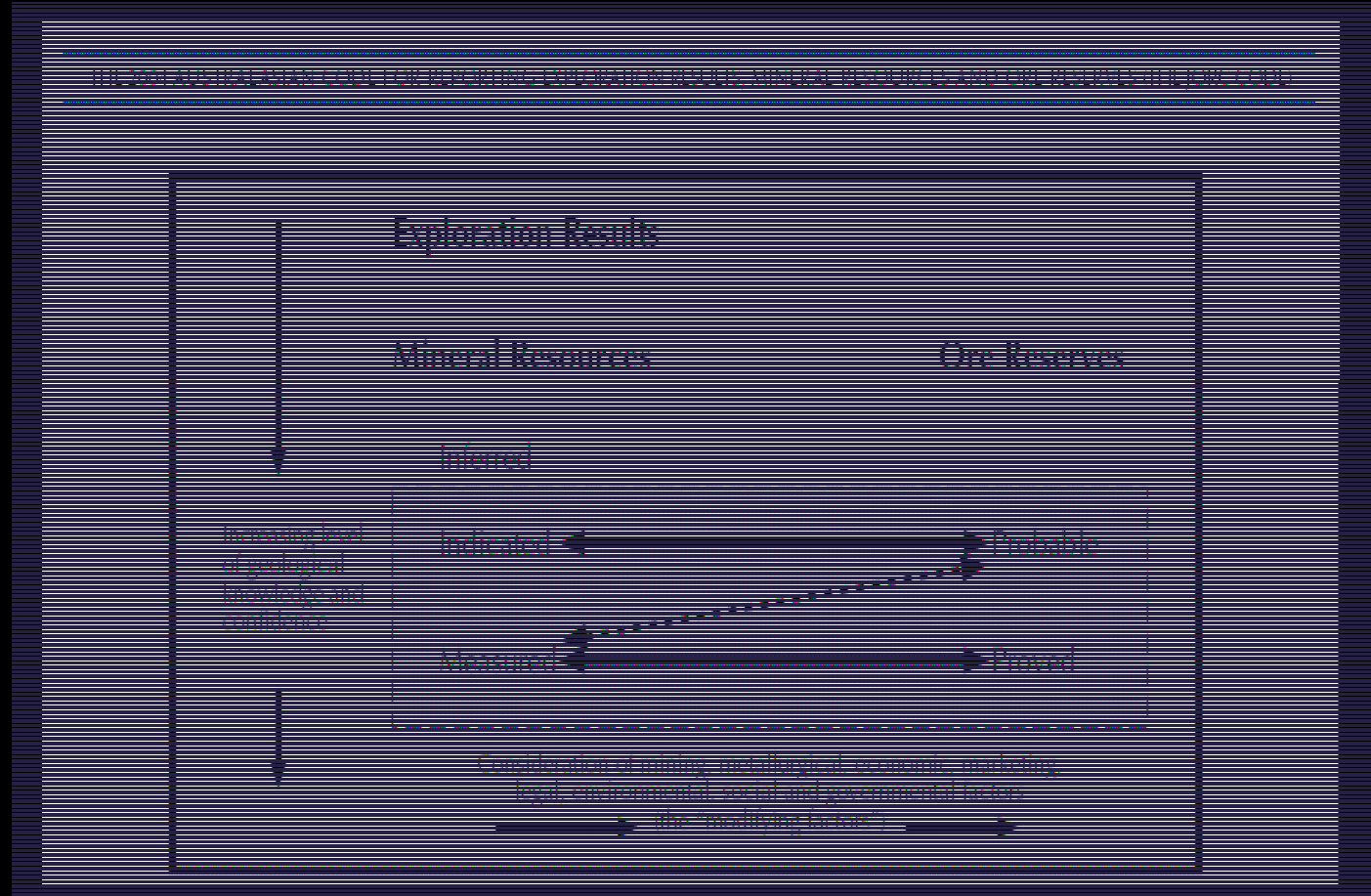
- > Need to distinguish: definition is at two levels
- > **Guidelines** for methodology: a comprehensive outline of *preferred* methodology and default parameters, not mandatory
- > **Reporting requirements**: much shorter document, has minimum *mandatory* requirements
- > Considerable scope left for individual judgement in how guidelines are applied
- > Relies on the professional judgement of an **accountable** “Competent Person”, who would often be independent from the project proponent

Two Dimensional Categorisation

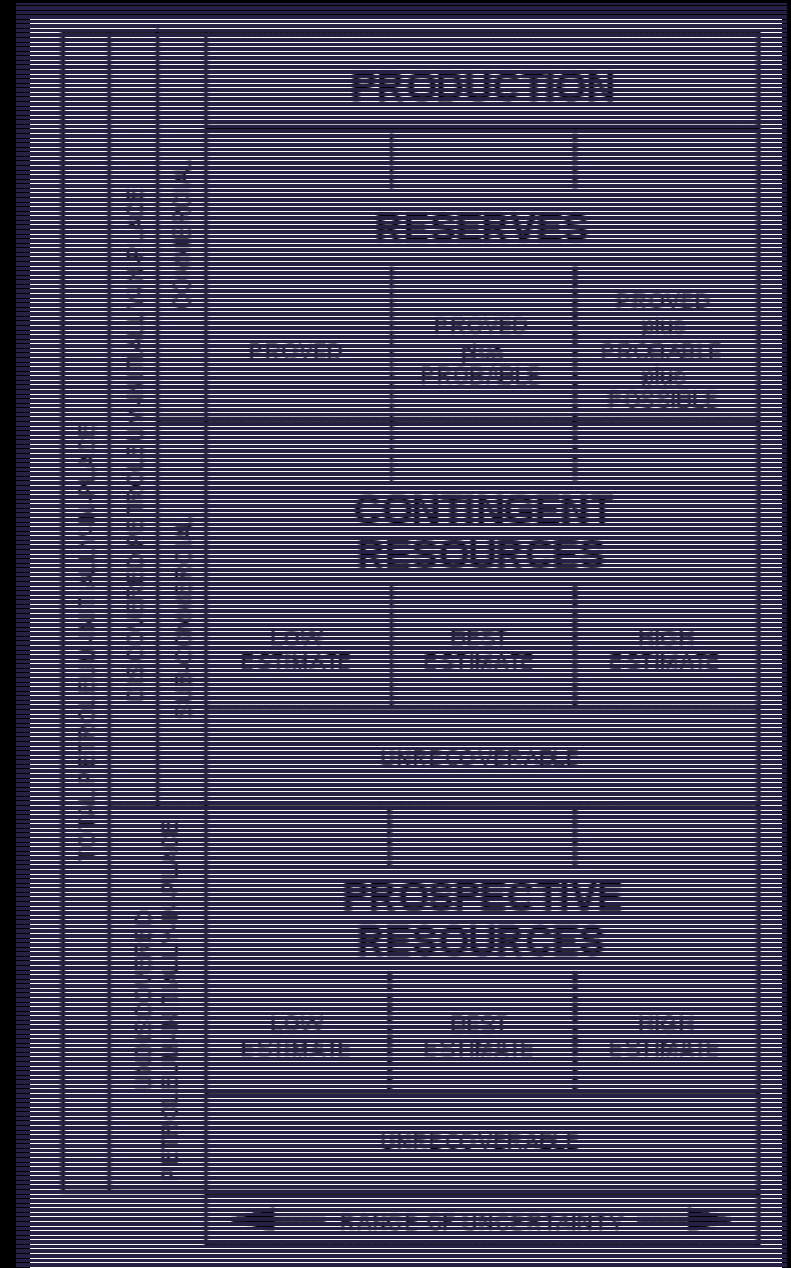
- > “Geological” Knowledge and Confidence
 - o The resource characteristics
 - o How reliably they are defined
 - o Typically : “Proven – Probable – Possible”

- > Commercial Extractability
 - o What can be commercially extracted - now
 - o What may be extracted under more favourable conditions
 - o Typically:
 - Reserve = commercial
 - Resource = as yet sub-commercial

Canadian Institute of Mining (CIM) and Australian Joint Ore Reserves Committee (JORC) Code for Minerals



SPE – Oil & Gas



Special Features of Geothermal

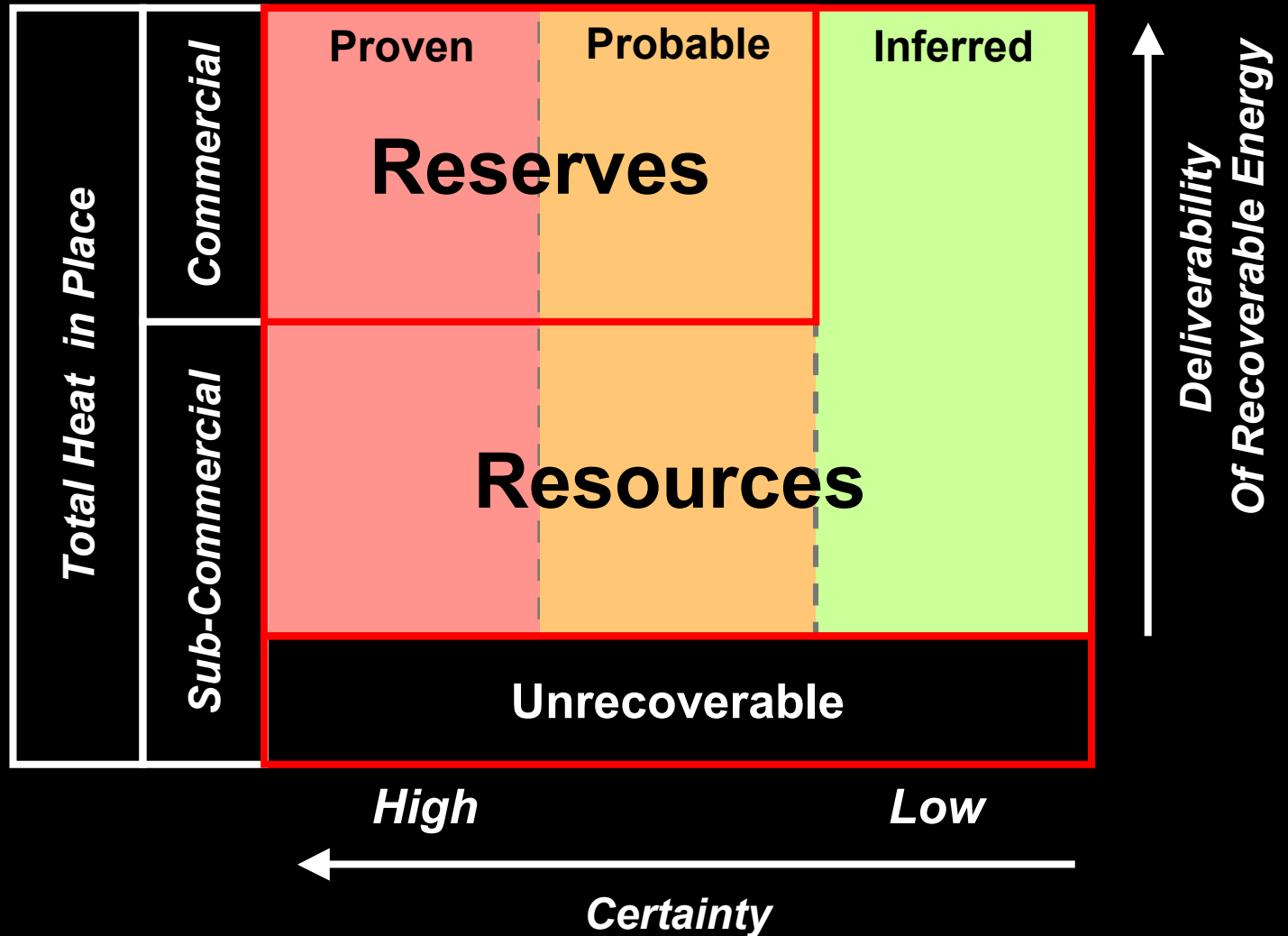
- > Potential for recharge on a human time scale in some resources
- > Power prices are site specific
- > In the case of HDR/HFR systems, may not be necessary or practical to tap all of the resource because of their vast size
- > Technology is rapidly changing



How: Proposed Approach

- > Use a 2-dimensional categorisation as in O&G and minerals
- > Draw on SPE for **principles & guidelines**
- > Draw on JORC for **implementation and reporting code**
- > Restrict use of “reserves” to commercially-extractable resources
- > Allow a range of estimation methodologies
- > But require a certain level of definition of the methodology/assumptions in each case
 - o Relate cut-off “grade” to a specific power price and/or technology

Proposed Classification



Commercial Criteria

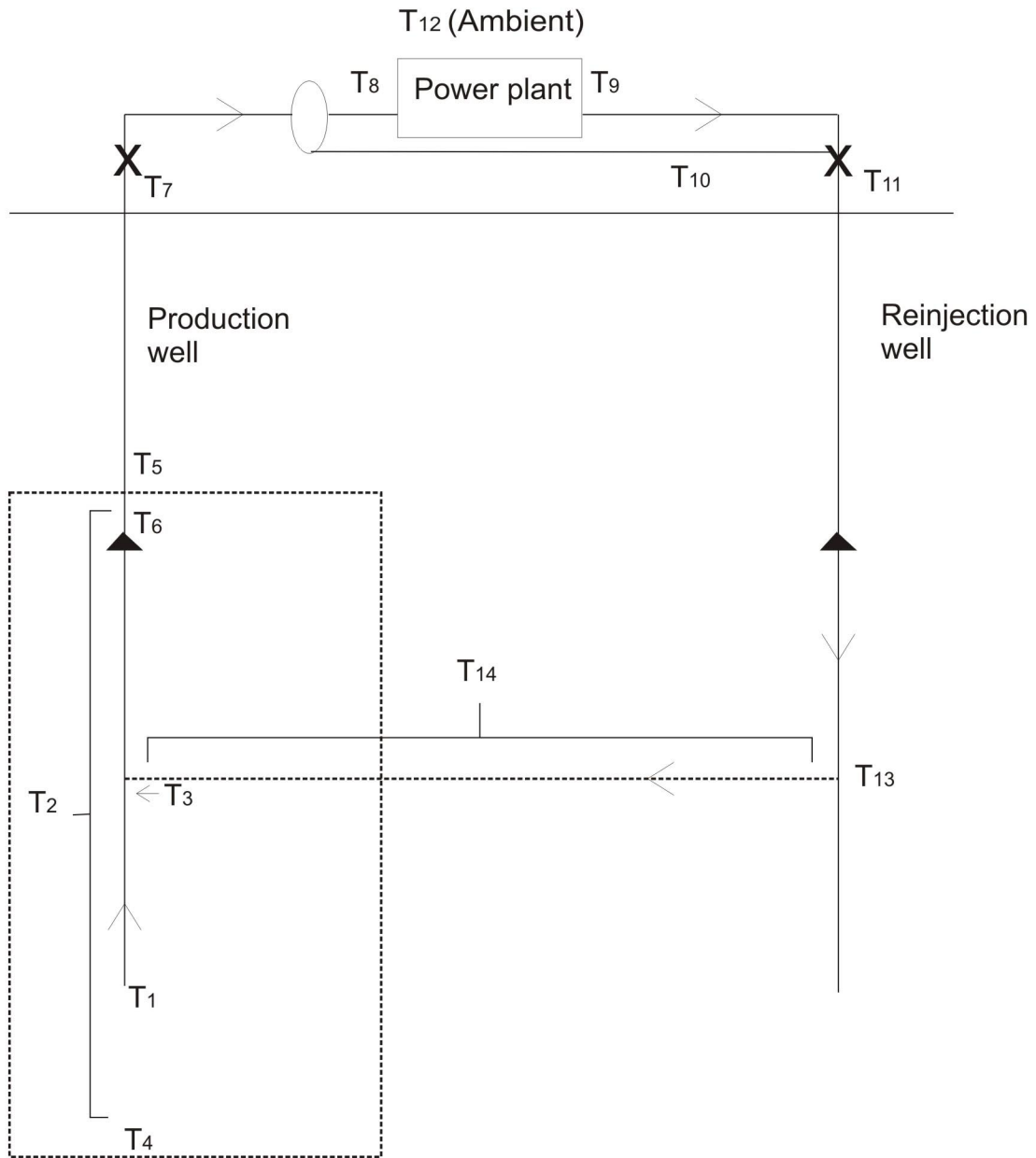
- > Electricity has severe limitations on its transportability
- > Hence unlike minerals and oil, which have a definable international \$ value, the value is **country-** and even **site-specific**
- > This affects:
 - o The economic drilling depth and hence the reservoir volume
 - o The cut off grade
 - o The plant type that is affordable and hence the efficiency

Commercial Extractability: Resources

- > Could be commercially extractable in foreseeable future
- > Technology identified, not yet necessarily economic or technically proven
- > Preference is to state resources in terms of energy in place in the reservoir and recoverable energy (heat units)
 - o I do not favour only energy in place as it can lead to misleadingly large estimates
 - o AGEG currently takes the opposite view
- > *Optional* to convert that to, say MW-years of extractable energy, but if so need to state the assumed power price and technology

Commercial Extractability: Reserves

- > Commercially Extractable in the context of a ***Stated Target Type of Development***
- > Can use Well Deliverability as a practical measure
- > Define areas / volumes that are extractable
- > Define temperature limits below which deliverability would be come un-commercial –
 - o the extraction Cut Off and/or Base Temperature
 - o NOT necessarily the same as the plant Rejection Temperature or ambient temperature



Commercial Extractability: Reserves

- > Commercially Extractable in the context of a ***Stated Target Type of Development***
- > But do NOT favour the JORC approach of requiring a full feasibility study before declaring Reserves

Certainty Classifications

- > Proven
 - o Sampled by wells
 - o Deliverability demonstrated
 - o “No surprises” expected in future drilling
 - o “Bankable Projects” need a feasibility study and PPA as well as proven reserves

- > Probable
 - o Less reliably characterised
 - o Temperature indicated by geochemistry or nearby wells
 - o Area defined by geophysics / temperature gradient mapping

- > Inferred
 - o Less direct indications of area, depth and character
 - o Sound reason for indicating resource – geochemistry

- > Exploration Results
 - o Can be less formally reported for interest but will not define resources

Correlation with Probabilistic Methods

- > Conceptually:
 - o P90 ~ Proven
 - o P50 ~ Probable
- > But not a rigorous mechanistic correlation
- > Probabilistic methods readily applicable to stored heat and other static or lumped parameter methods
- > Not so easily applied to dynamic reservoir simulation

What: Guidelines for Possible Methodologies

- > Not accepted except for very preliminary resource estimates
 - o Surface heat flow
 - o Aggregation of well outputs

- > Possible but not favoured methods
 - o Areal method
 - o Lumped parameter models
 - o Decline curve analysis

- > Favoured methodologies for resource and reserves
 - o Stored heat calculations – preferably probabilistic
 - o Numerical simulation models

Aggregation and Probability

- > Should only aggregate to lower levels of certainty
 - o e.g. probable reserves can include proven, but not vice versa

- > When aggregating probabilistic resources, should not just add arithmetically
 - o e.g. the P10- P90 range of two probabilities is smaller than the individual ranges

Other Methodology Considerations

- > Accommodating recharge
- > Non-energy constraints
 - o Environmental
 - o Regulatory
 - o Access
 - o Chemistry
- > Interpolation/extrapolation
 - o Geostatistical approach ?
- > Recovery factors
- > Efficiency of energy conversion / utilisation
- > Project lifetime/ sustainability

Other Issues: “Competent Persons”

> Should be:

- o Affiliated to an appropriate professional organisation
- o Qualified and experienced
 - – describe their background
- o Preferably independent
 - - declare any interests
- o Accountable

The Way Forward

- > Agree principles and preferred approach:
 - o June-July 2007 – initial meeting and follow up
- > Present to a wider audience:
 - o 1 August HDR conference – obtain feedback
 - o Circulate to IGA
 - o Kick off TSX working party
 - o Discuss with NZGA
- > Finalise draft through AGE G
- > Present to IEA and IGA in October
- > Finalise version for ASX by end 2007

Applicability to NZ

- > Major players in NZ different to Canada, Australia, USA in that Contact is the only publicly listed company
- > Not all projects funded by commercial banks
- > But – new players about to enter market ?
- > Even if not necessary for the markets, it would be good for NZ to have an agreed methodology for estimating resources, that conforms to international practice
- > Familiarity with the process will be advantageous to NZ companies working overseas