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Conceptual Uncertainty in Groundwater Models

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Models cannot provide certainty

- Decision makers are eager for certainty
- Models/Modellers **cannot provide certainty**
- Models affected by uncertainties in terms of:
  - **Conceptualisation (Structural Uncertainty)**
  - Parameterisation
  - Calibration
  - Prediction

Groundwater Model Uncertainty

- **Structural / Conceptual Model:**
  - physical framework, plus
  - hydrological processes & water balance.
- Simplify complex reality -> Uncertainty
  - structural uncertainty is a known-unknown:
    - we know we don't know everything about the aquifer system (we know we need more data)
  - structural uncertainty is an unknown-unknown:
    - how much and what type of data do we need to adequately characterise the system?
    - when do we have enough data?

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Structural Error/Uncertainty

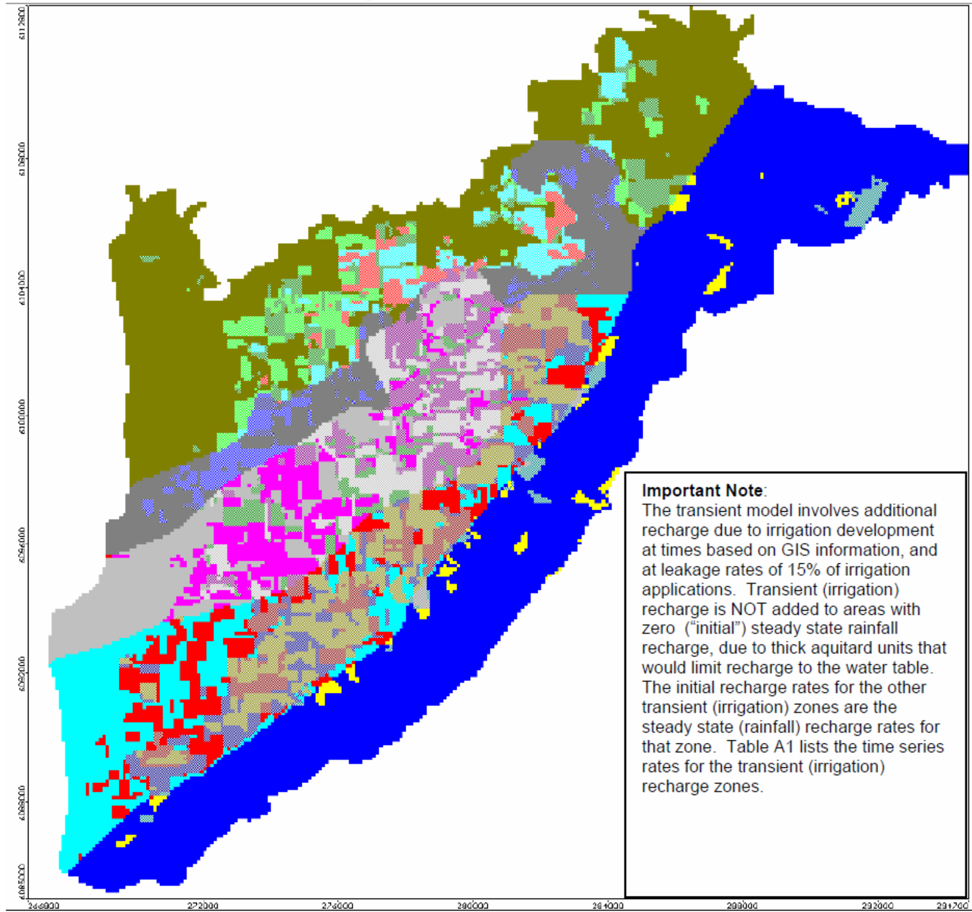
- Ye et al, Groundwater, 48/5 (716-28), 2010
  - Death Valley regional flow system (inc. Yucca Mtn)
  - (5 x RCH) & (5 x Geology) = 25 plausible models
  - methods: Monte Carlo & model averaging
  - Structural error has major effect on predictive uncertainty (more than parametric & recharge uncertainty)
  - most calibration obs. do not help resolve alternates (because weighted residuals varied little between models)
  - 2016 paper focus on inter-basin flow (yet more multi-models)
- Evaluate structural uncertainty via multiple model conceptualisations/parameterisations
  - also helps with communicating the effects
- Can/Do we investigate multi-models in practice?

McLaren Vale: 2 RCH models (2006)

- High & Low Recharge
- Two K distributions
- Scenarios run for each model to identify envelope of aquifer response
- Used to inform Water Allocation Planning

Acknowledgement: project principal was Onka CWMB; Aquaterra project for client REM; project mgr & tech director was Russell Martin (now with Aqueon); AQT modeller Joel Georgiou (now with Iluka).

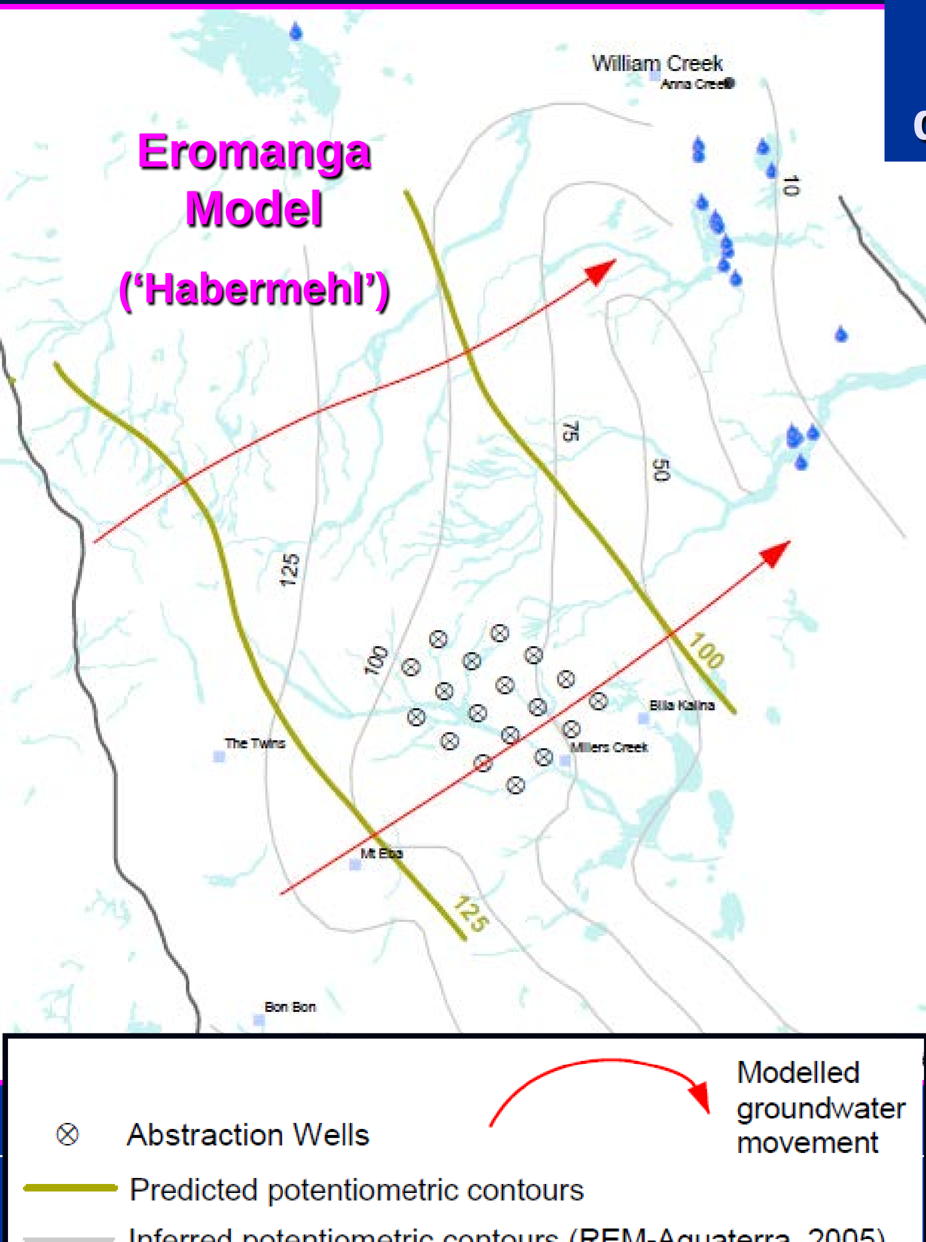
Figure A1 - Transient Model Recharge Zones

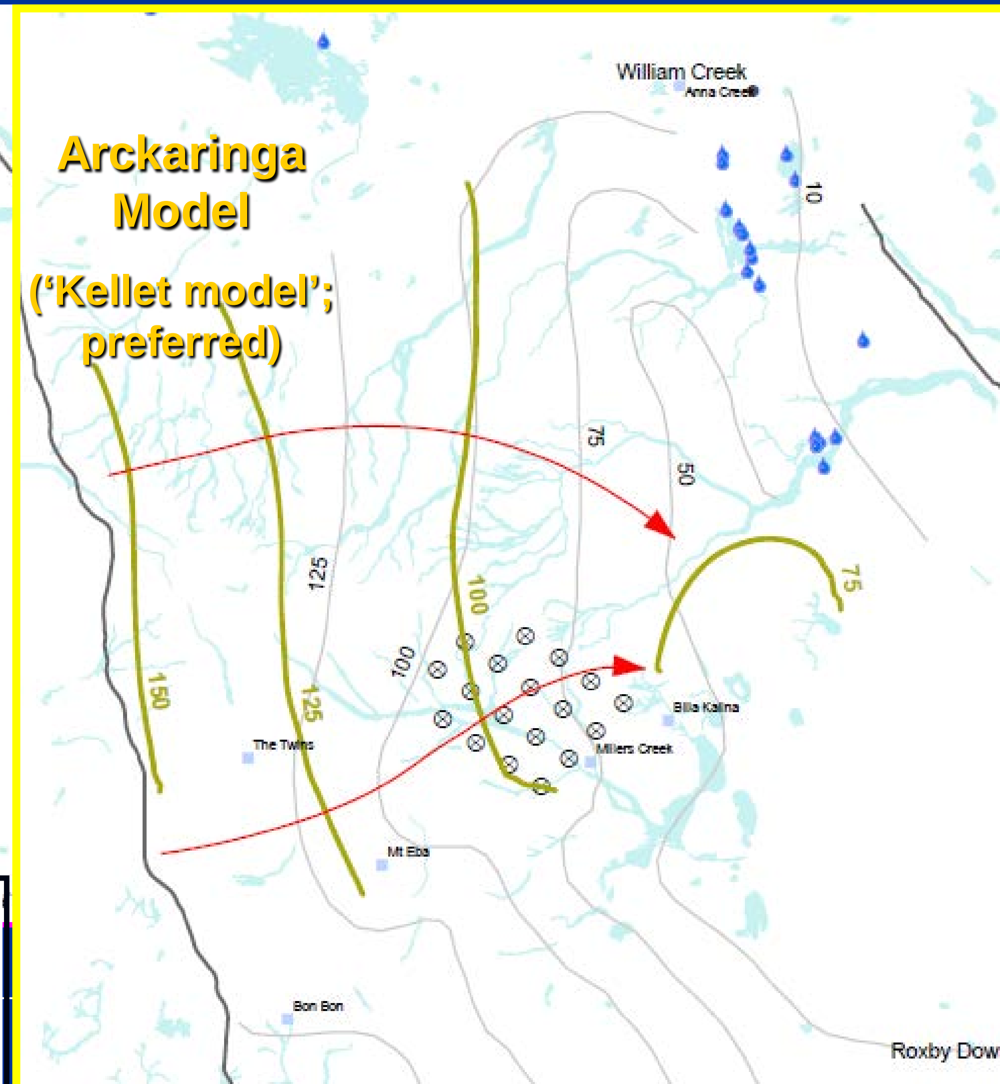


Legend	Zone Number	Zone Type	MV1 Rate (mm/yr)	MV2 Rate (mm/yr)	Legend	Zone Number	Zone Type	MV1 Rate (mm/yr)
	1	Steady Sate	7	12		11	Transient	0
	2	Steady Sate	0	0		12	Transient	10
	3	Steady Sate	10	15		13	Transient	17
	4	Steady Sate	0	5		14	Transient	0
	5	Steady Sate	17	20		15	Transient	10
	6	Transient	0	5		16	Transient	17
	7	Transient	10	15		17	Transient	0
	8	Transient	17	20		18	Transient	7
	9	Transient	0	5		19	Transient	7
	10	Transient	10	15		20	Transient	7

Case Study: West GAB – initially 2 models

Combinations of hydrogeology and geochemistry data and concepts; data quality issues affect initial studies



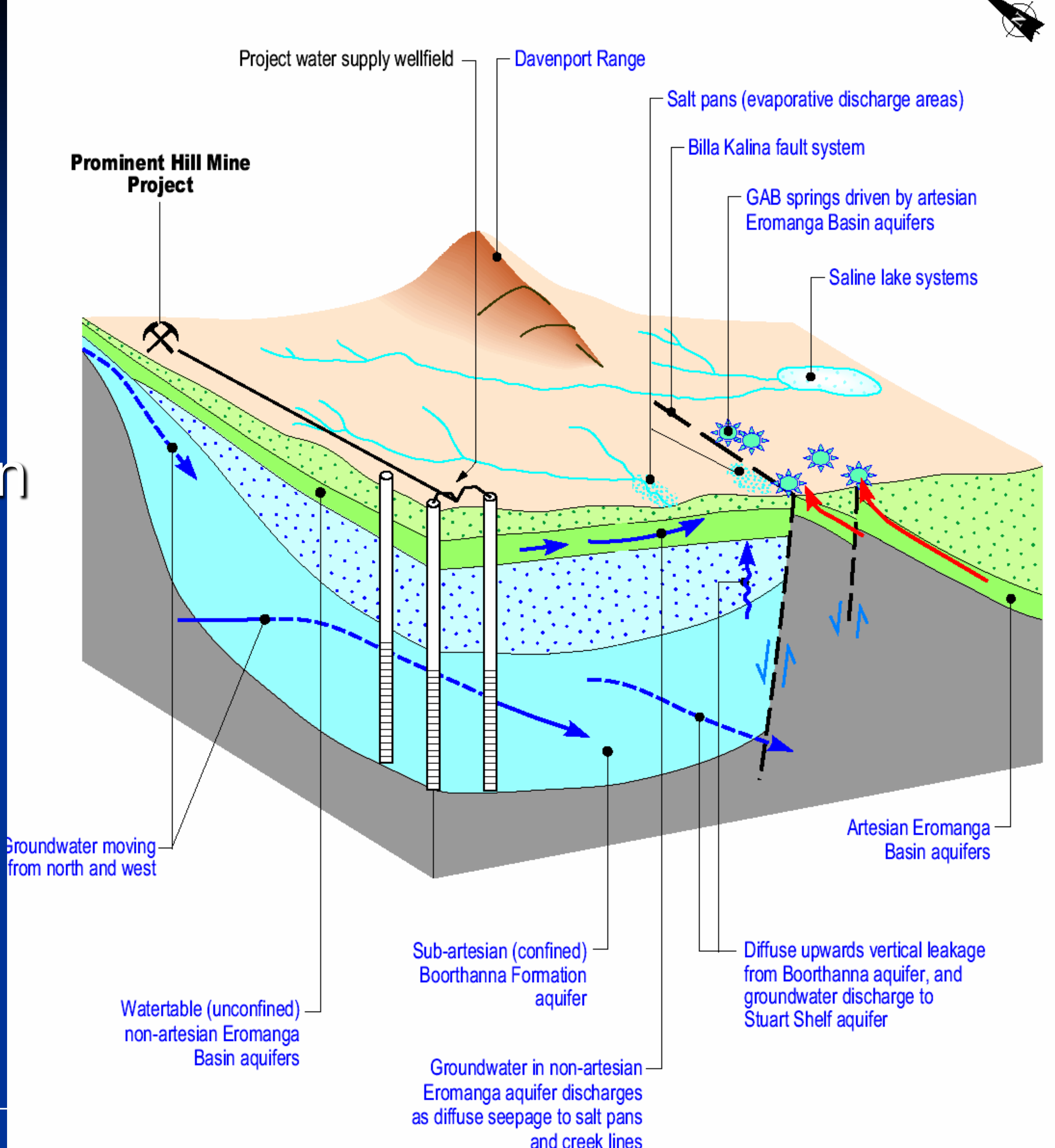


Western GAB (final)

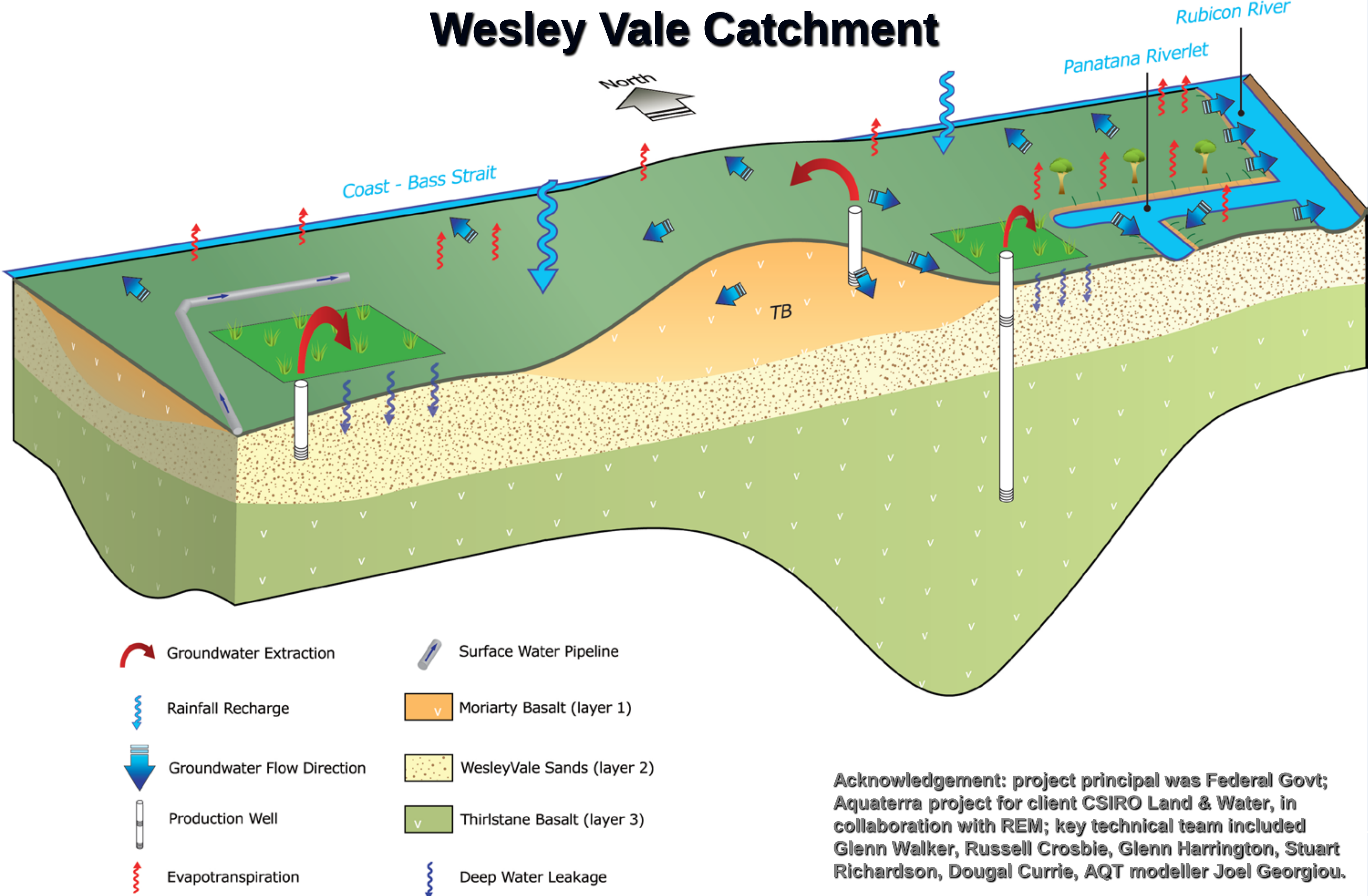
Subsequent investigations identified conceptualisation as combination of both initial models.

Used for mining approvals (2005 to 2009+?).

Acknowledgement: project principal was Oxiana (Prominent Hill); Aquaterra modelling project for client REM,; project mgr & tech director was Paul Howe (now with CDM Smith); AQT modeller was Doug Weatherill (now Jacobs).

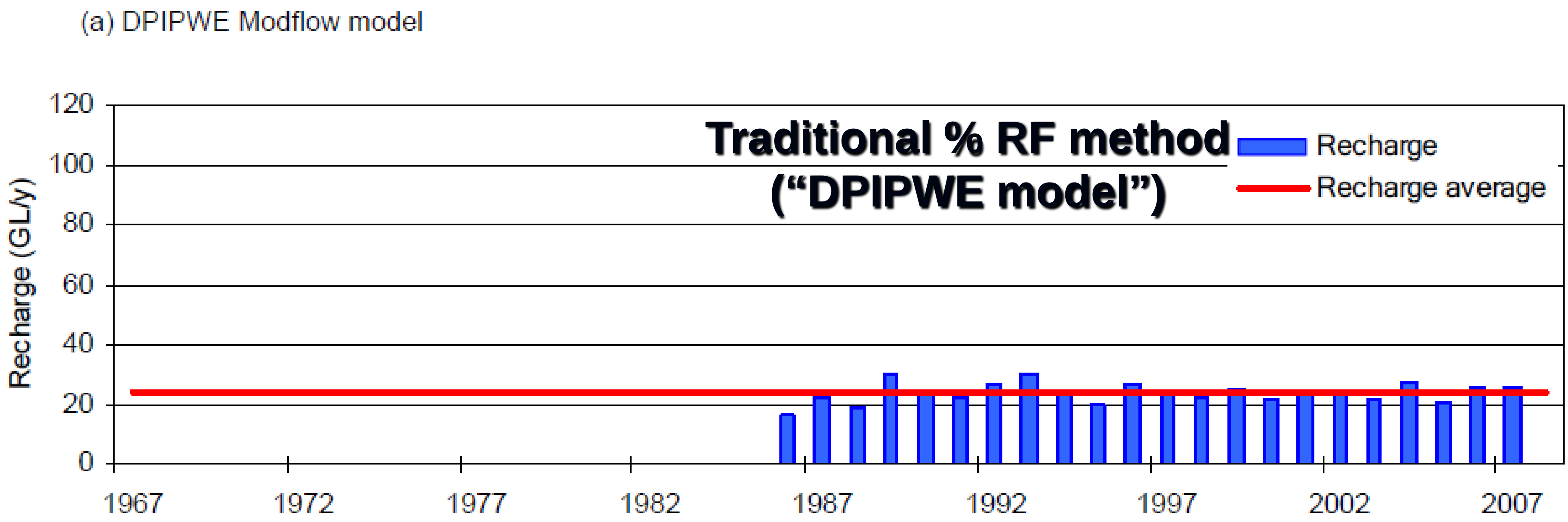


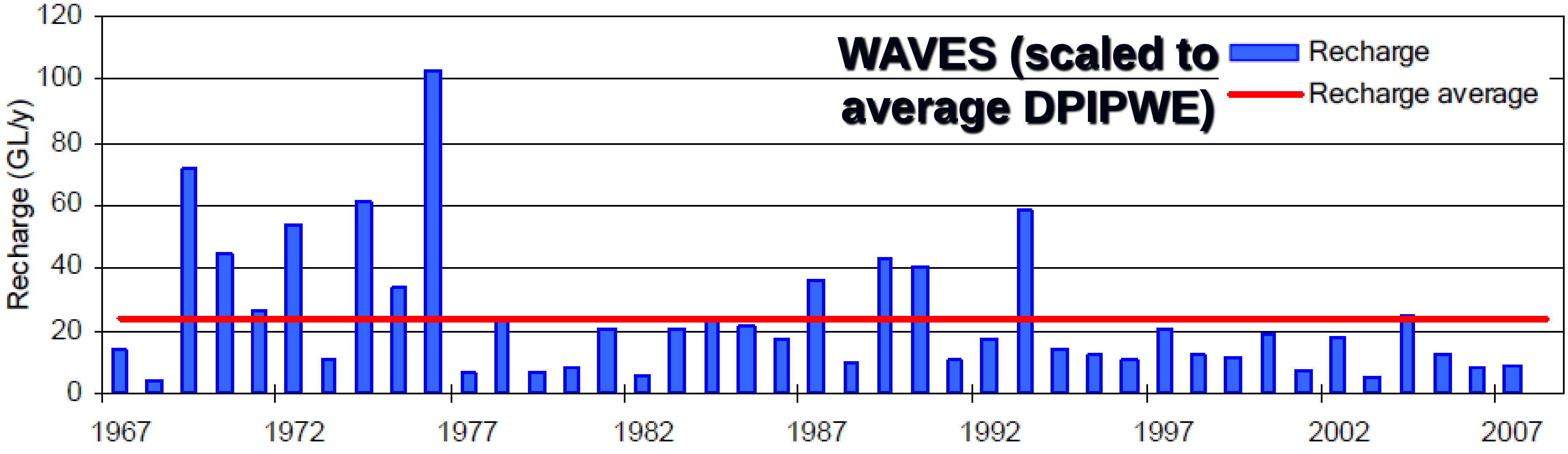
Tasmanian SY project (2009)



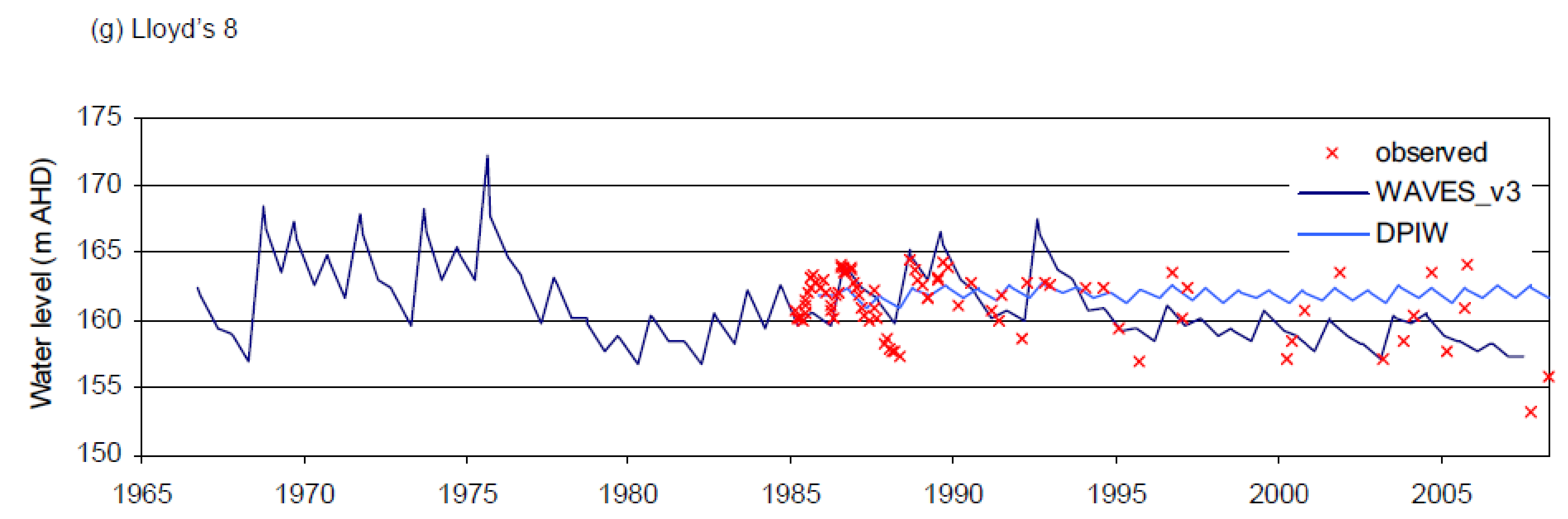
Acknowledgement: project principal was Federal Govt; Aquaterra project for client CSIRO Land & Water, in collaboration with REM; key technical team included Glenn Walker, Russell Crosbie, Glenn Harrington, Stuart Richardson, Dougal Currie, AQT modeller Joel Georgiou.

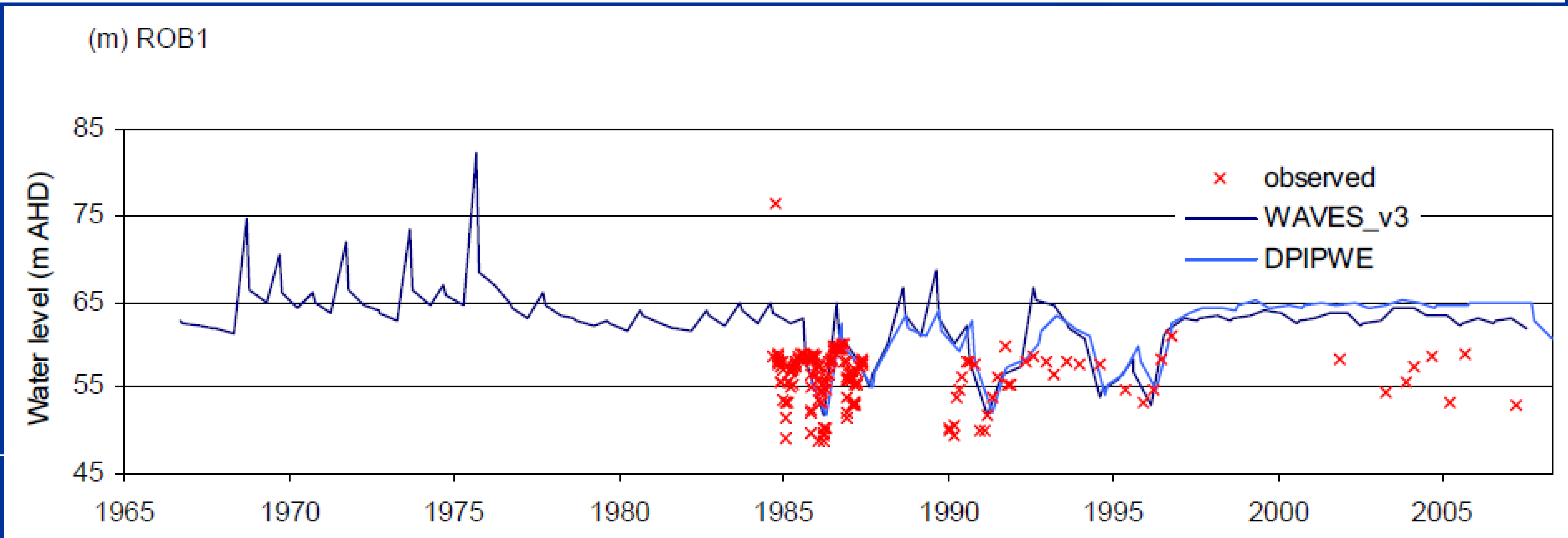
TasSY – Recharge Comparison





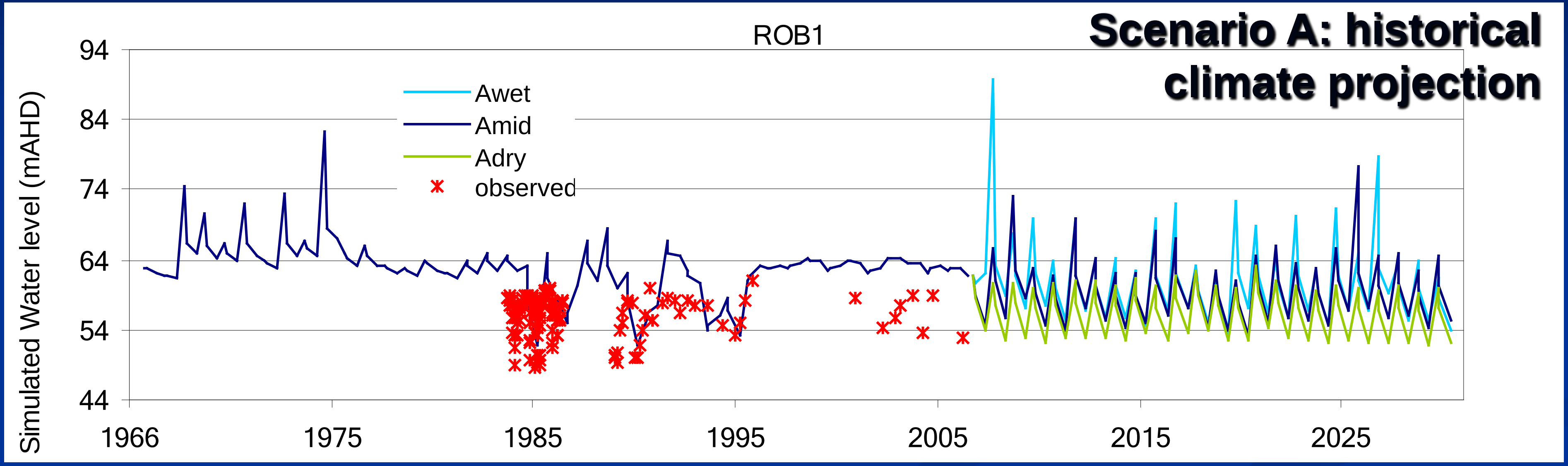
TasSY – model calibration

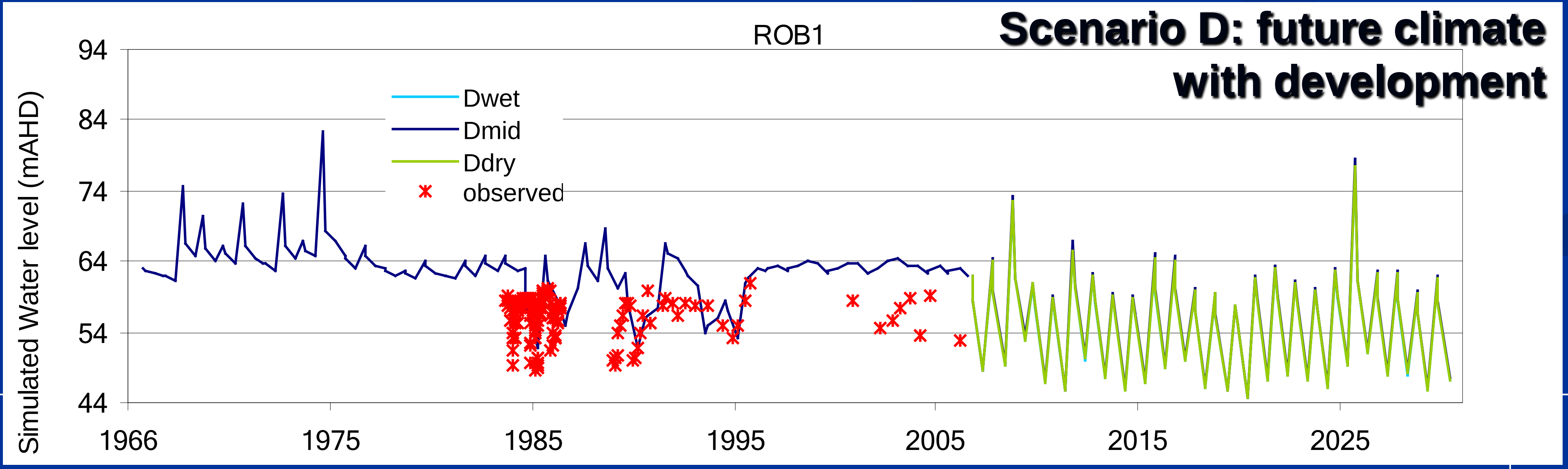




TasSY – model predictions

Despite data/model/climate/demand uncertainties, an adaptive water resource mgt objective of further irrig & forestry development is achievable

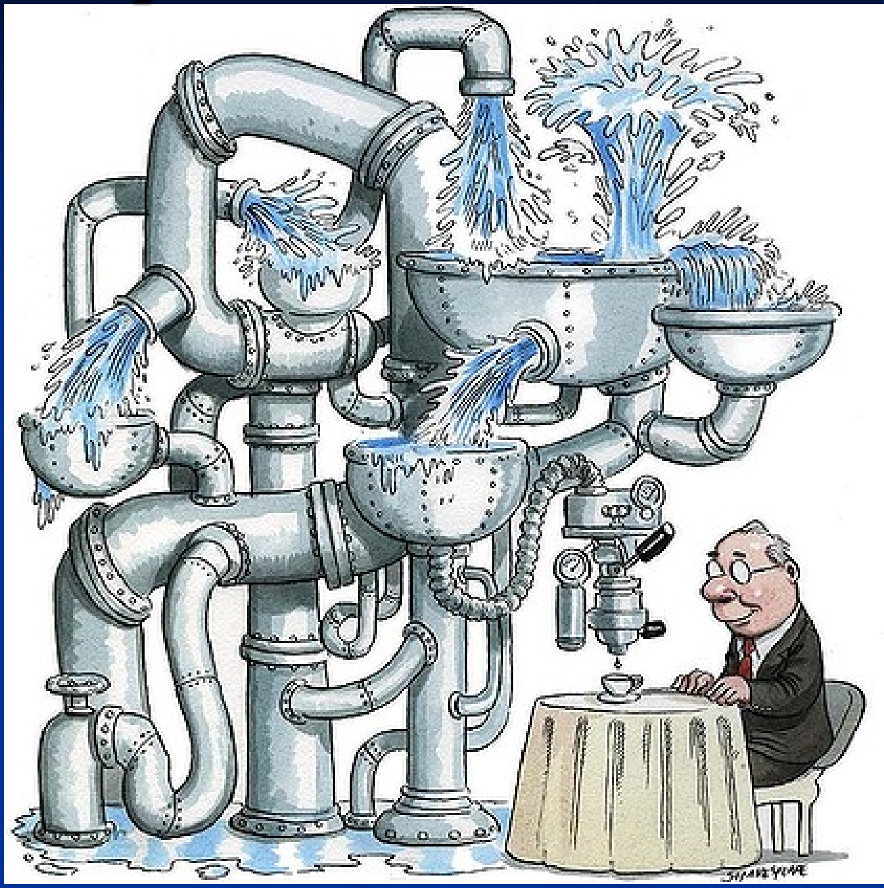




Model Uncertainty Cascade

- Future Projections:
  - GW pumping v.uncertain
  - Δallocation / Δdemand / Δuse
  - e-flows, other mgt initiatives

  - Climate Variability/Change
  - Δemissions -> RCPs/GCMs
  - Δtemp -> Δrainfall and ΔET
  - Δrunoff; Δstream flow/level
  - Δrecharge
  - gw model at end of cascade
  - (but what about feedbacks?)



- Do we really want to have groundwater models as the last drop in the uncertainty cascade?

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Models cannot provide certainty

- Acknowledge that we cannot predict future events with certainty:
  - all predictions will be wrong in some way
  - actual future climate, recharge, pumping, etc. will differ from scenario assumptions
- Consider alternative approach, paraphrasing John Doherty: models can't determine (exactly) what will happen but can demonstrate what outcomes won't/can't happen (&/or probabilities of such outcomes)
  - showing what can't/won't happen can provide as much insight as the traditional guideline workflow
  - Modelling Guidelines allow other approaches as best practice and encourage innovation in modelling techniques (provided they are justified)

Models can show what is not uncertain

- Biggest uncertainty is conceptual/structural
- 2012 Guideline "model confidence level classification" is not the best starting point
- Traditional workflow is not always the best (conceptualise, build, calibrate, predict); better to....
- Devise model aims/methods/approaches to address the "risk question" (ISO 31000:2009):
  - what is effect of uncertainty on project objectives?
- Use model to show what is not uncertain (show what has a very low probability of occurrence or a consequence that is not material to objectives)
- Use model to guide data program to reduce residual uncertainties