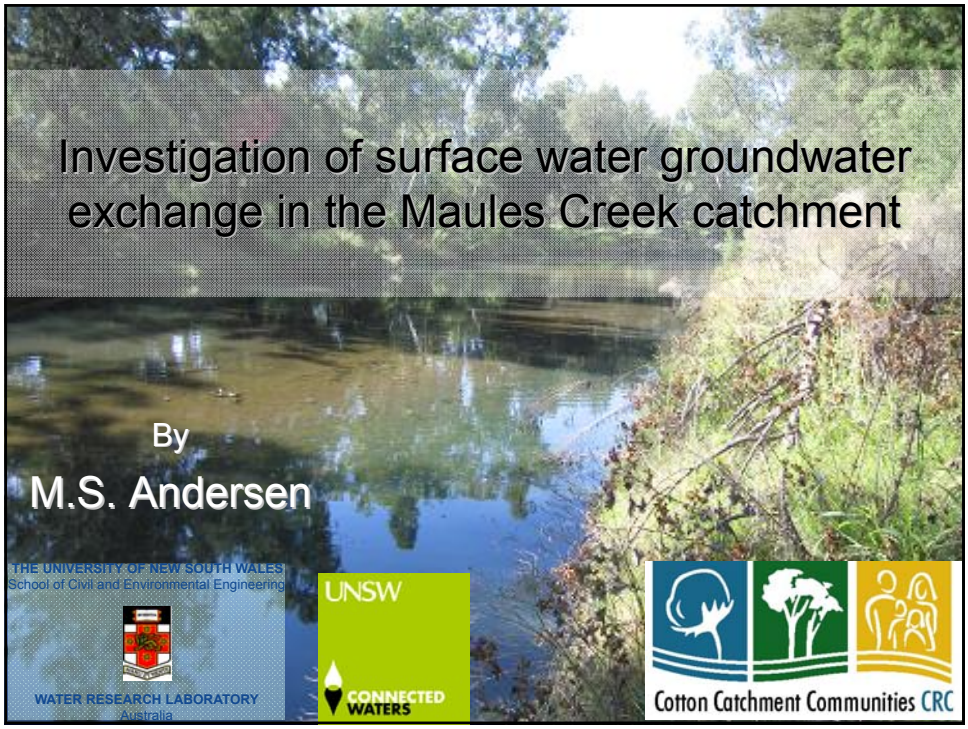

Co-workers

Ian Acworth (WRL/CWI)
Beatric Gambastiani (BEES/CWI)
Anna Greve (WRL/CWI)
Bryce Kelly (BEES/CWI)
Andrew McCallum (WRL/CWI)
Karina Meredith (ANSTO)
James Patterson (WRL/CWI now UTS)
Gabriel Rau (WRL/CWI)
Peter Serov (DWE)
Wendy Timms (WRL/CWI)

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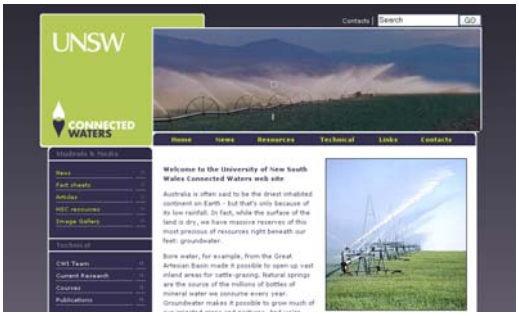
Further information:

www.connectedwaters.unsw.edu.au

Updated almost weekly!

General news & articles
Fact sheets
Research updates
Poster downloads
Publication lists
Journal abstracts
Team & alumni



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Outline

Background
The Maules Creek project
- Hydrographs
- Hydrogeology
- Stable Isotopes
- Heat tracing
- Stream bed chemistry
- Stygofauna
- Modelling the bigger picture
- ~~Climate data~~
- ~~Resistivity tomography~~
- ~~Deep drainage & mini-lysimeters~~

Water Research Laboratory

Background

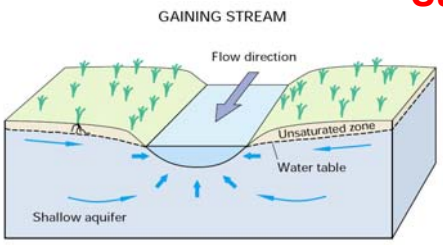
Allocation of water resources

- Groundwater and surface water allocated independently

→ Overallocation of the resource

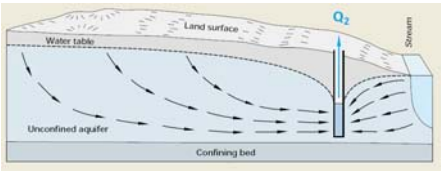
- Confilcts between users
- Impacts on river flow
- Impacts on the aquatic environment

Surface water - groundwater Interactions: The basics

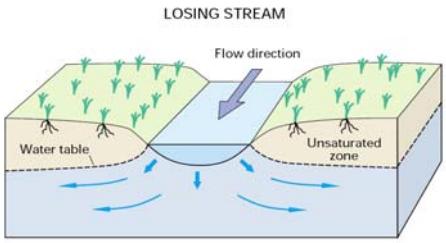


High groundwater levels (winter) and/or low stream flow

Change in time:
- location
- direction
- magnitude



Groundwater extraction



High stream flow due to flooding or dam releases

Winter et al. 1998

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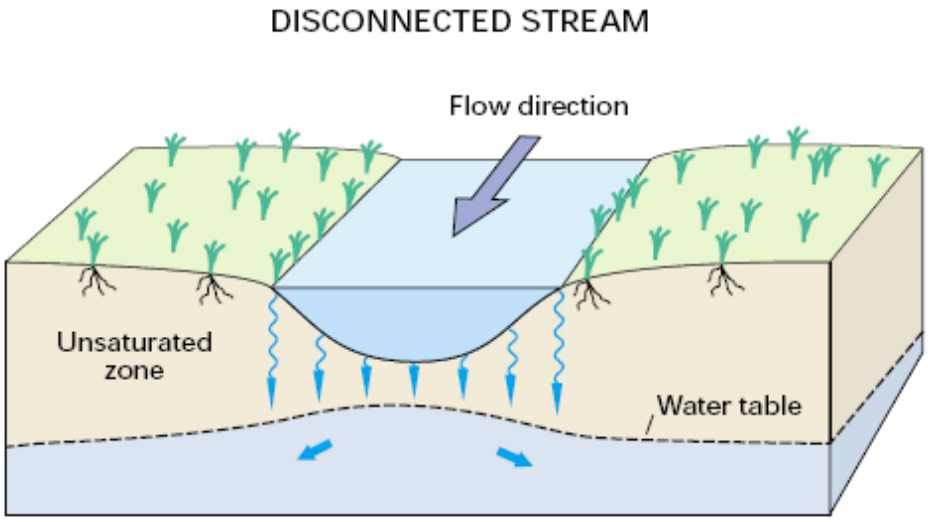
Potential implications for stream flow

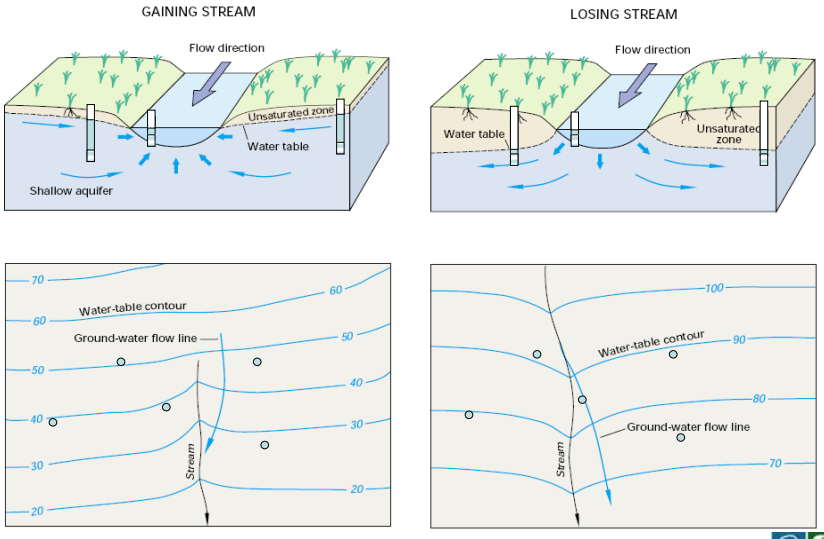


How do we measure surface water groundwater interactions ?

- Hydrograph analysis
  - Analysing changes in stream flow
- Physical methods
  - Hydrogeological methods
  - Heat
- Hydrochemical methods & tracers
  - Natural water chemistry
  - Injected tracers

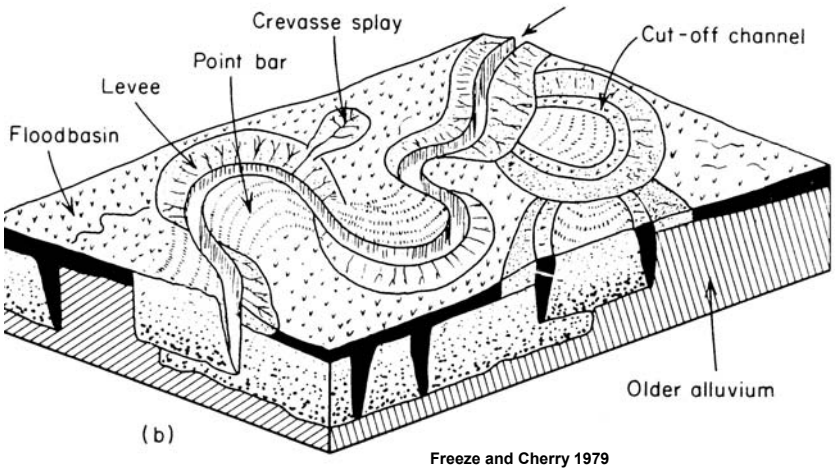
Hydrogeologic investigations

- Stream and groundwater level measurements



Winter et al. 1998

River deposits - are complex



Freeze and Cherry 1979

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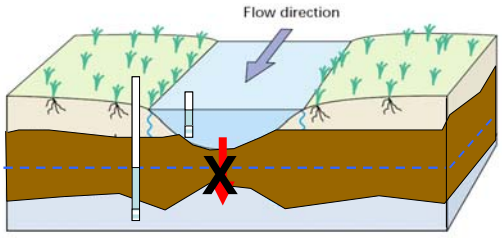
Hydrometric measurements

- Problem of connectivity



Winter et al. 1998

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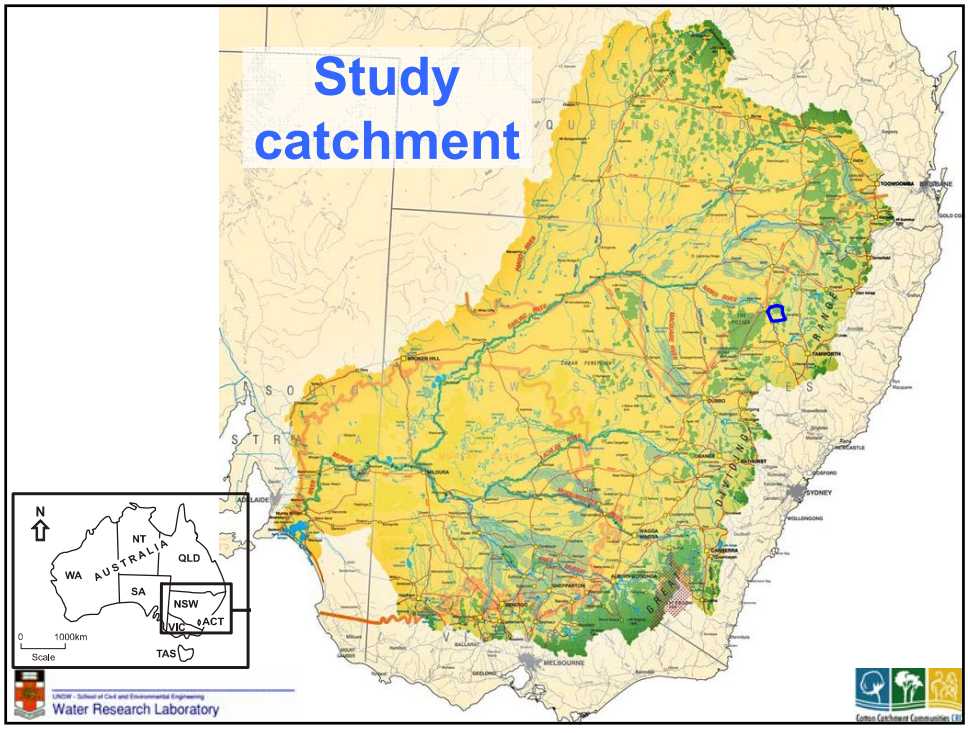
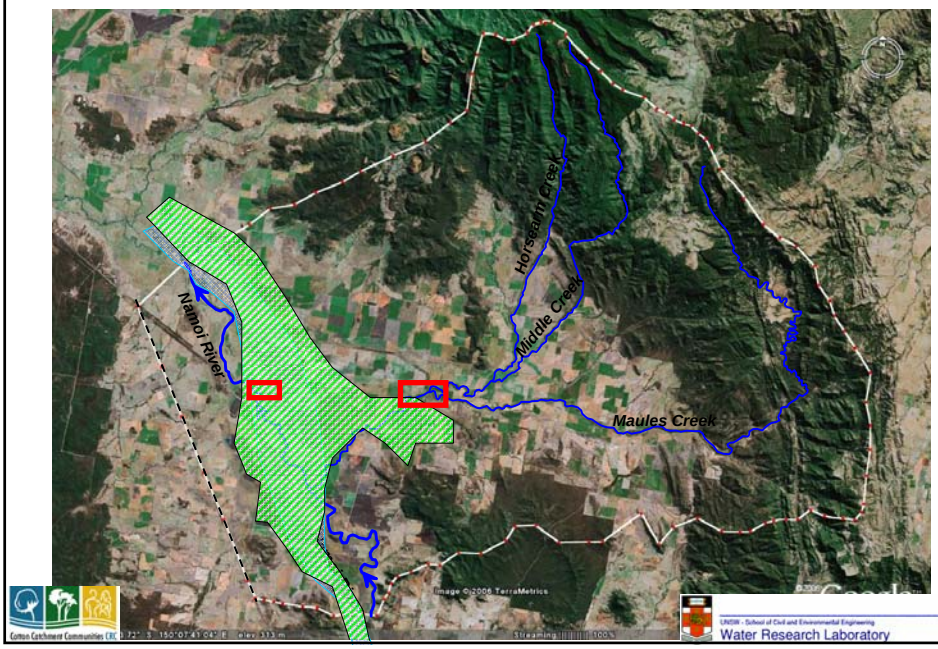
Project aims

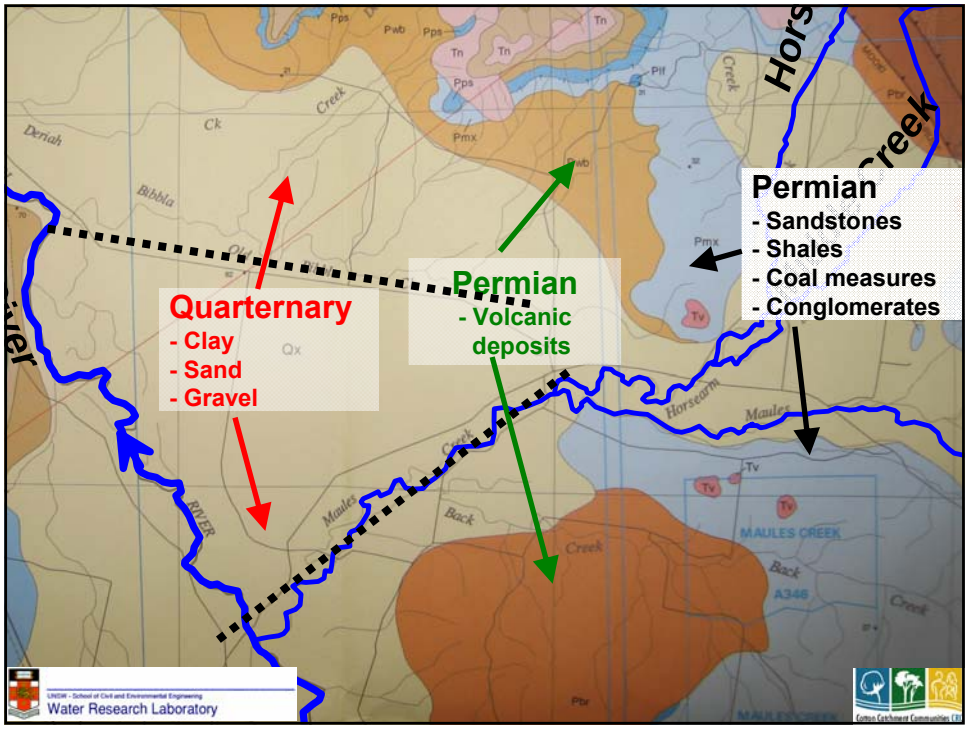
- Study dynamics of surface water groundwater exchange in a catchment with extensive groundwater abstraction and irrigation
- Develop tools and methodologies for mapping and quantifying the water exchange

⟶ Experimental work in a small catchment on the Namoi River, NSW

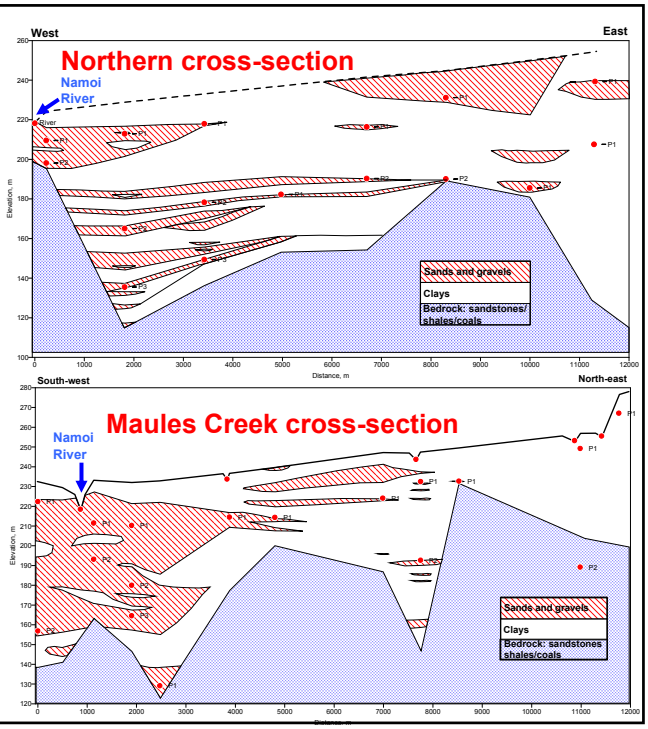


Maules Creek catchment





Geological cross-sections



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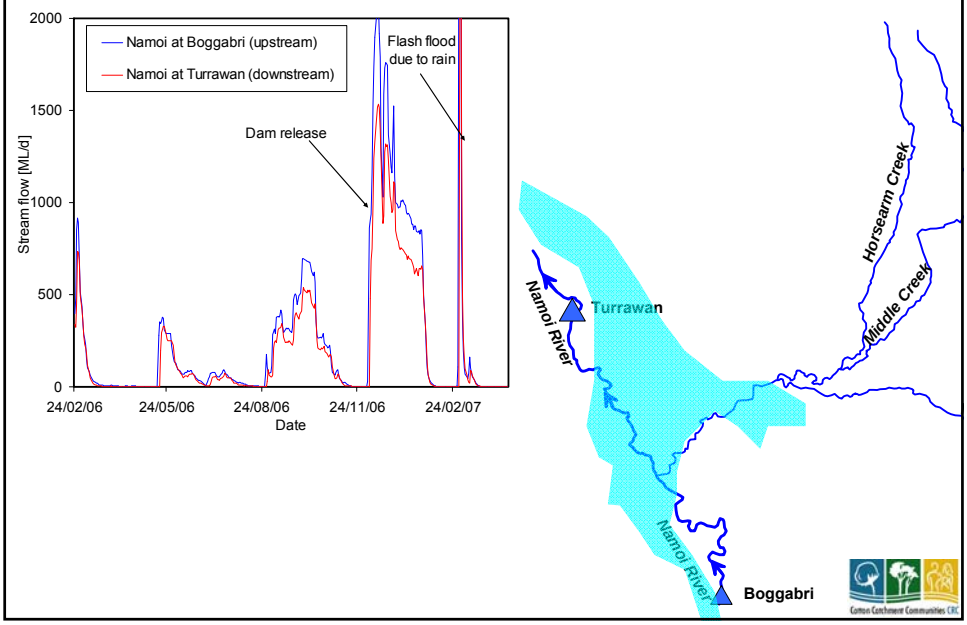
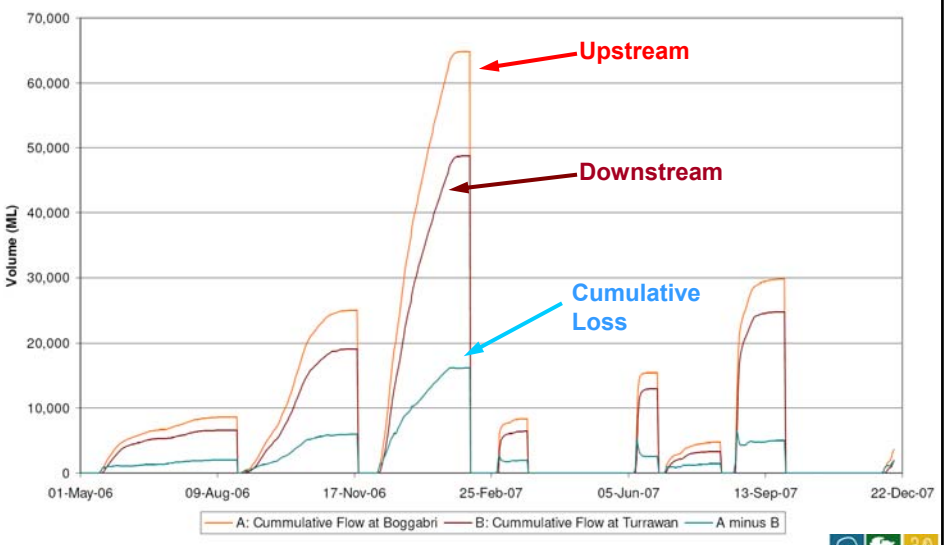
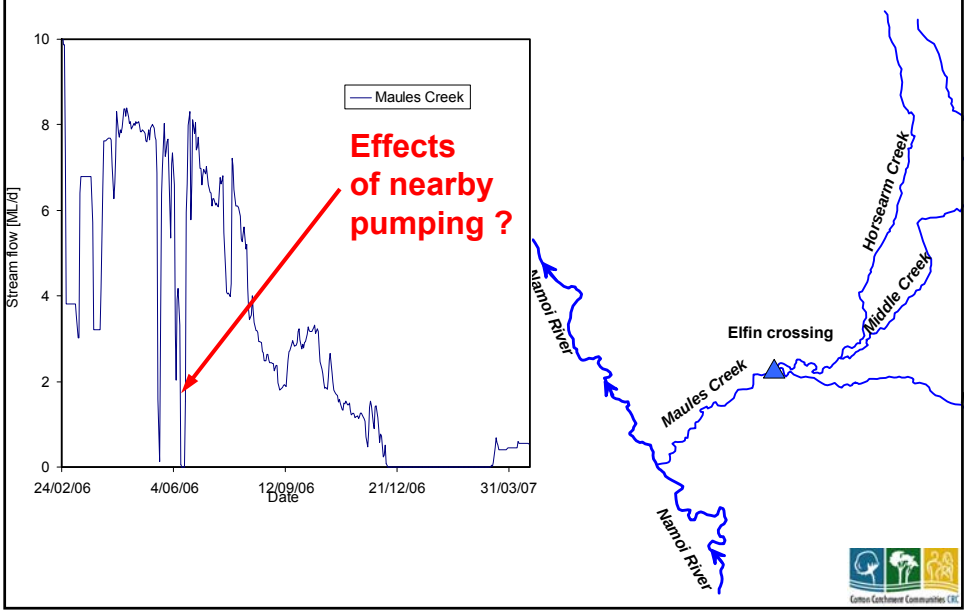
Stream flow: Namoi River



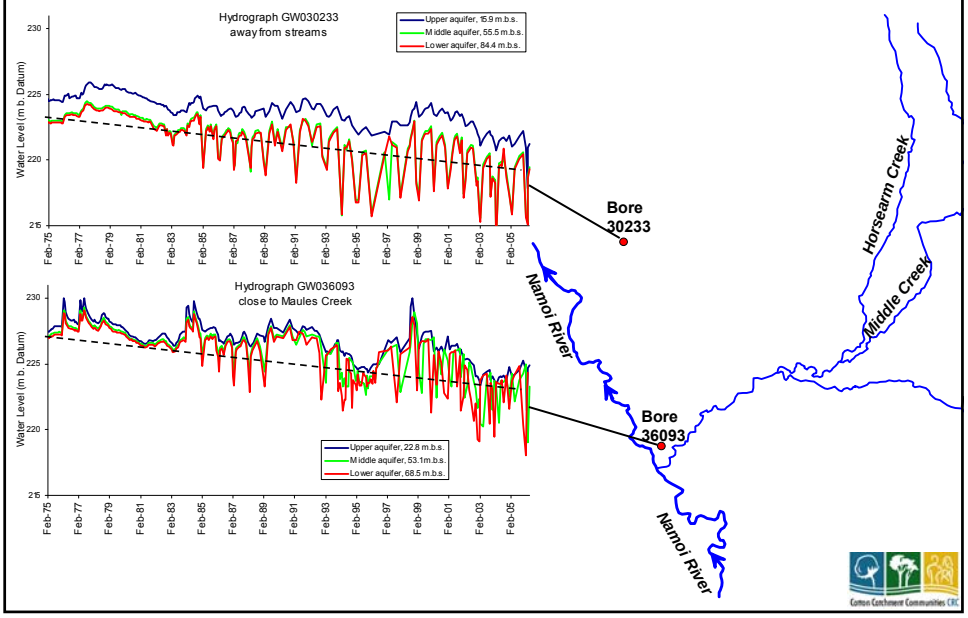
Stream flow loss: Namoi River



Stream flow: Maules Creek



Groundwater hydrographs

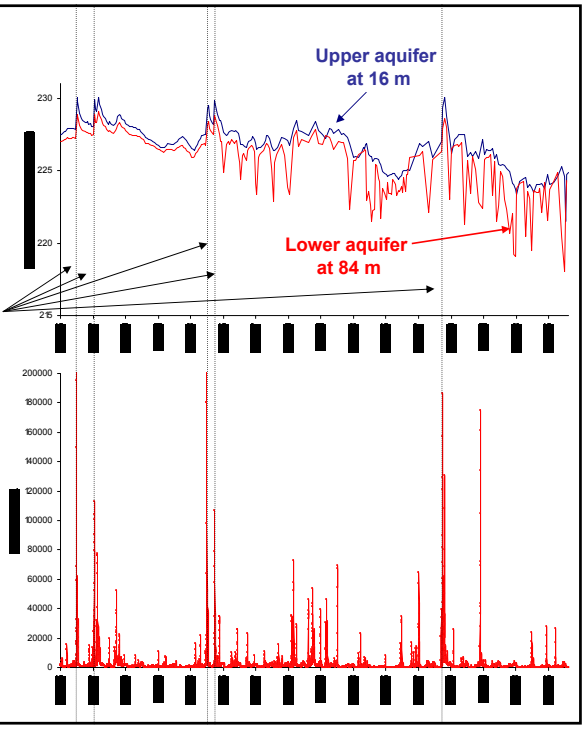


Recharge ?

Groundwater levels in well close to river

River recharge events ?

Flow in the Namoi River



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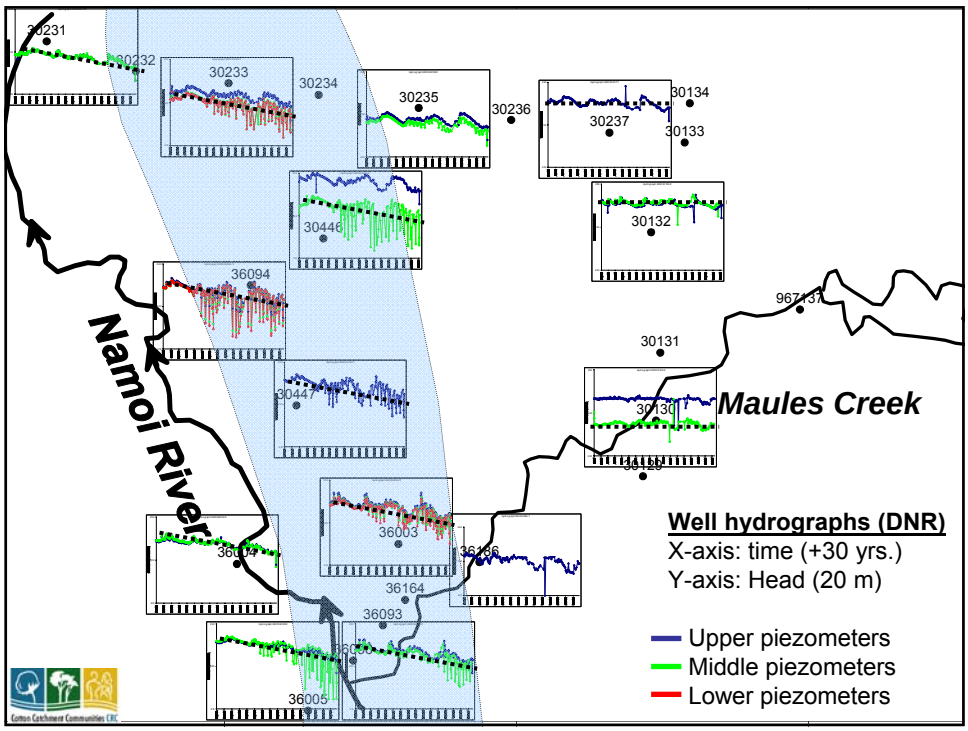
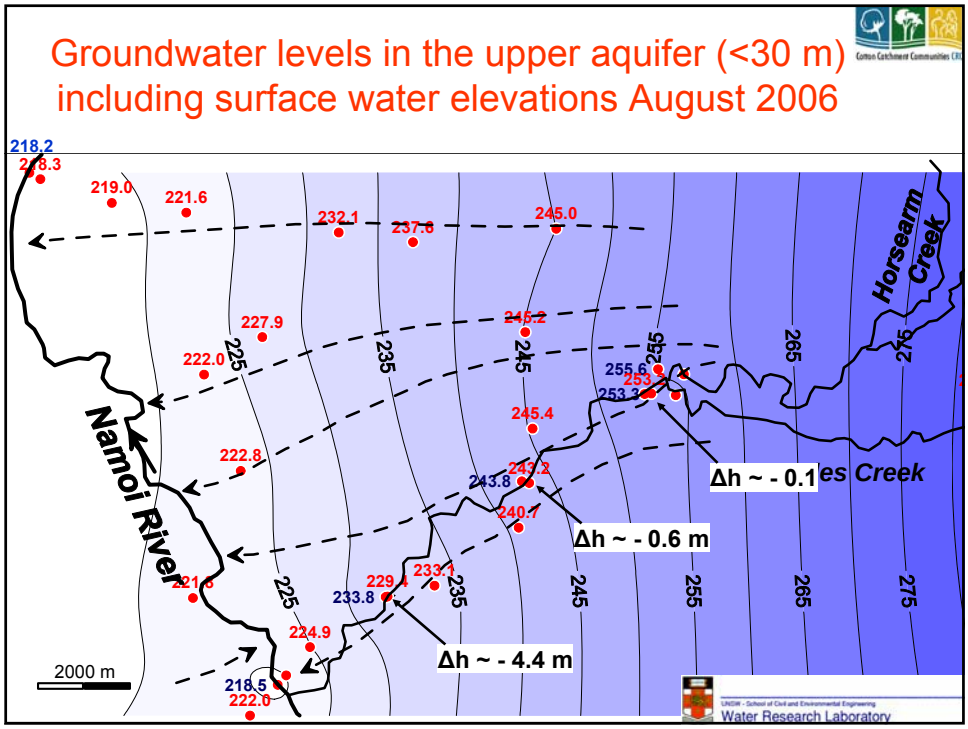

30231
30232
30233
30234
30235
30236
30237
30134
30133
30132
30446
36094
30131
Maules Creek
Namoi River
30447
36003
36164
36093
36005
Well hydrographs (DNR)
X-axis: time (+30 yrs.)
Y-axis: Head (20 m)
Upper piezometers
Middle piezometers
Lower piezometers


Groundwater levels in the upper aquifer (<30 m)
including surface water elevations August 2006
218.2
218.3
219.0
221.6
232.1
237.6
245.0
227.9
222.0
245.2
255.6
253.3
245.4
222.8
243.8
240.7
Namoi River
Horsearm Creek
Δh ~ - 0.1
Δh ~ - 0.6 m
Δh ~ - 4.4 m
233.8
229
233.1
224.9
218.5
222.0
225
235
245
255
265
275
2000 m
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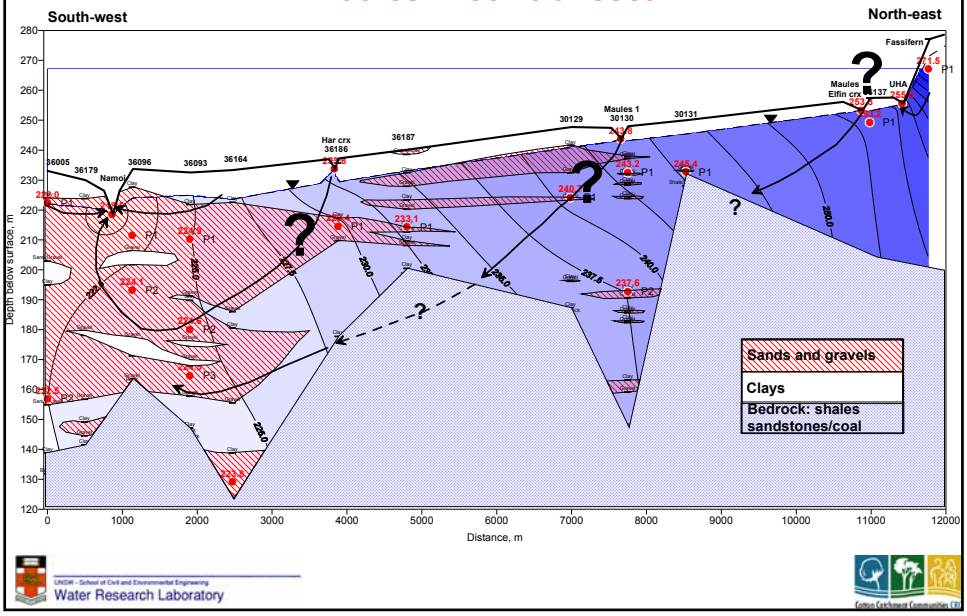
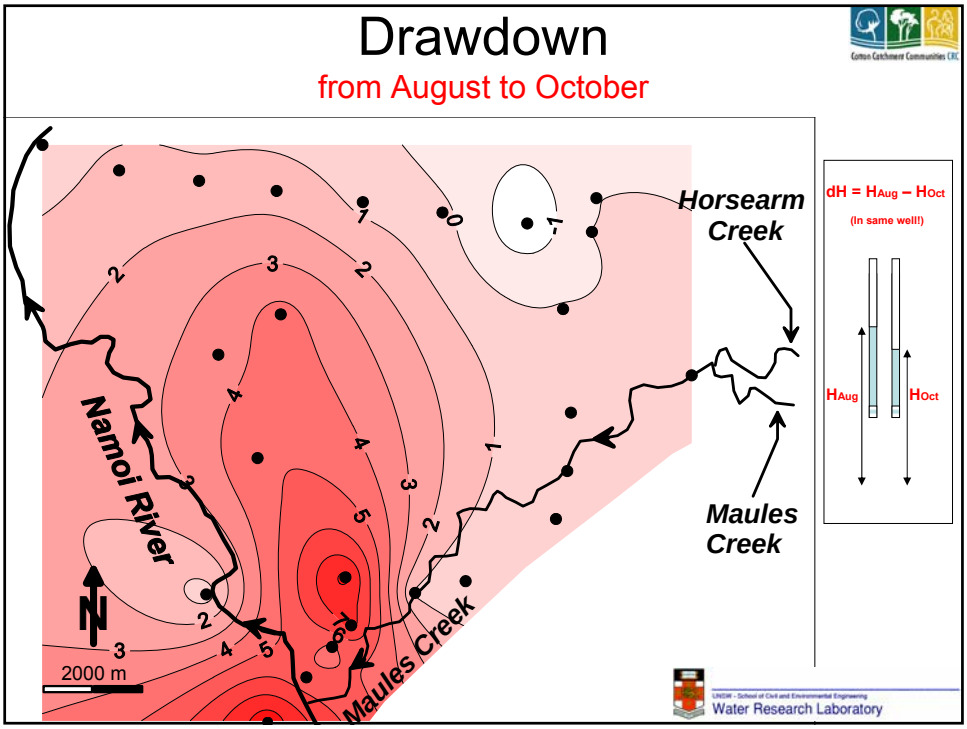
Heads

Maules Creek transect

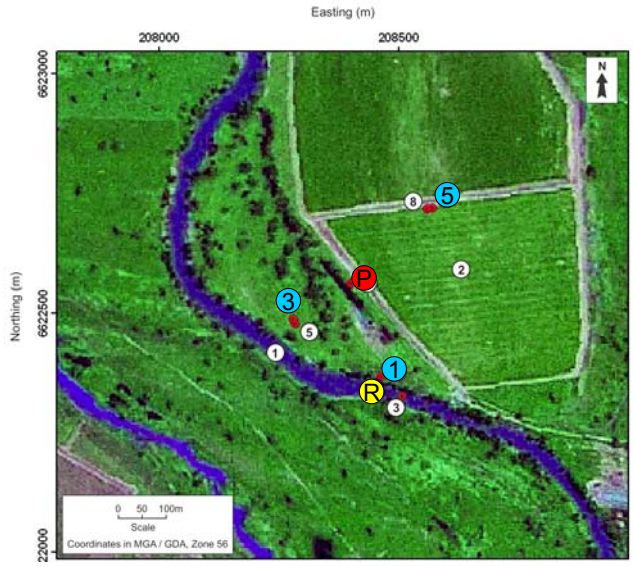


Drawdown

from August to October



Field site at the Namoi River



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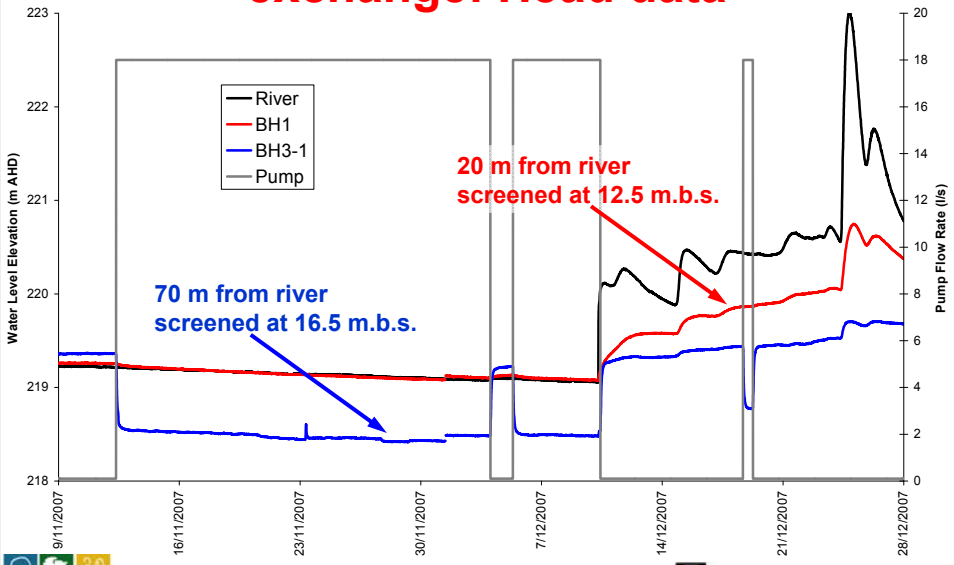
Evidence for surface and groundwater exchange: Head data



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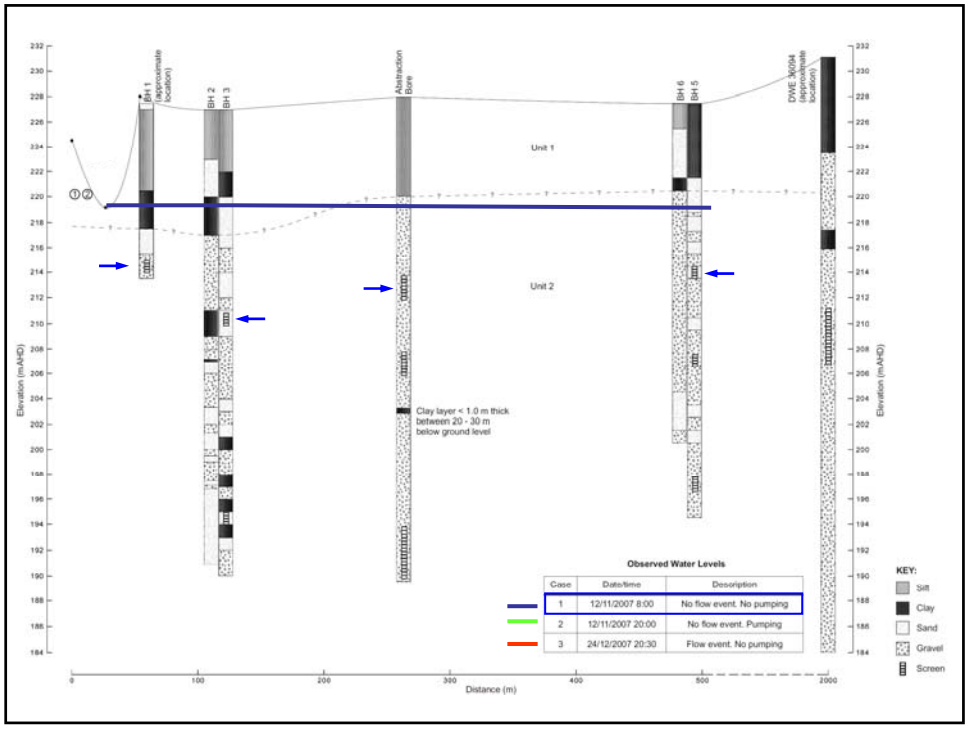
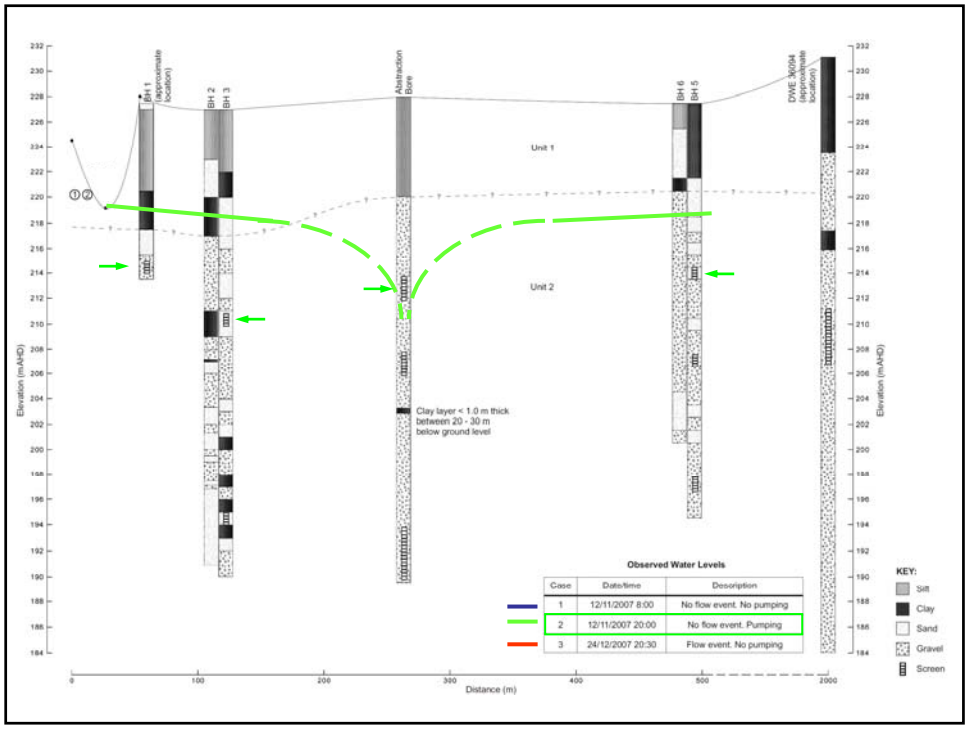

BH 1 (approximate location)
BH 2
BH 3
Abstraction Bore
BH 6
BH 5
DWE 36094 (approximate location)
Unit 1
Unit 2
Clay layer < 1.0 m thick between 20 - 30 m below ground level
Elevation (m AHD)
Distance (m)
Observed Water Levels
Case
Date/time
Description
1
12/11/2007 8:00
No flow event. No pumping
2
12/11/2007 20:00
No flow event. Pumping
3
24/12/2007 20:30
Flow event. No pumping
KEY:
Silt
Clay
Sand
Gravel
Screen


BH 1 (approximate location)
BH 2
BH 3
Abstraction Bore
BH 6
BH 5
DWE 36094 (approximate location)
Unit 1
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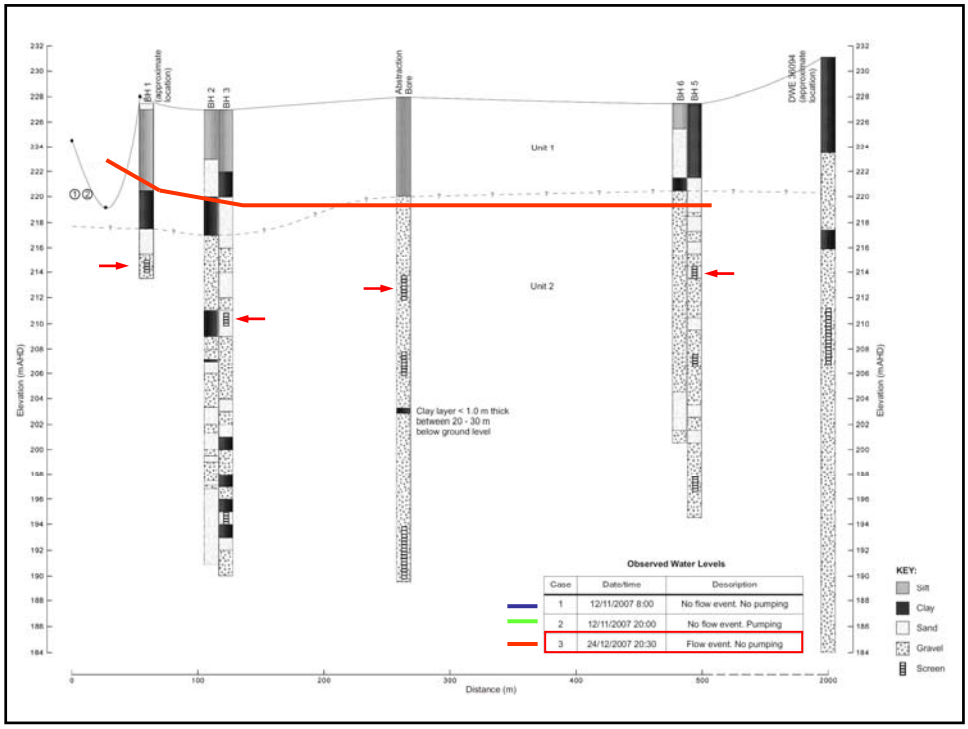
Flow event. No pumping
KEY:
Silt
Clay
Sand
Gravel
Screen



Stable isotopes of surface and groundwater ($\delta^{18}O$ and $\delta^{2}H$)

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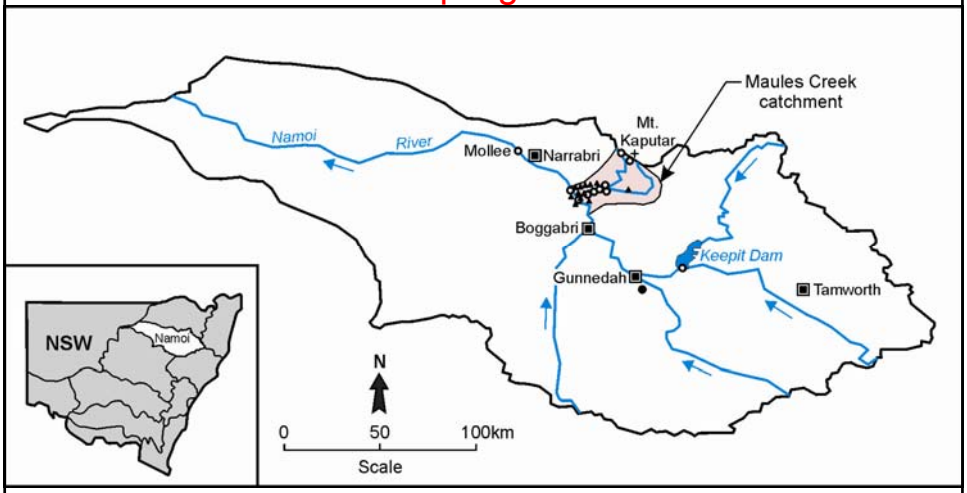
Stable isotopes of surface and groundwater in the Namoi Valley

Sampling sites



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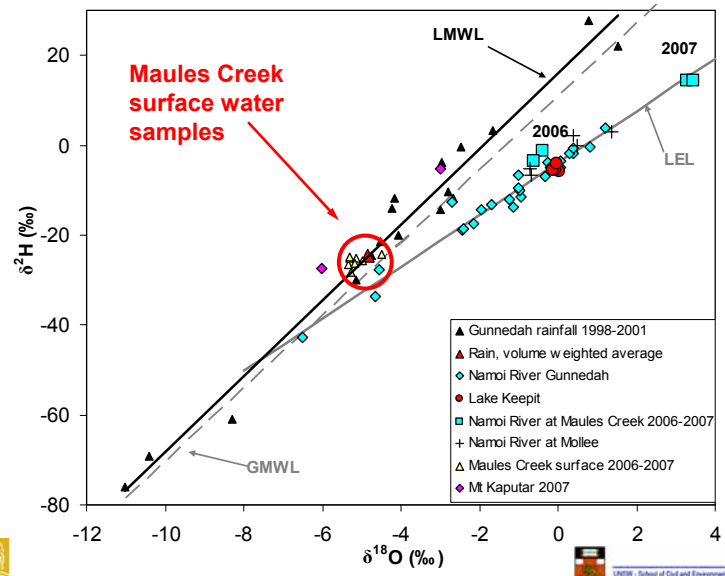
Stable isotopes of rain and surface water in the Namoi Valley



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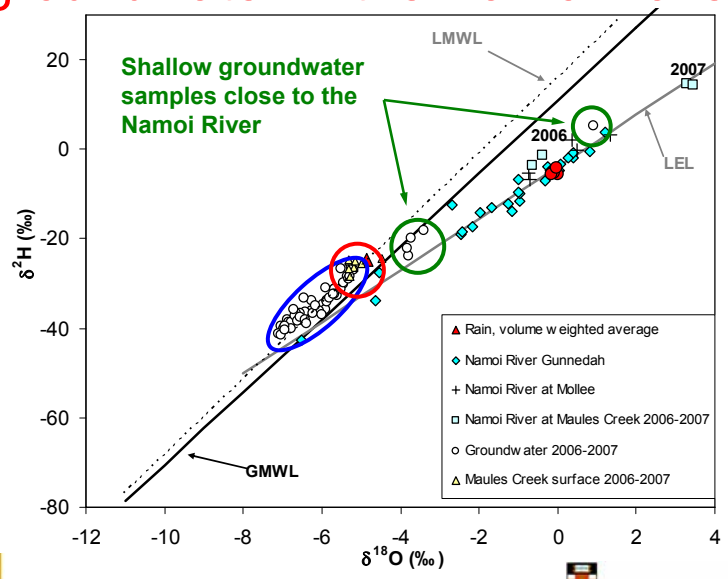
Stable isotopes of surface and groundwater in the Namoi Valley



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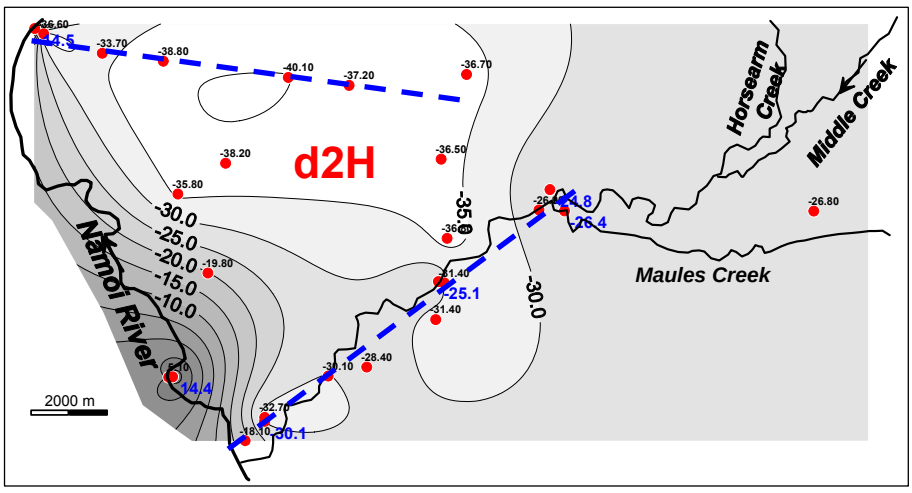
δ^2H of shallow groundwater (< 30 m) in the Maules Creek catchment



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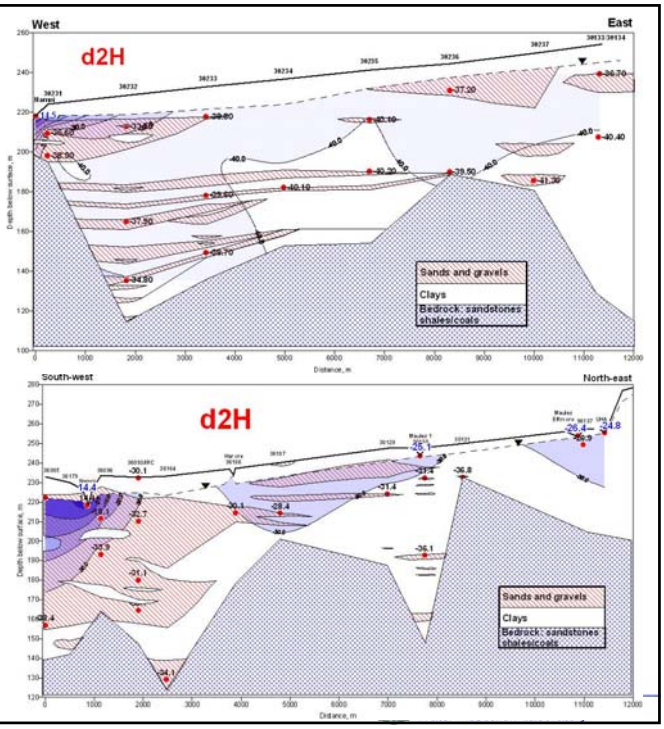
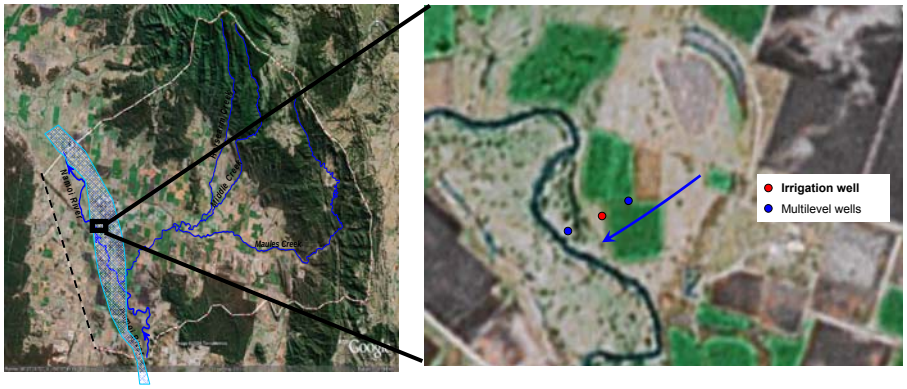
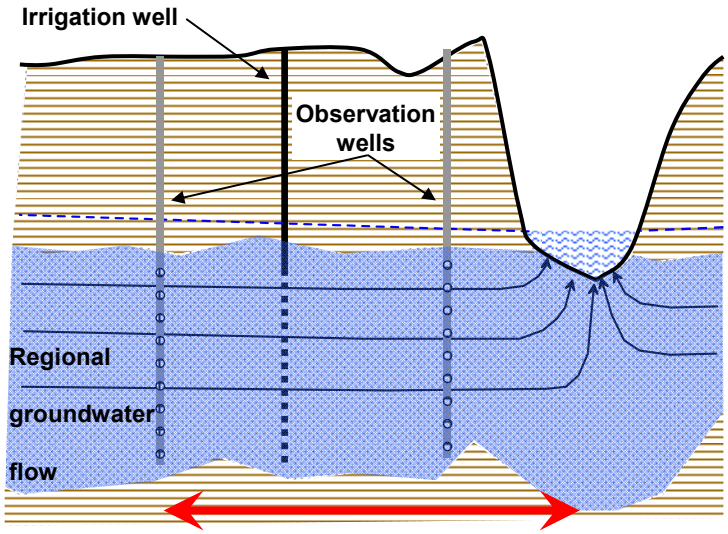
δ^2H: Maules Creek catchment



Groundwater stable isotope study near the Namoi River



Natural flow/winter



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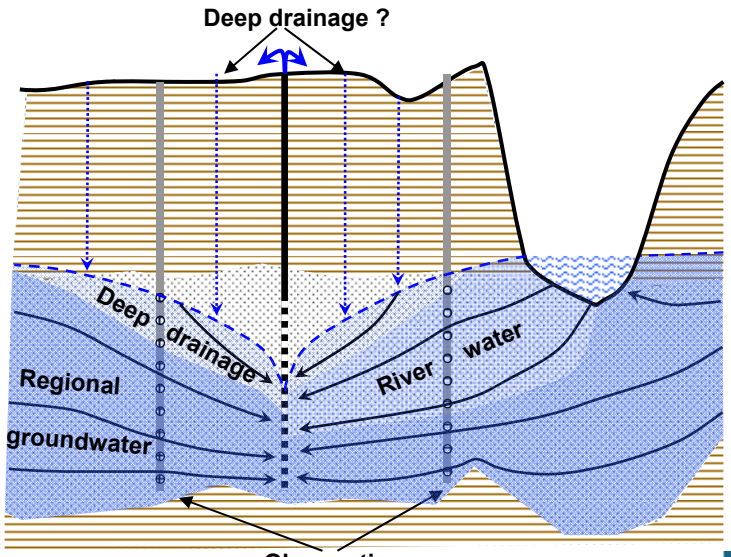
Irrigation



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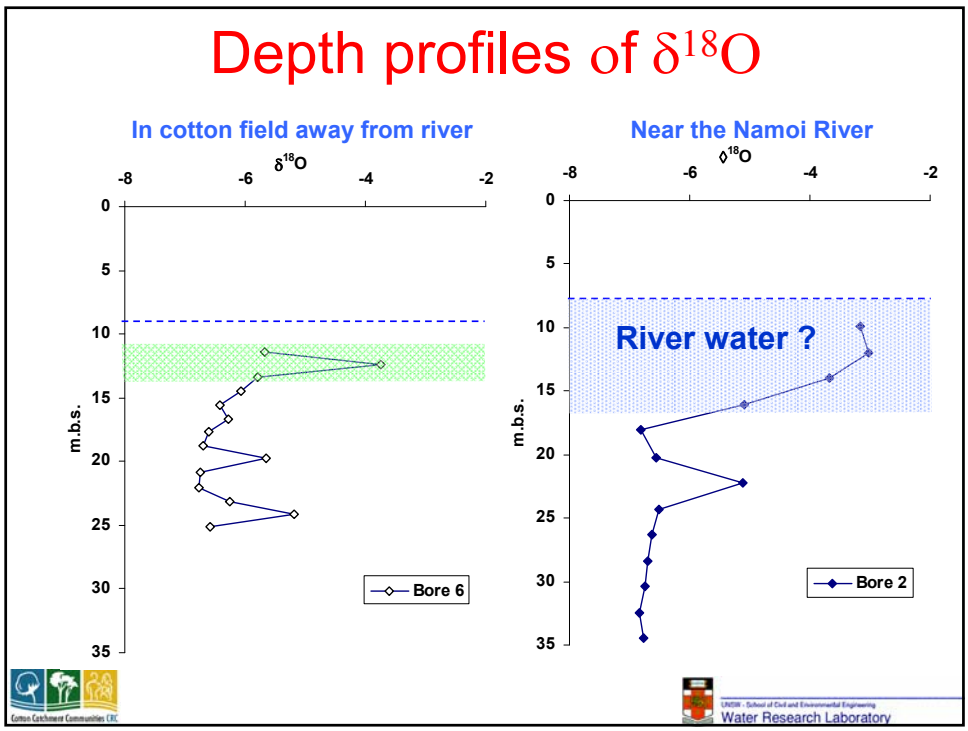
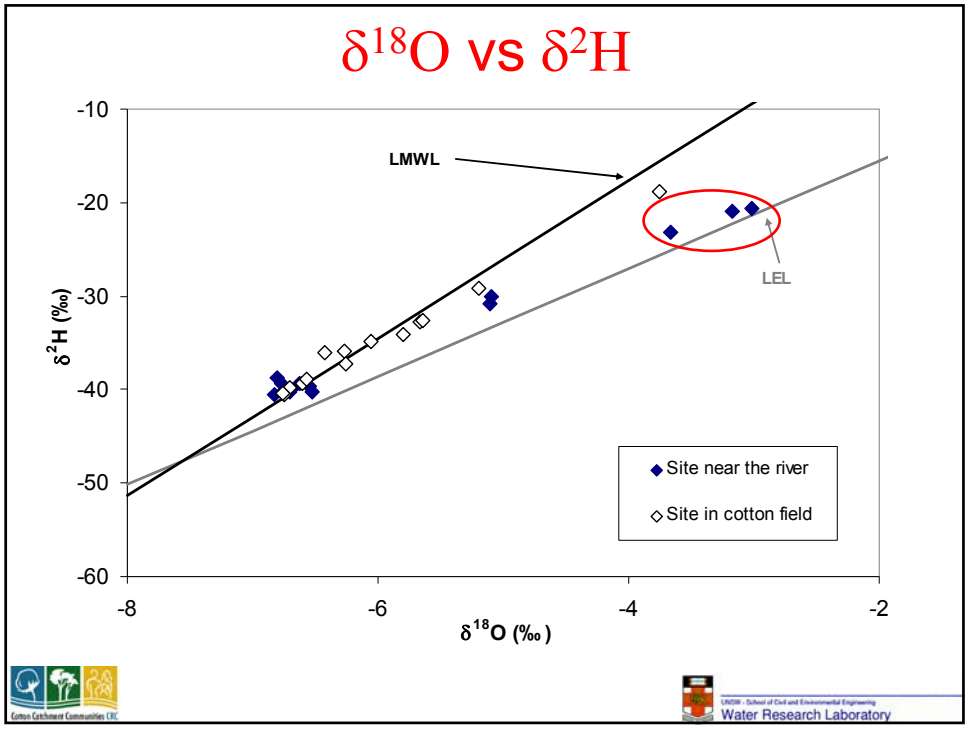
Depth profiles of $\delta^{18}O$




δ18O vs δ2H
-10
-20
-30
-40
-50
-60
δ2H (‰)
LMWL
LEL
Site near the river
Site in cotton field
-8
-6
-4
-2
δ18O (‰)
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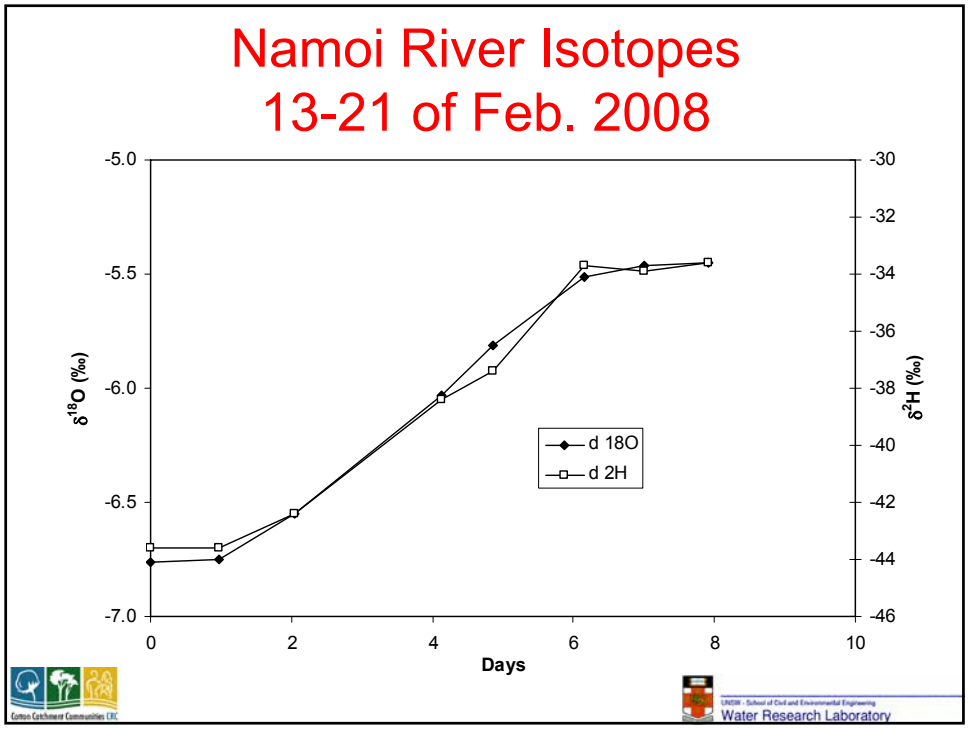
Namoi River Isotopes
13-21 of Feb. 2008
-5.0
-5.5
-6.0
-6.5
-7.0
δ18O (‰)
-30
-32
-34
-36
-38
-40
-42
-44
-46
δ2H (‰)
d 18O
d 2H
0
2
4
6
8
10
Days
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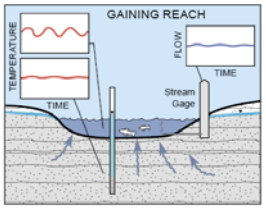
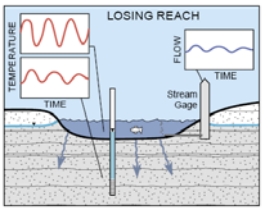
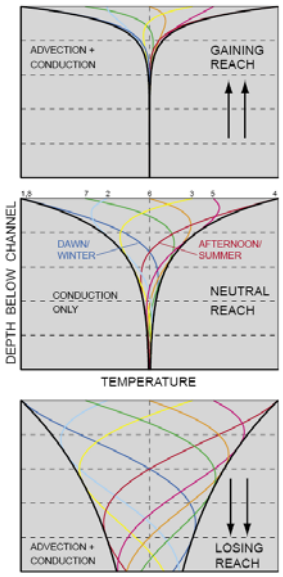
Use of heat transport for studying surface water groundwater interactions

Source: USGS Fact Sheet 2004-3010







Cotton Catchment Communities CRC

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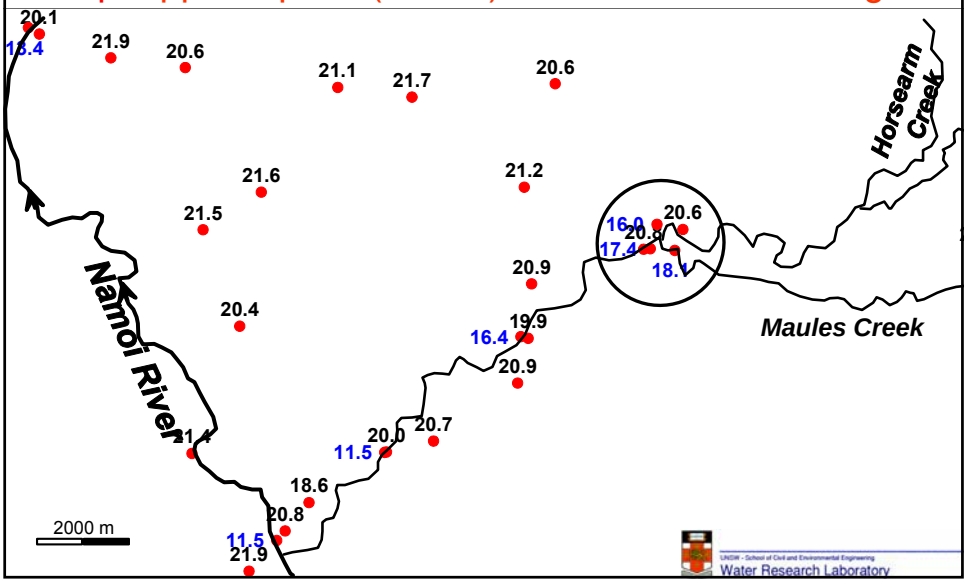
Heat as a tracer

Temp. upper aquifer (<30 m) and surface water August



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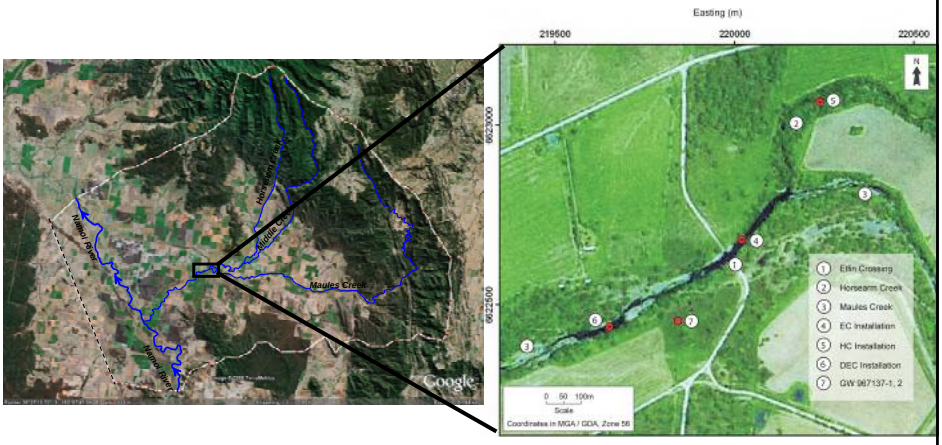
Field example Maules Creek, NSW

Using streambed temperature profiles



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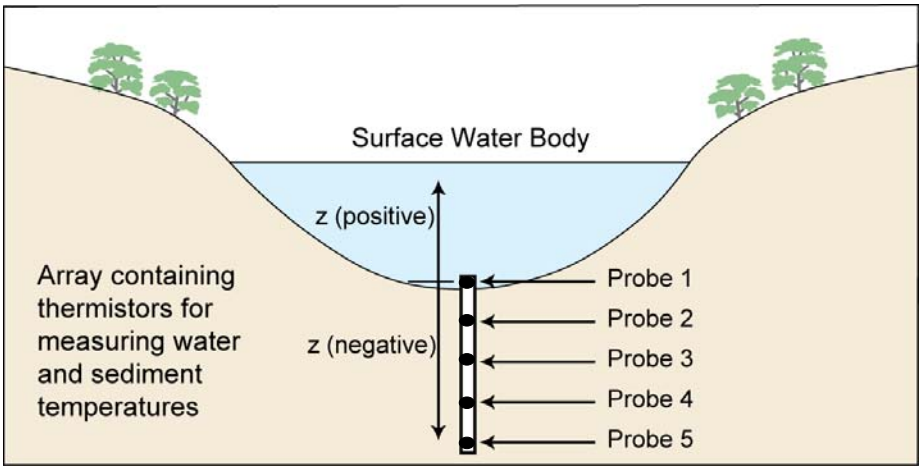
Data requirements



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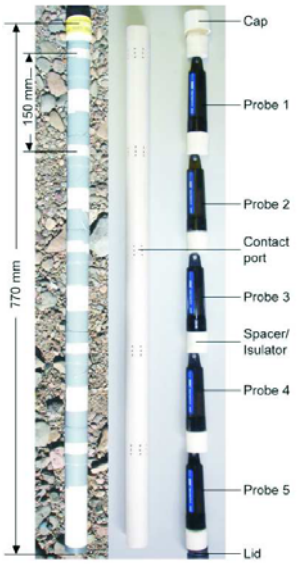
Temperature array construction



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Field installation

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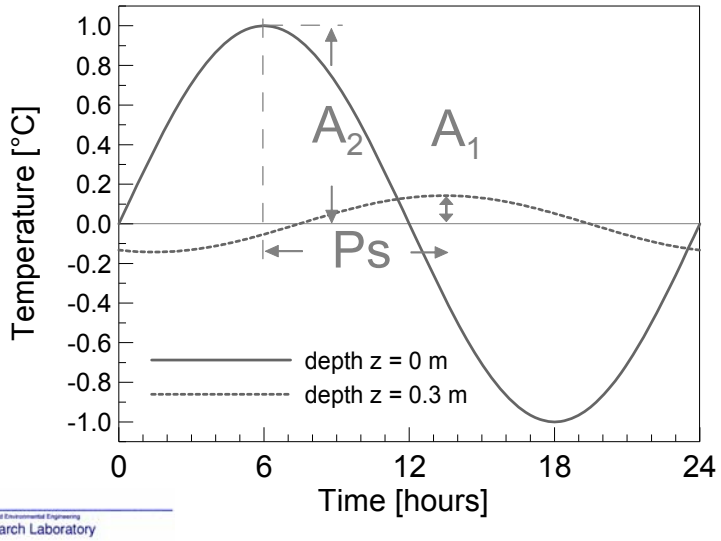
Numerical solution to heat flow



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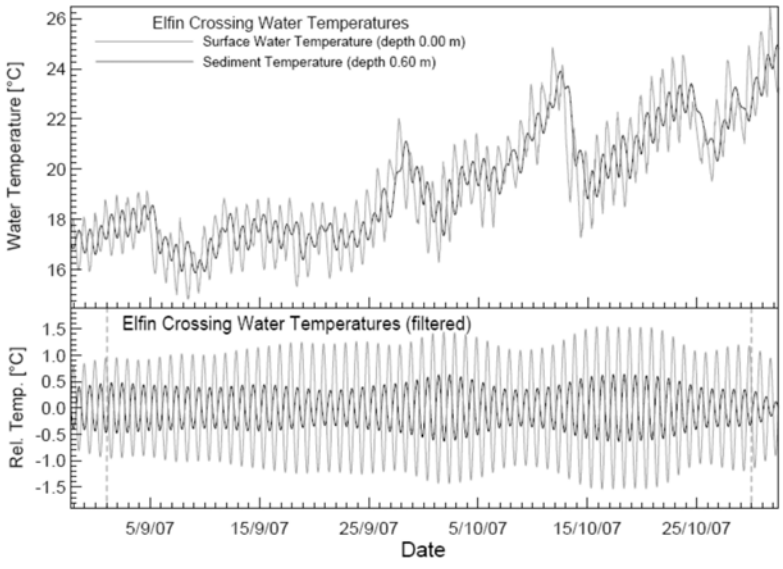
Data collection and processing



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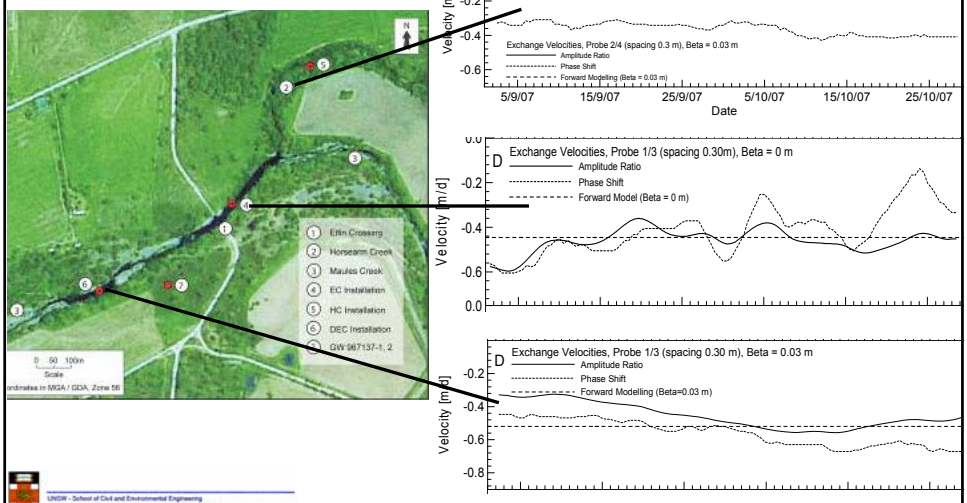
Some results



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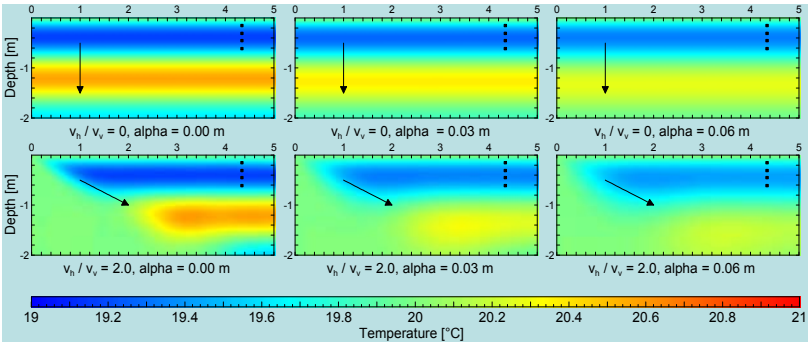
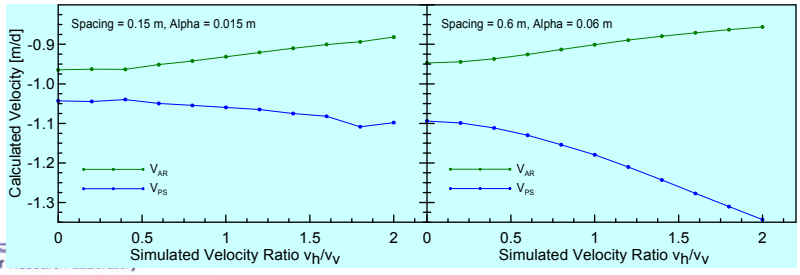
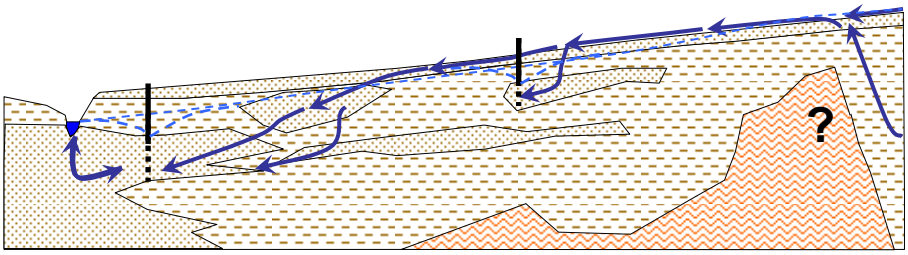
Effects of dispersion and deviation from the 1-D flow assumption





Conceptual model

for surface water groundwater interactions



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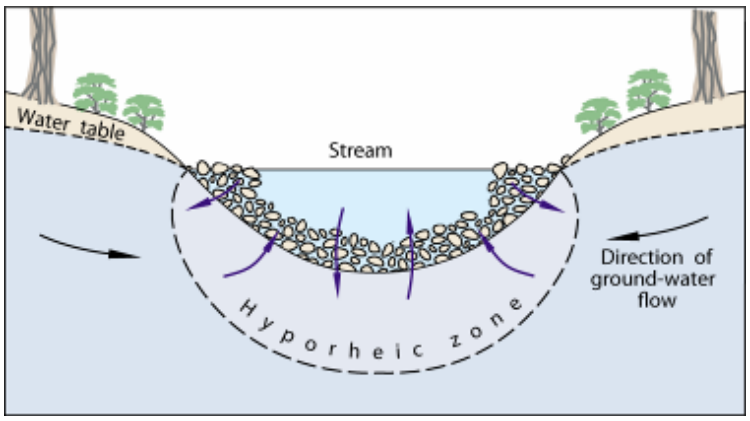
Streambed chemistry and stygofauna sampling



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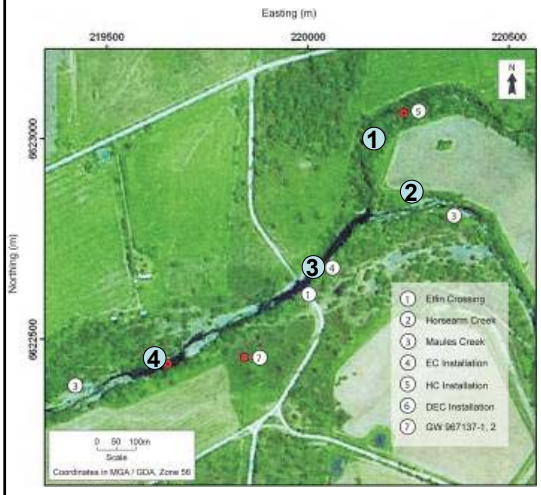
Sampling sites



Cotton Catchment Communities CRC

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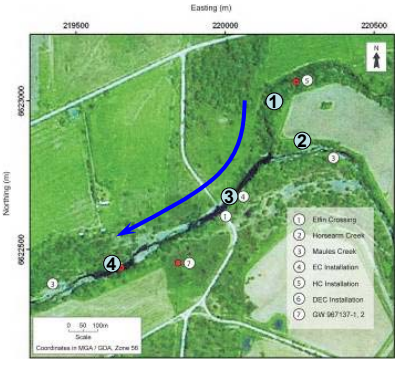
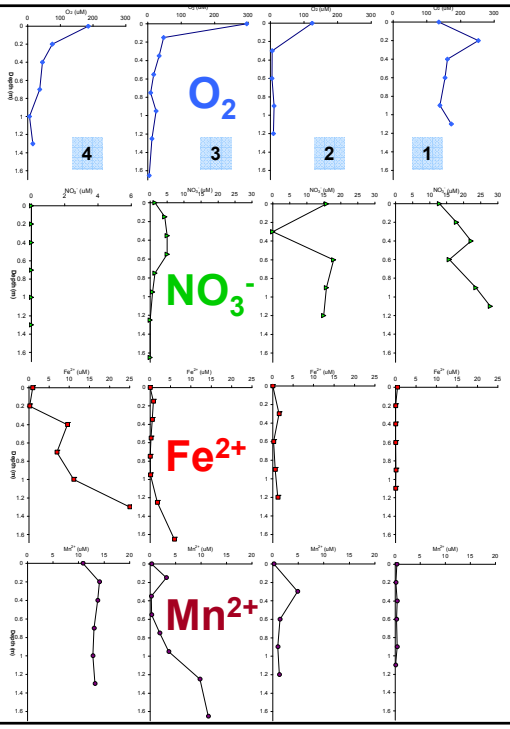
Streambed chemistry results





Redox-processes

related to reactive organic matter in the stream

Oxygen reduction:

$$O_2 + CH_2O \rightarrow CO_2 + H_2O$$

Nitrate reduction:

$$4NO_3^- + 5CH_2O \rightarrow 2N_2 + 4HCO_3^- + CO_2 + 3H_2O$$

Iron oxide reduction:

$$4FeOOH(s) + CH_2O + H_2O \rightarrow 4Fe^{2+} + HCO_3^- + 7OH^-$$

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Stygofauna from the region

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Modeling and data integration

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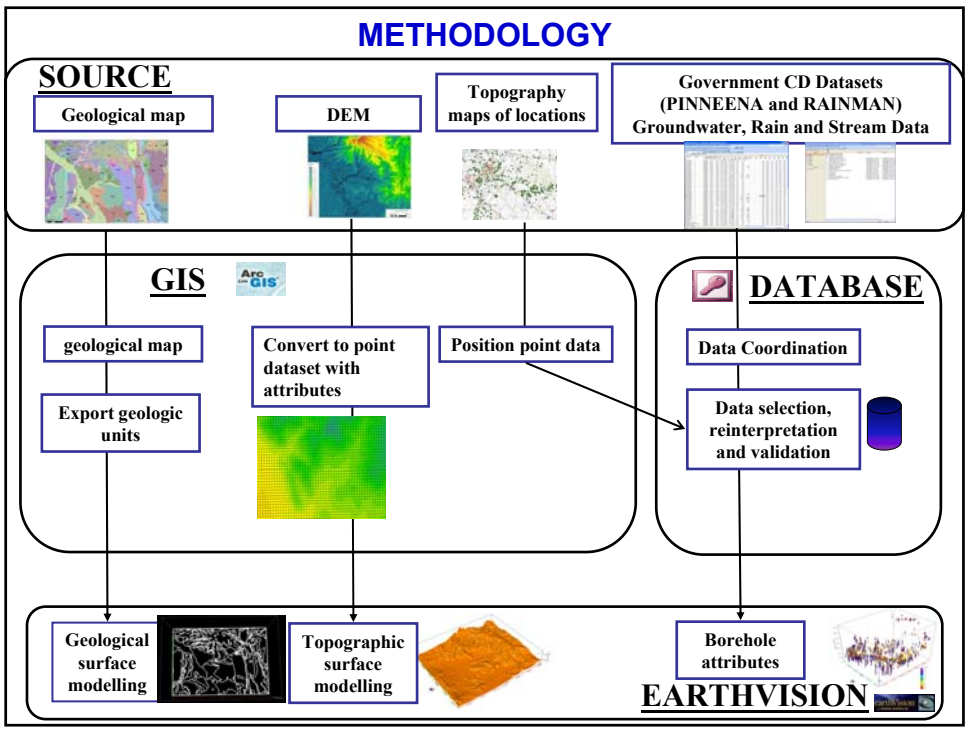
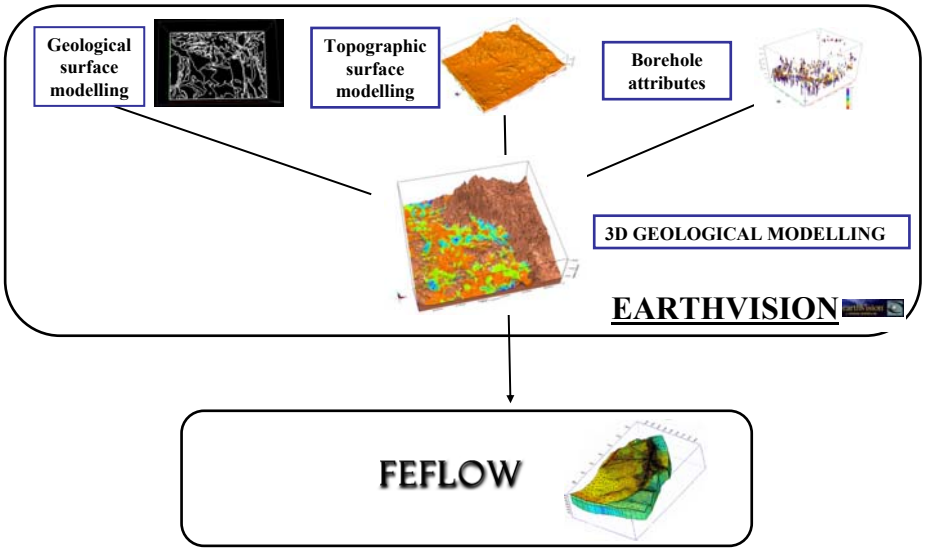
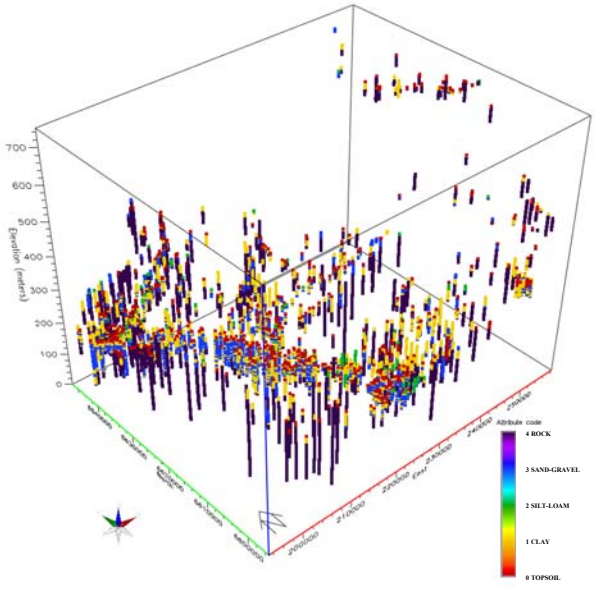


METHODOLOGY

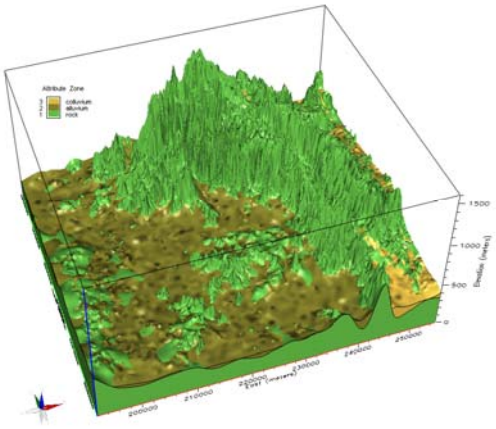


MAULES CREEK BORE LITHOLOGY ANALYSIS



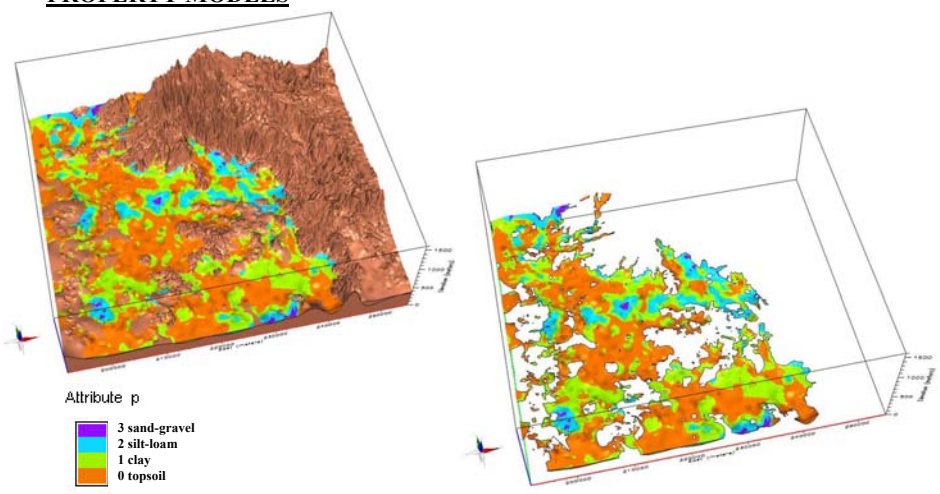
3D GEOLOGICAL MODEL

(3D structural model of colluvium, alluvium and rock)

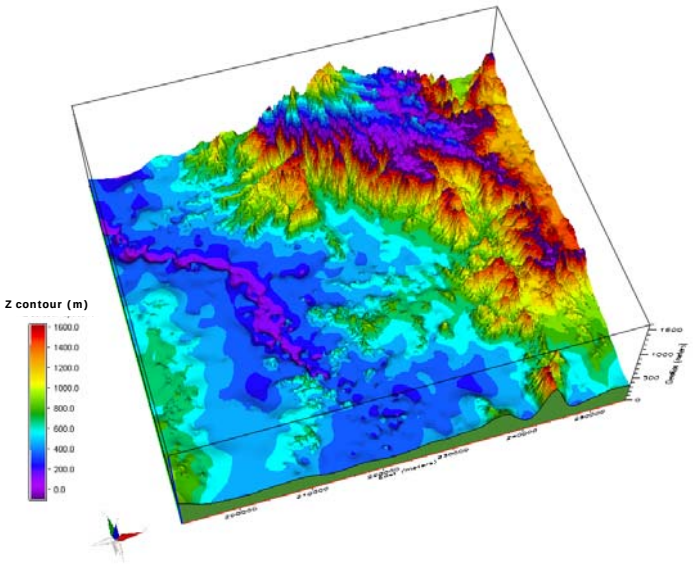


3D LITHOLOGY MODEL – MAULES CREEK

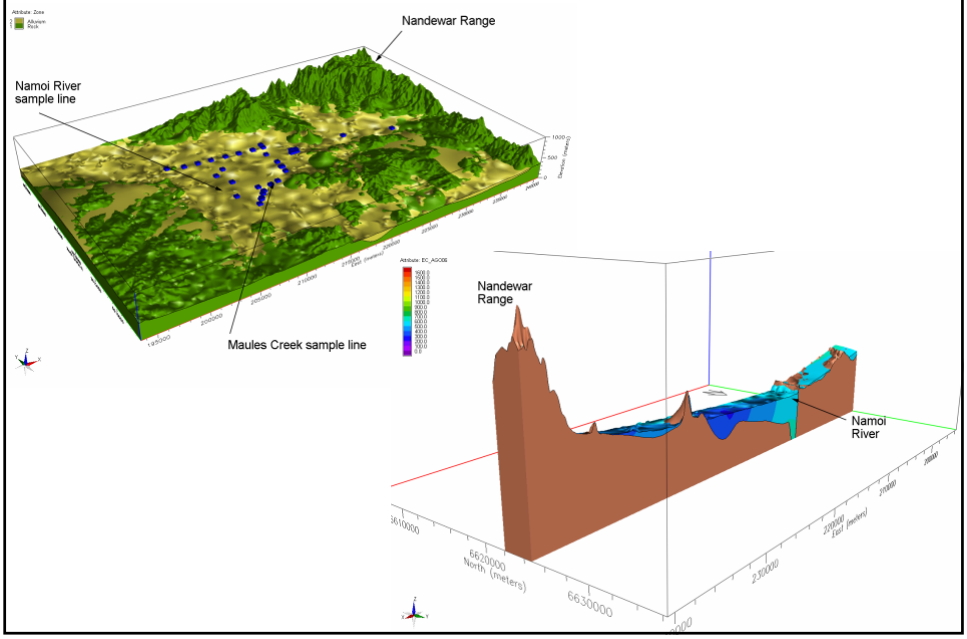
PROPERTY MODELS



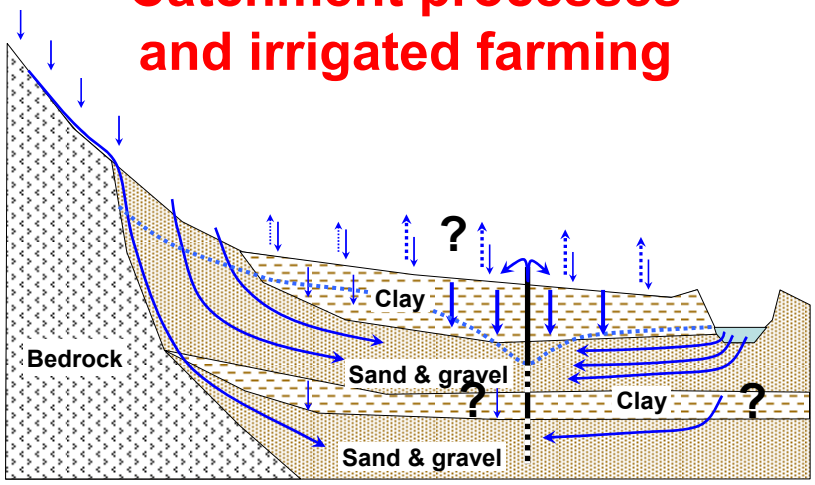
NAMOI RIVER PALEOCHANNEL



View various properties in sections



Catchment processes and irrigated farming



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Conclusions

- Groundwater abstraction seems to cause long term decreasing water levels in the aquifer.
- Groundwater abstraction appears to enhance recharge from rivers and streams.
- The location of exchange is largely controlled by variations in the geology and the location of abstraction.
- Changes in flow regimes from gaining to loosing may have impacts on water quality and in turn on streambed ecology.
- Direction of flow and sources of water can sucessfully be determined by:
  - Streambed temperature profiles
  - Hydrogeology
  - Chemical tracers (stable isotopes)
- In the time to come a big challenge will be to quantify processes on catchment scale.

Acknowledgements

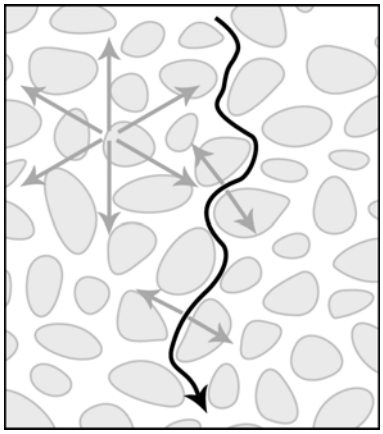
- CCC-CRC for project funding.
- Department of Water and Energy (DWE) for letting us sample their monitoring wells and for supplying us with basic data from their archive.
- Mr Gary Johnson, CEO of Jaycar Electronics for funding the Gary Johnson Chair at UNSW.

Conduction and convection of heat

Rate of change | Conduction | Convection (flow)

$$\frac{\partial T}{\partial t} = \kappa_\epsilon \frac{\partial^2 T}{\partial z^2} - \frac{\phi v_f \rho_f c_f}{\rho c} \frac{\partial T}{\partial z}$$

T is temperature which varies with time (t) and depth (z),
κ_ϵ is effective thermal diffusivity,
Φ is porosity,
v_f is vertical fluid velocity,
ρ_f is fluid density,
c_f is heat capacity of the fluid
ρ is density of the saturated sediment-fluid system and
c is the heat capacity of the sediment-fluid system.

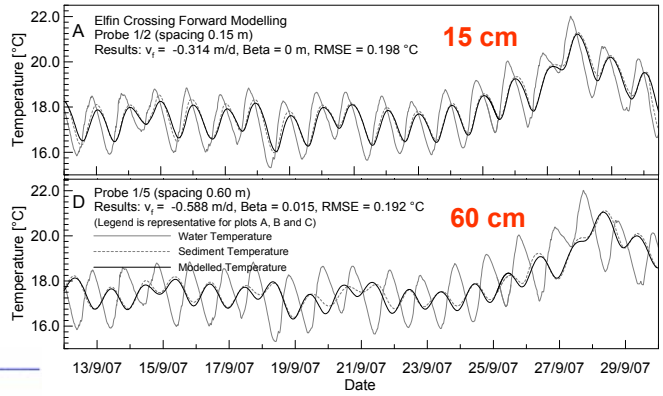


Numerical solution to heat flow

Approach 1: Forward modelling. Procedure:

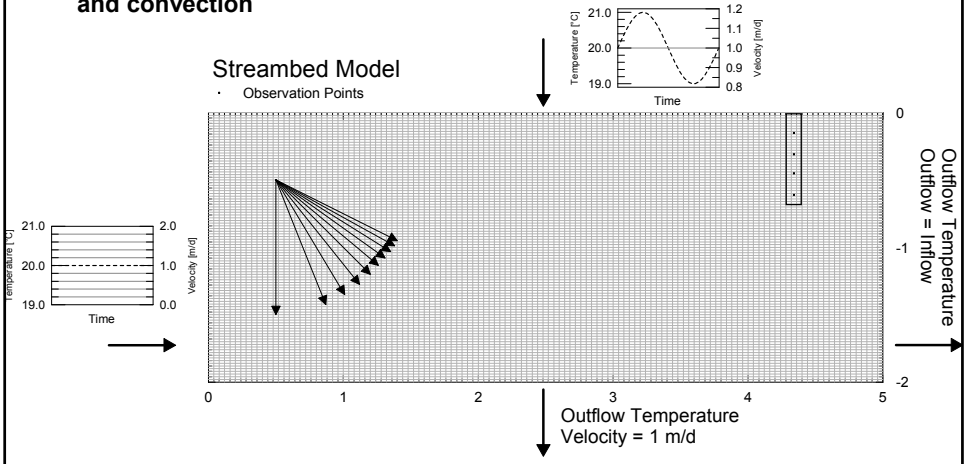
- calculate temperature variations at a given depth using measured surface temperature and a water flow velocity
- compare to the observed temperature at that depth
- change water flow velocity til best fit is obtained

Works only for a relatively constant water velocity !!!



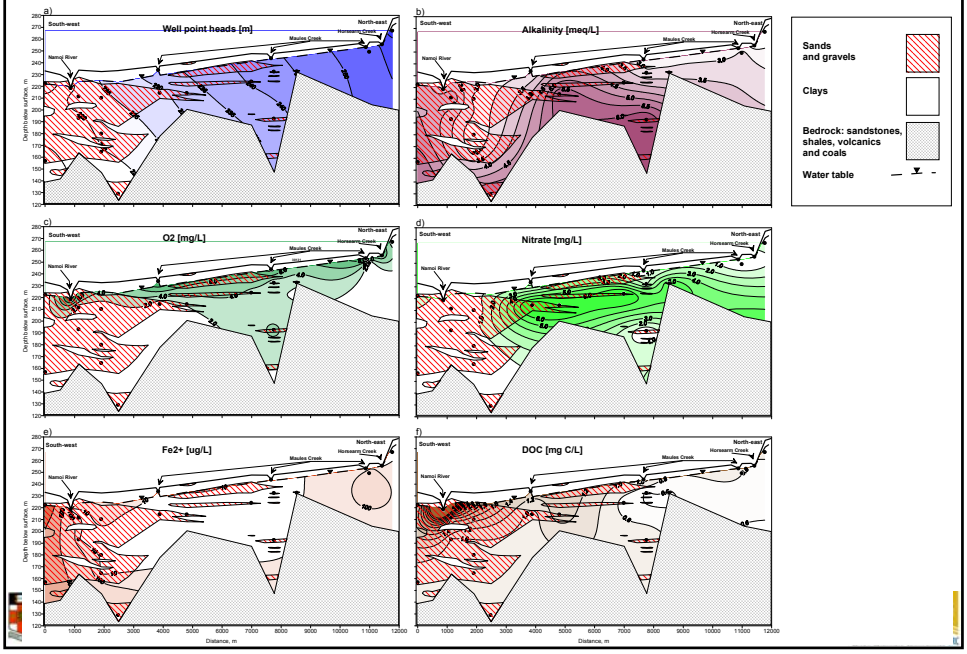
Numerical solution to heat flow

Approach 3: 2/3-D numerical modelling of water flow and heat conduction and convection

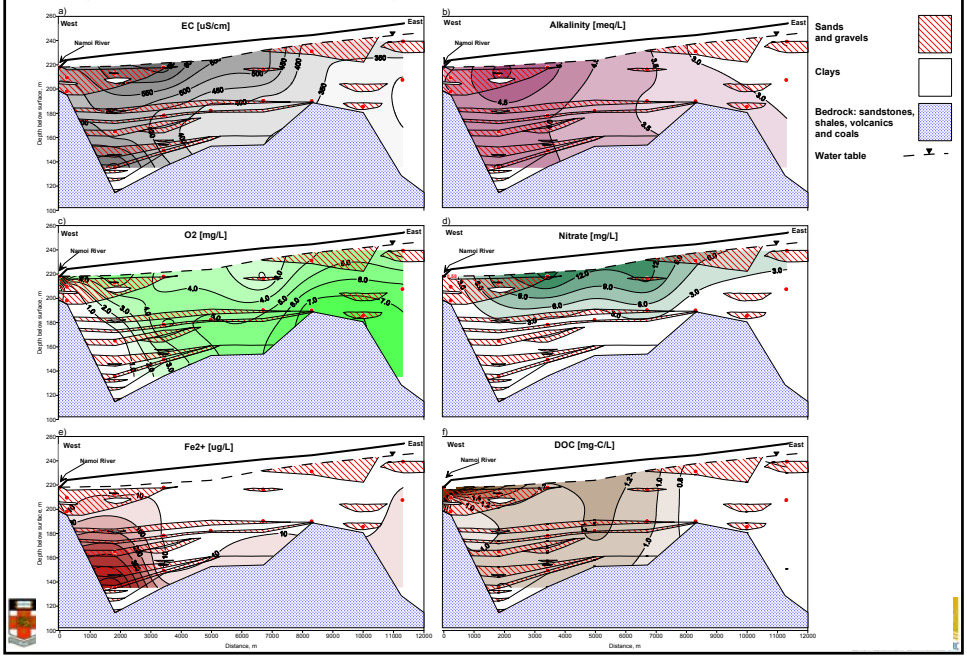


Free USGS software: VS2DHI
www.usgs.gov.us

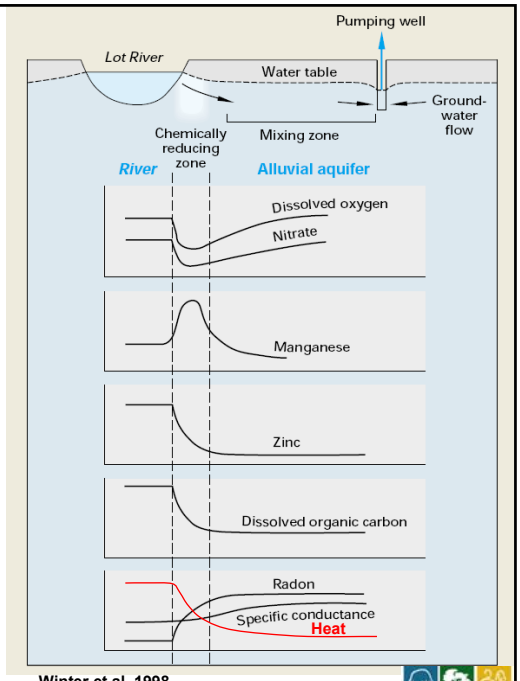
Hydrochemistry – Maules Creek



Hydrochemistry – Northern transect



Hydrochemical and Tracer methods



Winter et al. 1998

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