Pressures on groundwater

Handling the impacts of urbanisation

Andrew McKenzie
British Geological Survey
aam@bgs.ac.uk

Implications of urbanisation?

- What can we expect (aspiration/ vs reality)?
- What does it mean for the basin?
- What do we know?
- What do we need to know?

"Girls carrying water in India" by Tom Maisey - Flickr. Licensed under CC BY 2.0 via Commons - https://commons.wikimedia.org/wiki/File:Girls_carrying_water_in_India.jpg#/media/File:Girls_carrying_water_in_India.jpg

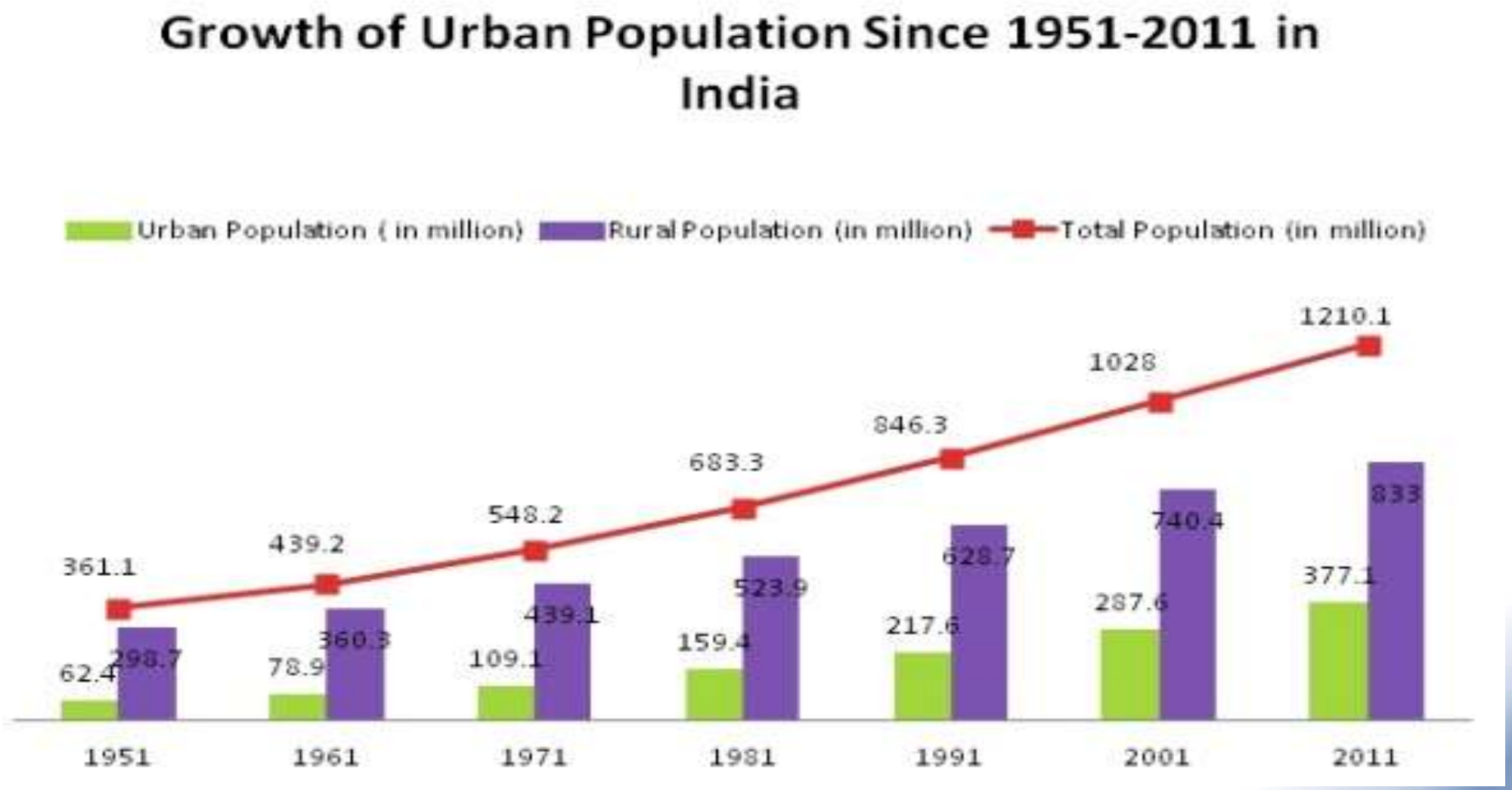
Image: Arne Huckelheim, Wikimedia

Girls carefully opens the water taps in the kitchen

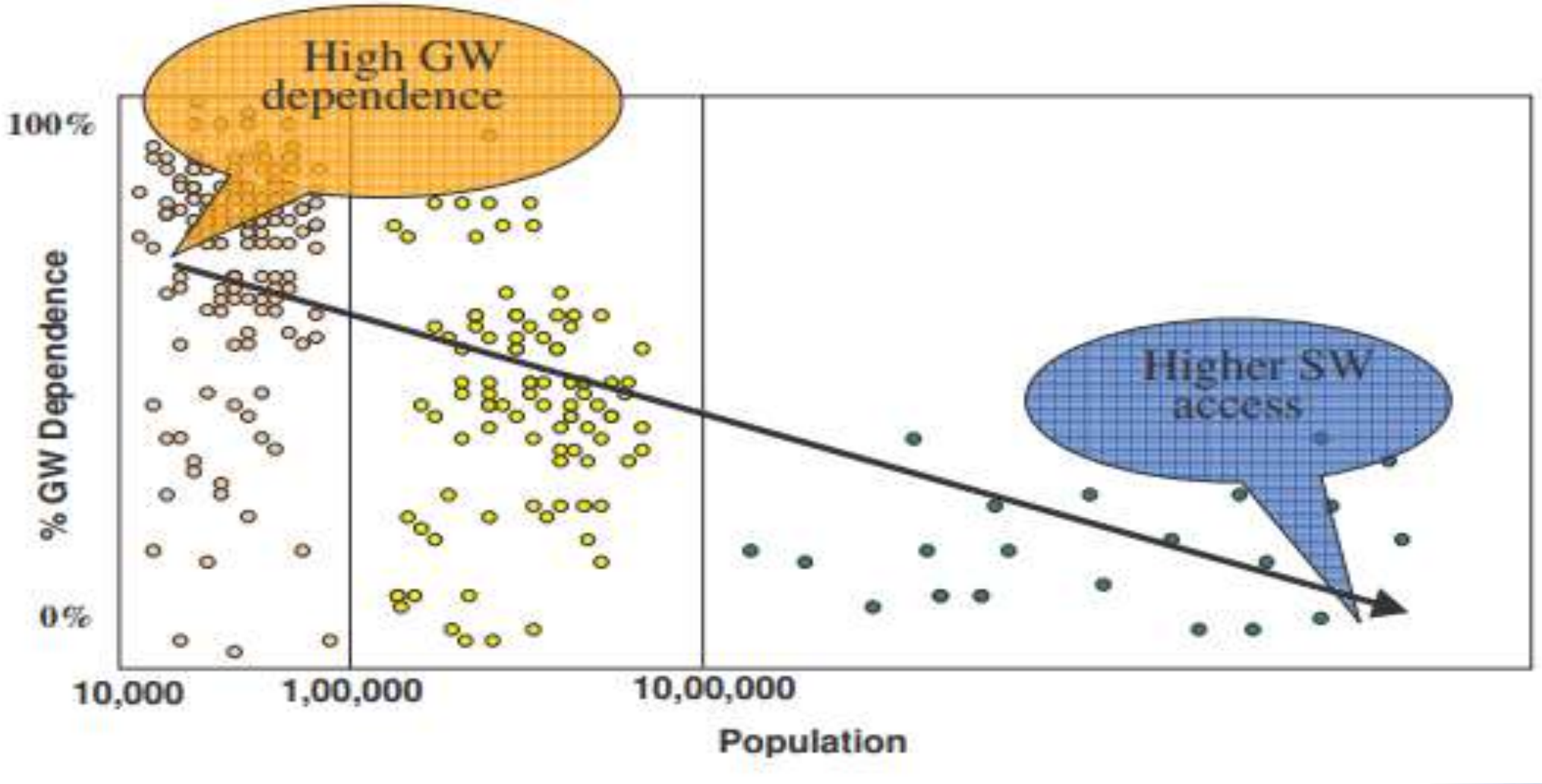
Implications

- More abstraction for urban consumers and industry
  - Sustainable abstraction needs more rural wellfields?
  - Less abstraction for irrigation?
- More piped water in urban areas
  - Less local groundwater use and more leakage?
  - Move from groundwater resource scarcity to groundwater as a problem?
- More treated wastewater
  - Opportunities for waste water reuse?
  - Need to control/clean up industrial pollution?

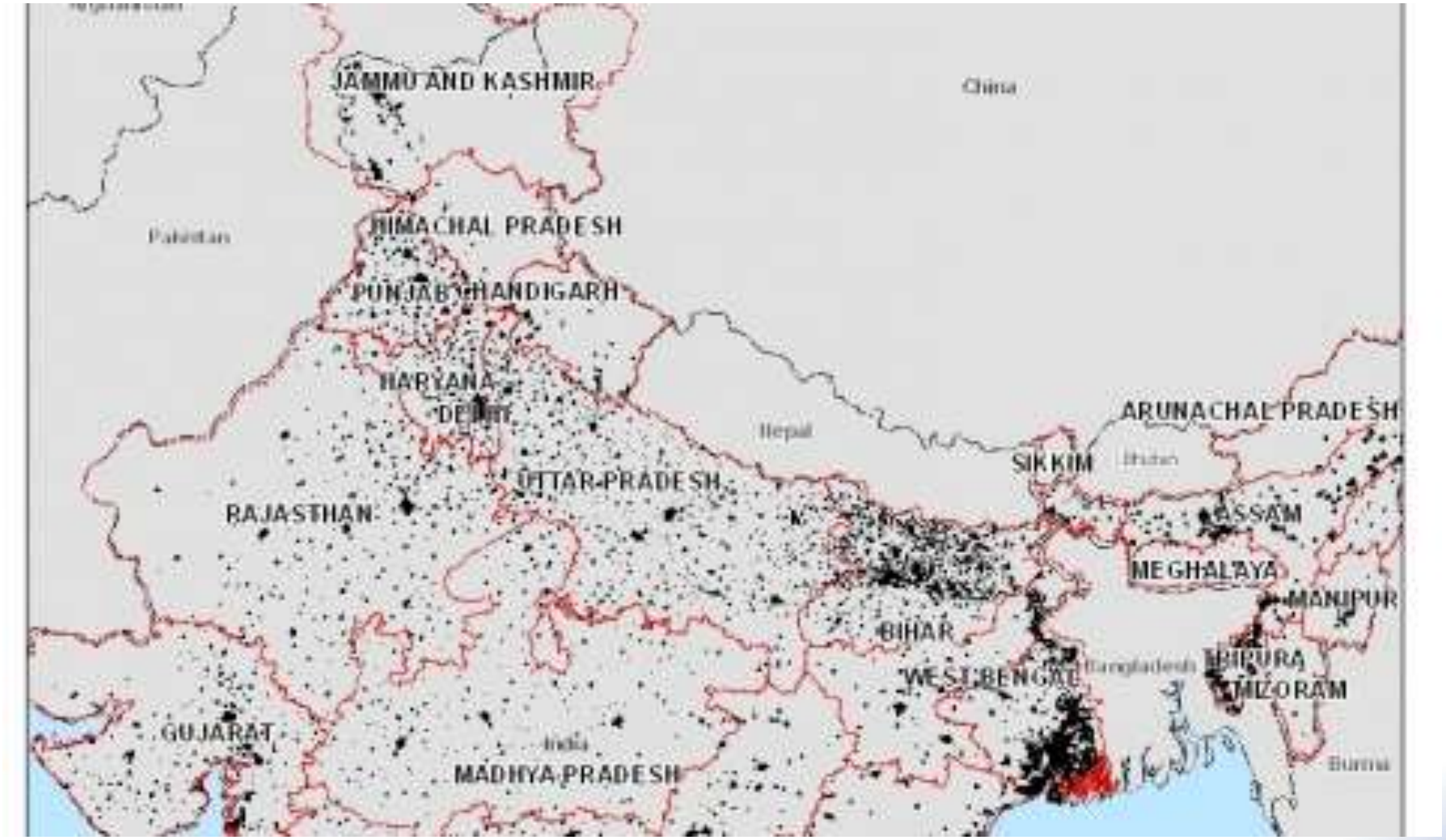
Population growth and demand



Groundwater dependence



Towns with > 10K Inhabitants

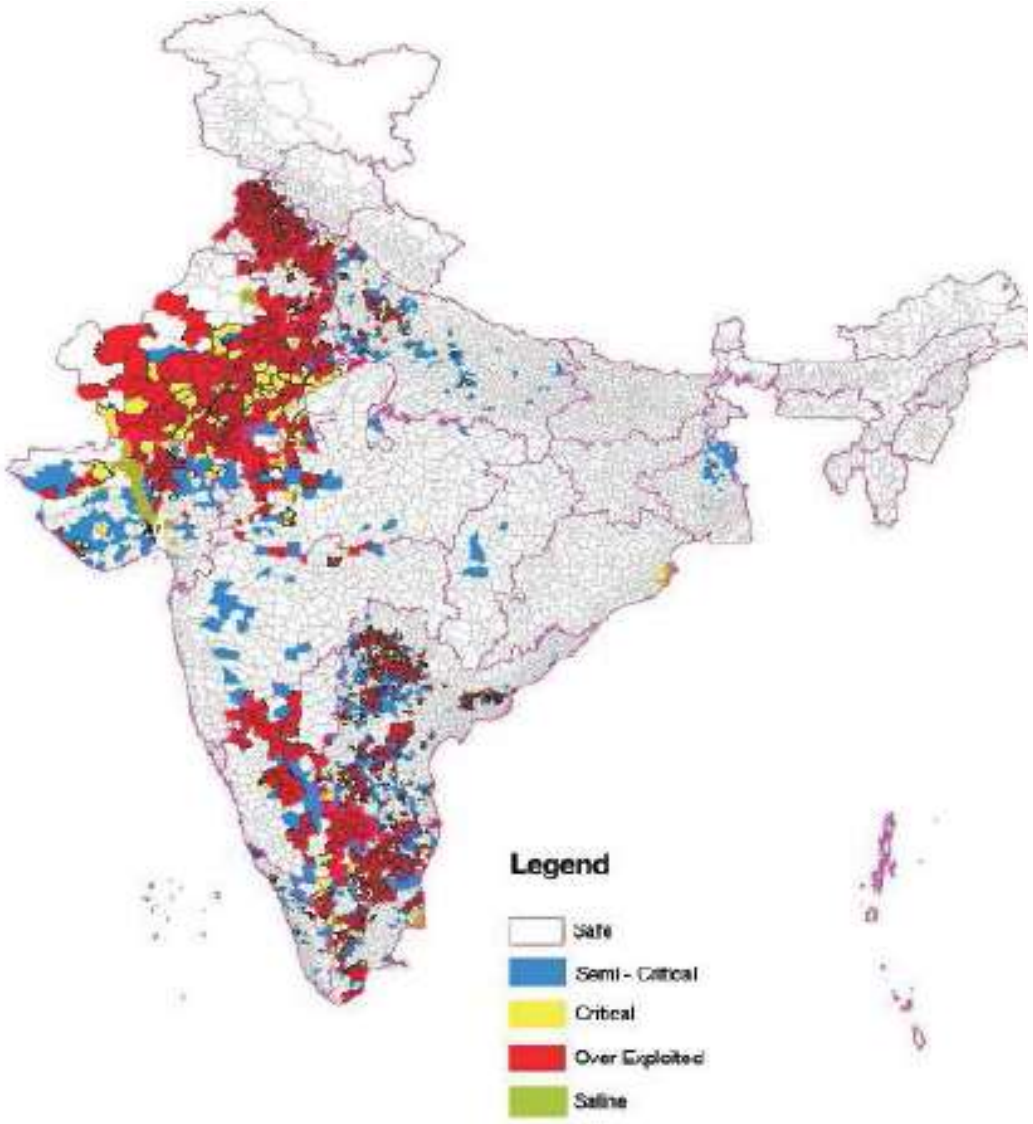


Demands

- Current annual Ganga groundwater abstraction 122 km^3, 10% urban, so 12 km^3
- 0.6 Billion people, assume 50% groundwater = approximately 110 l/person/day (less leakage)
- If we increase to 1 billion people, maintain 50% from groundwater, and aspire to 120 l/person/day, assume 20% leakage, we need 25 km^3
- If current groundwater is ‘sustainable’ urban supply will require 20% of the resource.


Photo ‘Simply CVR’

Sustainability



The Indian EXPRESS

Home › India › India-News-India › Varanasi villagers blame Coca-Cola for water scarcity

Varanasi villagers blame Coca-Cola for water scarcity

Coca-Cola uses the same groundwater source to meet its production needs -- placing it in direct competition with the local community, environmentalists say.

Like 121 Share 27 Tweet 5 Comments (5)

By: Thomson Reuters Foundation | New Delhi | Updated: November 28, 2015 12:05 pm

Varanasi villagers are clear that Coca-Cola is not welcome in Mehdiganj.

CURRENT RESULTS FIXTURES

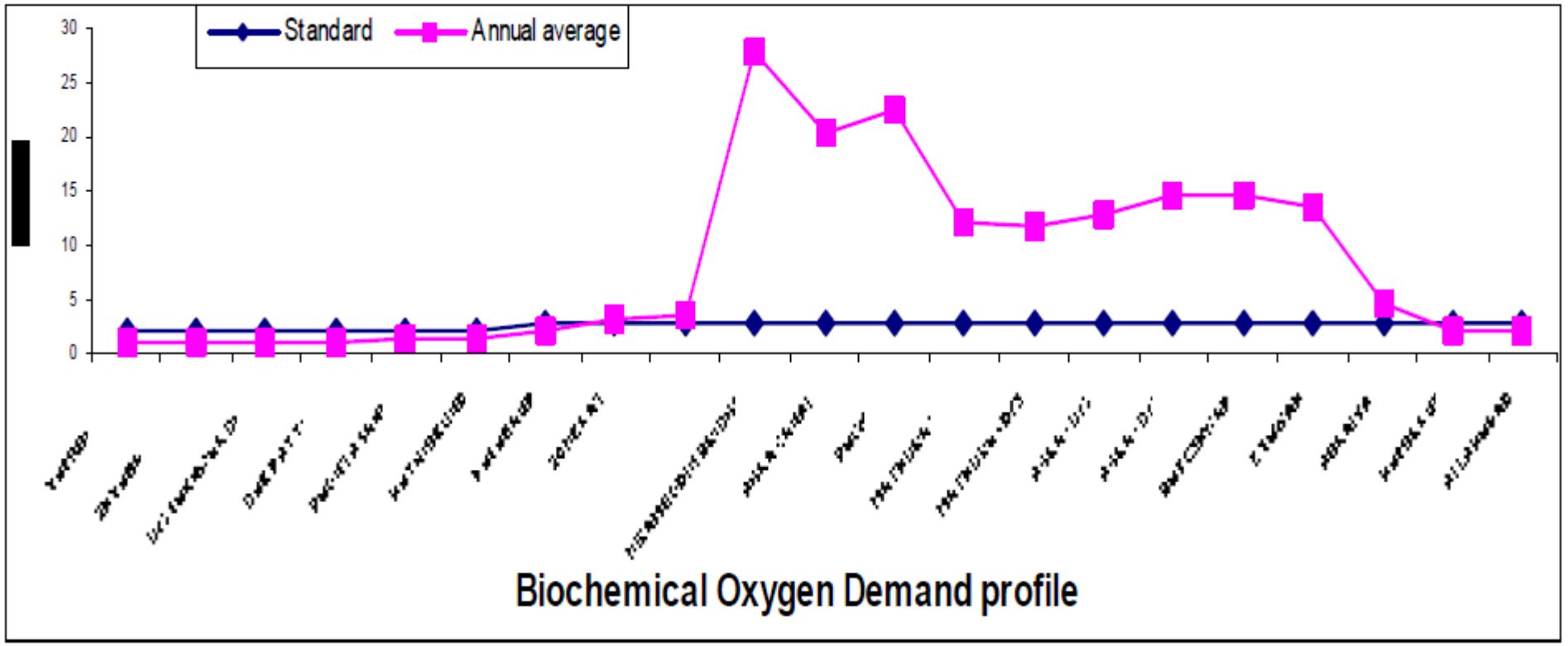
AFG 160/4 (20.0 OV)
OMN
SCORECARD

PHOTOS

Limits on direct extraction?

- Quantity
  - Delhi, 1484 km^2, 16 Million people, rainfall 0.7 m/annum
  - 92 m^2/person, recharge 0.07 m/annum, 6.5 m^3/person, 17 l/p/d
  - ? 9 l/p/d by 2050?
- Quality
  - Industrial contamination
  - On site sanitation
  - Leakage of sewers

BOD - Yamuna



Rising water table in SE Delhi poses flood threat

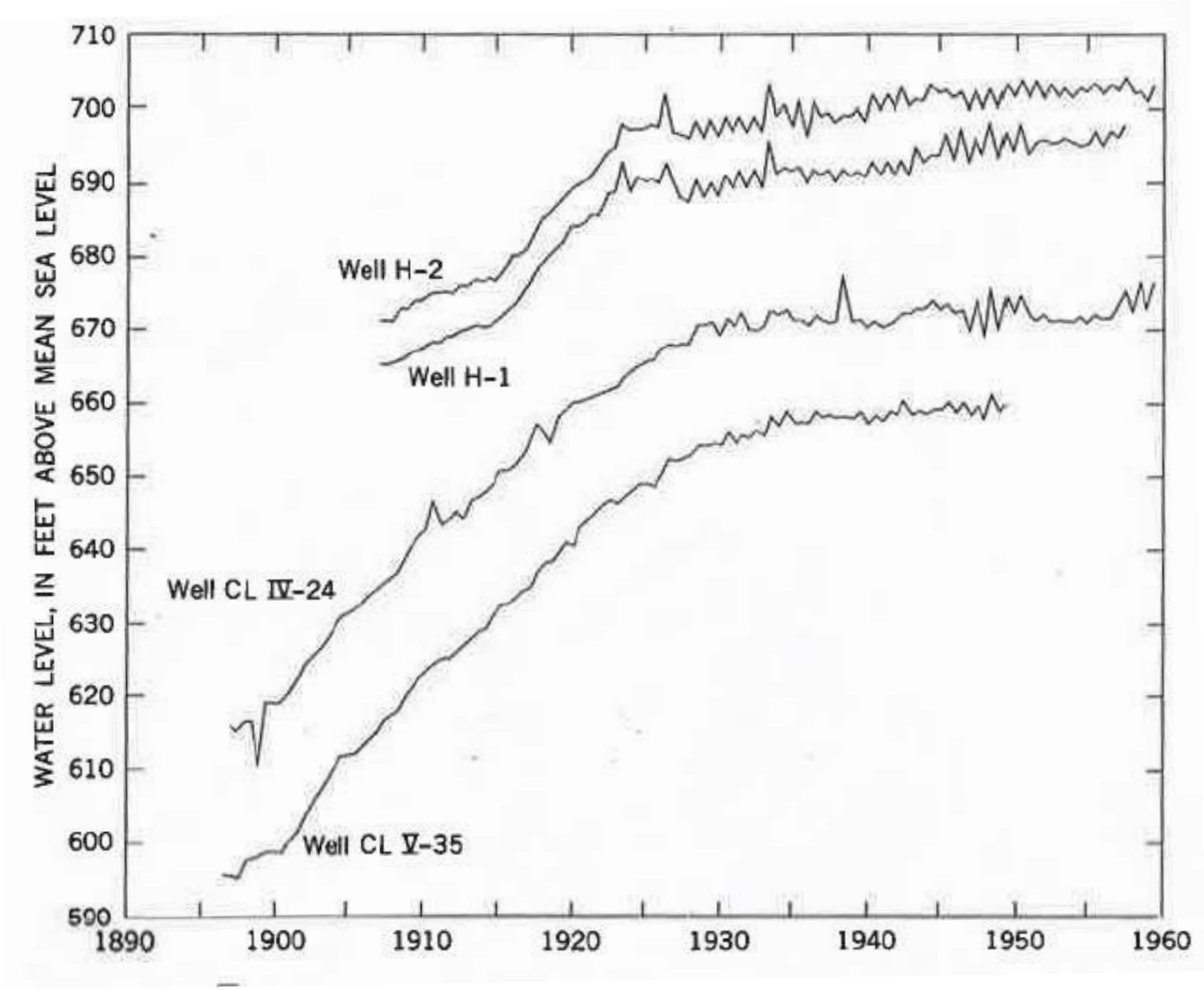
Jayashree Nandi, TNN | Sep 11, 2015, 12.10AM IST

NEW DELHI: Believe it or not, rising groundwater level in parts of southeast has caused flooding of basements. Central Ground Water Authority (CGWA), which was investigating a number of complaints by residents, has stumbled upon the shocking fact.

A lapse in the monitoring of the groundwater levels has made these areas vulnerable to massive flooding in future. About 10 years ago, Delhi Jal Board (DJB) started supplying piped water to these areas from a water treatment plant nearby.

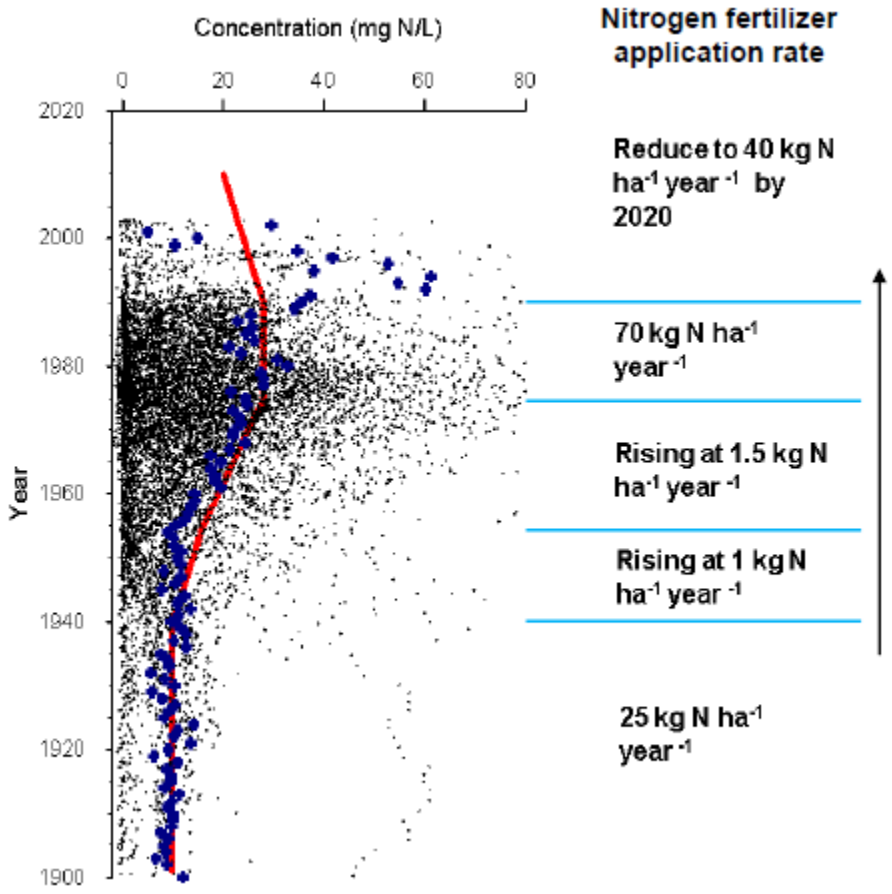
Residents who were completely dependent on borewells stopped using them. But these changes were not monitored. Ironically, all these areas are still notified as "over-exploited" zones.

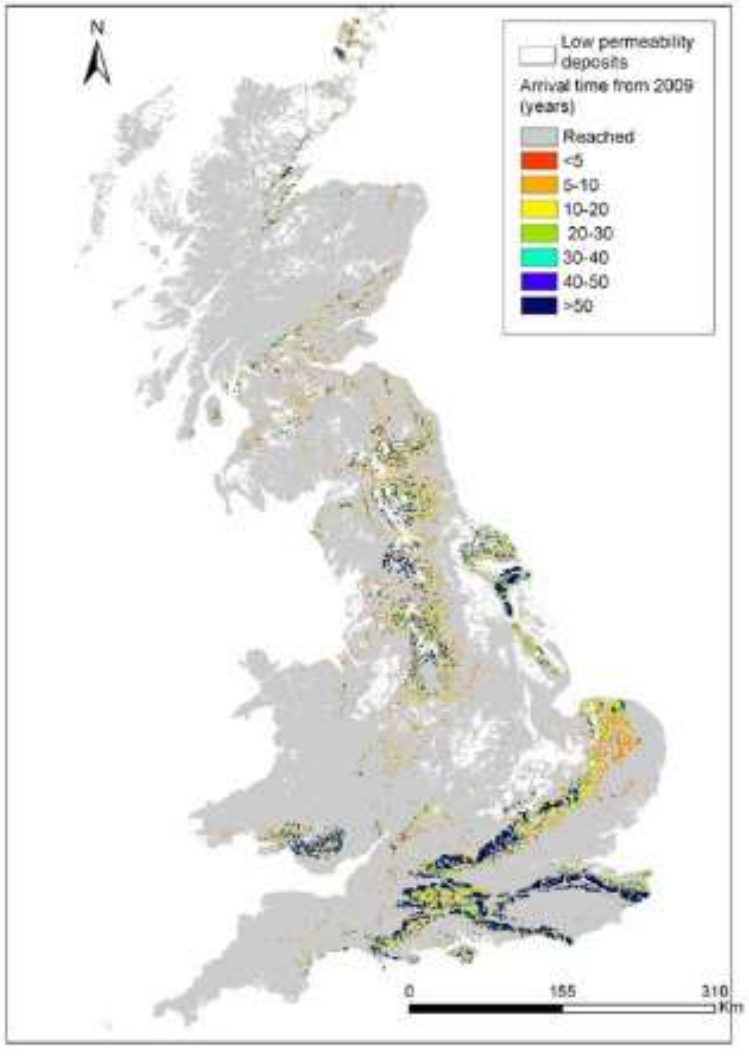
Timescales



- Groundwater system response is slow!
- Vertical + horizontal flow velocities measured at metres/year
- Vertical flow normally orders of magnitude < horizontal flow
- High storage anisotropic aquifers can take a long time to equilibriate

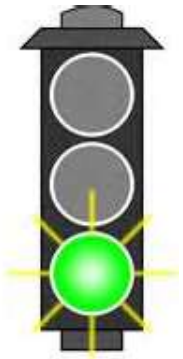
The UK Nitrate ‘timebomb’



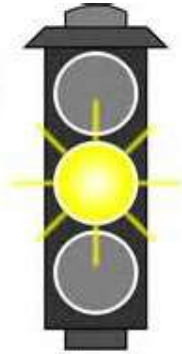


Where are we?

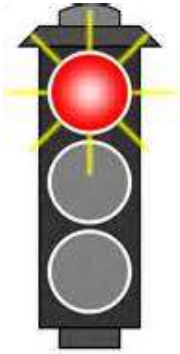
- What?
  - Multiple studies
  - Good national and international exemplars
  - Still resource focussed?



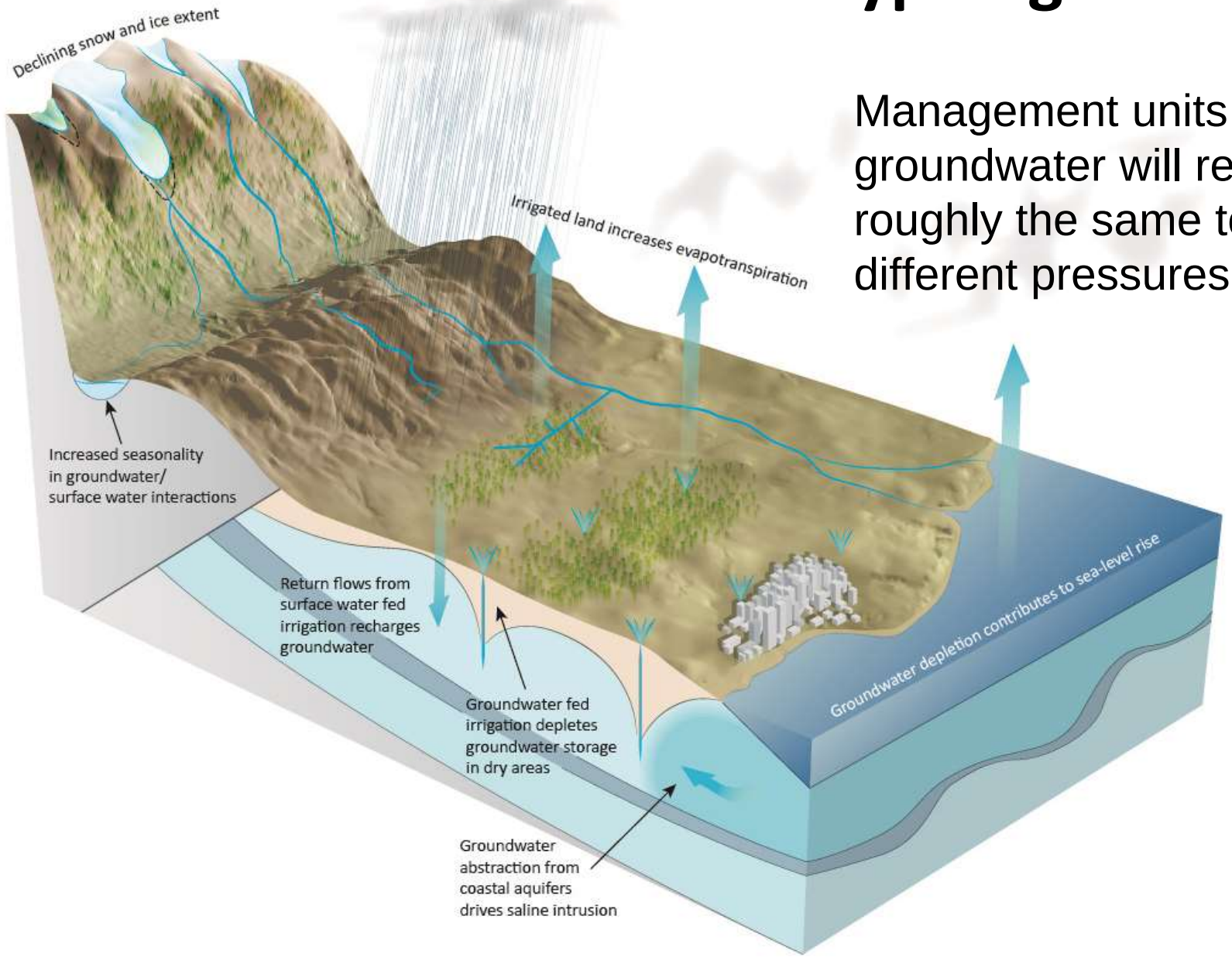
- Where?
  - Sparse monitoring networks at urban scale (3rd dimension)
  - ‘Purpose driven’ and academic monitoring – lack of long term focus



- Why?
  - Difficulties of 3D characterisation of urban aquifers

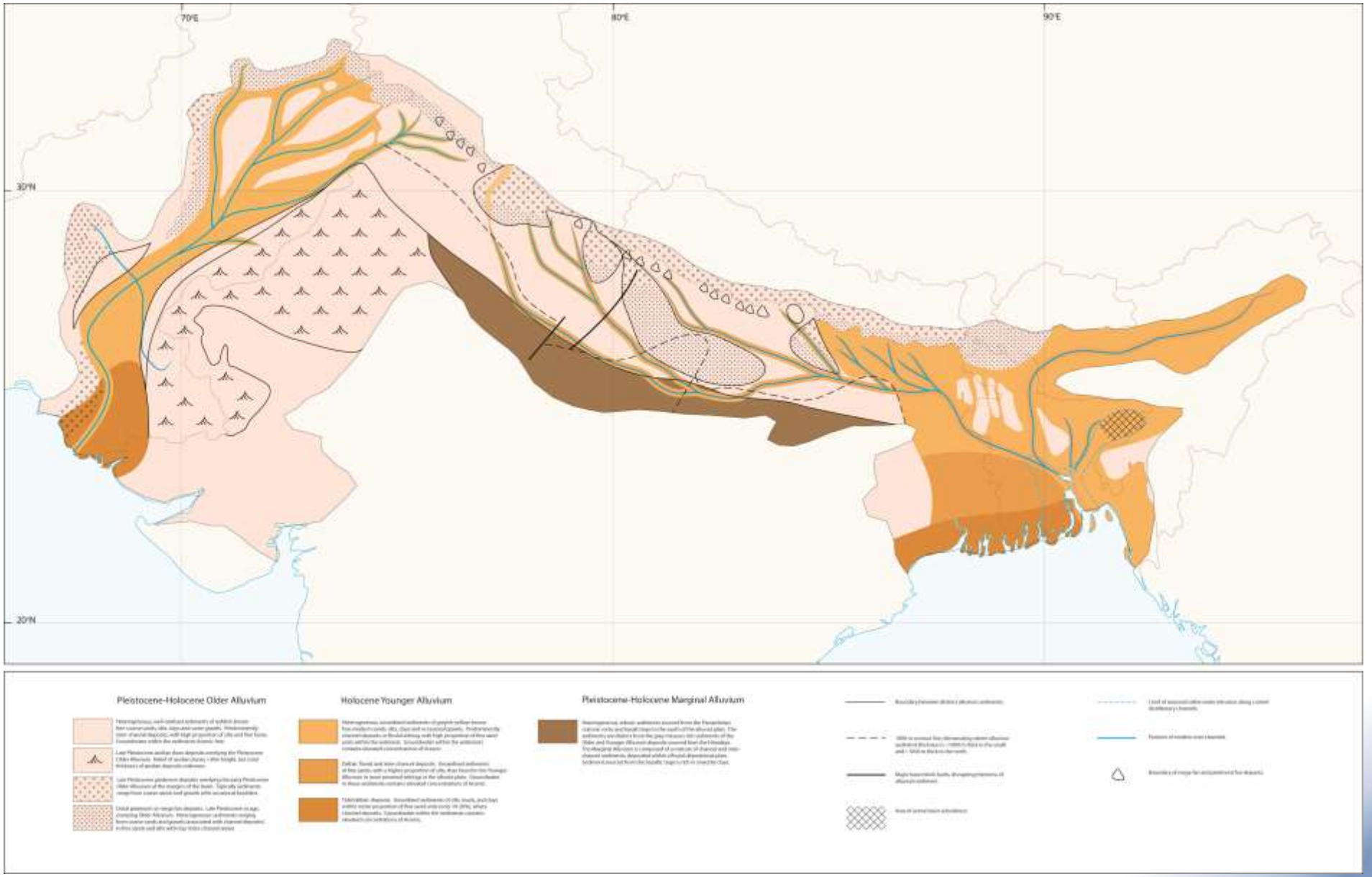


Groundwater typologies

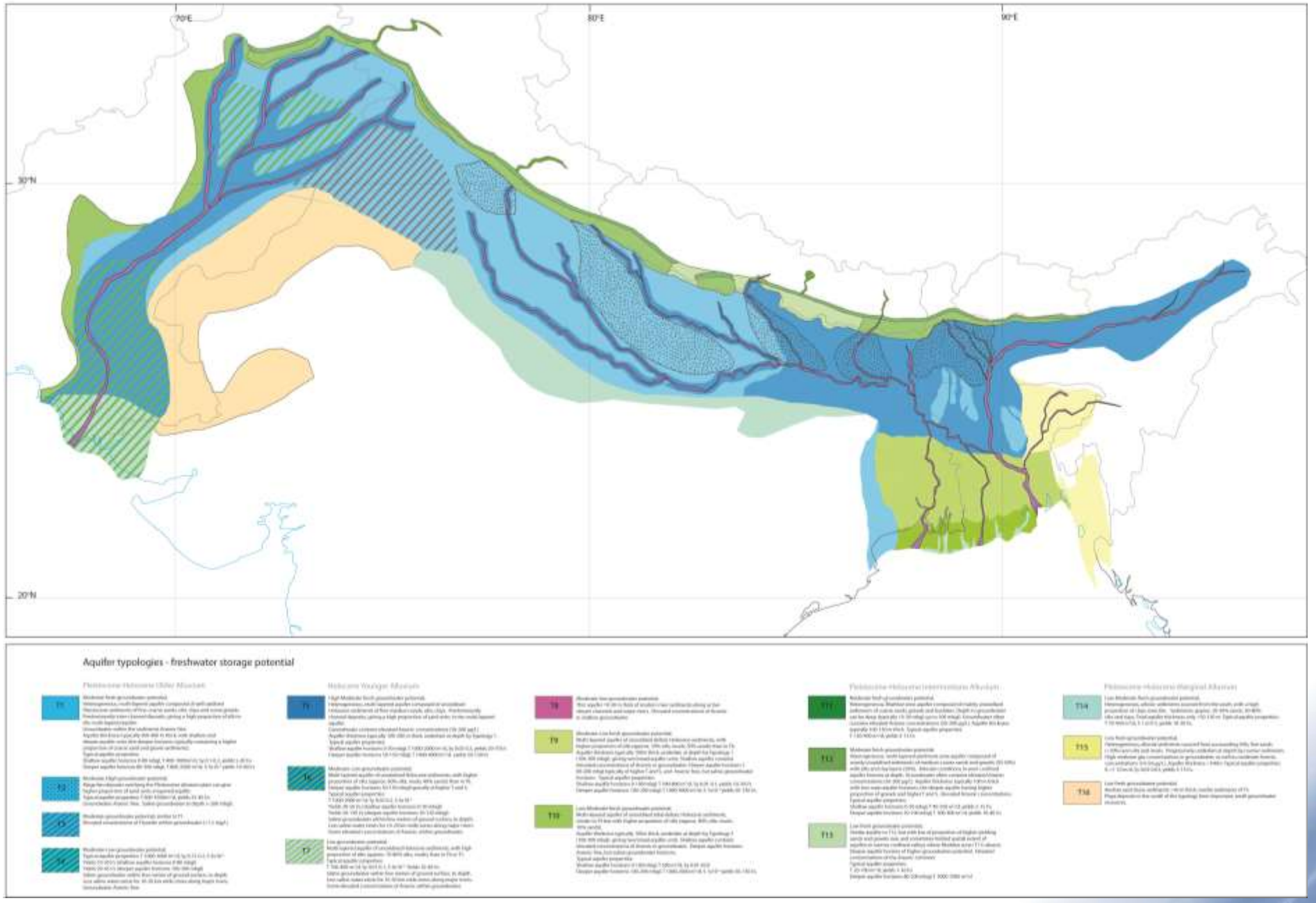


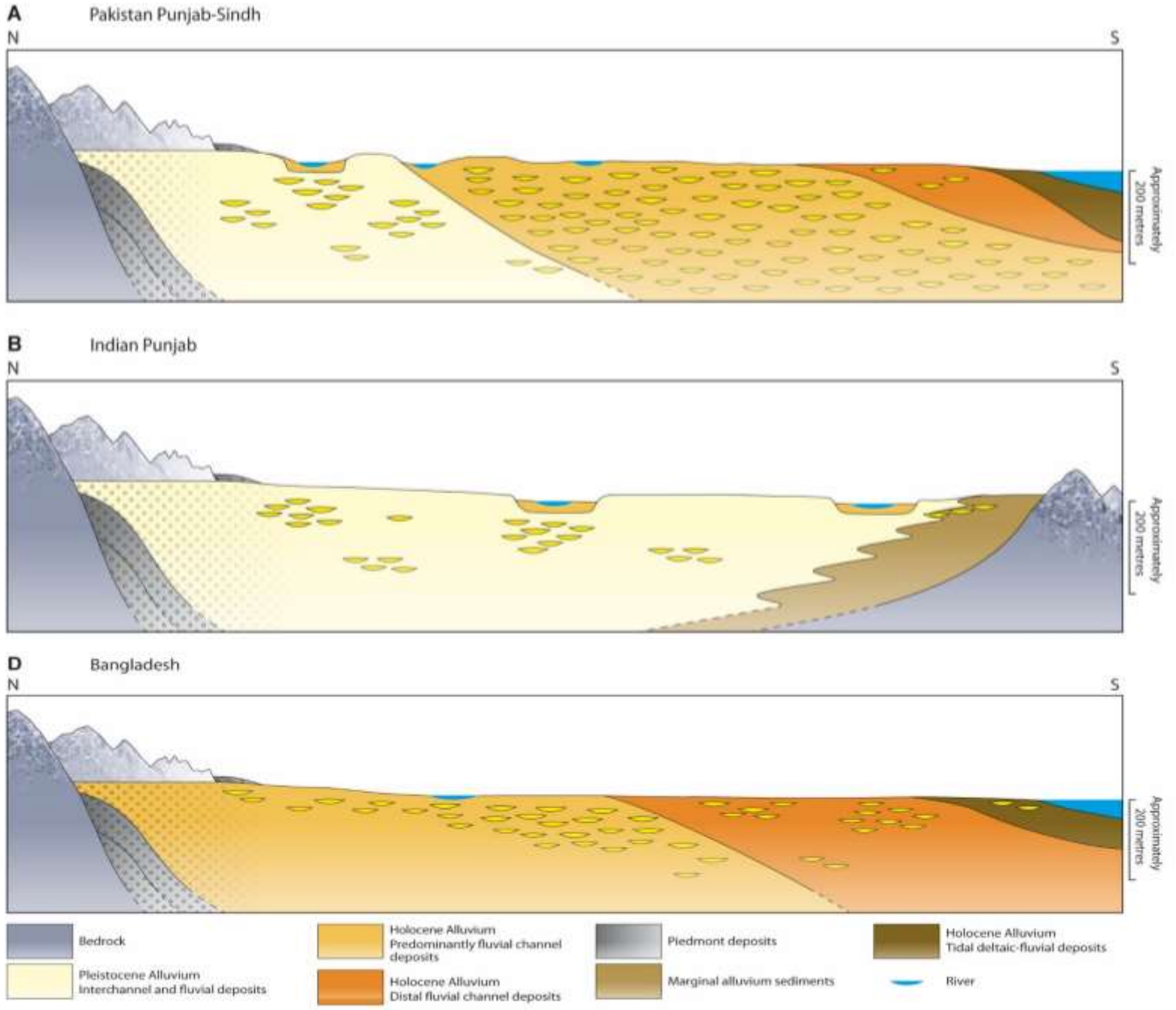
Management units – where groundwater will respond roughly the same to different pressures..

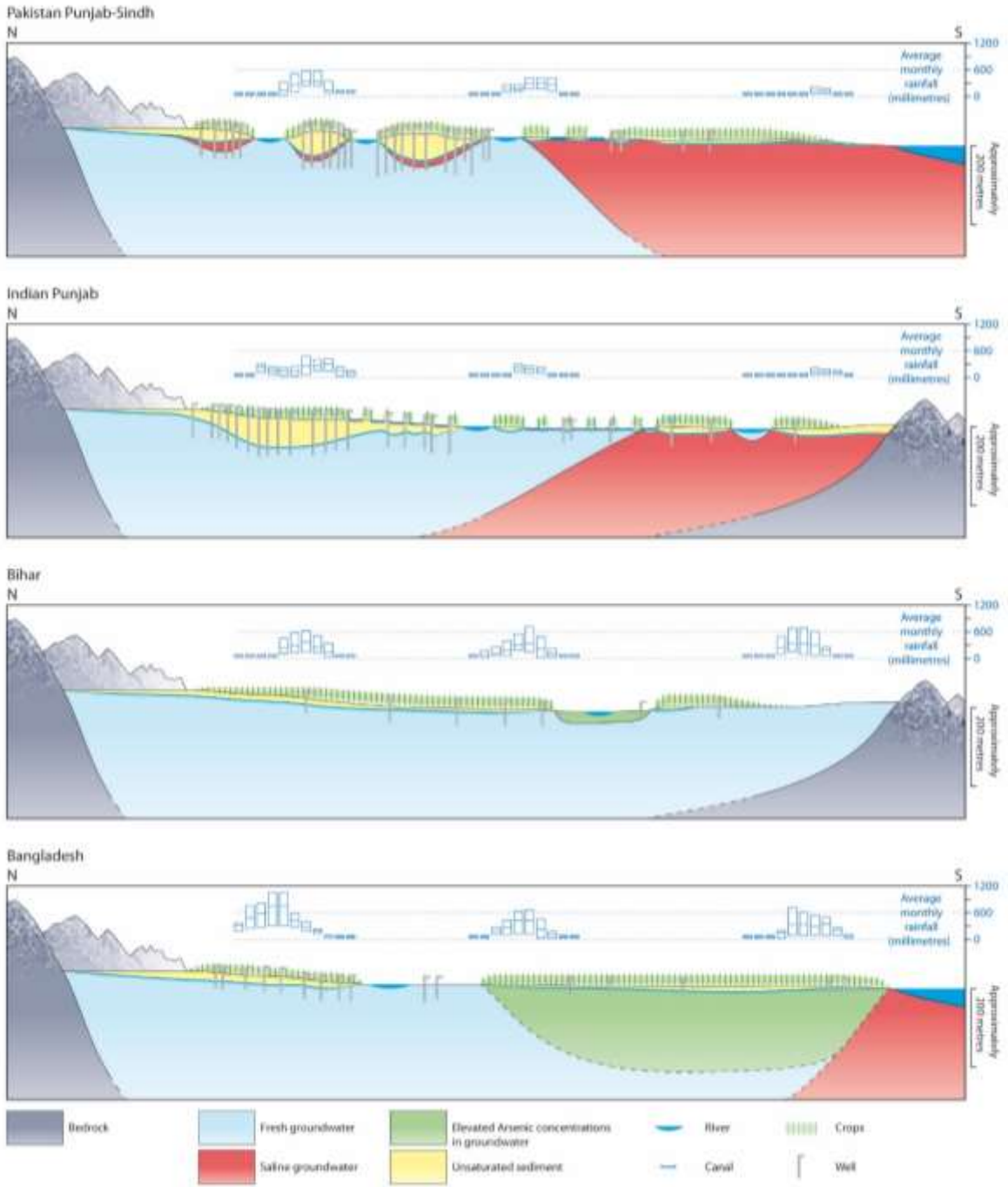
Geological typologies



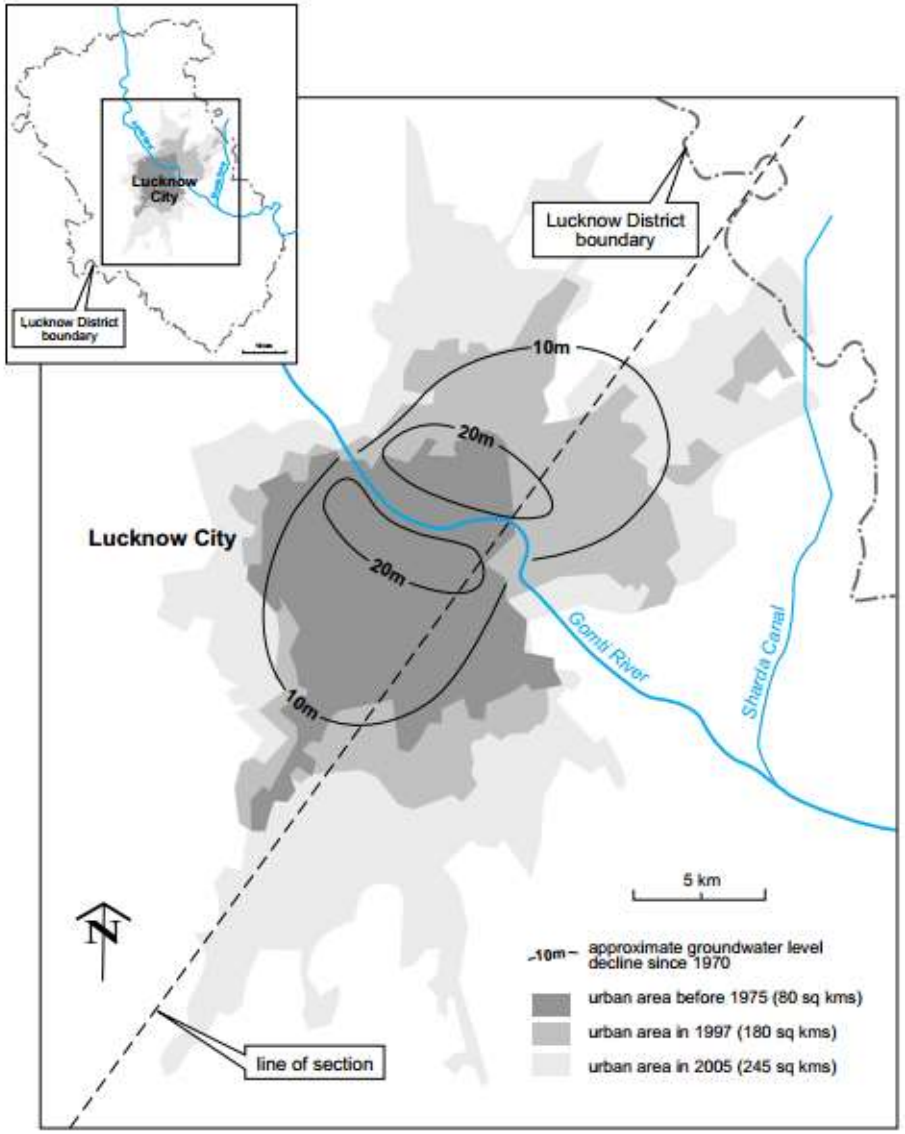
Aquifer resource typologies

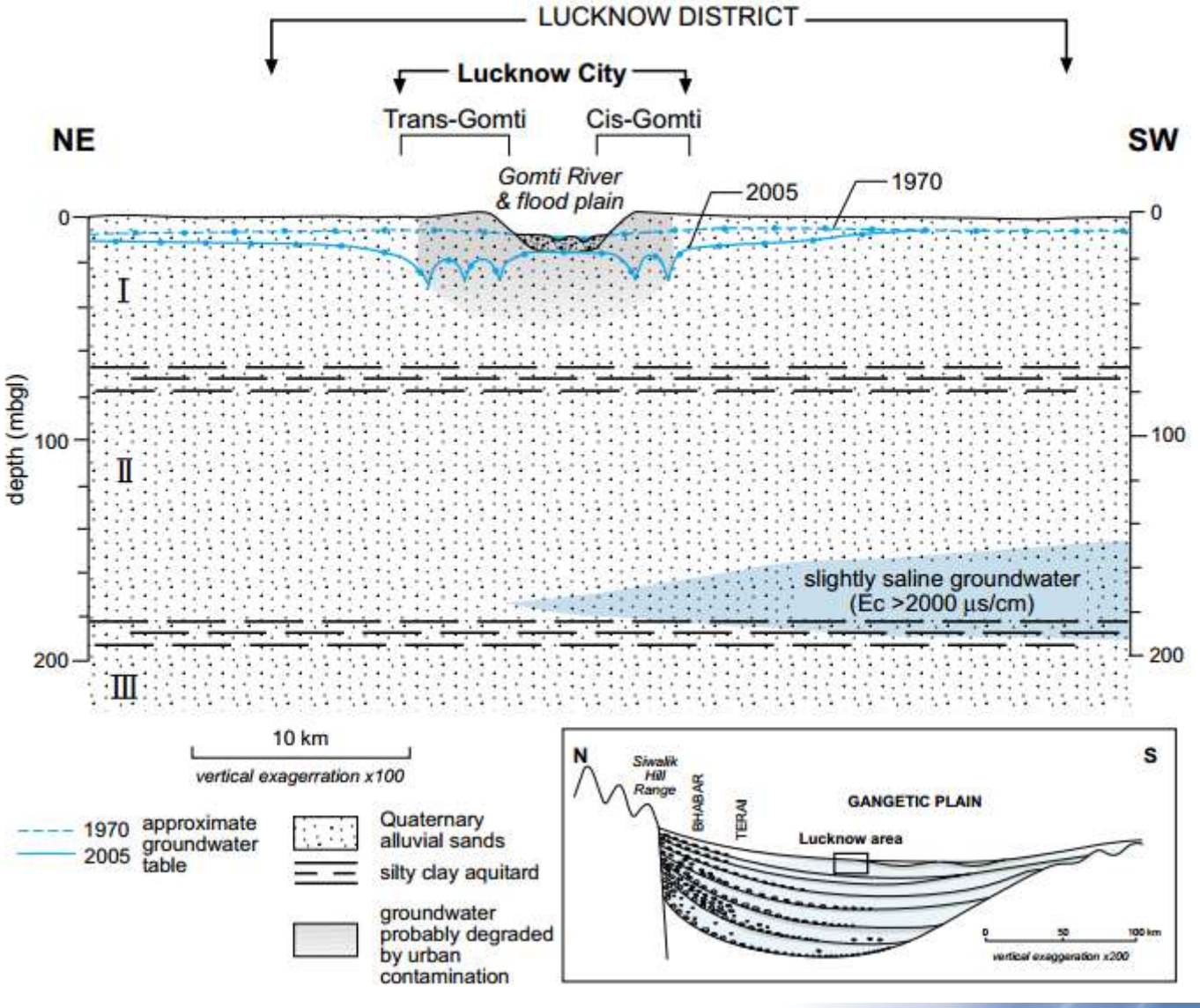






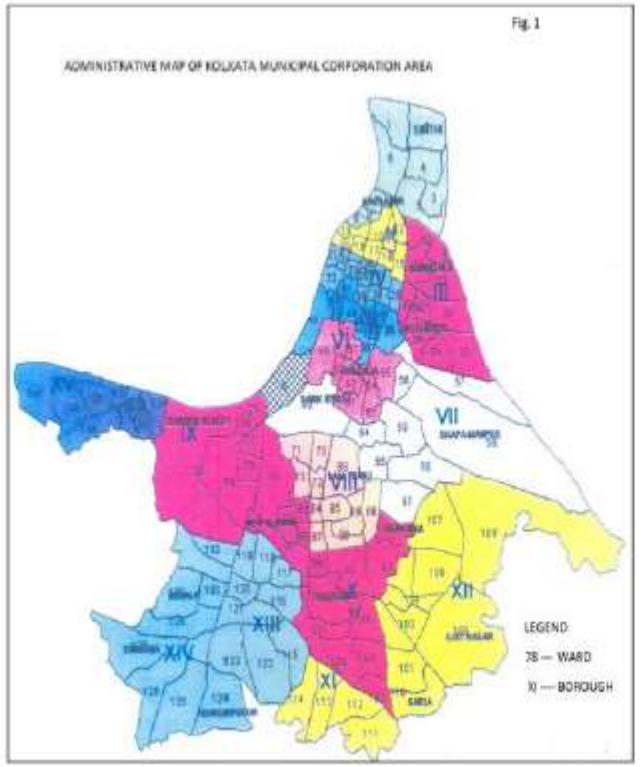
Lucknow

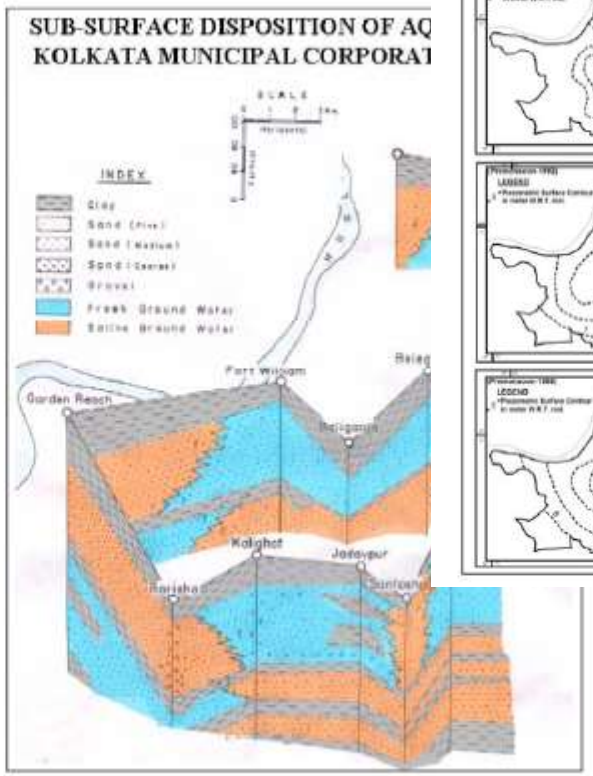

Lucknow City
Lucknow District boundary
Lucknow District boundary
10m
20m
20m
10m
Lucknow City
Gomti River
Sharda Canal
5 km
N
line of section
10m approximate groundwater level decline since 1970
urban area before 1975 (80 sq kms)
urban area in 1997 (180 sq kms)
urban area in 2005 (245 sq kms)

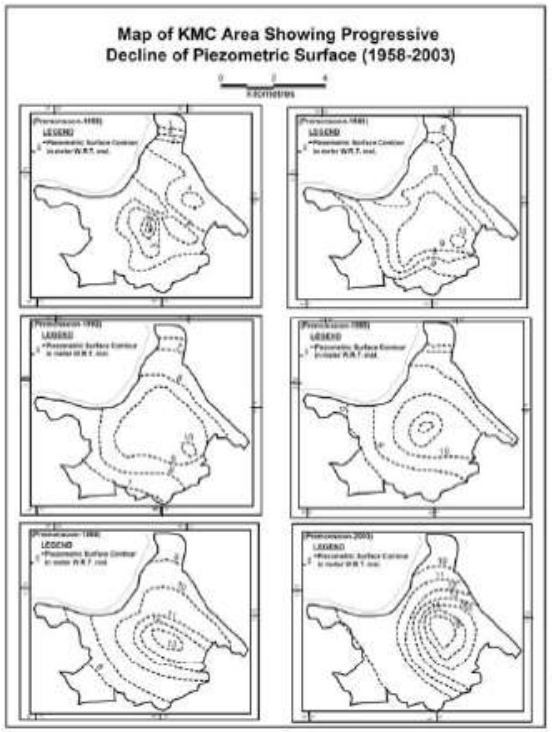

LUCKNOW DISTRICT
Lucknow City
Trans-Gomti
Cis-Gomti
NE
SW
Gomti River & flood plain
2005
1970
0
100
200
depth (mbgl)
I
II
III
slightly saline groundwater (Ec >2000 µs/cm)
10 km
vertical exagerration x100
1970 approximate groundwater table
2005
Quaternary alluvial sands
silty clay aquitard
groundwater probably degraded by urban contamination
N
S
Siwalik Hill Range
BHABAR
TERAI
GANGETIC PLAIN
Lucknow area
0 50 100 km
vertical exaggeration x200

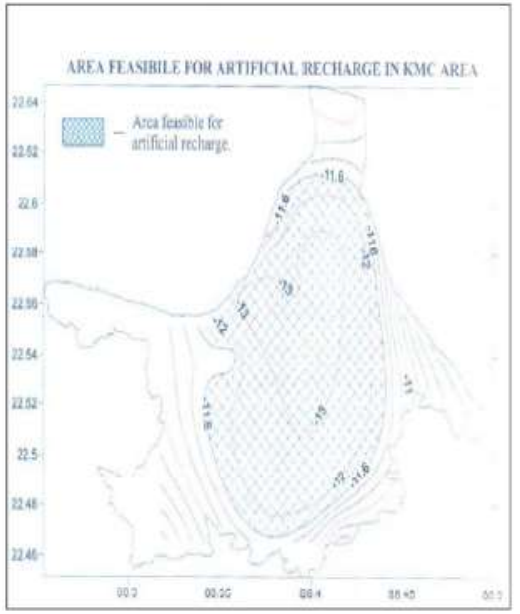
Kolkata

Kolkata

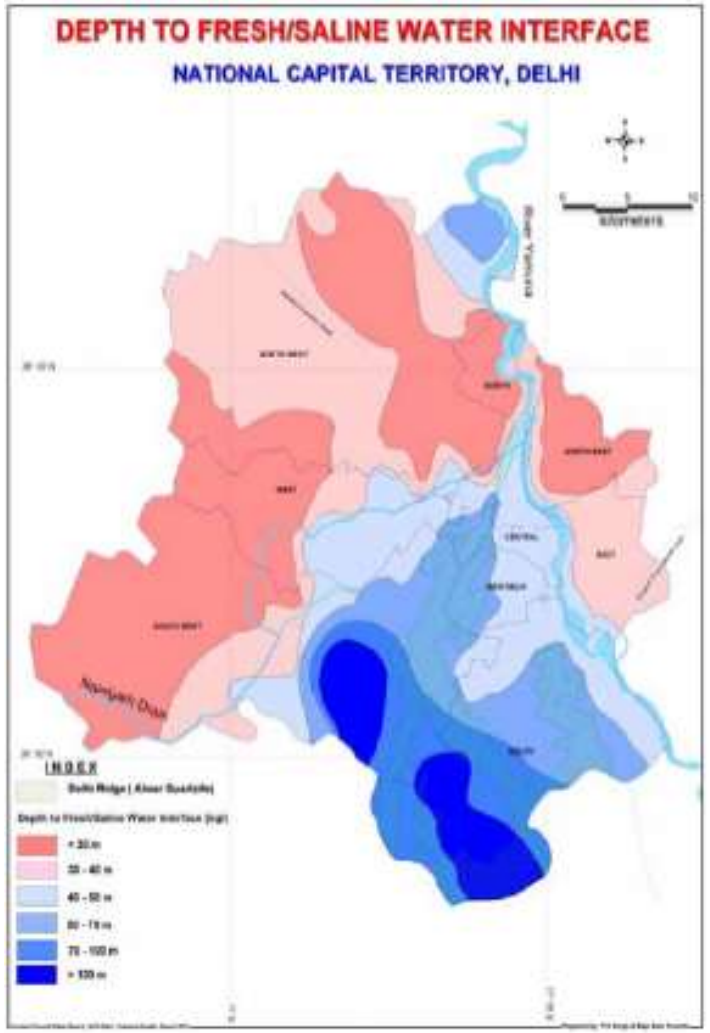


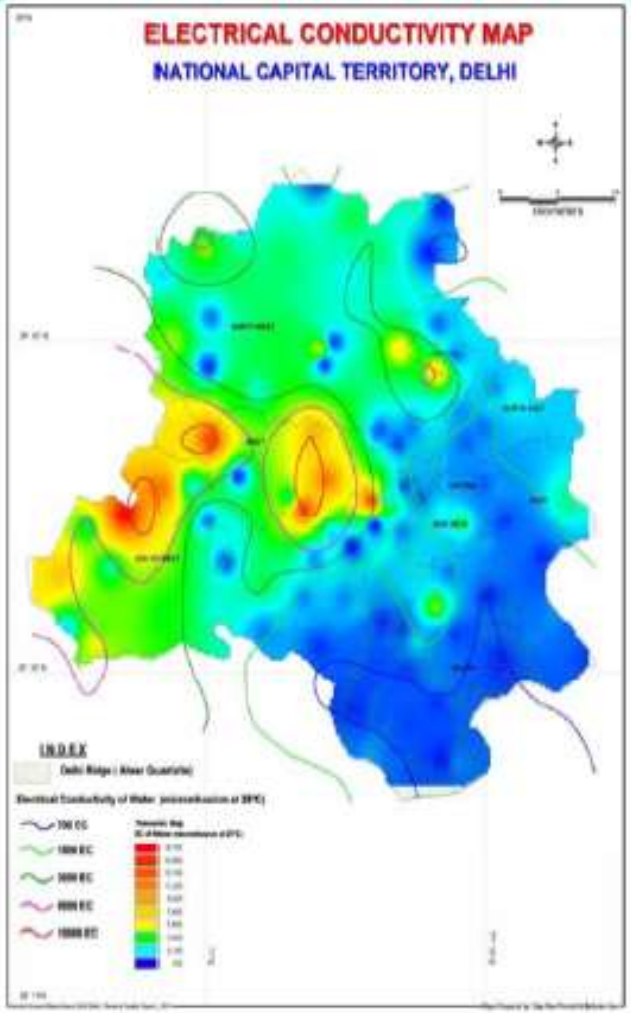


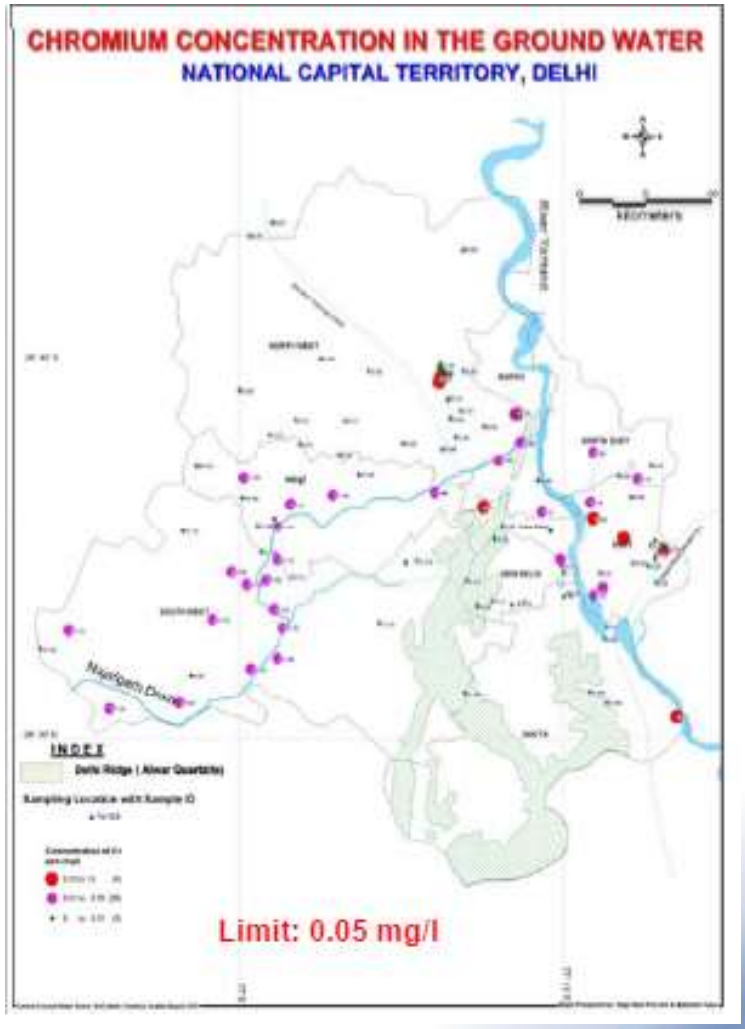




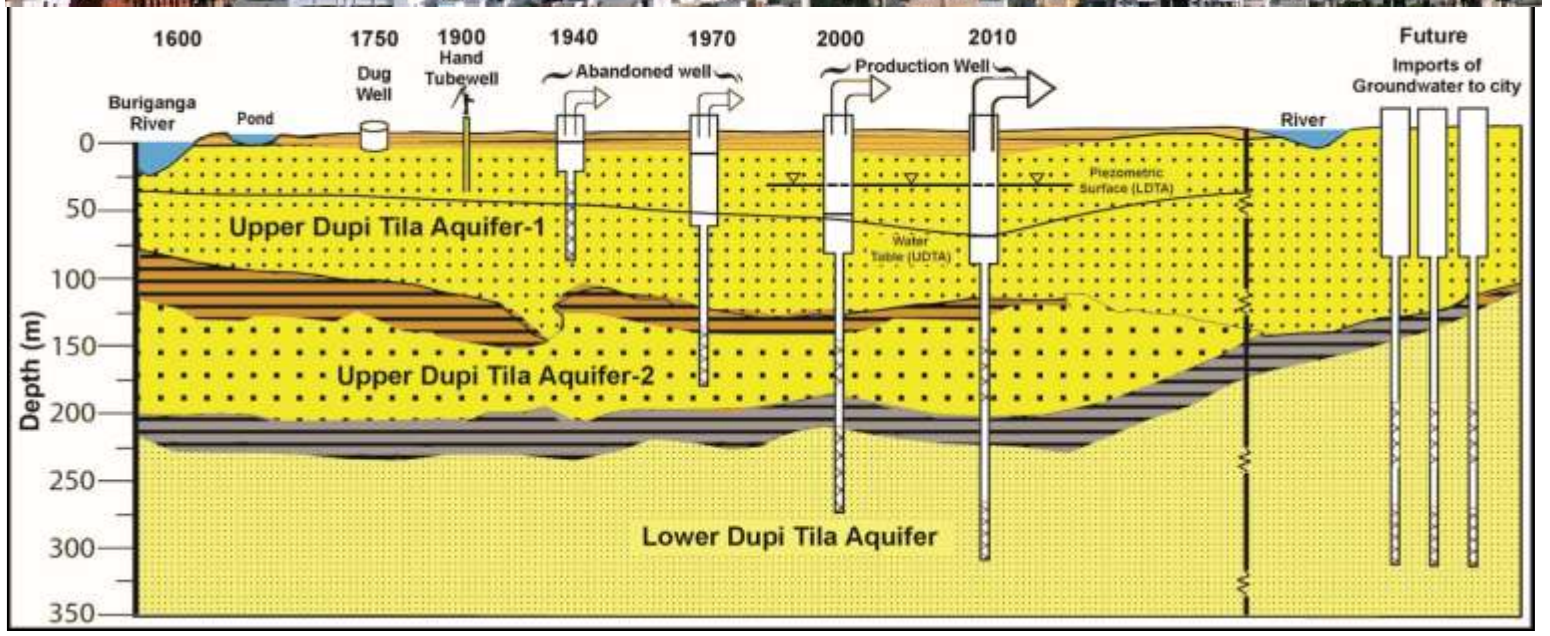
Delhi







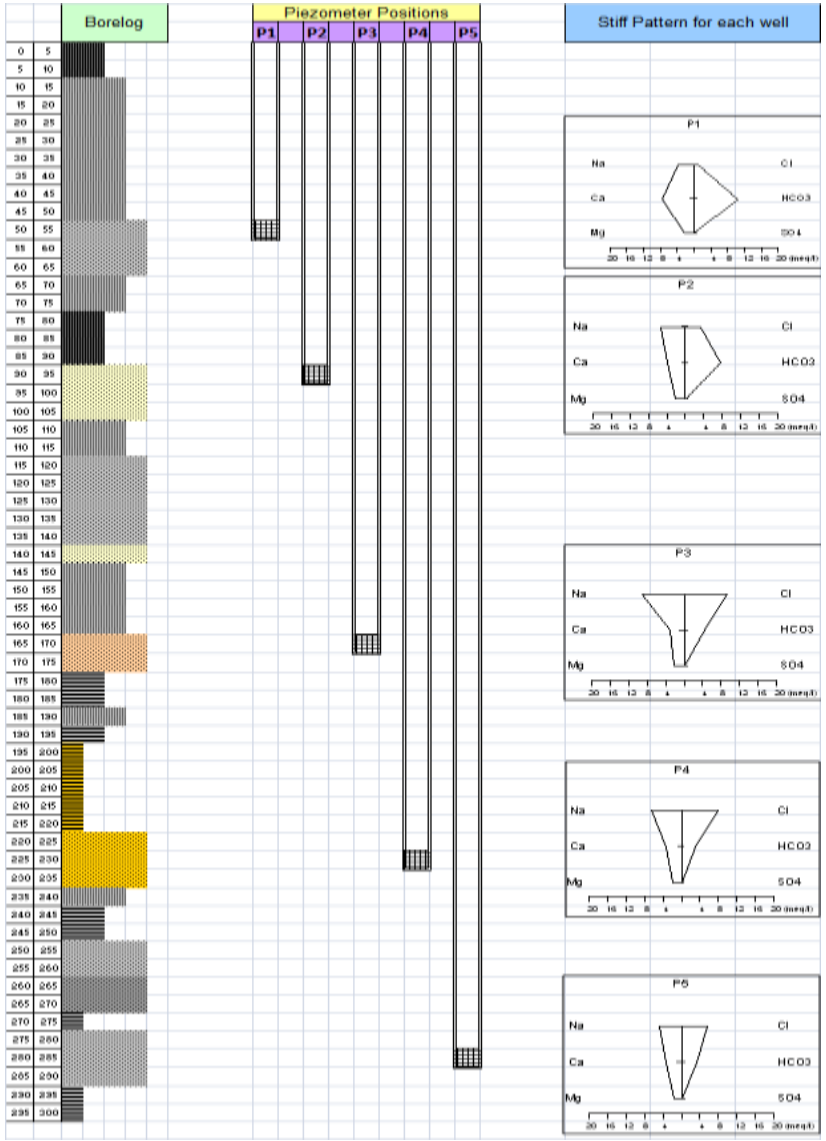
Dhaka

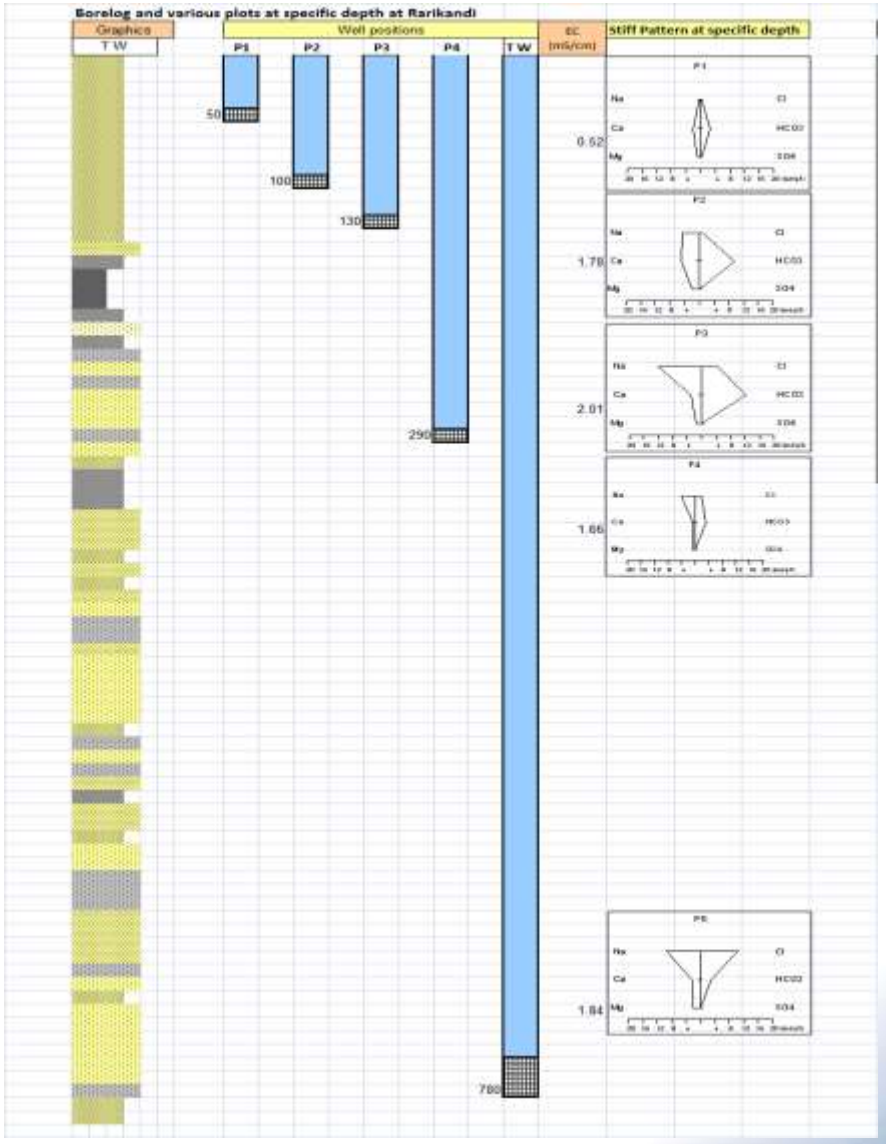


Where do we need to go?

- Monitoring at urban scales
- Characterising complex aquifers in 3D and at urban scales
- Understanding urban systems of water abstraction and antropogenic modification
- Understanding and modelling flow velocities in these complex systems
- Understanding the services provided by groundwater in urban environments

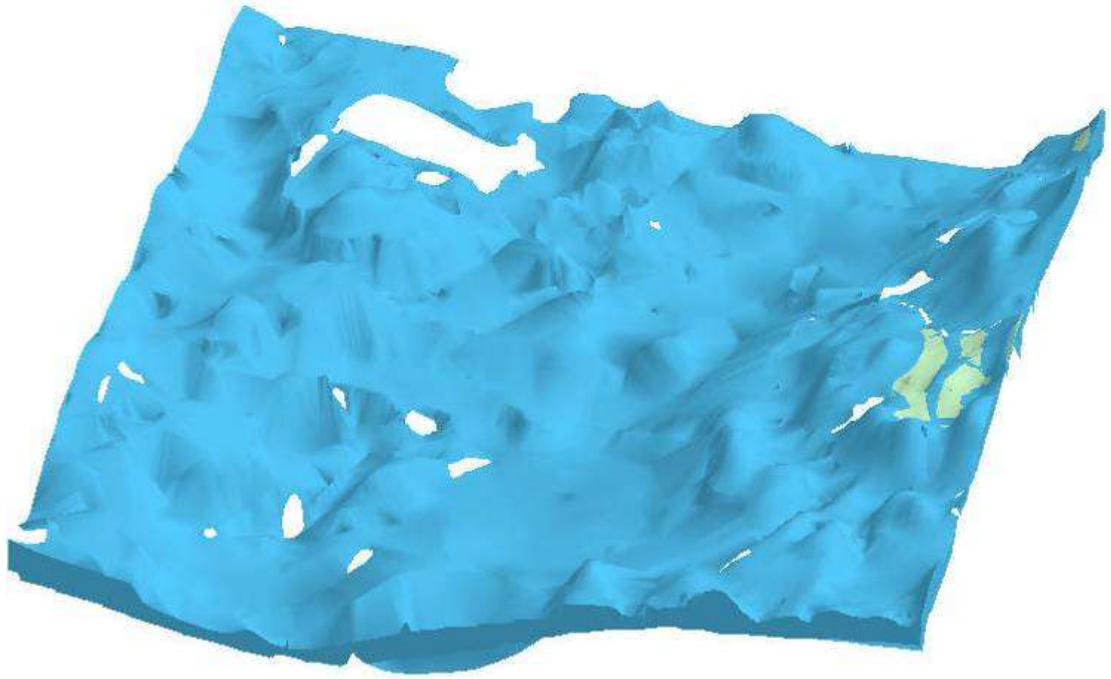
More monitoring – in 3D





Characterising urban geology in 3D

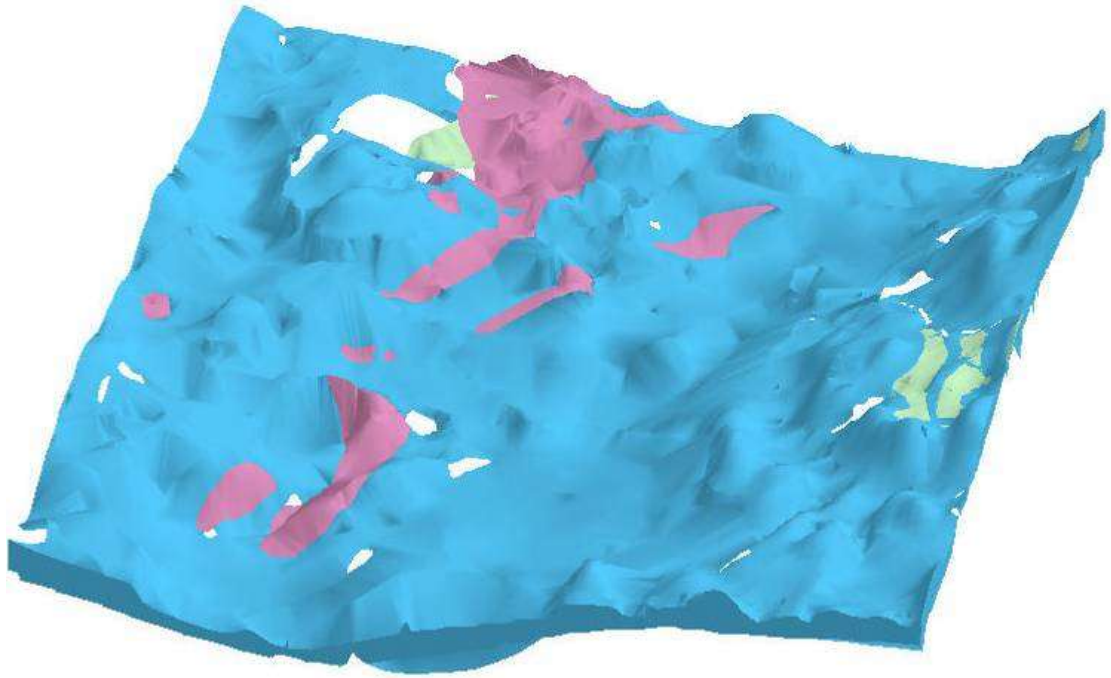
Glacial Till
(Wilderness
Formation



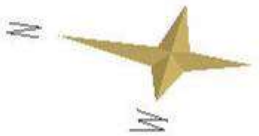
e.g. STRENGTH (or texture, grainsize, SPT, permeability)
Firm to stiff laminated CLAY and SILT
Firm to stiff gravelly sandy CLAY with dense sand and gravel beds

Characterising urban geology in 3D

Ice contact deposits (Broomhead Formation)

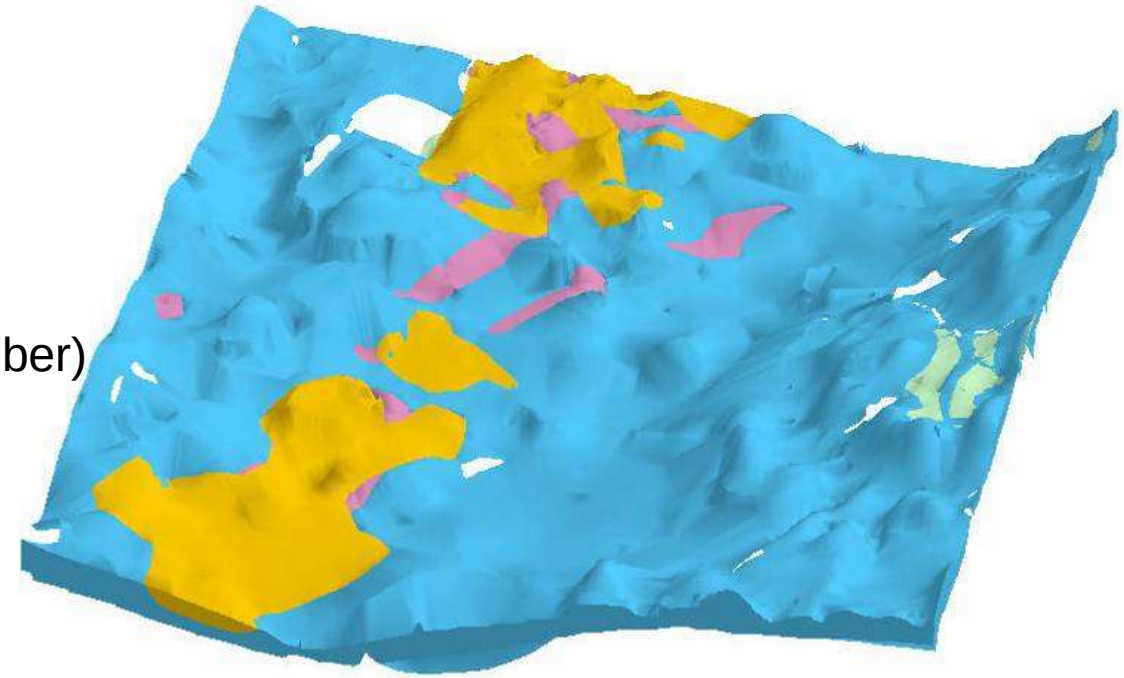


Medium to very dense silty SAND and GRAVEL with coarser particles

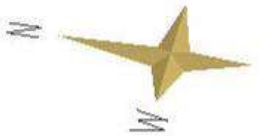


Characterising urban geology in 3D

Flood deposits
(Bridgeton Member)

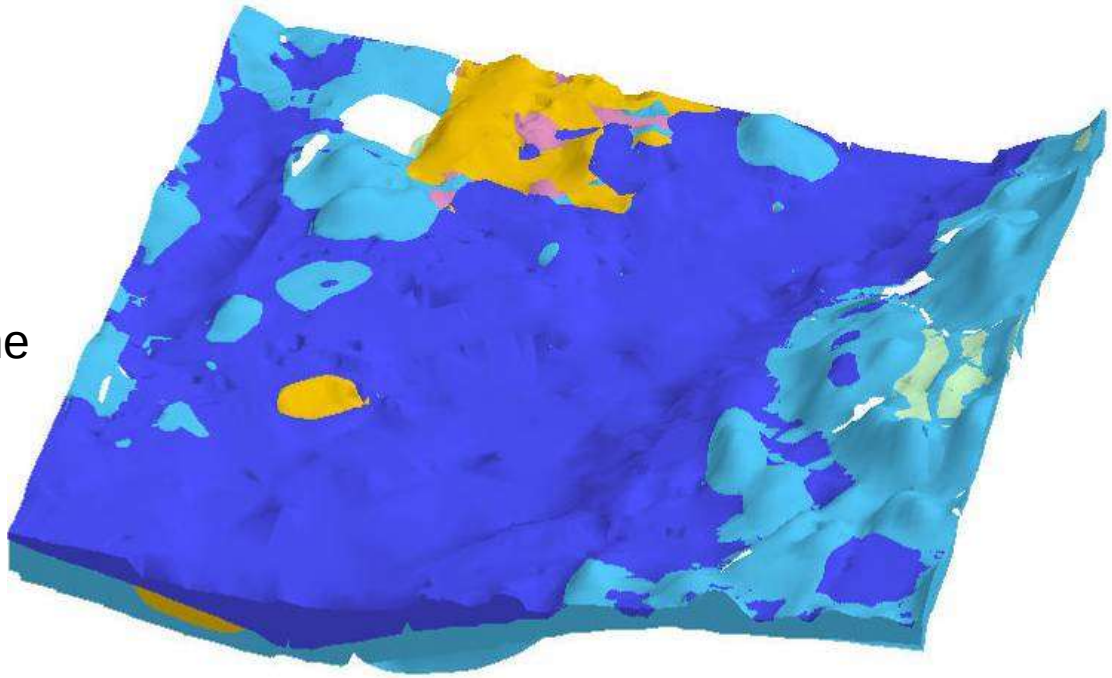


Loose to medium dense silty SAND and SAND



Characterising urban geology in 3D

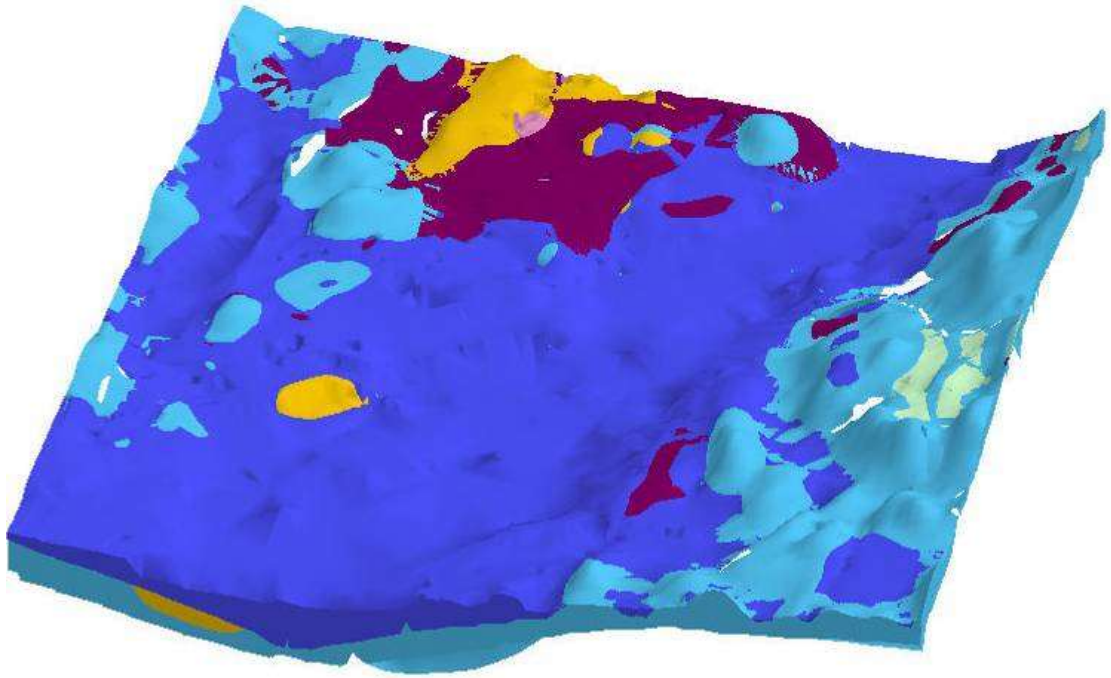
Raised glaciomarine deposits
Paisley Member)



Very soft to firm laminated CLAY and SILT some local sand beds

Characterising urban geology in 3D

Delta +
River terrace
(Killearn
Member)

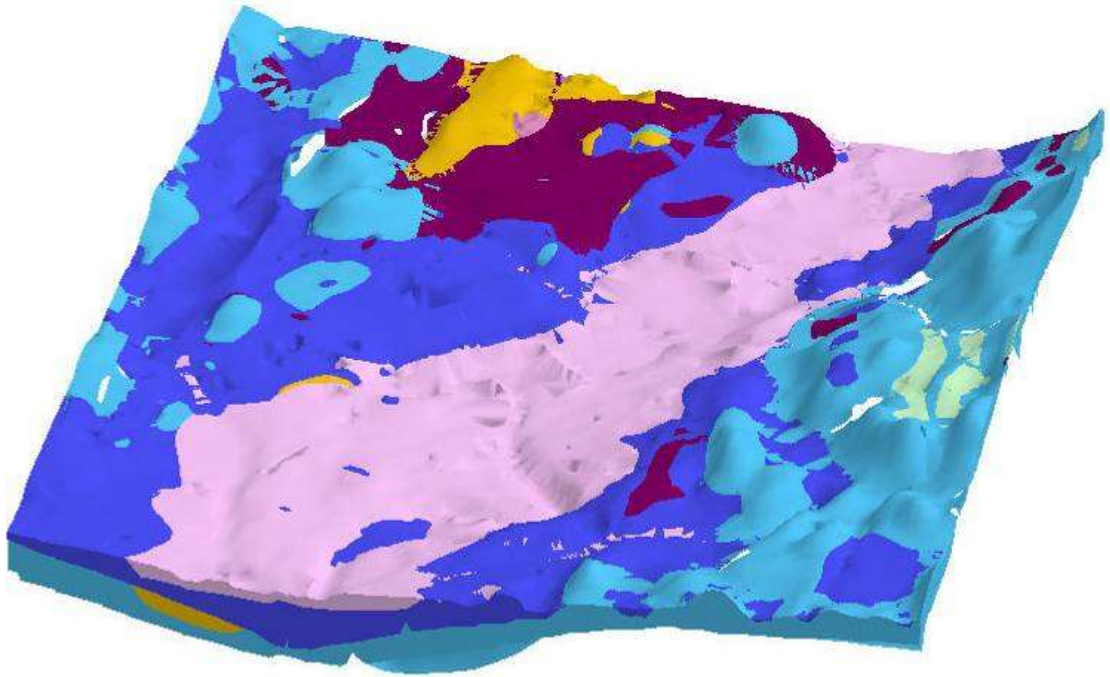


Loose to medium dense silty sand and sand

Characterising urban geology in 3D

Estuarine/ fluvial

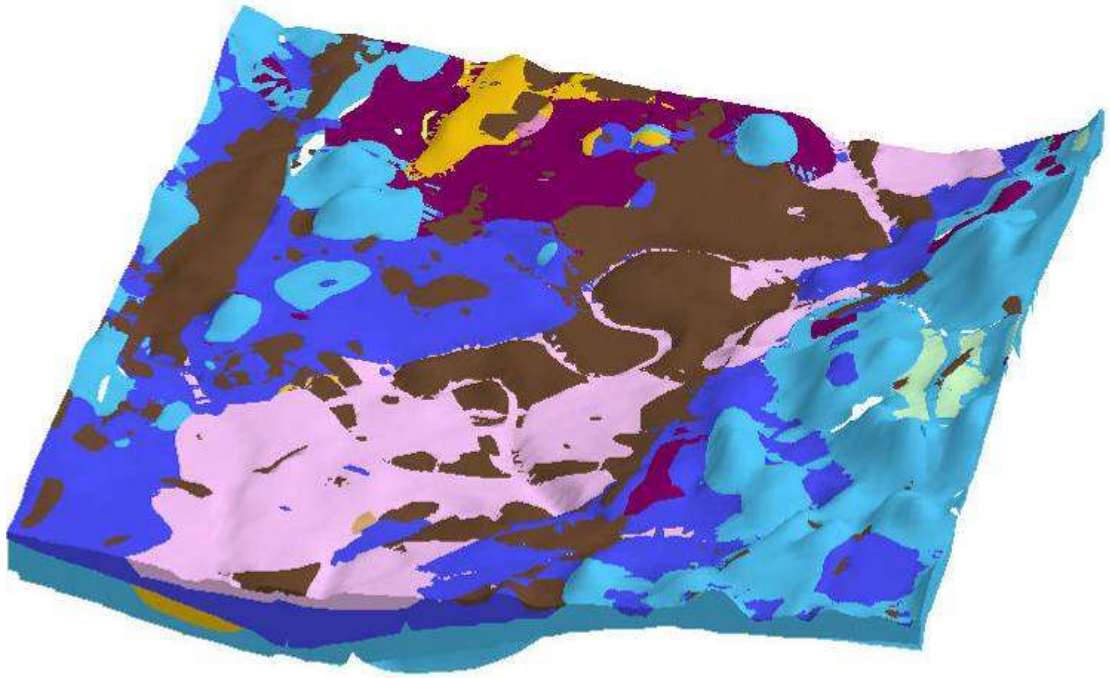
(Gourock Formation)



Upper part very soft to very stiff CLAY and SILT occasional peat
Lower part loose to medium dense SAND and GRAVEL,

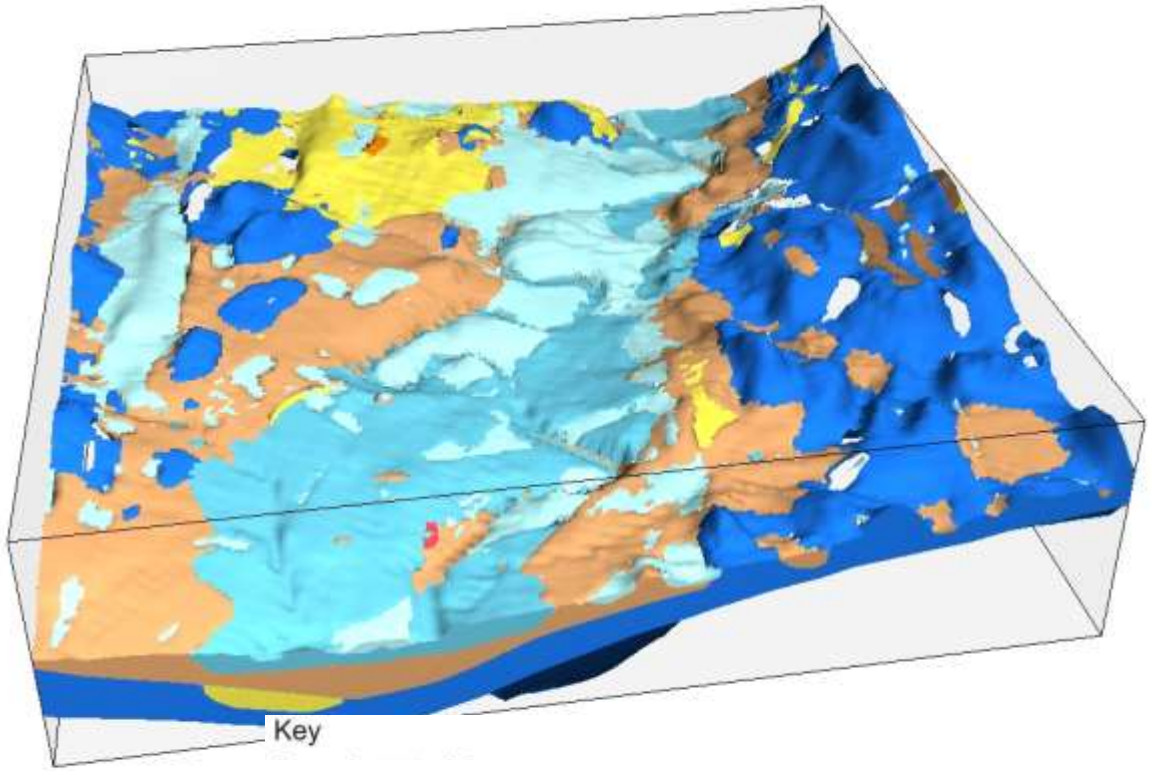
Characterising urban geology in 3D

Artificial ground



Highly variable, very loose to very dense sand and gravel
or very soft to stiff CLAY and SILT, natural or man-made materials

Attributed geology model – base for our management



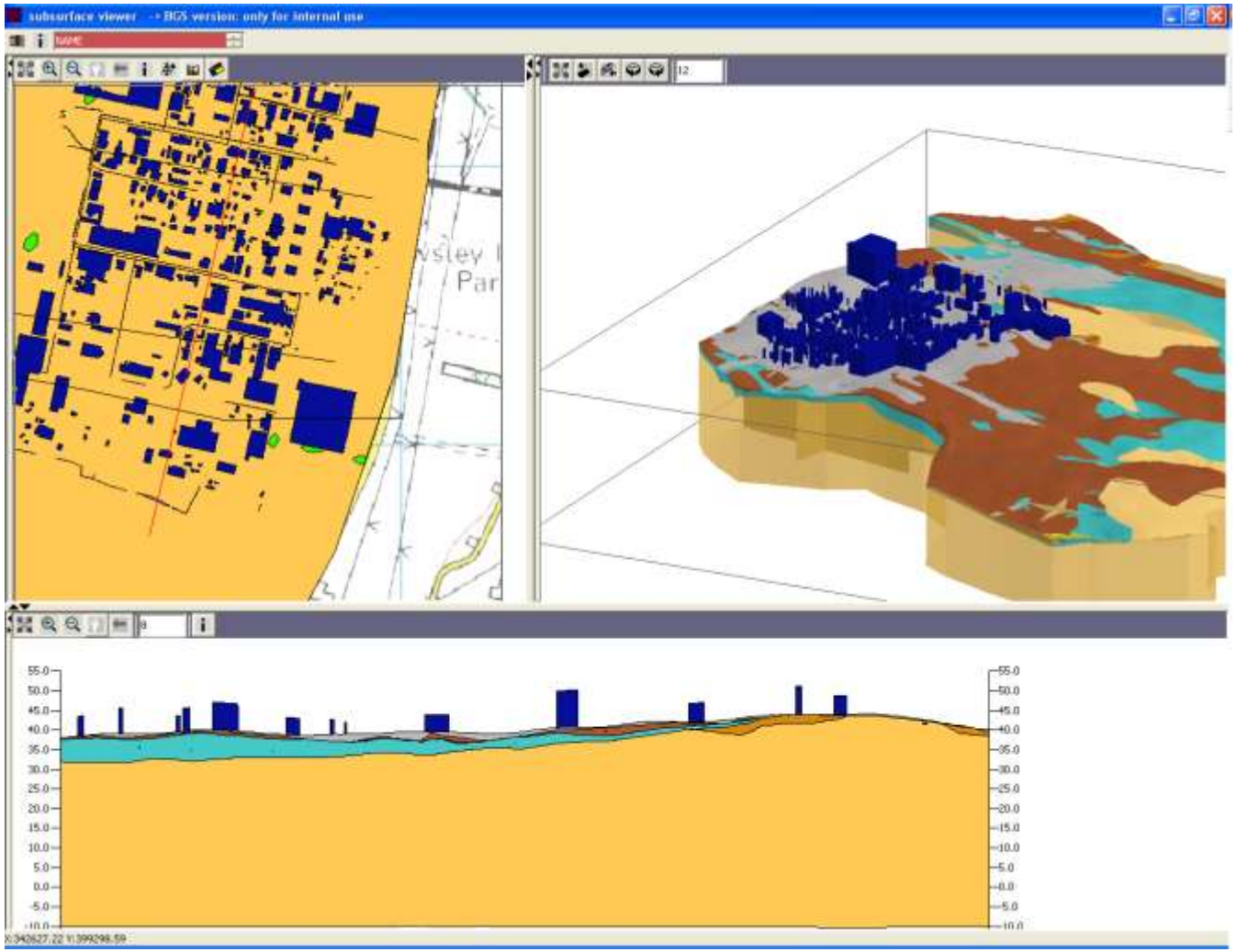
Organic soil

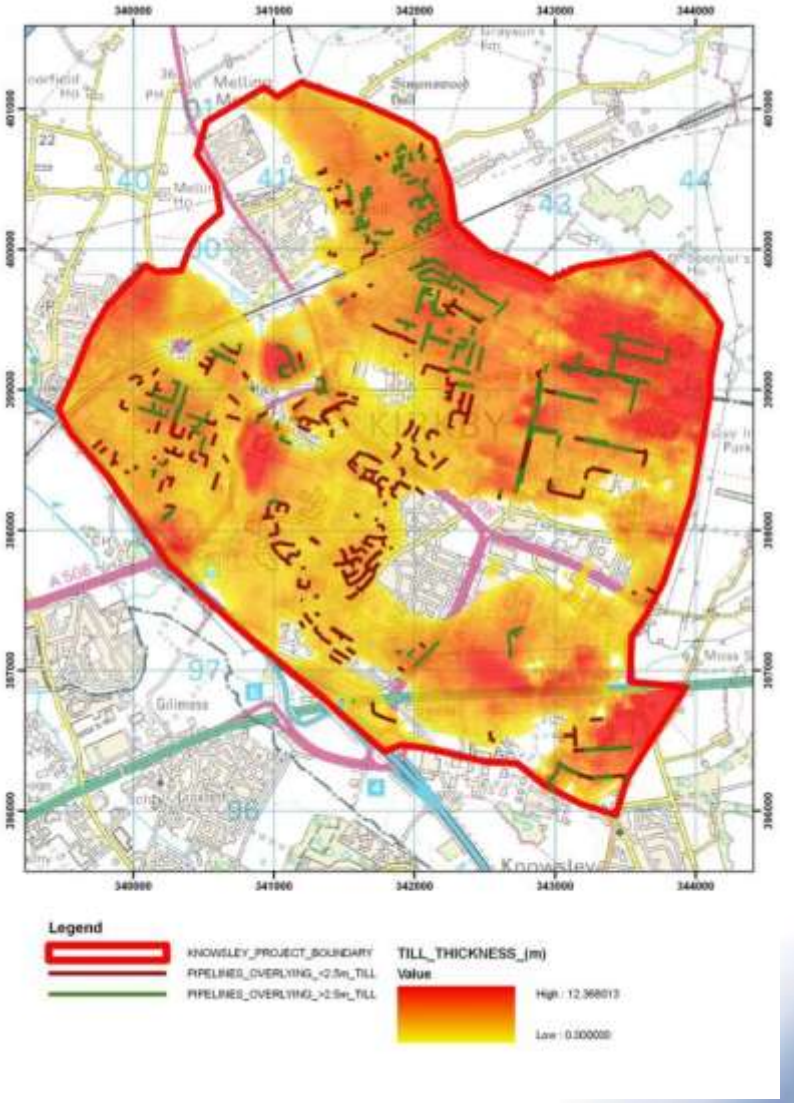
Mixed fine and course

Mostly fine-grained

Mostly coarse-grained

Infrastructure interaction





Flow velocities and ‘dating’

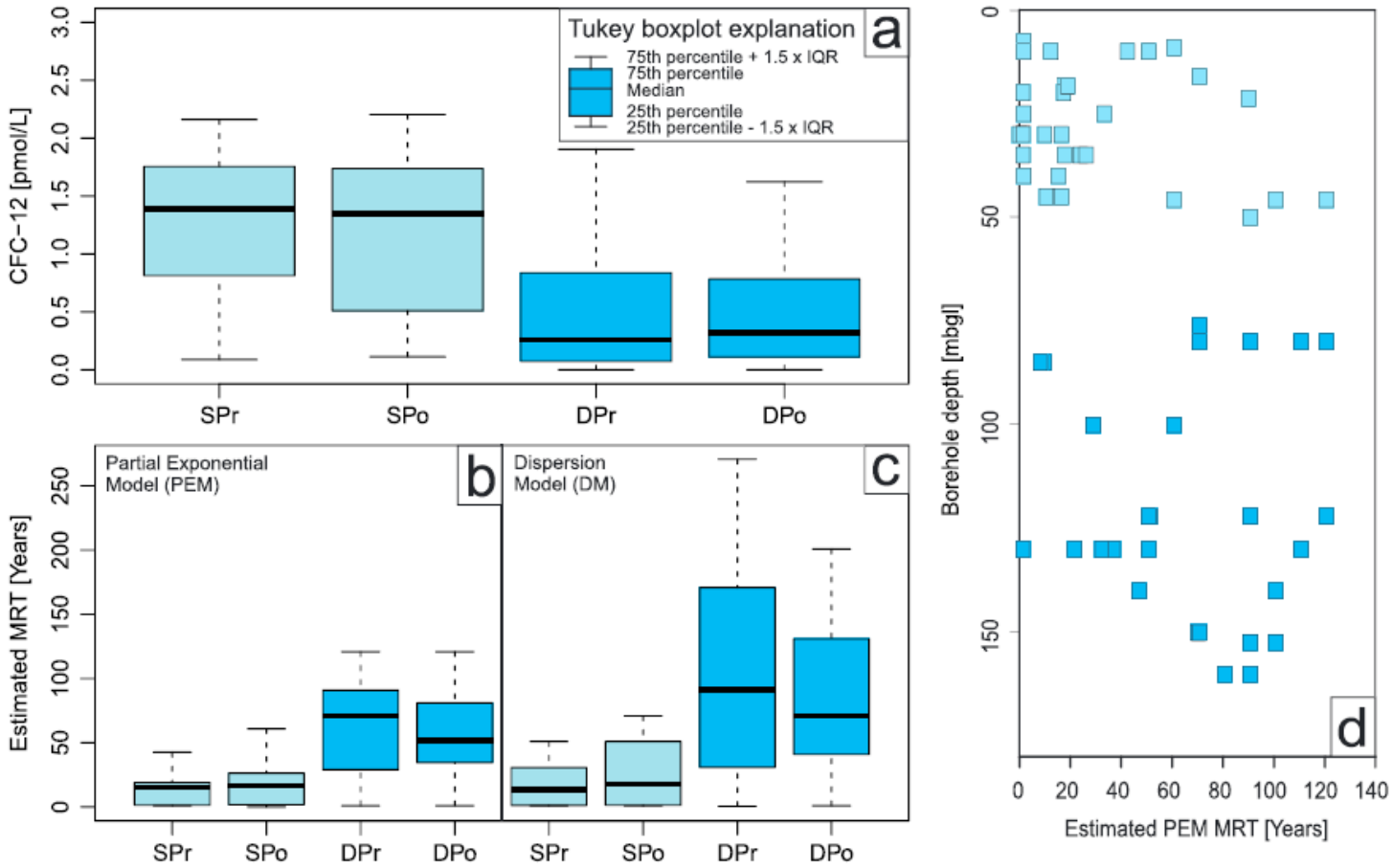
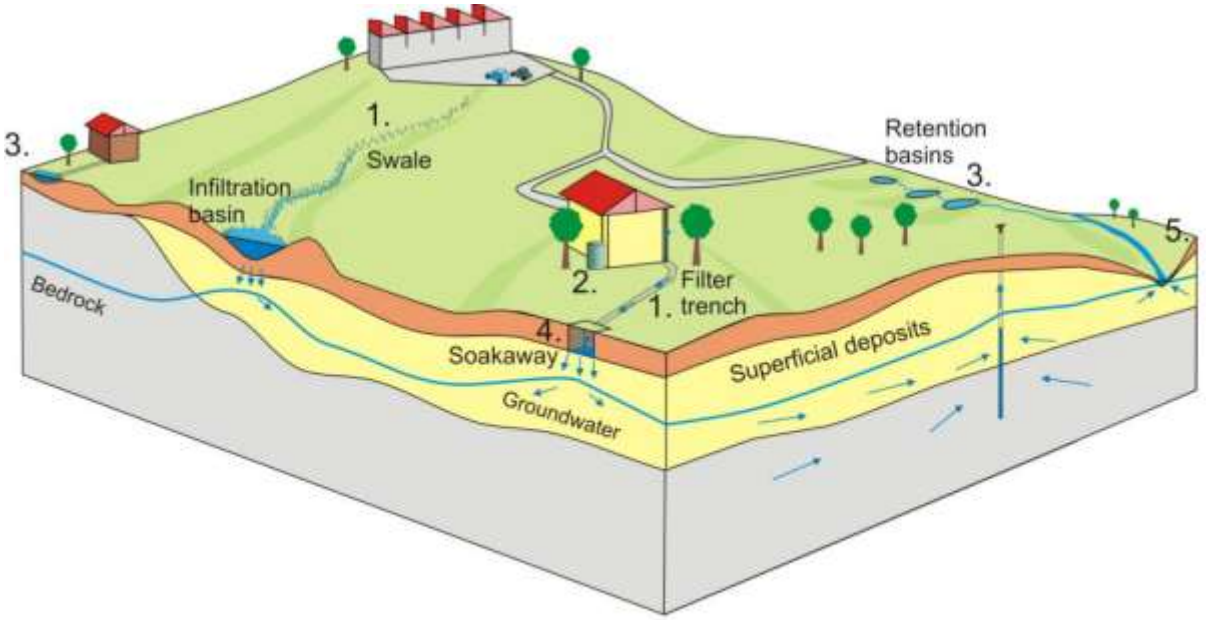


Figure 1. Residence time tracer results: (a) summary of groundwater CFC-12 concentrations, (b) estimated MRTs for shallow and deep groundwater samples using a partial exponential model, (c) estimated MRTs for shallow and deep groundwater samples using a dispersion model, and (d) variation in MRT (PEM estimates) with depth SPr = shallow groundwater premonsoon, SPo = shallow groundwater postmonsoon, DPr = deep groundwater premonsoon, and DPo = deep groundwater postmonsoon. Over modern values have been excluded from the analysis. Data shown from 16 paired boreholes, where shallow (8–50 mbgl) and deep (>76–160 mbgl), sampled premonsoon and postmonsoon.

Groundwater and the subsurface as a service

- Not only a resource for abstraction!
  - Drought proofing
  - Supporting baseflow
  - Supporting ecosystems in wetlands
  - Filtration + bioremediation
  - **Flood storage**
  - Heat (cooling) reservoir



During a storm event, surface water flows through swales and filter trenches that remove entrained polluants (1). The peak river discharge is delayed and reduced by; storage of water for re-use (2), storage in ponds (3), or infiltration of water to the ground through infiltration basins and soakaways (4). This process improves the quality of water in rivers and decreases peak river discharge (5).

+ the challenge we can't solve as 'natural scientists'