

**Earth Observation Techniques
- Global Navigation Satellite System
(GNSS) and Interferometric Synthetic
Aperture Radar (InSAR) - for
Groundwater Water Resource and
Drought Management:
GEO proposal plan**

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Outline

- GEO proposal call
- DAGEOS Project
- Blossoms Prospect, Little Karoo
- Monitoring and experimental results
- Future development?

**Group on Earth Observation
(GEO)
proposal call and response**

Aims

- To demonstrate the use of high-precision GNSS technology as a tool for groundwater resource monitoring and assessment
- To demonstrate the use of high resolution radar satellite (SAR) imagery as a tool for groundwater resource monitoring and assessment
- To develop the methodology for relating SAR image interpretation and GNSS measurements of natural or abstraction-induced surface deformation and conjunctive hydrogeological data in order to derive the in-situ, bulk elastic properties (e.g., skeletal compressibility) of an underlying confined fractured-rock aquifer
- To build South African capacity to establish the technical infrastructure (e.g., telemetry systems) and implement the data-processing methods required for a pilot GNSS-for-Groundwater scheme

Partners

Following institutions (participants) to be ***project partners***:

- Purdue University, USA (Eric Calais)
- University of Nevada at Reno, USA (Hans-Peter Plag)
- University of New Brunswick, Canada (Brigitte Leblon)
- International GNSS Service (IGS) Central Bureau, USA (Ruth E. Neilan)
- Department of Rural Development and Land Reform – National Geospatial Information Directorate, South Africa (Richard Wonnacott)

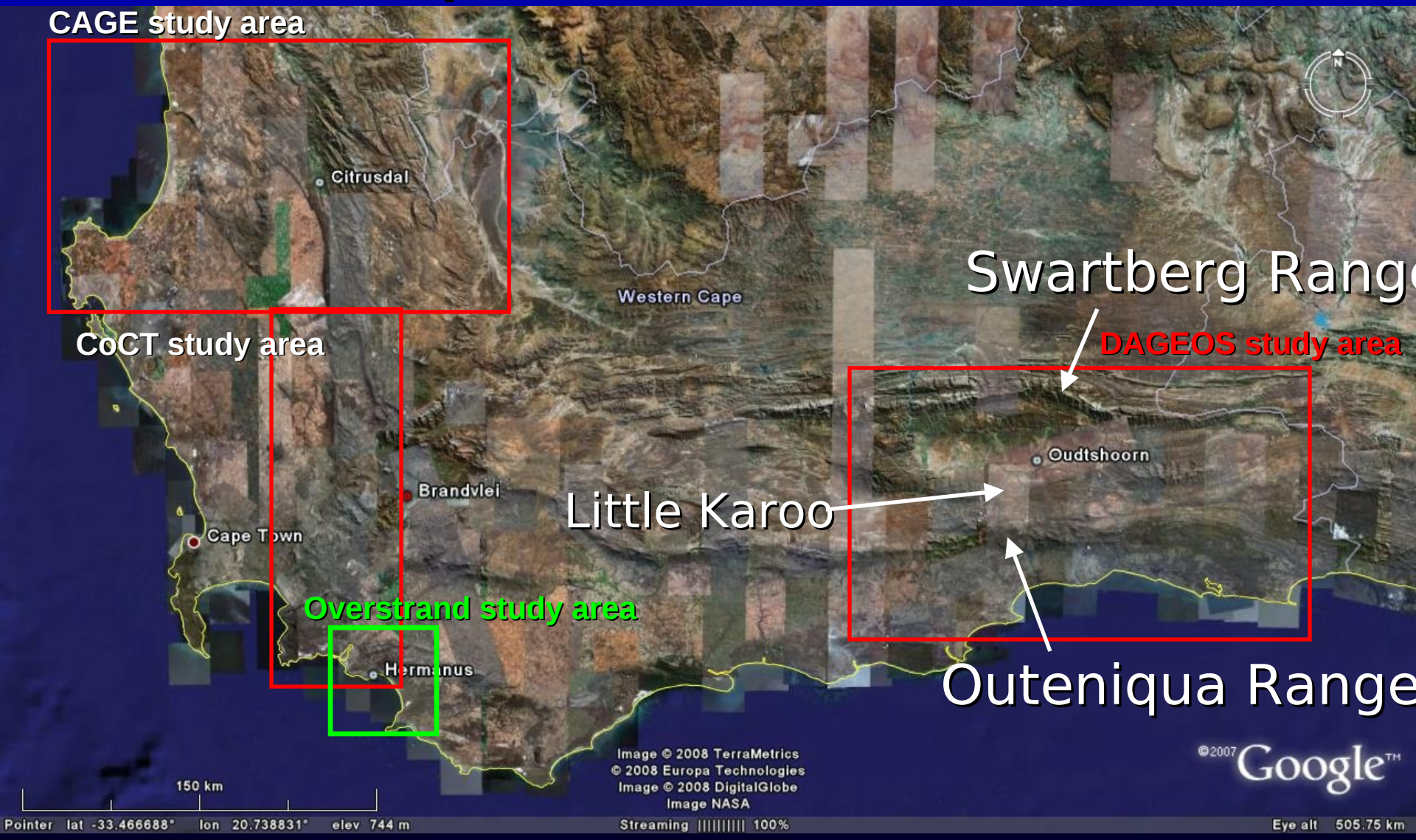
Requested Assistance

- Access to radar imagery covering Oudtshoorn (DAGEOS) project area
- Provision of approximately six new geodetic GPS receivers
- Support for training and capacity building on GPS software (e.g., GAMIT/GLOBK) and radar data processing (e.g., SAR and Interferometric processing)
- Funding for project human resource and operational costs, estimated at Euro 240 000 for a period of 3 years

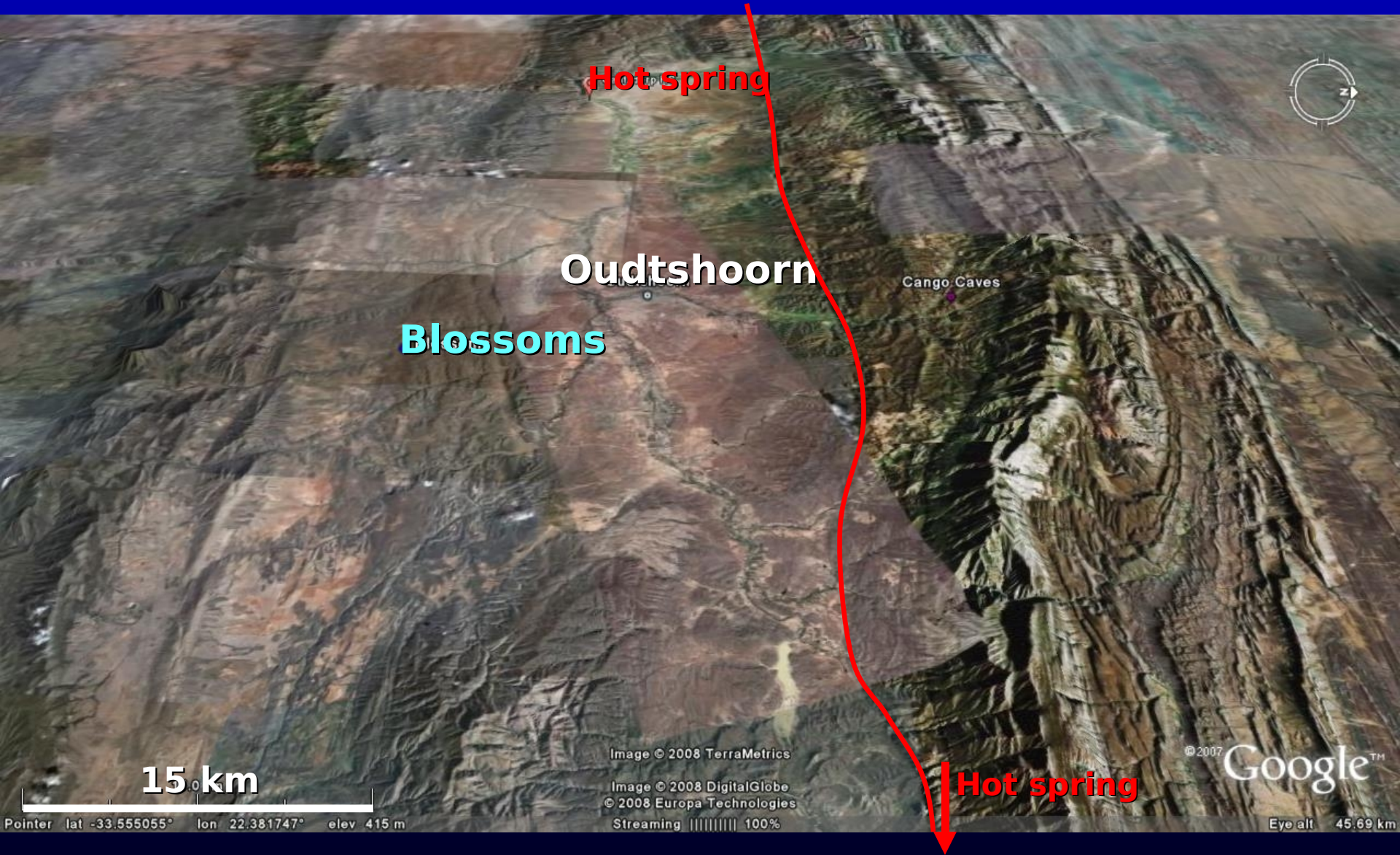
Deep Artesian Groundwater for Oudtshoorn Supply (DAGEOS)

Deep groundwater studies

Cape Fold Belt context

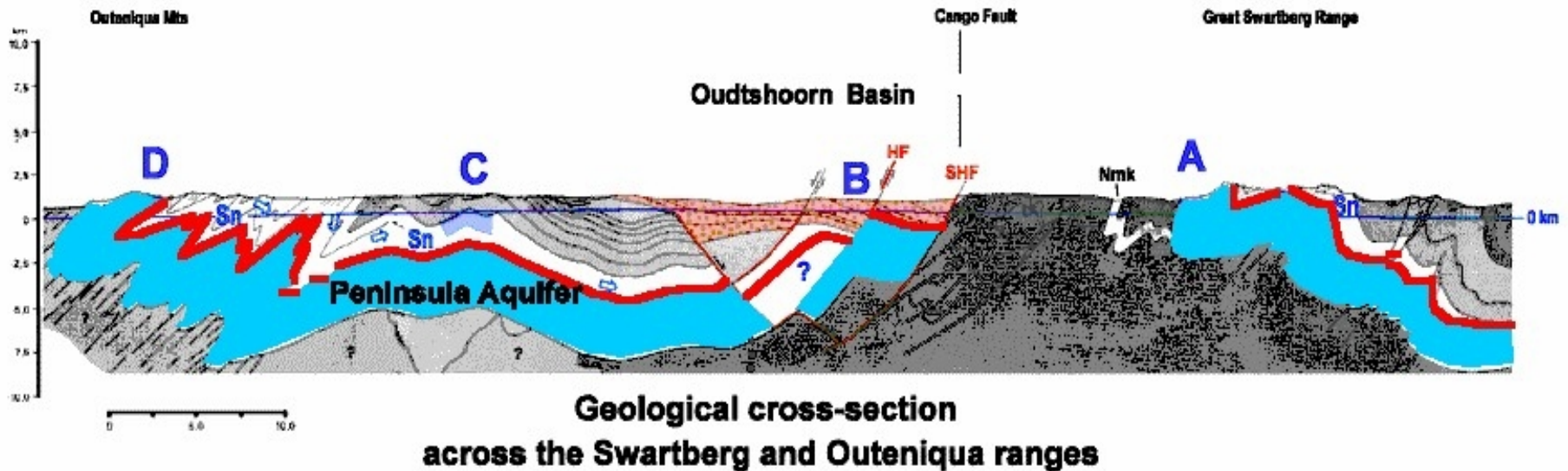


DAGEOS oblique view

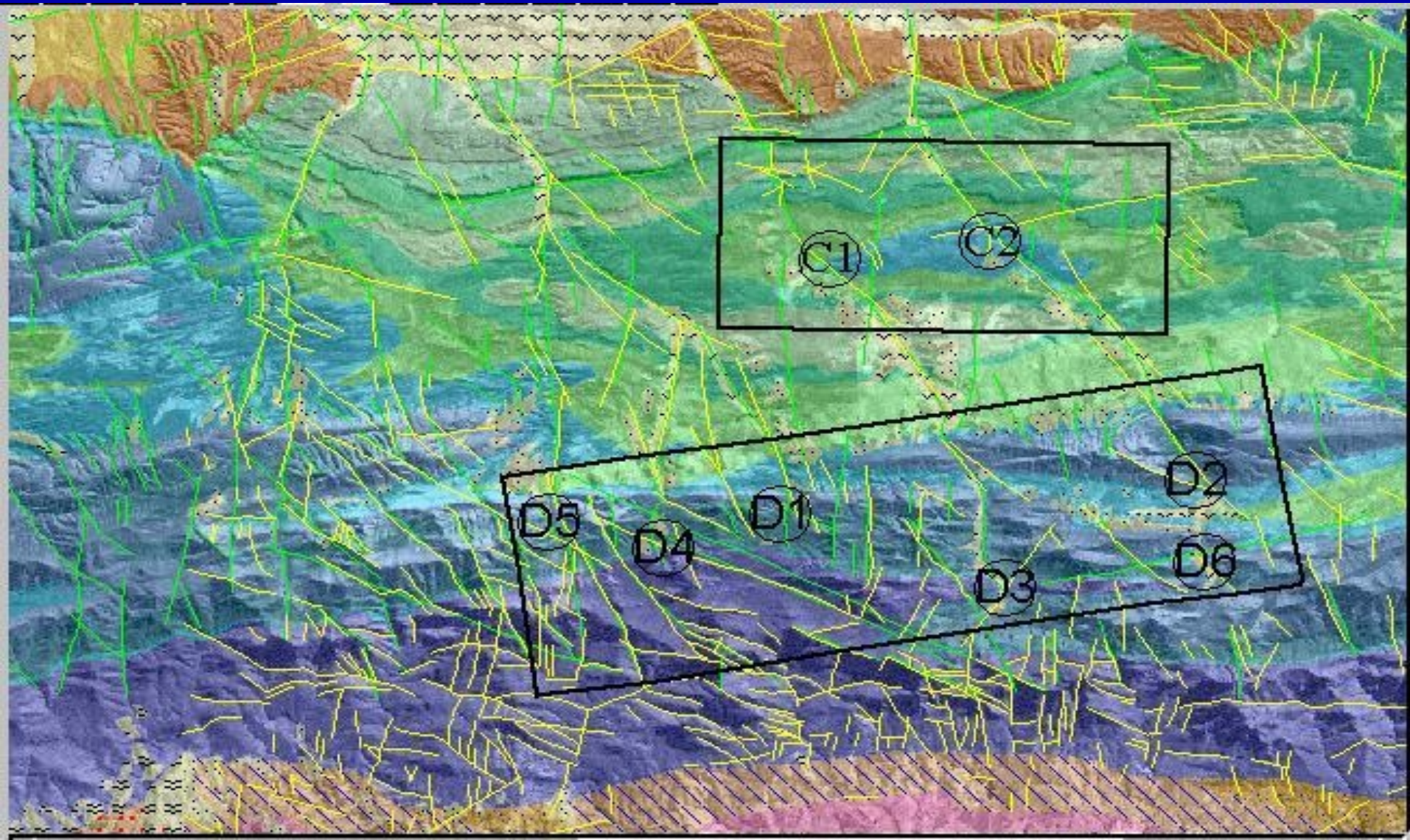


Outeniqua-Swartberg structural profile

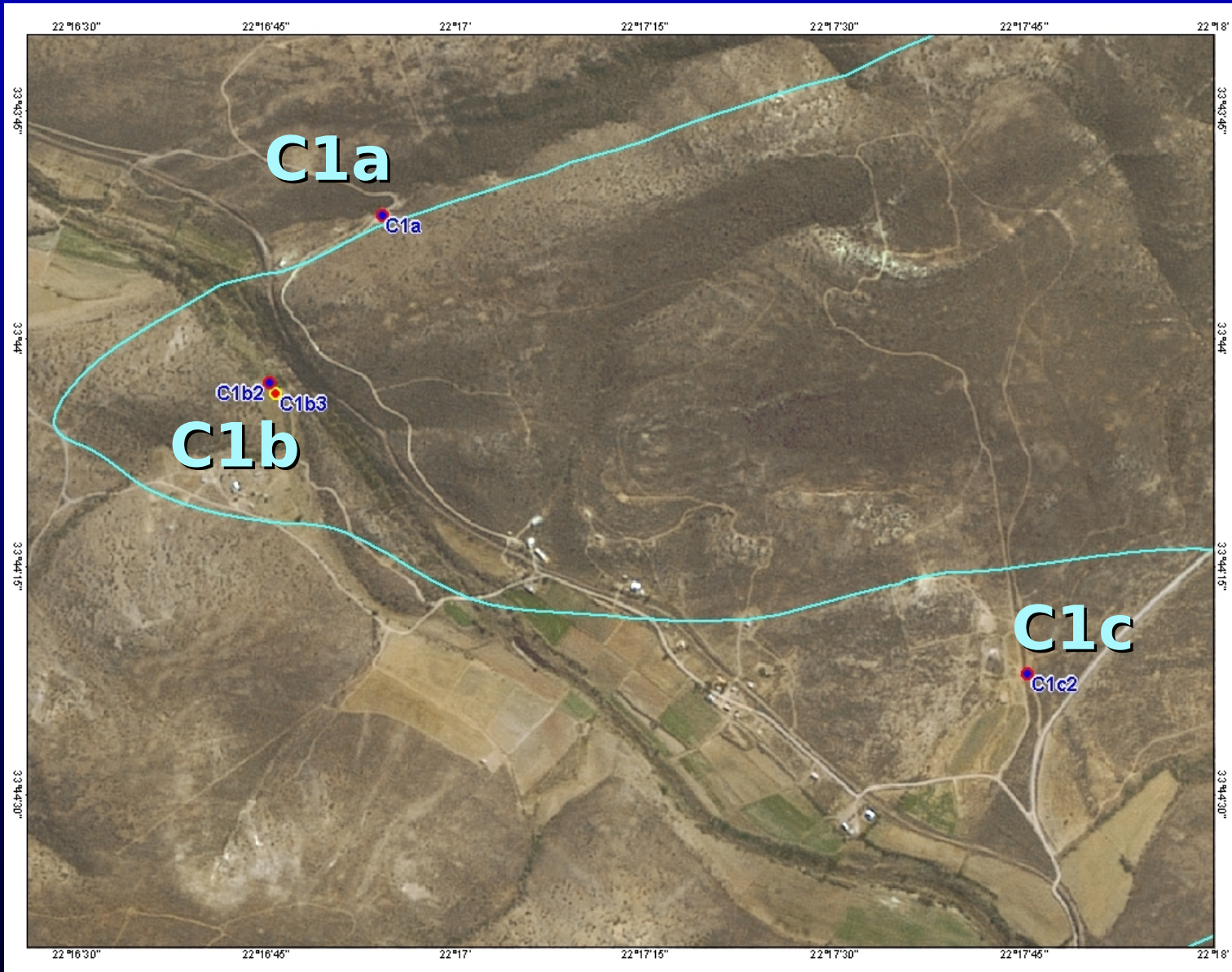
(after Coetzee & Haelbich, 1983)



Southern DAGEOS Targets

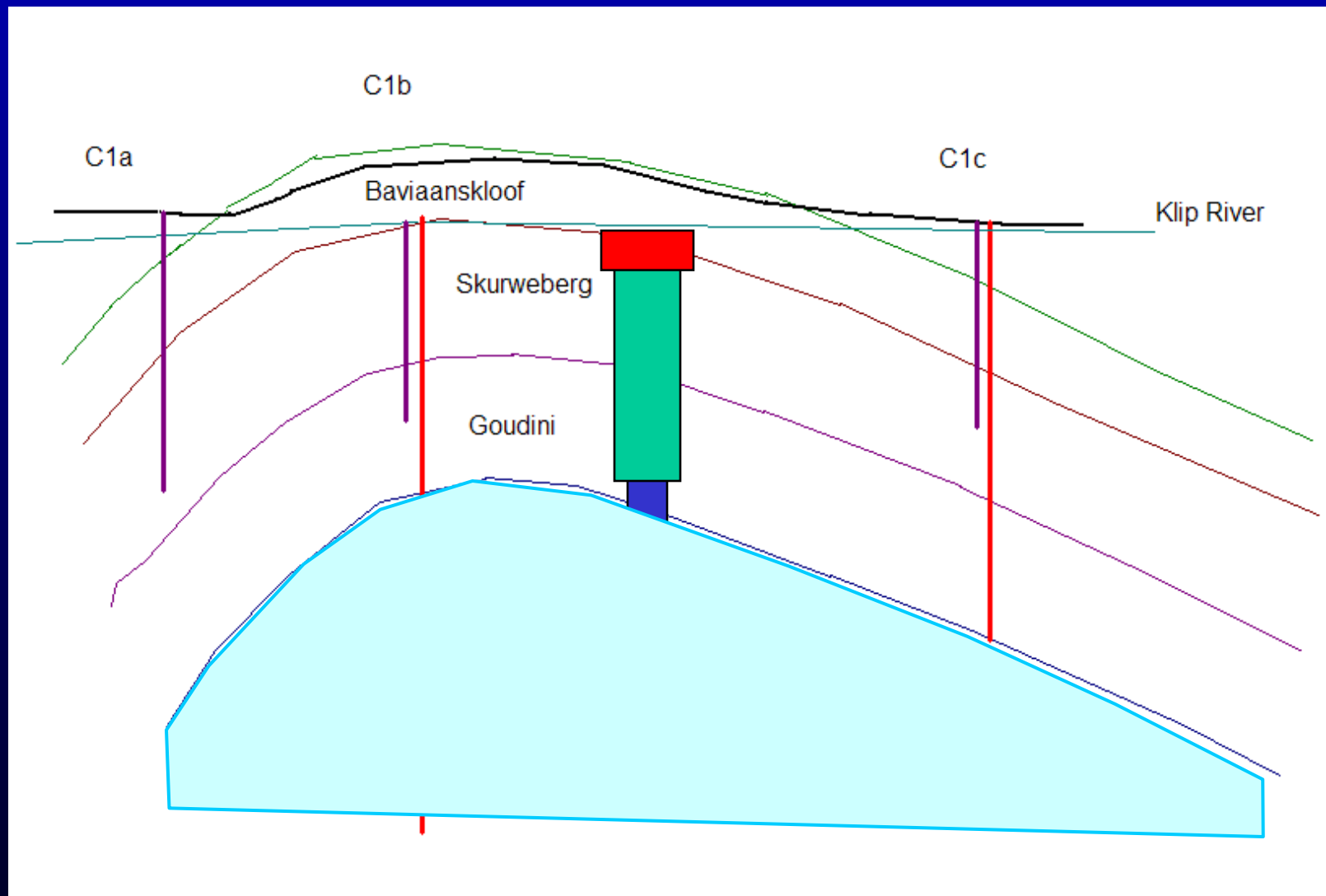


Target C1 Sub-areas



**Blossoms prospect,
Little Karoo**

C1 schematic cross-section



Exploration borehole drilling

Complete core record of TMG
lithostratigraphy and fracture
structure

Top of Peninsula Aquifer at
~300 m depth

Sealed casing to depth 426 m

End of hole at 715 m
below ground level

Continuous hourly pressure log
for deep aquifer



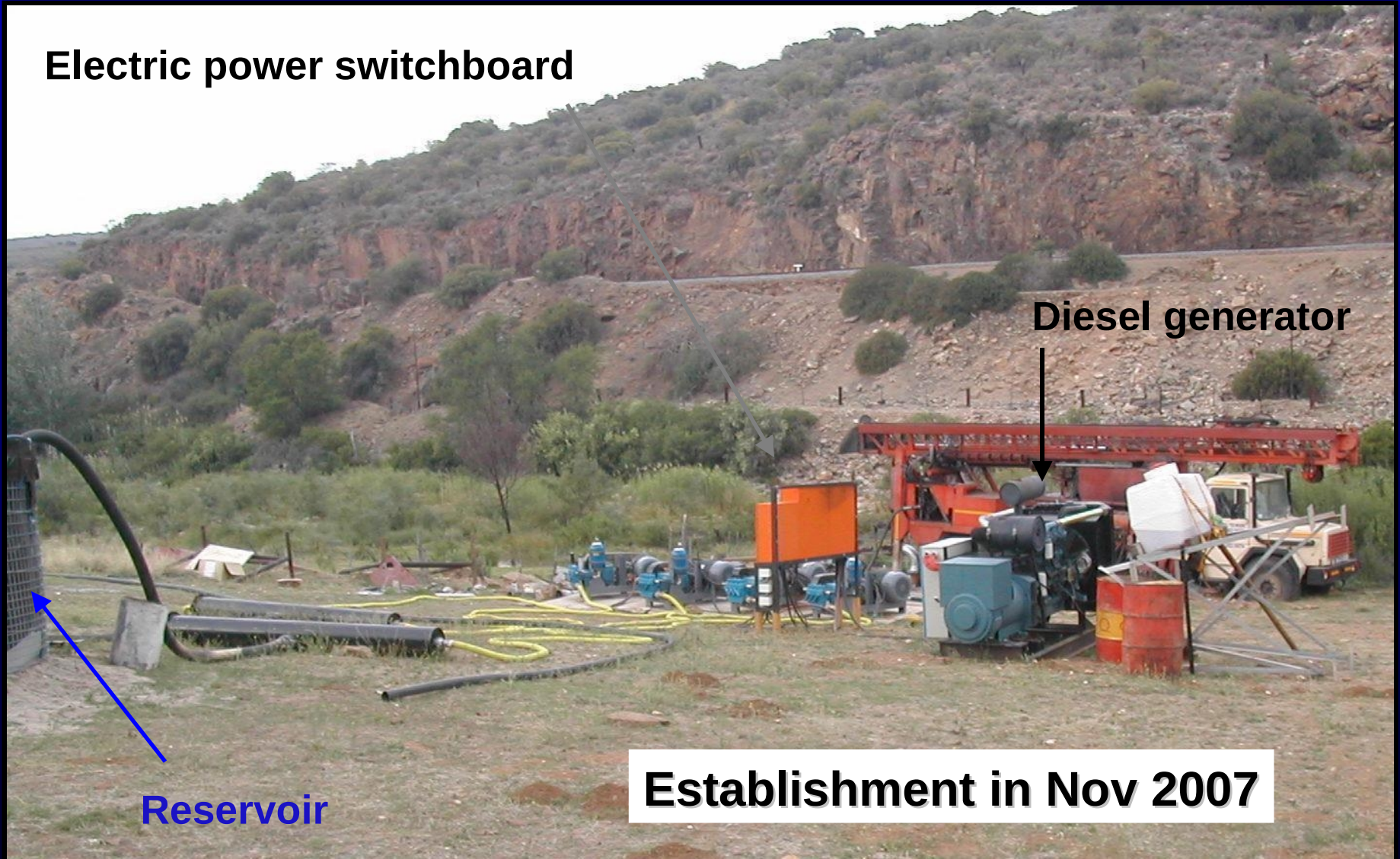
Production well drilling

Electric power switchboard

Diesel generator

Reservoir

Establishment in Nov 2007



Water-hammer technology



Compressor (160 bar / 16 MPa) array



**C1b3: Artesian flow
during drilling**



**Artesian free-flow
test (July 2008)**

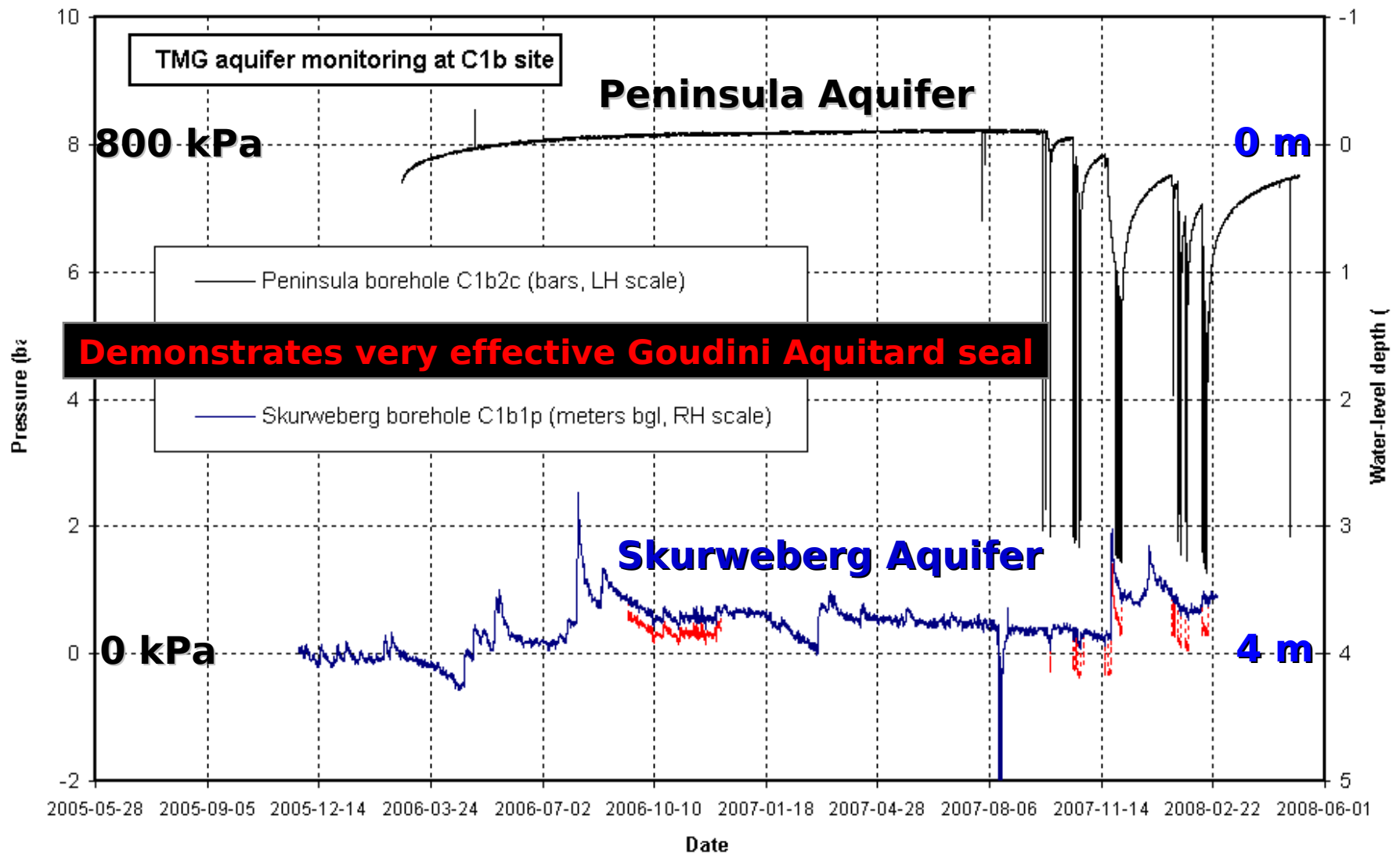
Artesian flow test – Sep-Nov 2009

- Layflat hose with discharge in furrow ~5 m above wellhead

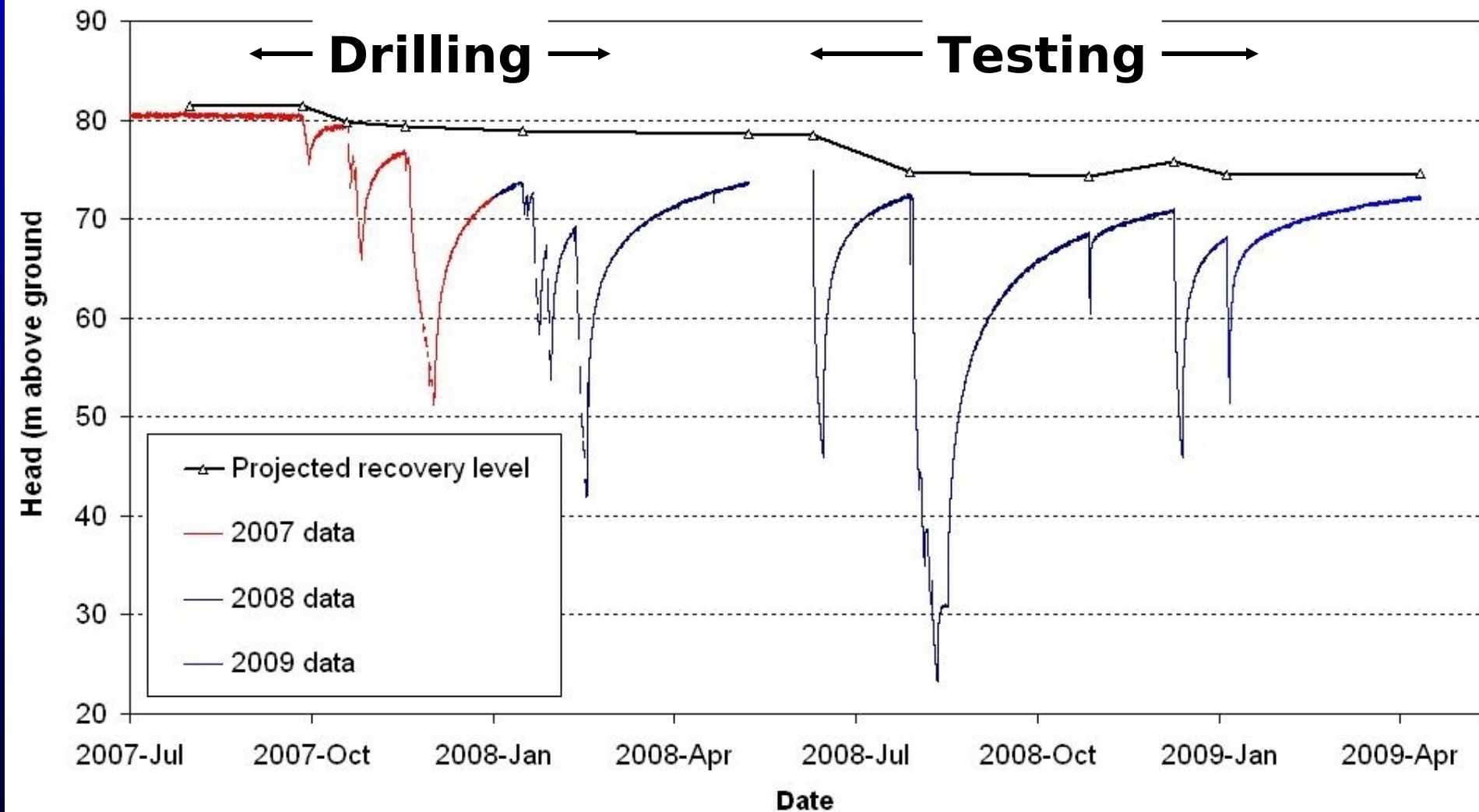


Monitoring and experimental results

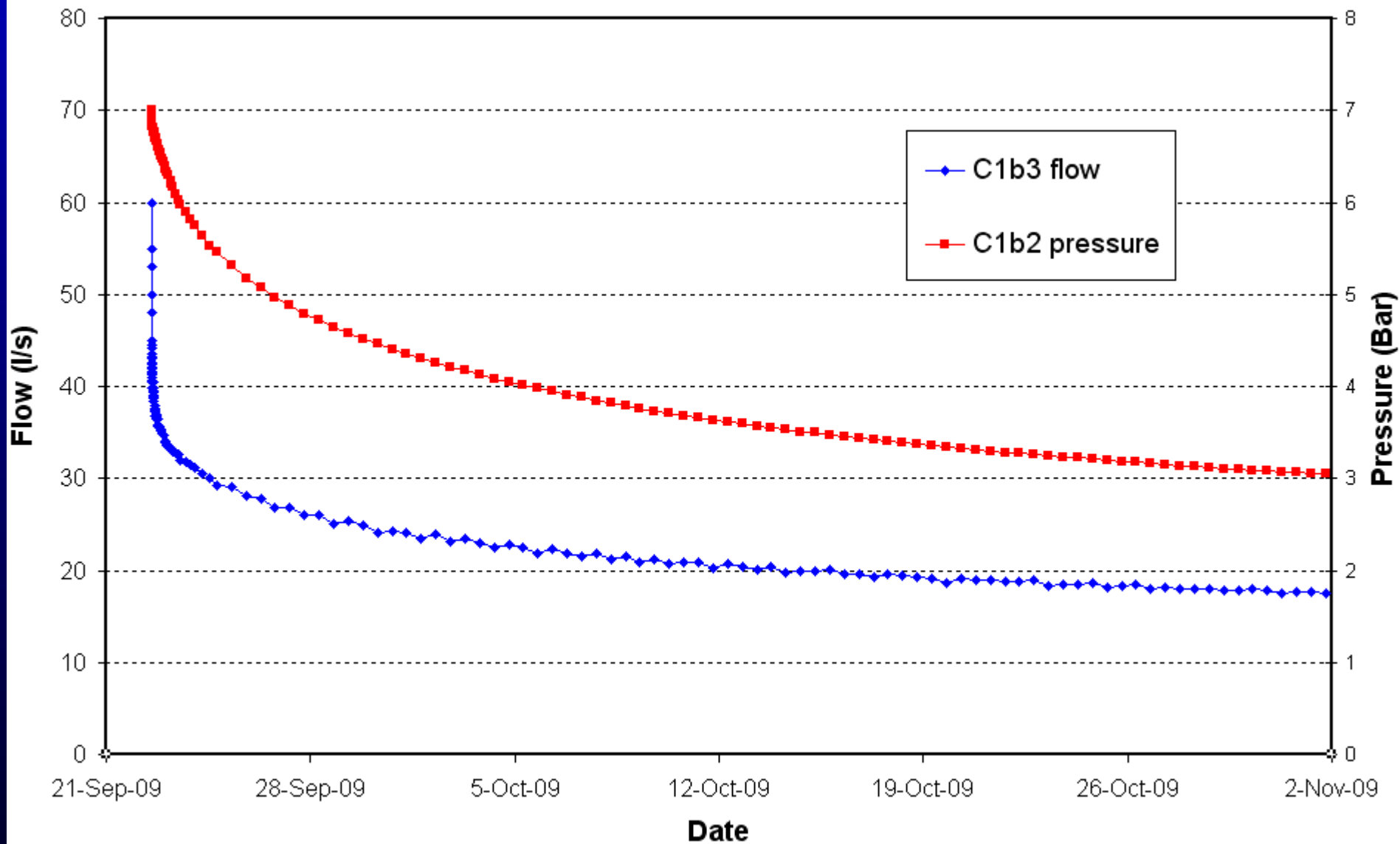
Pressure / WL monitoring



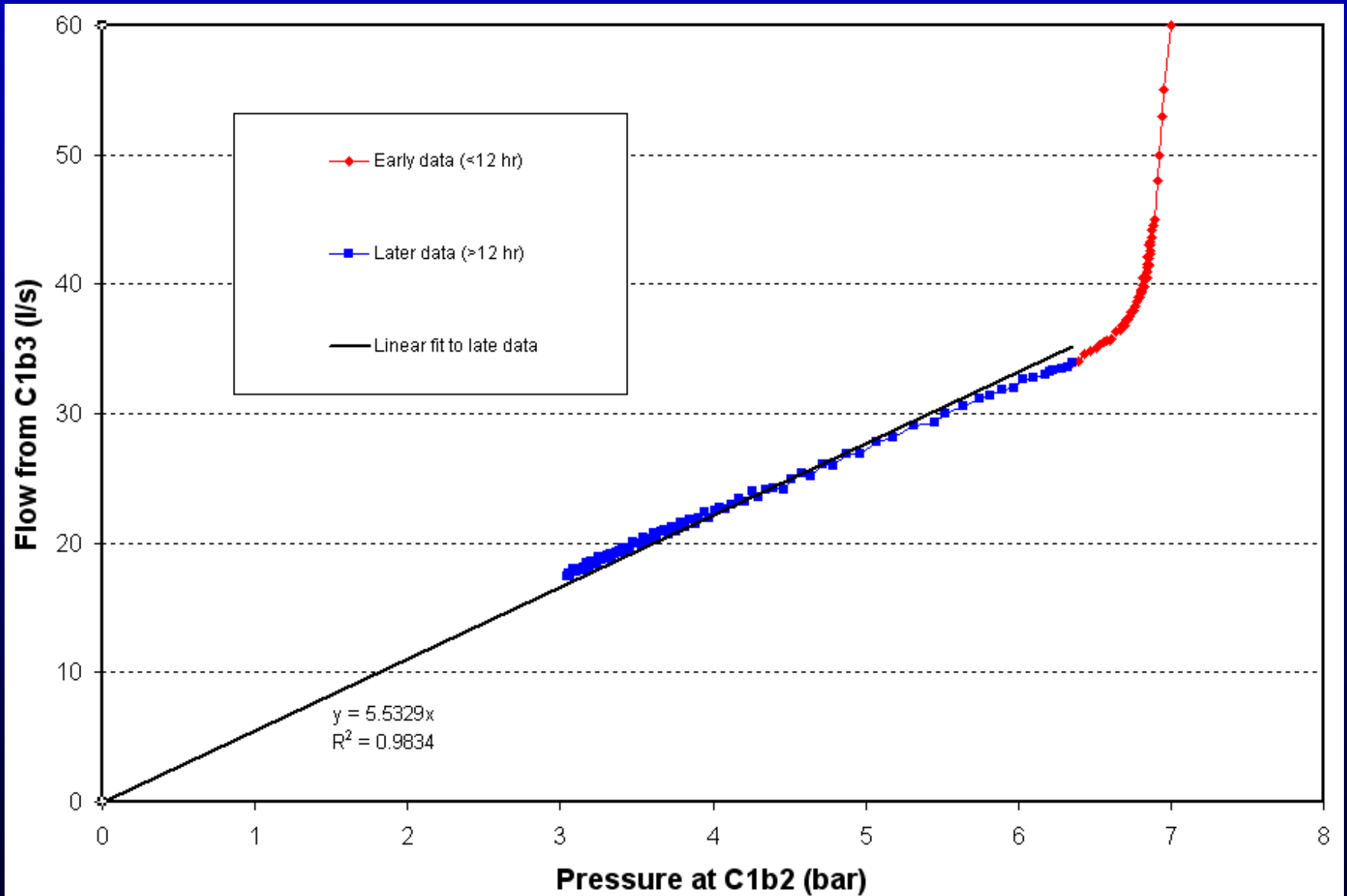
Recovery analysis



Recent free-flow test

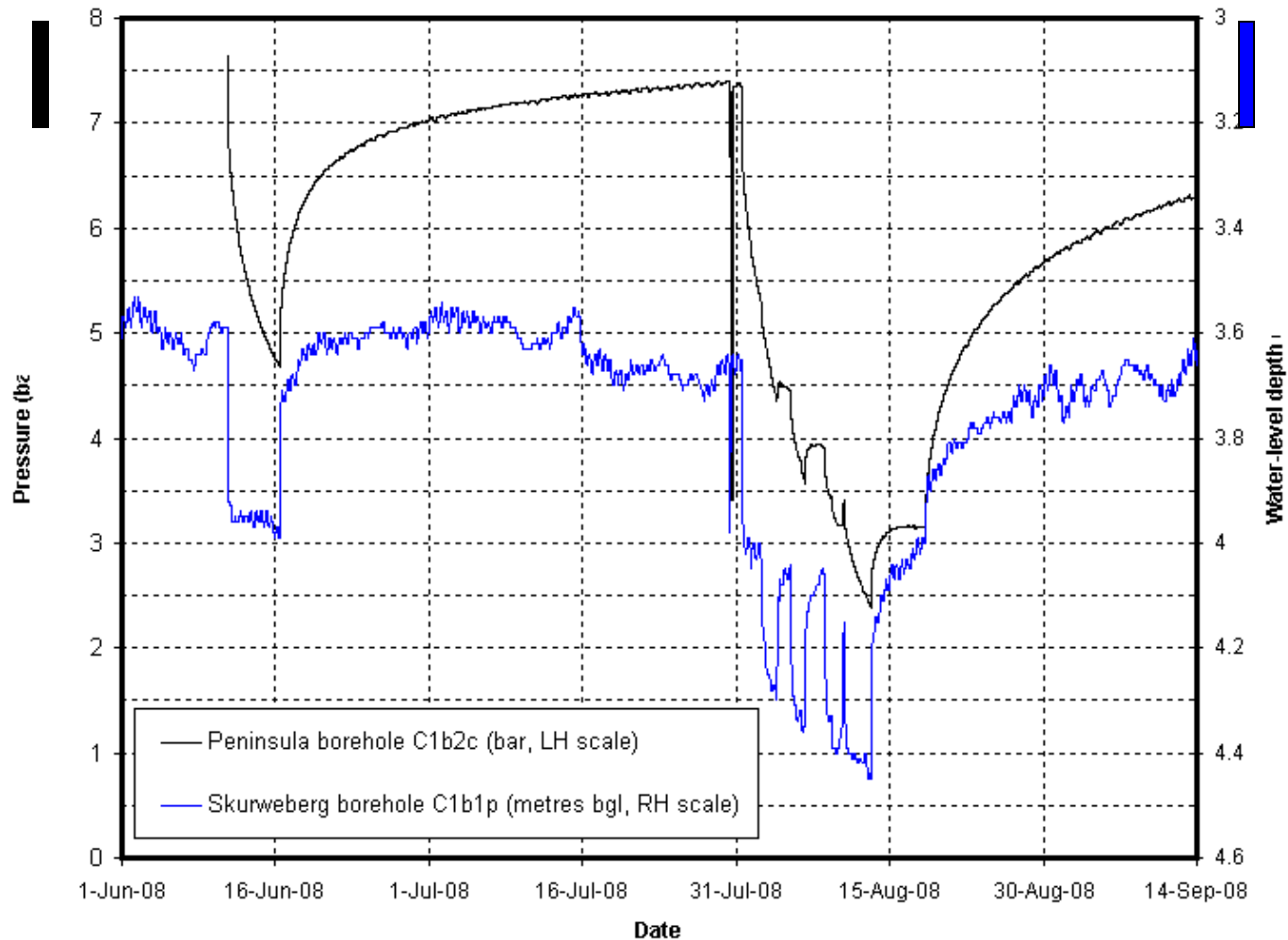


Flow rate-pressure correlation



Peninsula-Skurweberg interactions

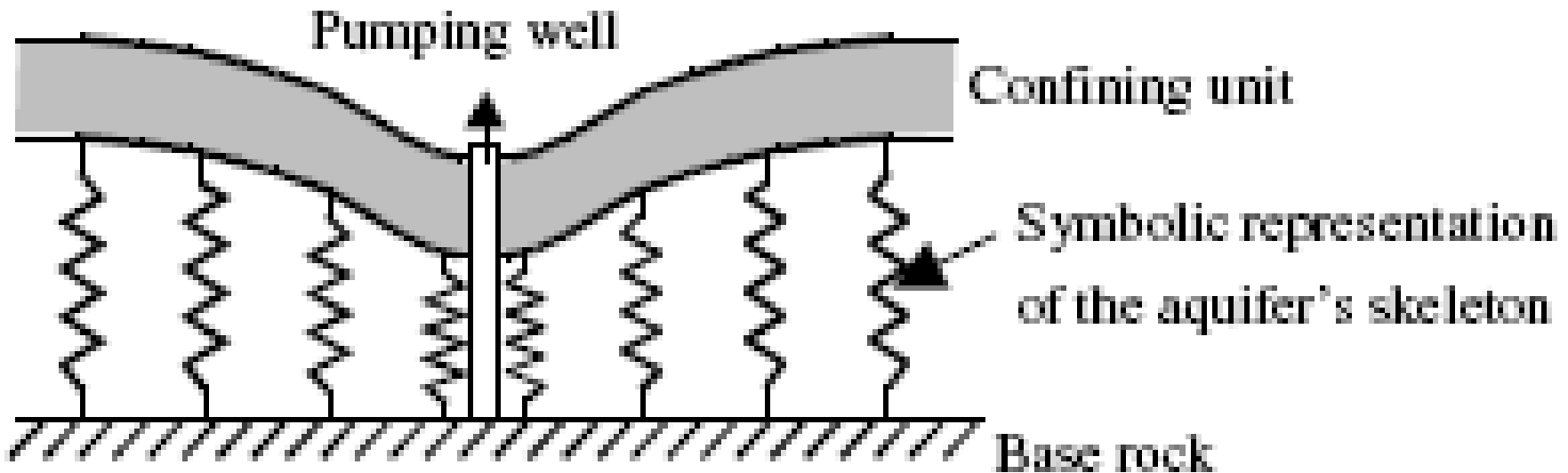
~10 m



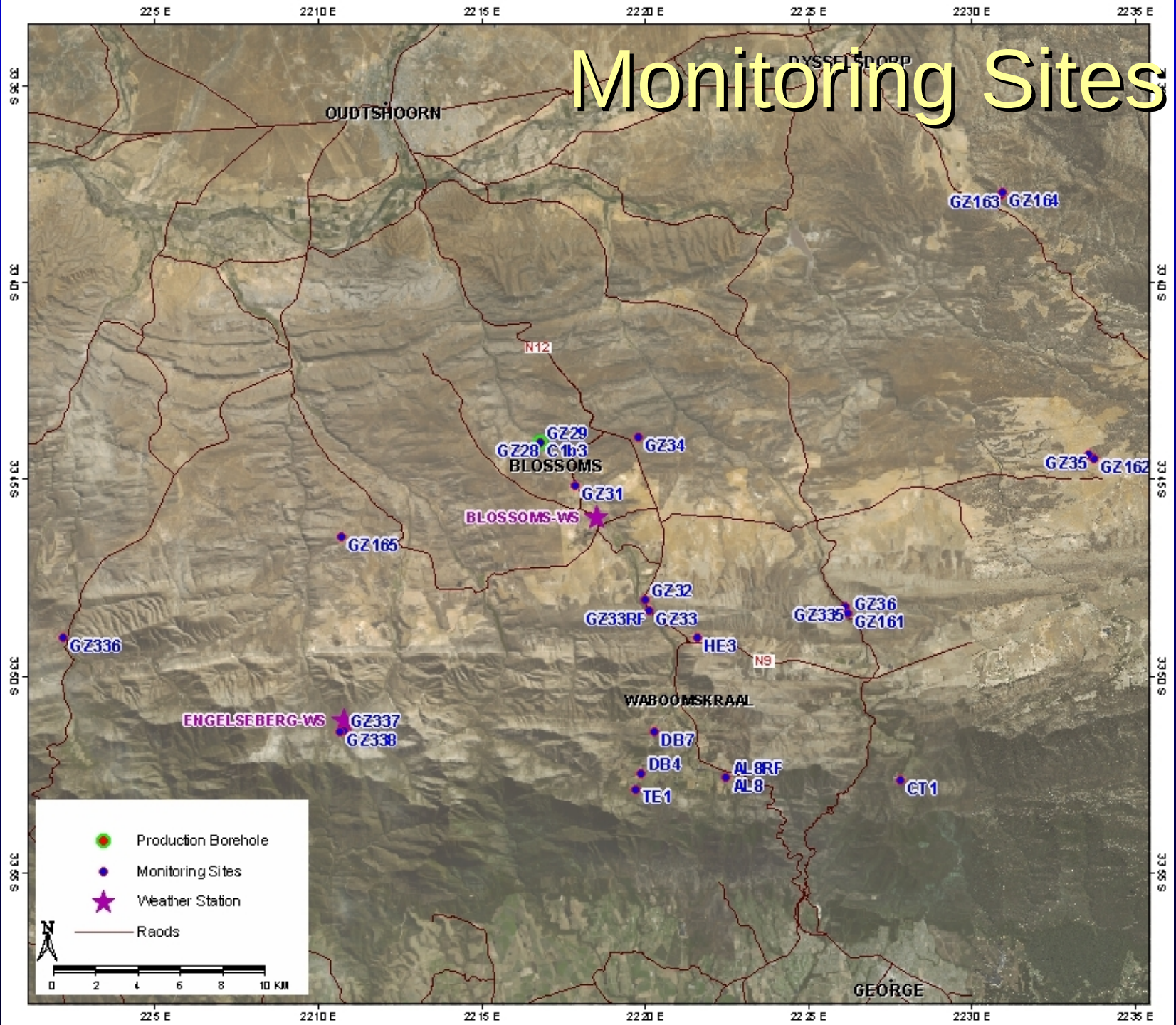
cm

Elastic-plate bending of confining unit

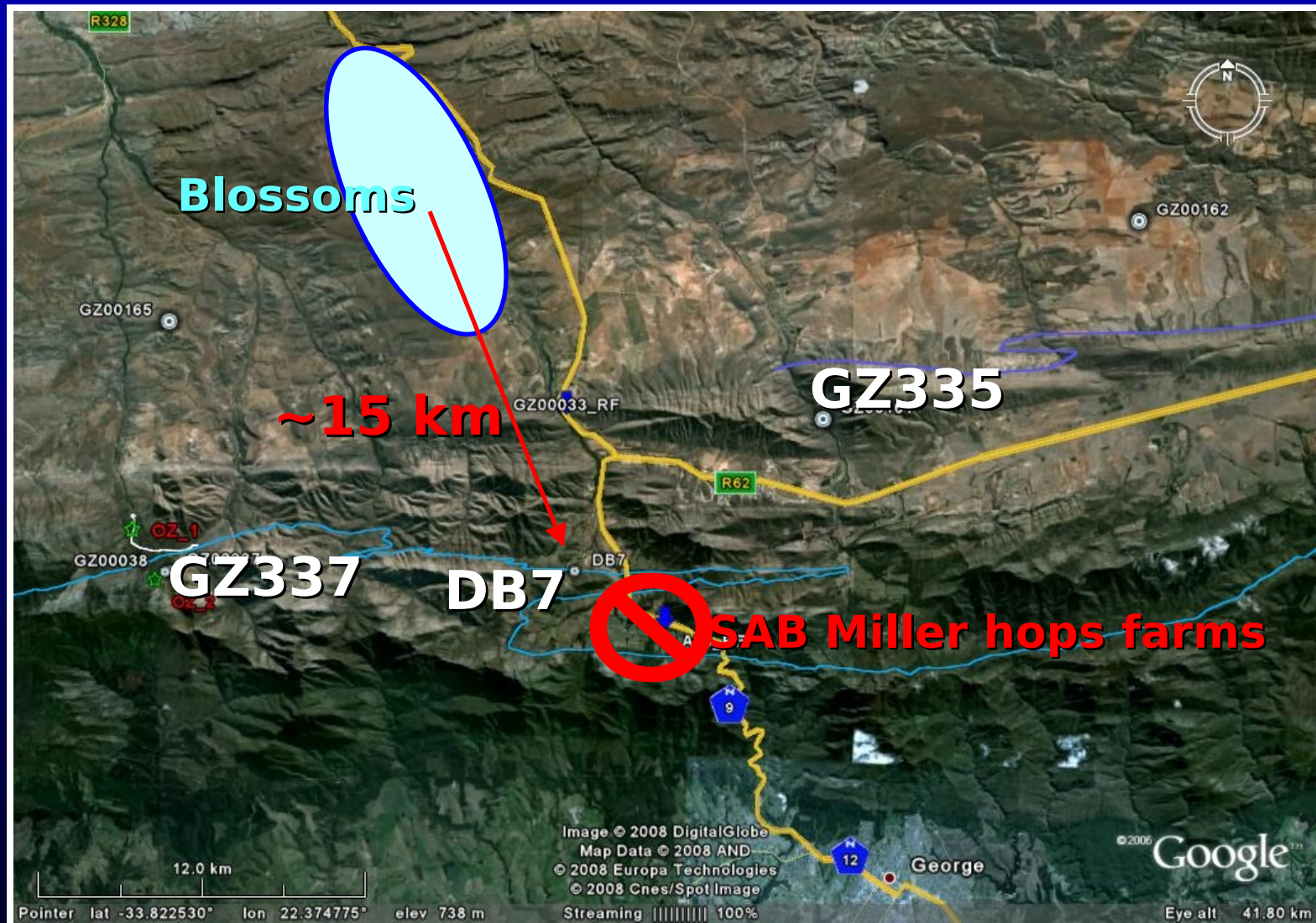
Explains instantaneous response (~30 cm) of Skurweberg water level to pressure changes in Peninsula aquifer



Future development?



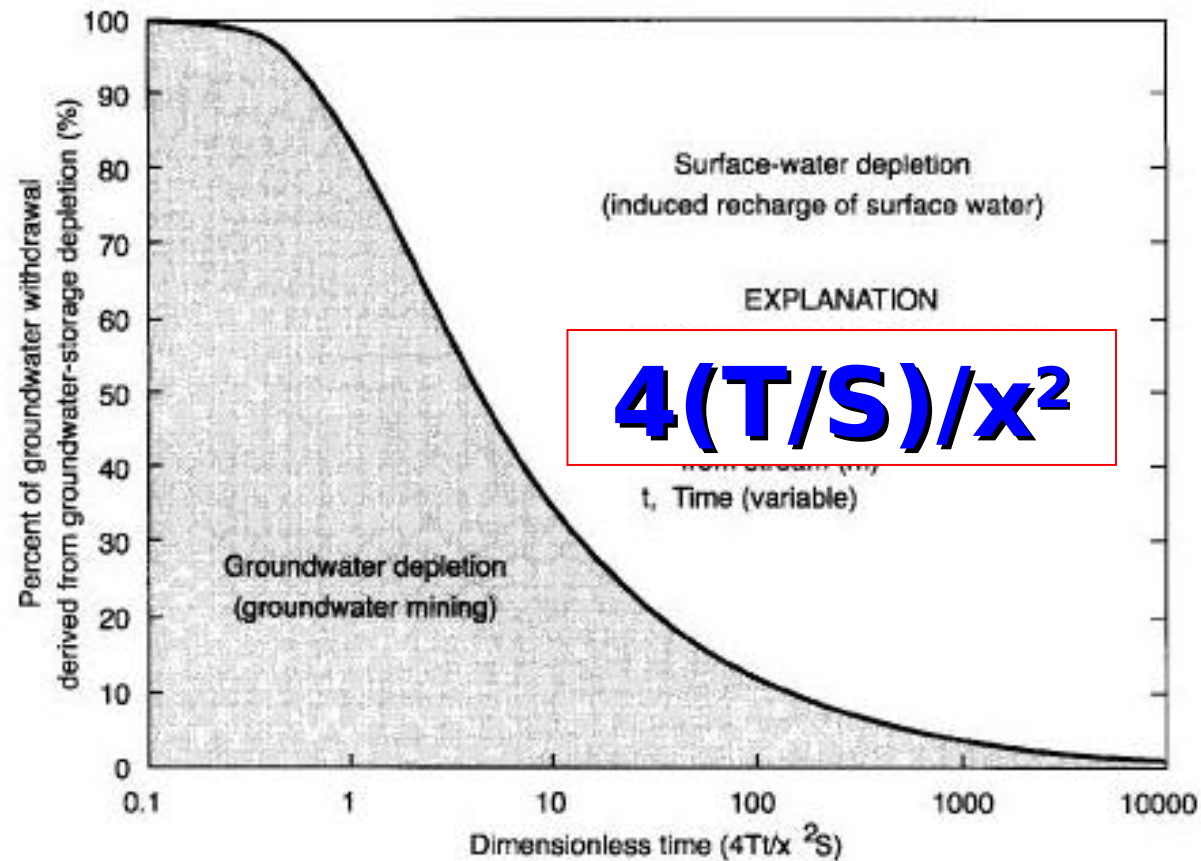
Far-field impact monitoring



Transition from reliance on GW storage

Illustrates temporal change in % of withdrawal derived from gw storage depletion

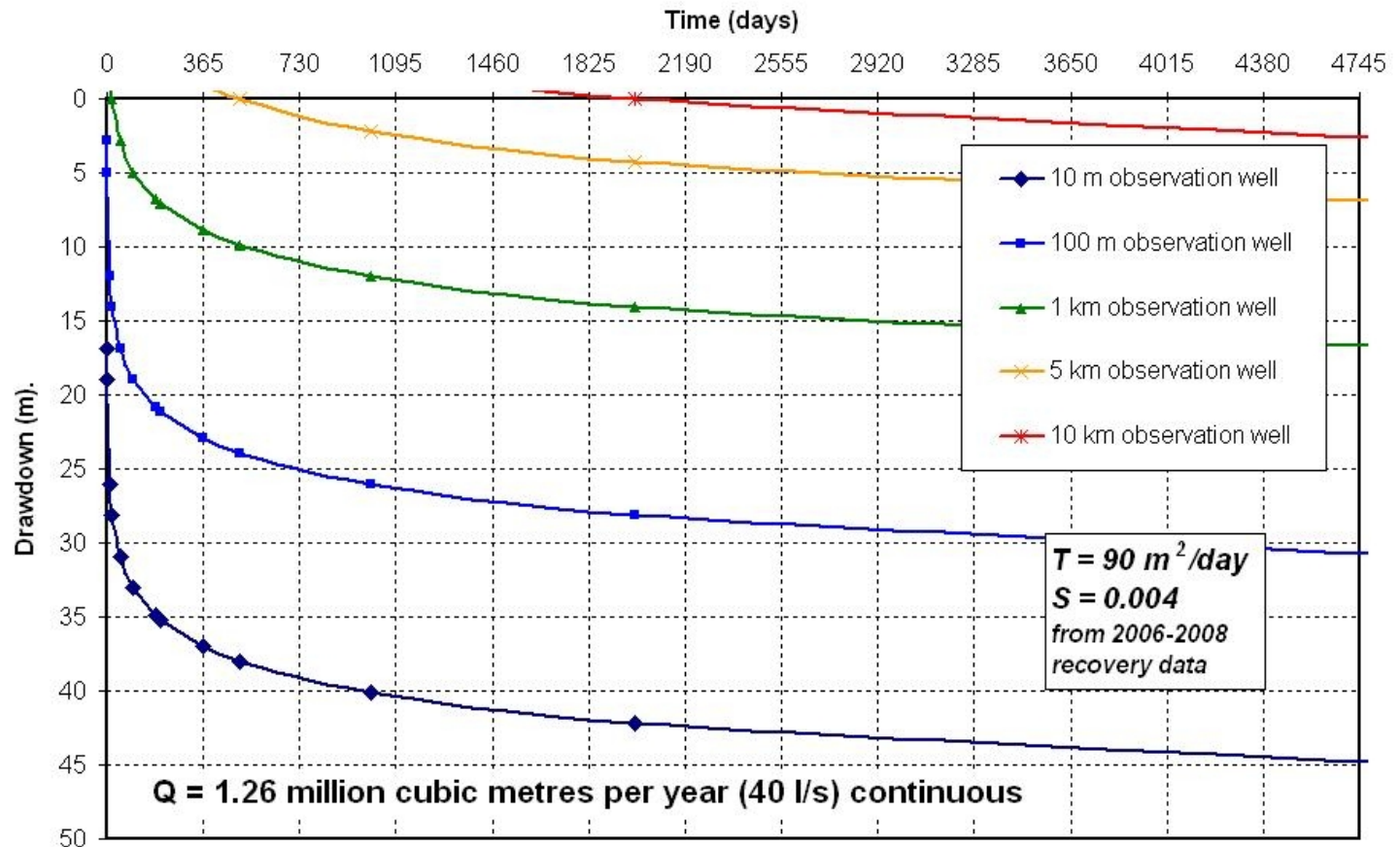
- NB - log scale of **dimensionless time**
- TMG parameter ranges
 - $T = 10 - 400 \text{ m}^2/\text{day}$
 - $S = 0.00001 - 0.05$
- DAGEOS estimates
 - $T = 90 \text{ m}^2/\text{day}$
 - $S = 0.004$



From Sophocleus, 2002, Fig. 9,

Drawdown-time graphs (DAGEOS case for continuous Q)

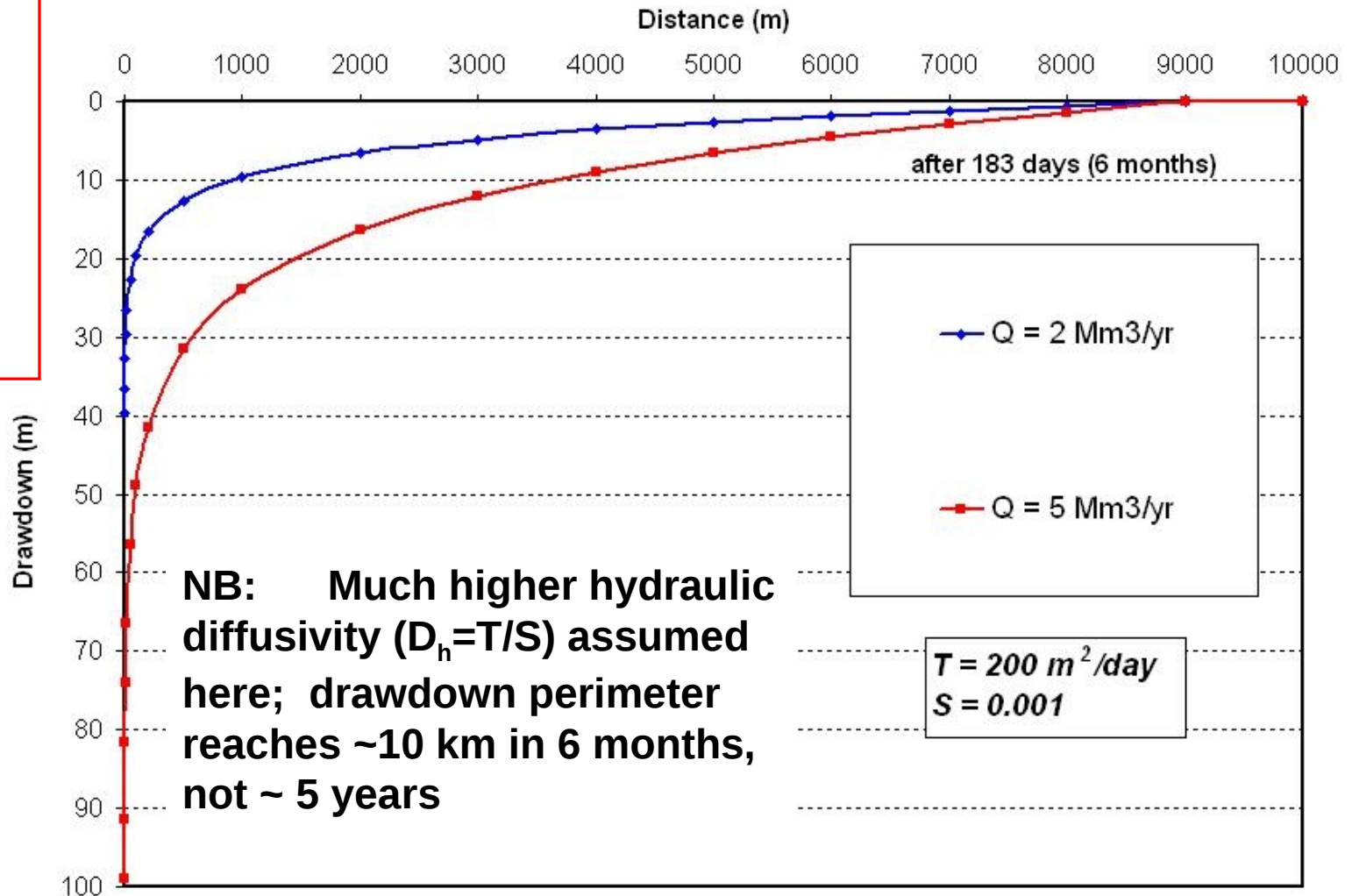
Best known T ,
 S parameters
for deep
confined TMG
aquifer based
on long
recovery from
extended
artesian flow



Hydraulic diffusivity ($D_h = T/S$) is controlling factor

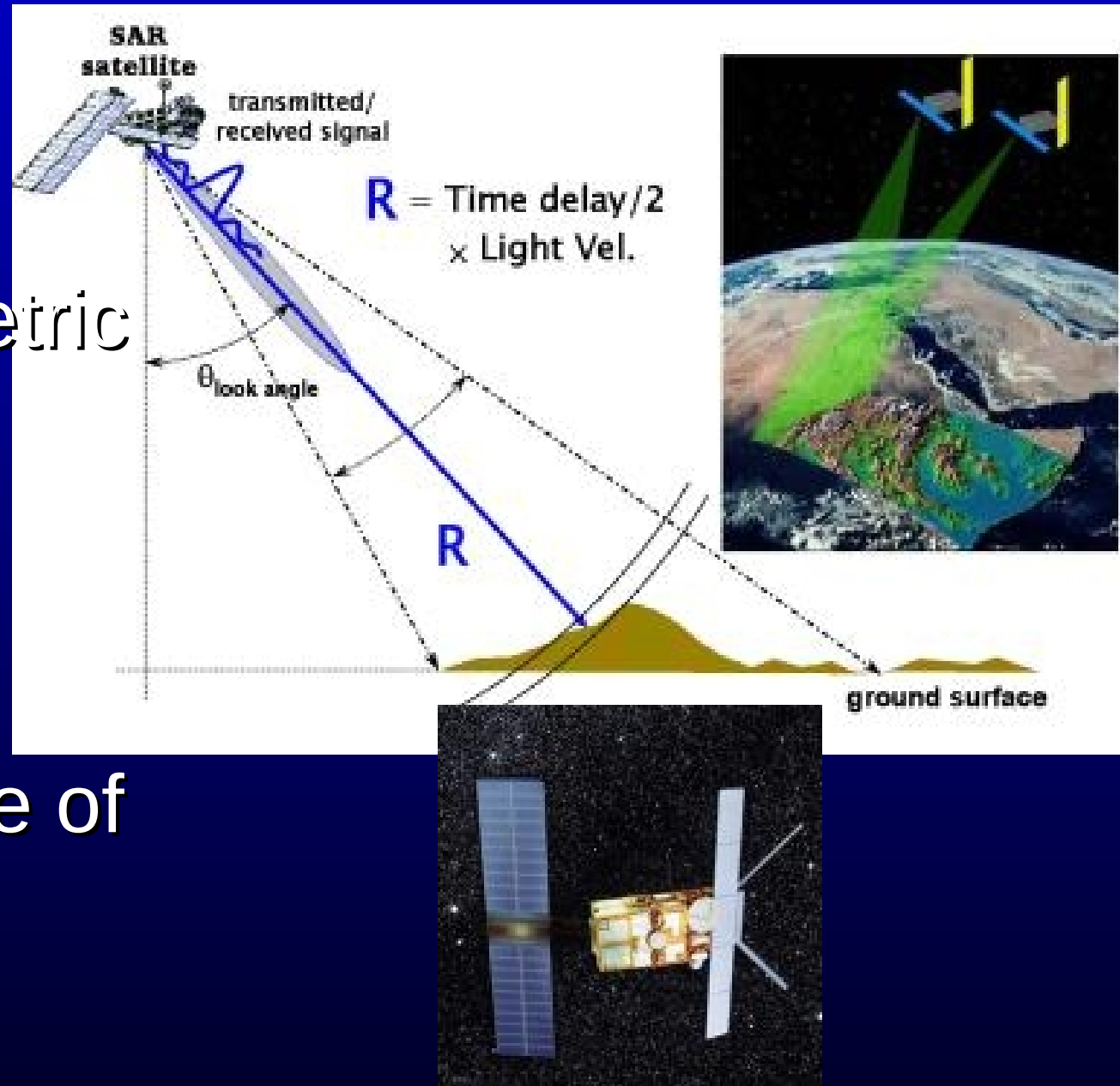
Theis drawdown-distance models

NB:
Pumping rate Q
affects
depth of
drawdown,
but not
radius of
influence



InSAR

- Interferometric Synthetic Aperture Radar
- Uses phase of reflected radiation



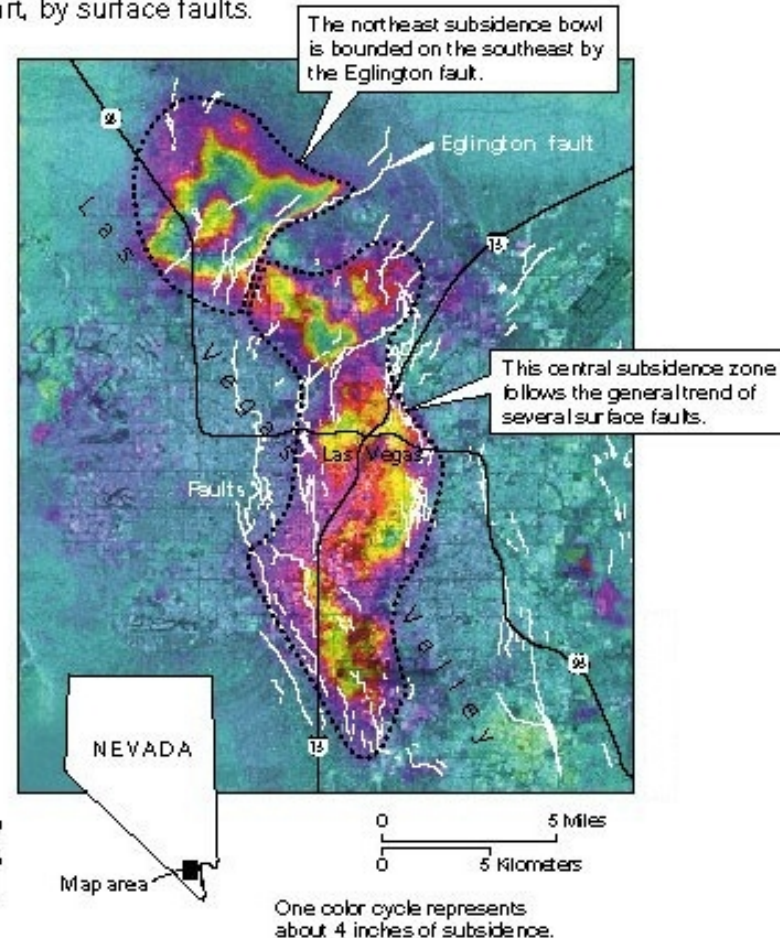
Aquifer deformation mapping

InSAR ... powerful tool to measure deformation of Earth's crust at unprecedented spatial detail and high degree of measurement resolution ... often less expensive than obtaining sparse point measurements from labour-intensive spirit-leveling and Global Positioning System (GPS) surveys

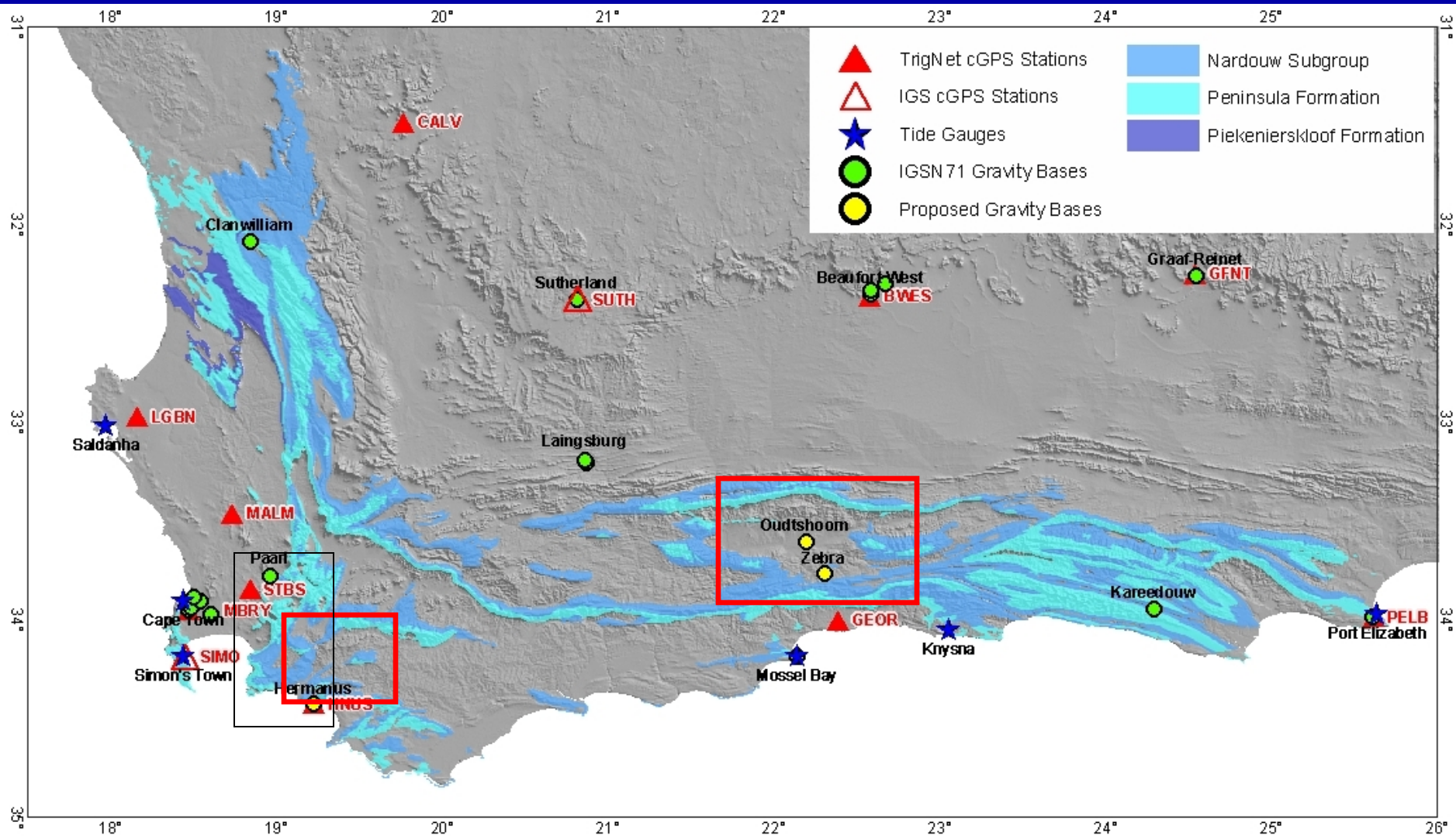
Amelung, Falk, Galloway, D.L., Bell, J.W., Zebker, H.A., and Lacznia, R.L., 1999, Sensing the ups and downs of Las Vegas - InSAR reveals structural control of land subsidence and aquifer-system deformation: Geology, v. 27, no 6, pp. 483-486.

Las Vegas Valley, Nevada

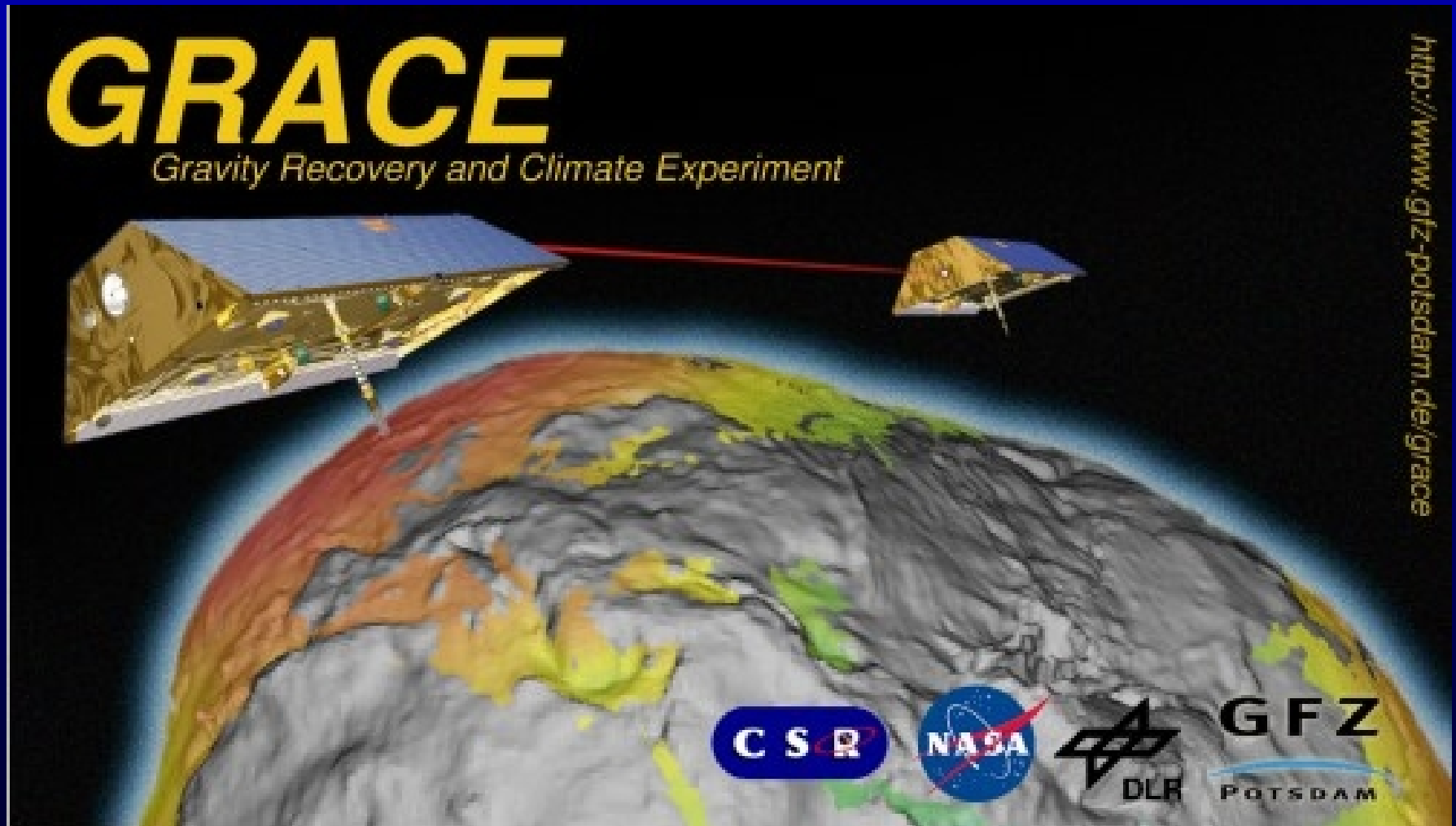
Stacked interferogram shows subsidence caused by compaction of the aquifer system between April 1992 and December 1997. The subsidence is controlled in part, by surface faults.



Wider “Natural Laboratory” concept

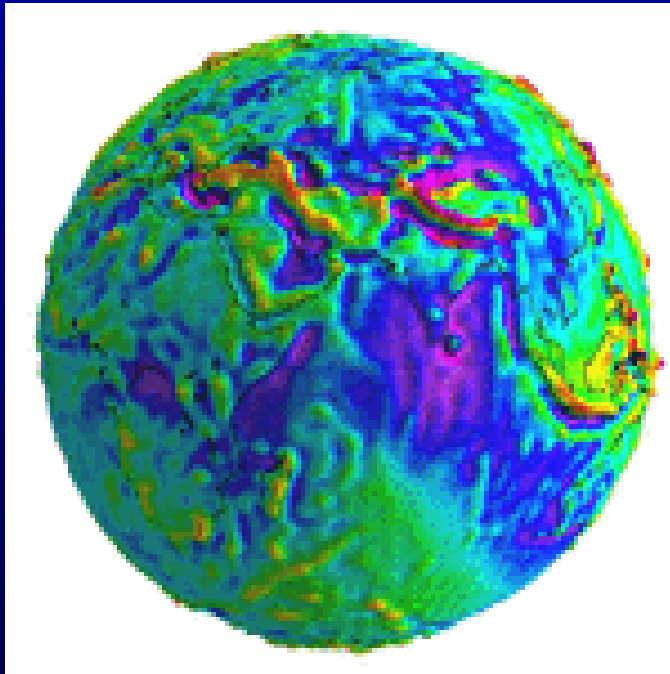


GRACE Satellite Configuration

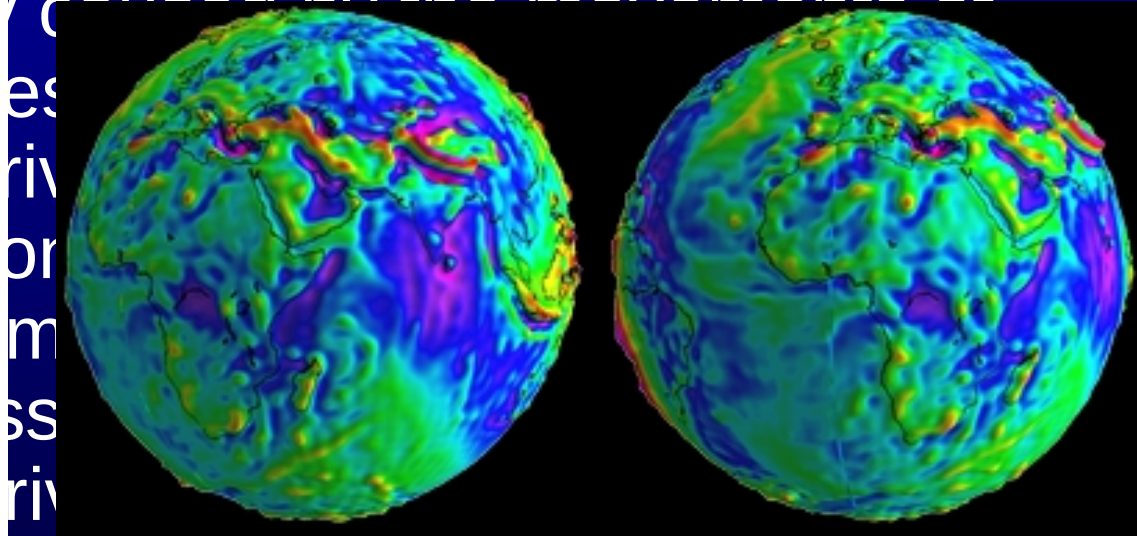


GRACE

- **G**ravity **R**ecovery **A**nd **C**limate **E**xperiment satellite mission – co-PI: Byron Tapley (UT Austin)



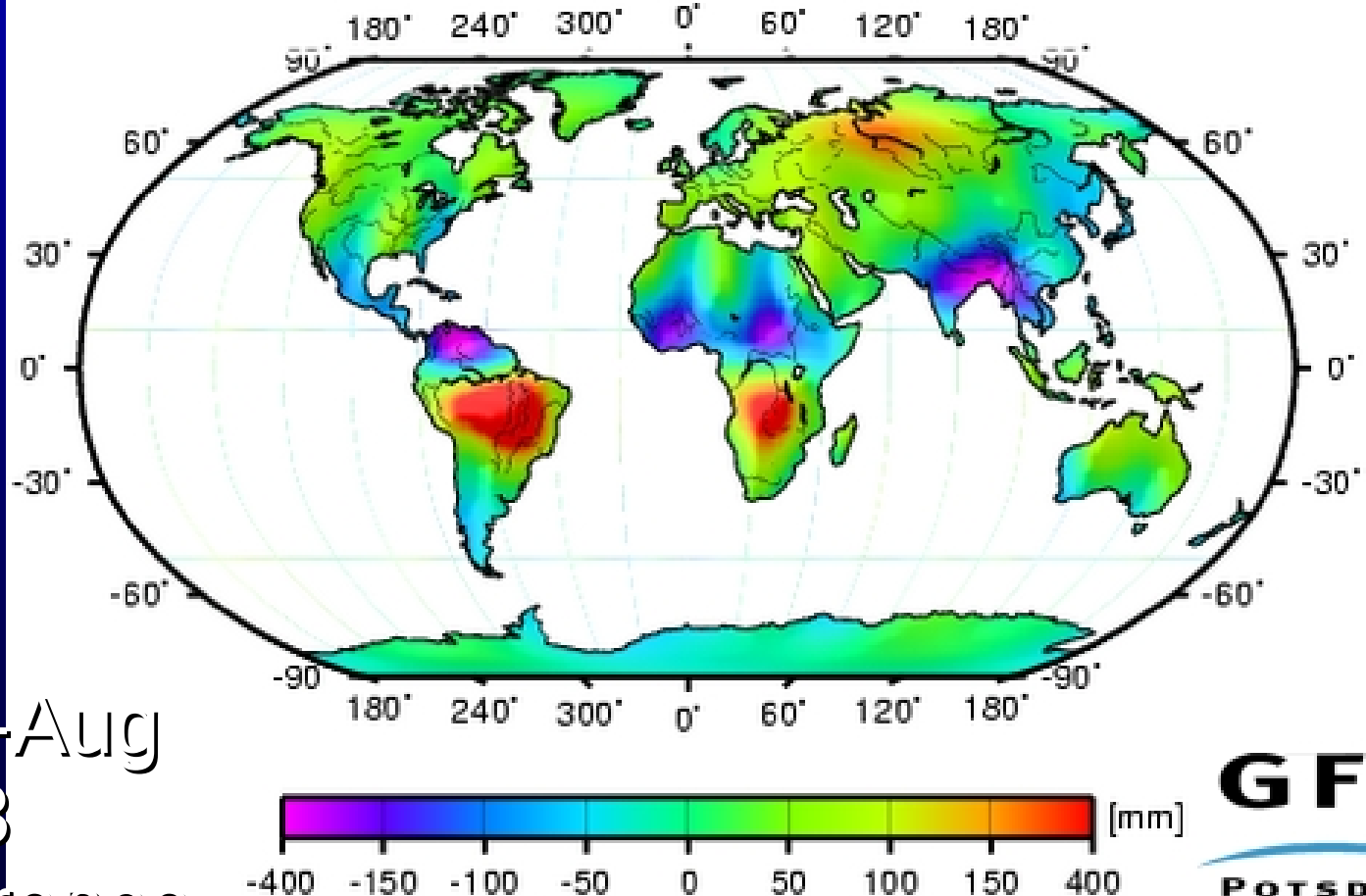
card is its ability to measure the
y caused by the movements of



- “Eventually,” says Tapley, “we will be able to let countries in Africa know how their aquifers are changing”.

Continental Water Storage

Monthly GRACE solution 04u05-2003 vs 08-2003
(Gauss Filter 750 km, $N_{\max} = 100$, C_{20} excluded)



- May-Aug
2003
difference

Acknowledgements

- Oudtshoorn Municipality, in particular town engineer, Mr Kobus du Toit, for co-operation
- Mike Smart and Piet Havenga (DWA Western Cape) for strong technical support
- CapeNature and Western Cape Department of Environmental Affairs and Development Planning for interest and advice