



Civil Engineering and the Environment

Embankment and cut slope monitoring and analysis

Dr Joel Smethurst



Introduction

A number of instrumented sites have been used to:

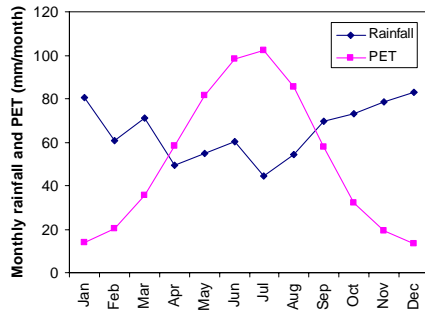
- Monitor seasonal changes in soil moisture and pore water pressure/suction
- Understand vegetation effects
- Assess impact of natural variation in climate
- Consider performance under climate change



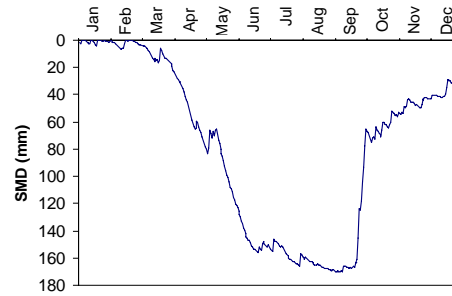
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Climate of the South-East

Rainfall and potential evapotranspiration, South-East England (Southampton)

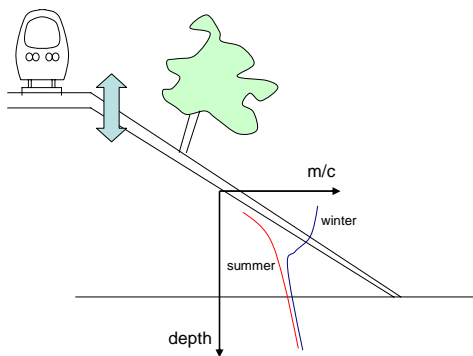


Soil moisture deficit (SMD) = amount of water required to recharge the profile



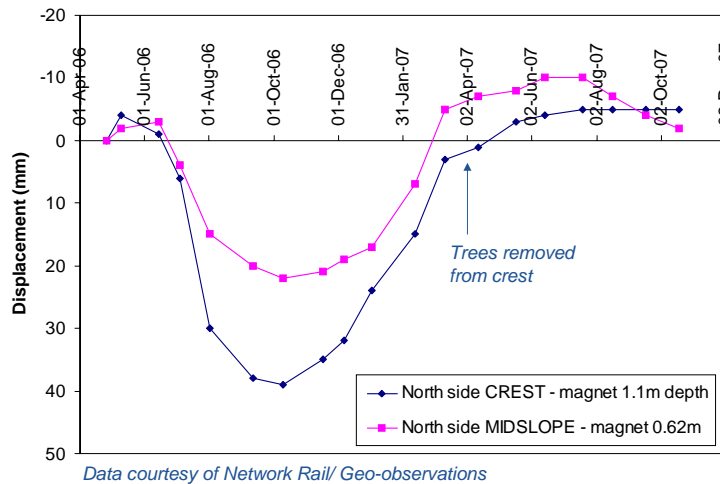
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Track quality



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Vertical extensometer displacements



Data courtesy of Network Rail/ Geo-observations



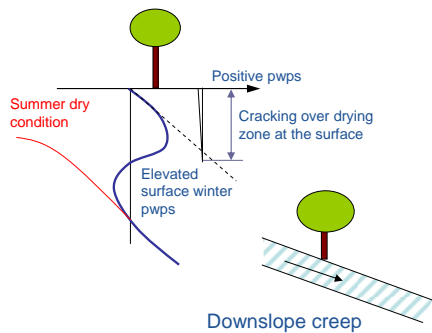
Magnolia Road, Southend North side



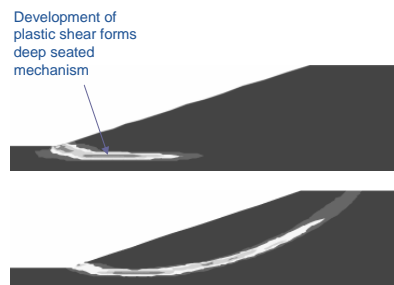
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Slope instability

Shallow instability/creep caused by elevated surface pwp's



Strain softening of clays and deep seated failure



Taken from Ellis and O'Brien (2007)

To link together

Climate > vegetation > changes in soil moisture > vertical and lateral displacements



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Long term continuous monitoring of soil moisture, climate and pore water pressures in a London Clay cutting



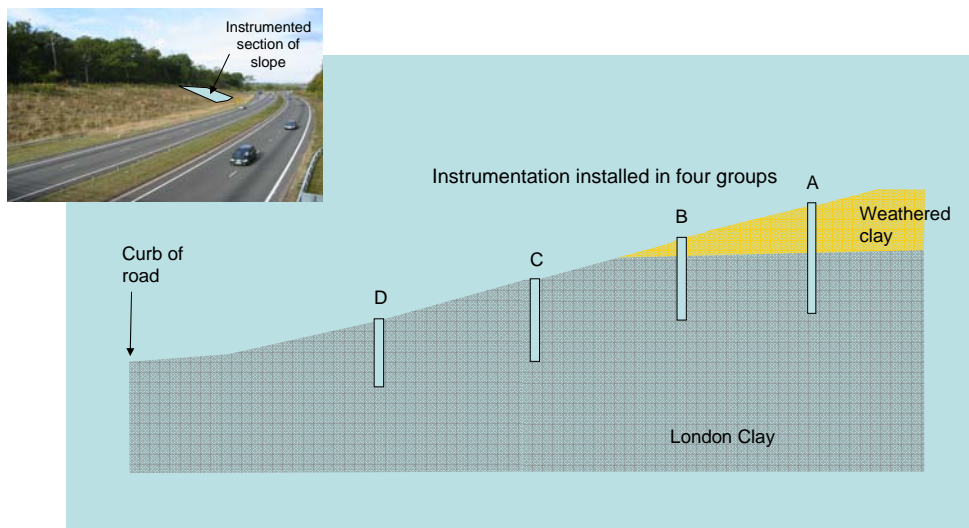
Newbury site

- Cut slope in London Clay (constructed 1997)
- Uniform geology
- Shallow slope angle $\sim 16^\circ$
- Grass/small shrubs vegetation cover

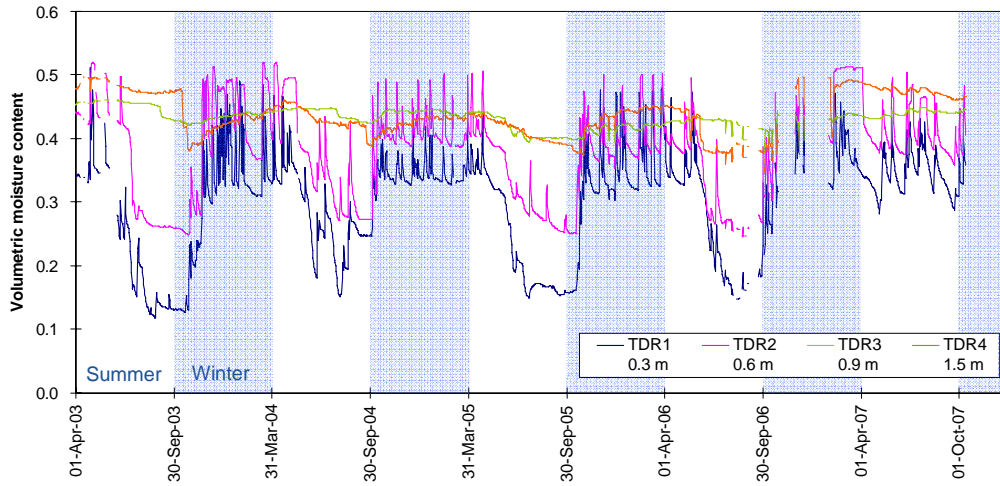
Measurement of:

- Pore pressure
- Climate
- Soil moisture content

Newbury - instrumentation

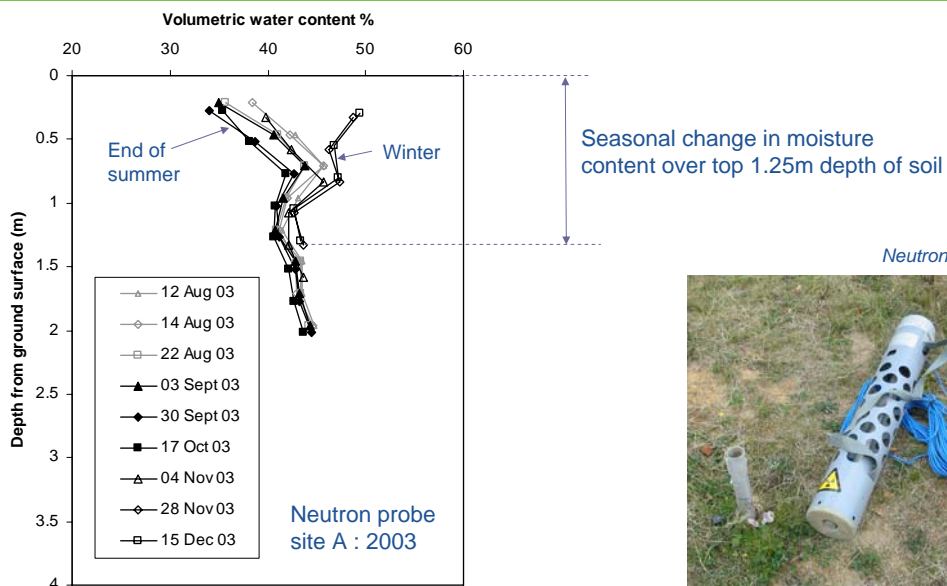


Newbury – measured moisture contents in weathered clay (Group A)



Moisture content measured by TDR ThetaProbes

Newbury – changes in volumetric moisture content – in weathered clay



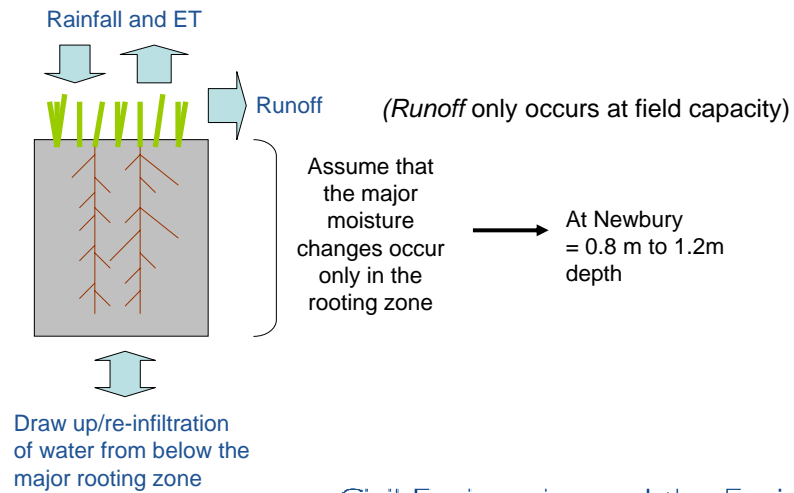
Neutron Probe



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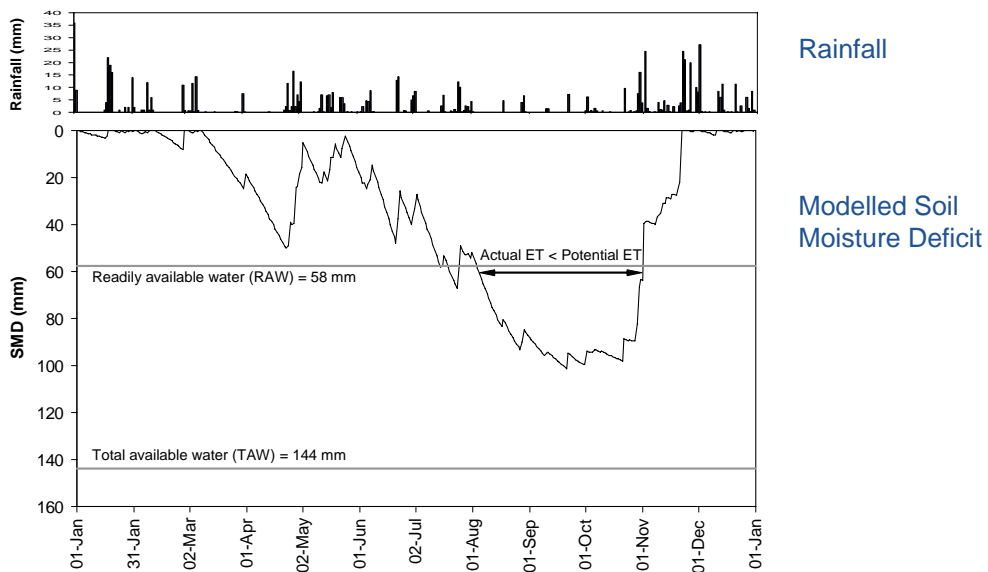
Newbury – soil water balance

Simple 1-D soil moisture balance model



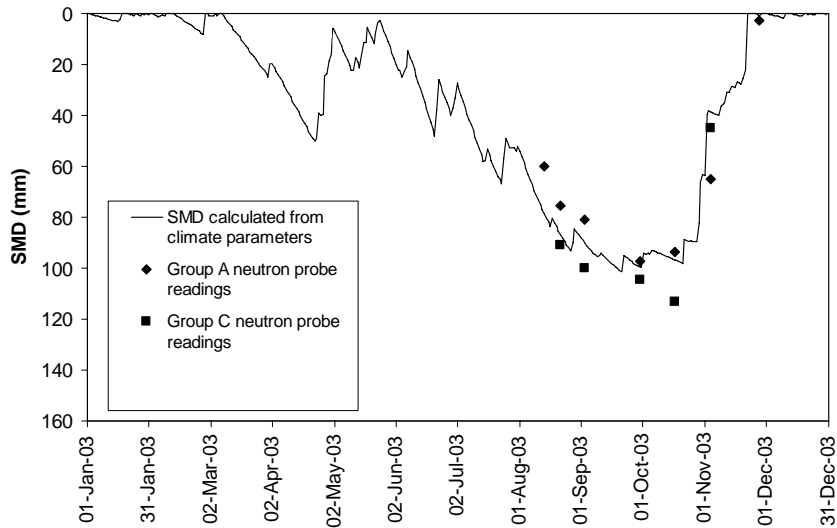
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Newbury – estimated soil moisture deficit 2003



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Newbury – estimated SMD and measured drying



Acknowledgements

Co-investigators: Prof. William Powrie, Dr Derek Clarke

Funded by: 

Collaborators:   

Old railway embankments suffering serviceability (shrink/swell) problems



Magnolia Road,
Southend



Pound Green,
Reading

Magnolia Road/Pound Green

- Old (> 100 yrs) poorly compacted London Clay embankments
- Ground conditions mixed – ash and ballast materials on the top of the embankments/old counterfort drains
- Large mature tree cover and permanent moisture deficit

Measurement of:

- Lateral and vertical displacement
- Pore water pressures
- Soil moisture content
- Rainfall

Site locations



Newbury site – Vegetation changes between summer-winter



09 May 03

09 July 03

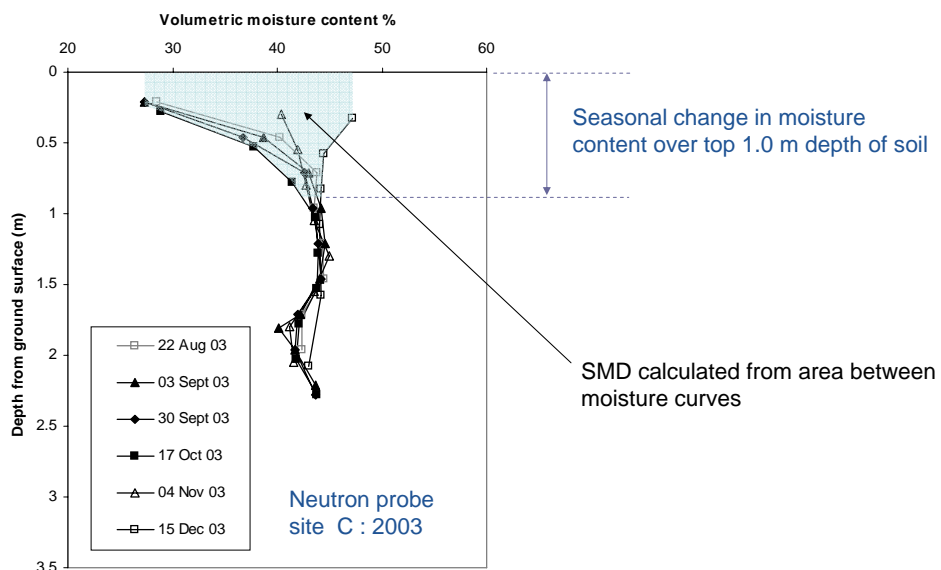
10 Sept 03

24 Oct 03



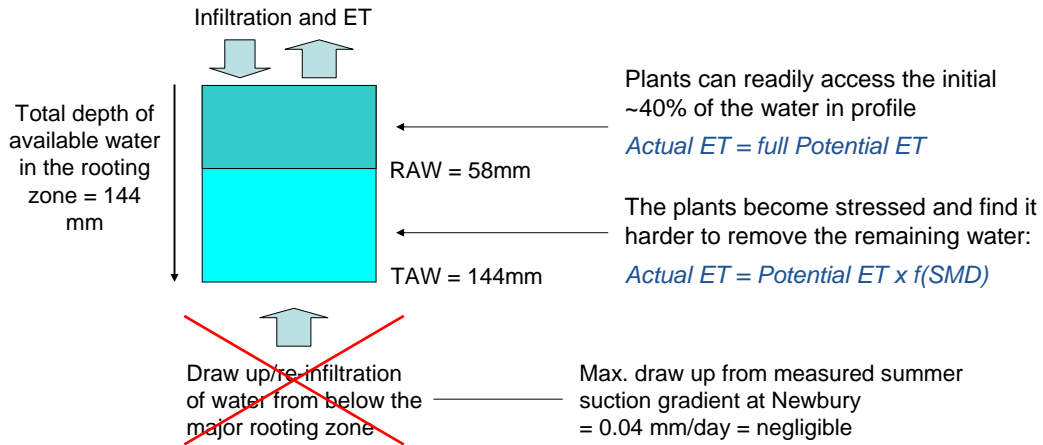
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Newbury – changes in volumetric moisture content – in grey clay

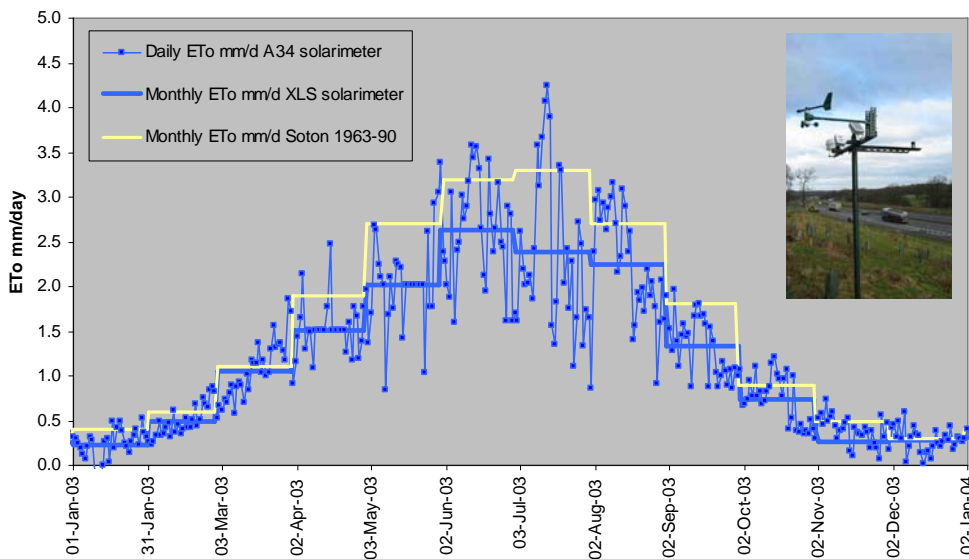


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Newbury – soil water balance



Newbury – estimated potential evapotranspiration (Penman – Monteith)



Modelling London Clay slopes (grass cover) with future climate data

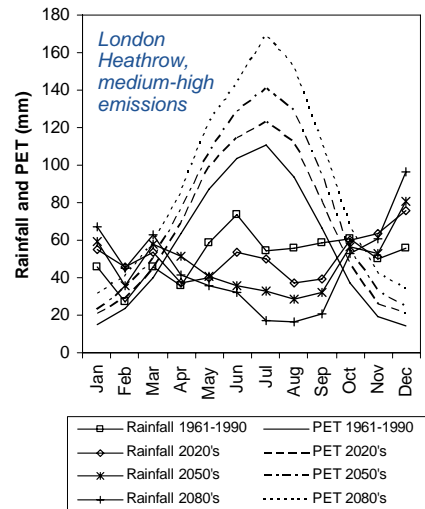
We have used the BETWIXT (Watts *et al*, 2004) future climate data sets to simulate SMD's from 2010 – 2100 (based on Hadley 2002 model)

Data for London near Heathrow Airport

Assumptions

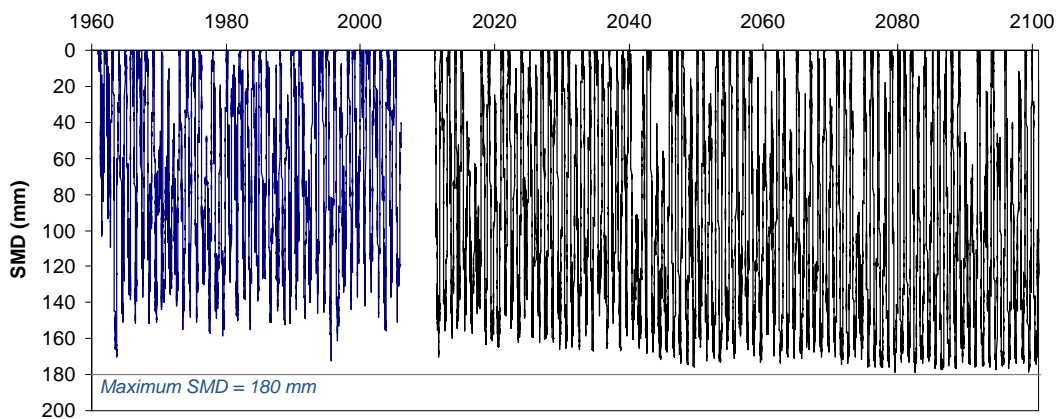
- Maximum SMD = 180 mm
- Rough grass/herbs cover
- No climate effect on vegetation

Grass cover typically returns to SMD = 0 in winter, so more informative about summer drying



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Simulated daily soil moisture deficits 1960-2100 (London Heathrow Apt)

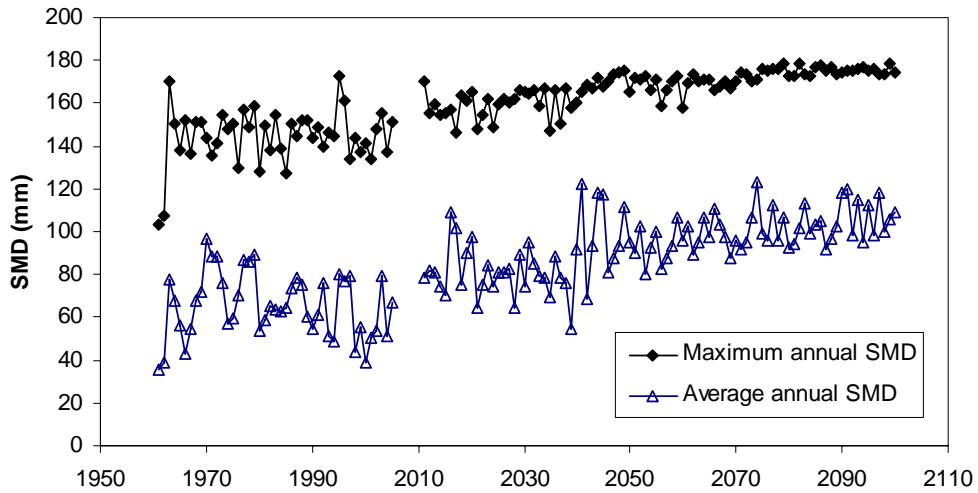


Met Office data, 1960-2005
 Betwixt medium high scenario, 2010-2100
 Grass cover, TAW = 180 mm, RAW = 90 mm



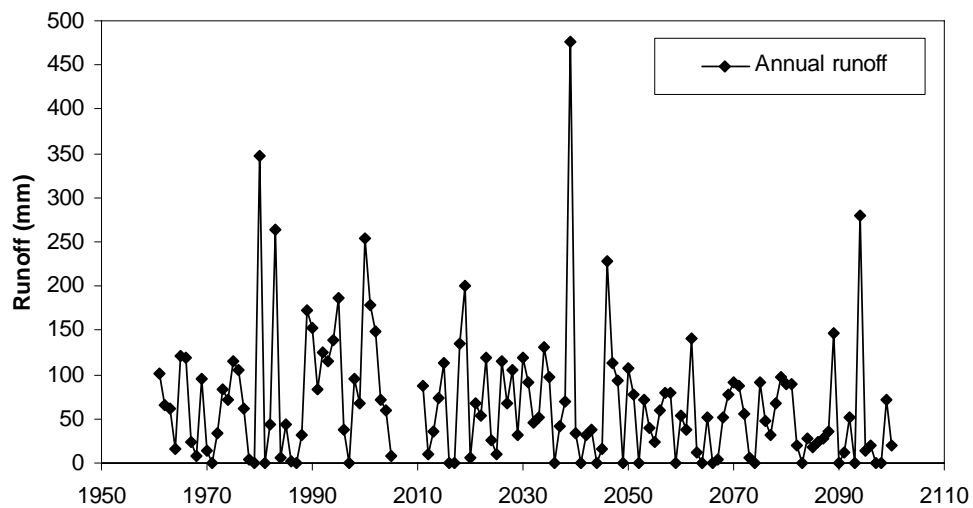
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Maximum and average annual Soil Moisture Deficit



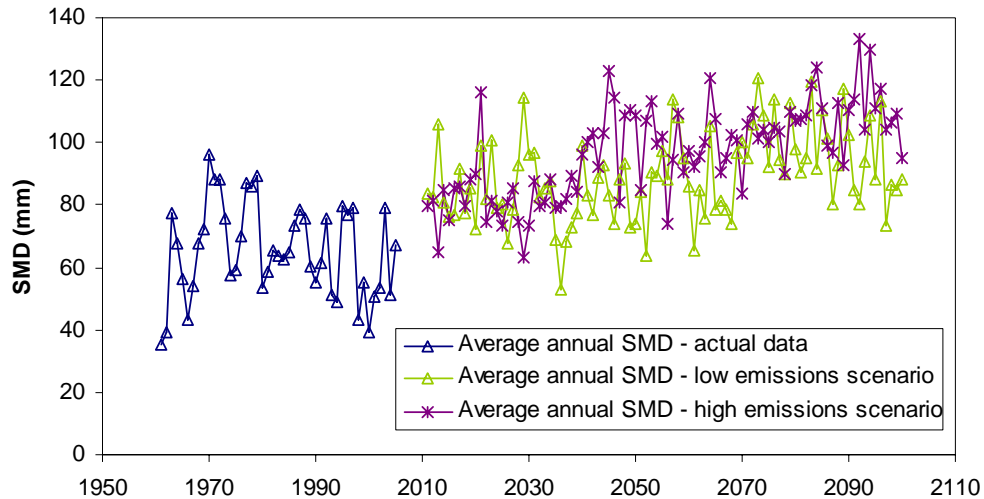
Grass cover, TAW = 180 mm, RAW = 90 mm
Betwixt medium high scenario, London Heathrow

Excess rainfall that becomes Runoff



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Different emissions scenarios



Future climate modelling

Pattern shows:

- Increase in maximum SMD
- Increase in summer drought (higher average SMD)
- Most winters the soil still re-wets (although at slightly lower frequency)

Implications:

- Greater clay shrinkage for longer periods
- Increase in the magnitude of shrink-swell cycles
- Vegetation will become stressed (die back) earlier in the year and more often
- Possible reduction in vegetation cover (leading to erosion problems)

Limitations:

- Climate models
- No modelled change in vegetation type, or the influence of this on soil drying

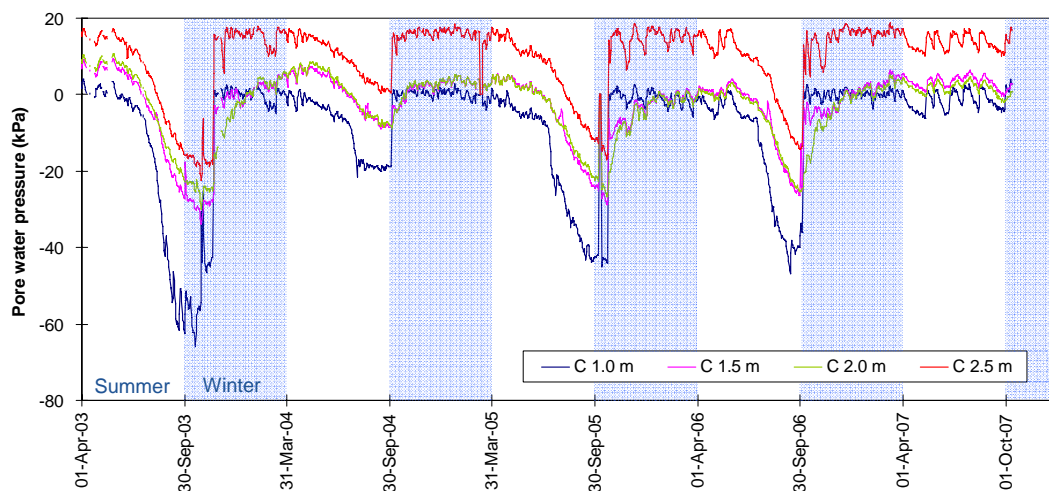
Conclusions

- Seasonal moisture and pore water pressure changes cause a number of embankment serviceability and failure problems
- Measured changes in soil moisture content can be closely correlated with a simple water balance (SMD) model
- The SMD model and climate scenarios can be used to estimate the likely future cycles of soil moisture



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Newbury – measured pore water pressures in grey clay



Pore water pressure measured by vibrating wire piezometers

Newbury – surface suctions in grey clay

