Land Use Management: A Dryland Salinity Mitigation Measure (Western Cape, South Africa)

International Interdisciplinary Conference on Land Use and Water Quality Reducing the Effects of Agriculture
The Hague, the Netherlands (10 June 2013 – 13 June 2013)

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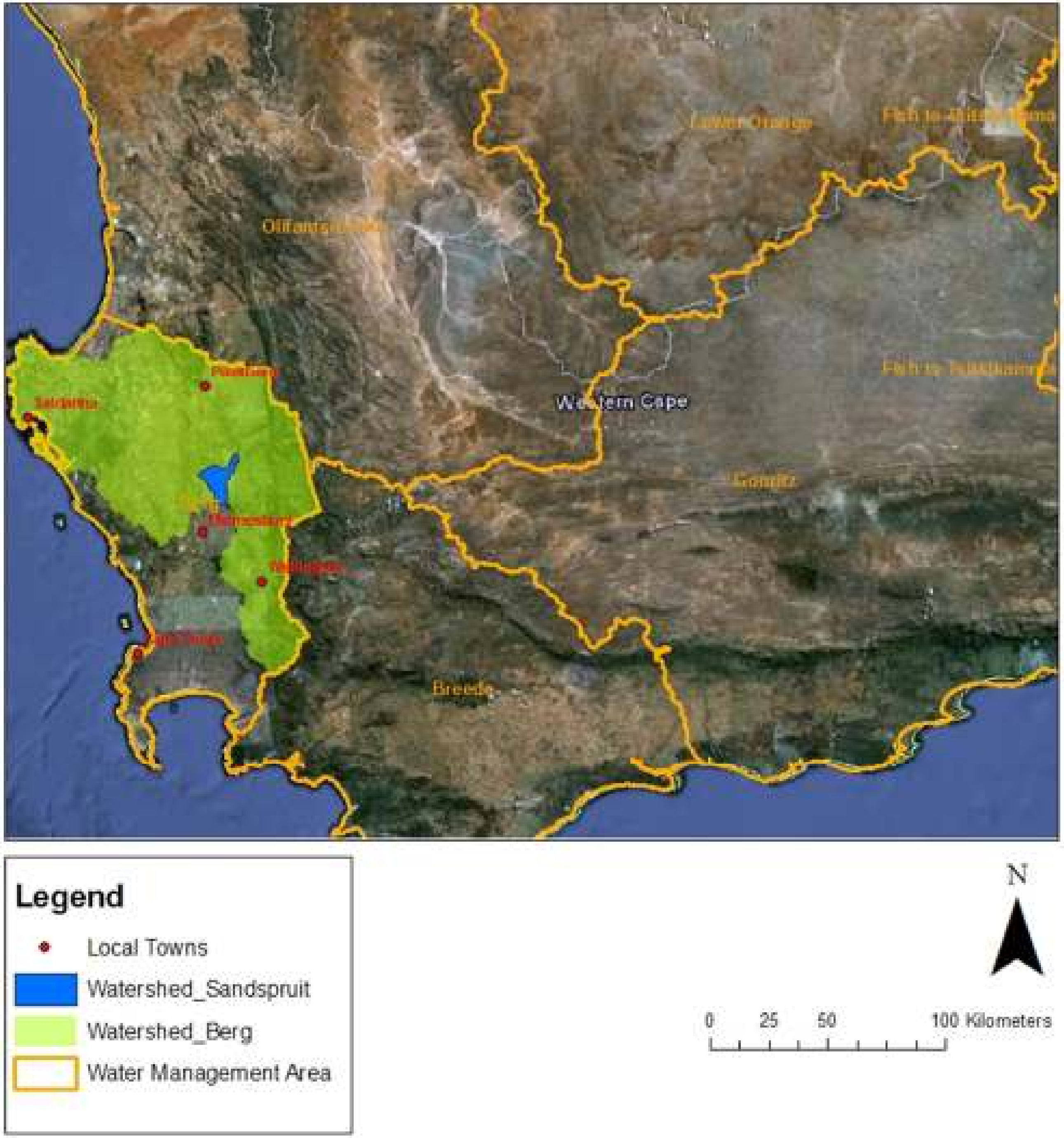
Locality



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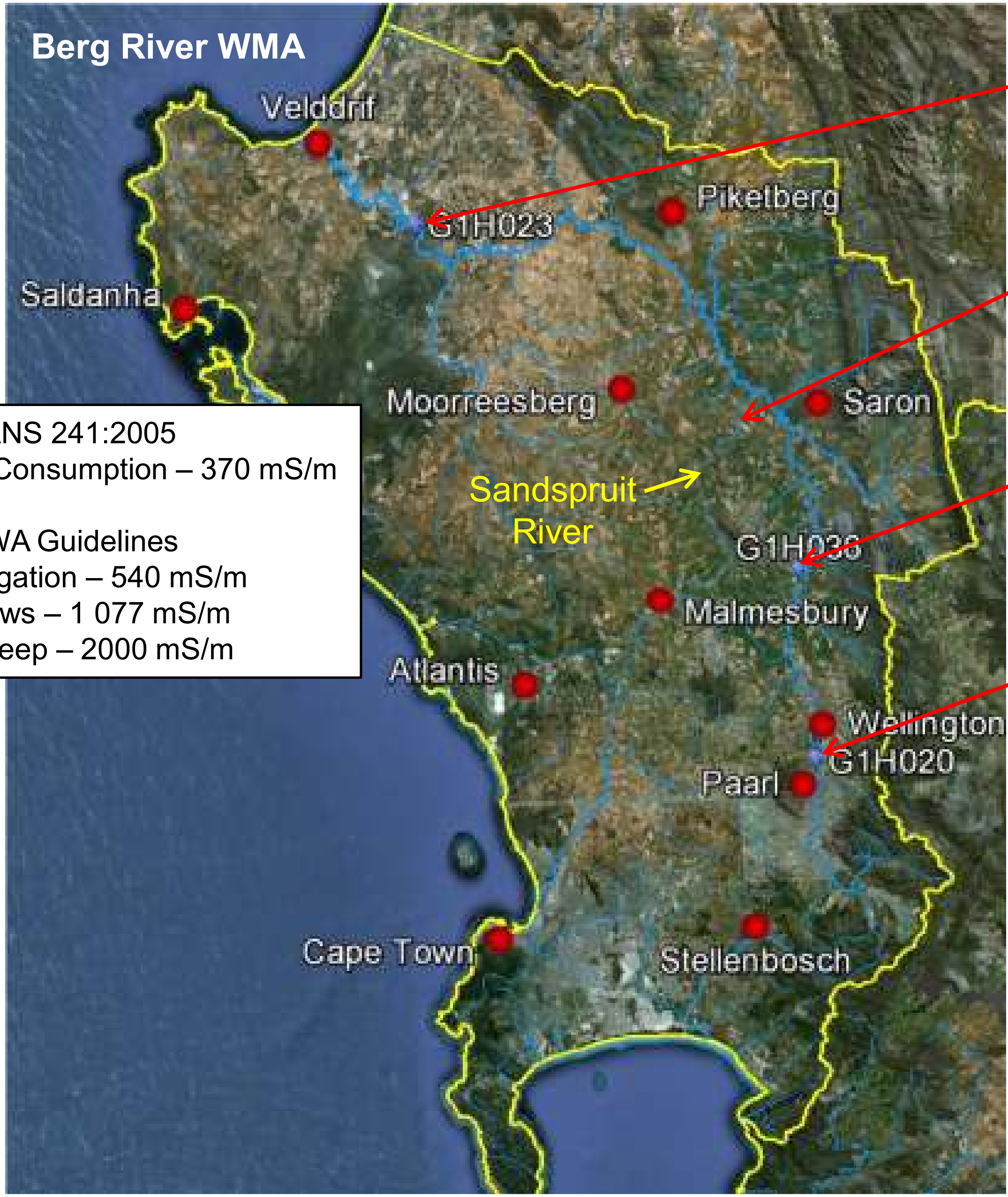
Background and Motivation



SANS 241:2005
H Consumption – 370 mS/m

DWA Guidelines
Irrigation – 540 mS/m
Cows – 1 077 mS/m
Sheep – 2000 mS/m

Min = 12.7 mS/m
Average = 102.3 mS/m
Max = 737 mS/m

Min = 4 mS/m
Average = 813 mS/m
Max = 1 780 mS/m

Min = 6.5 mS/m
Average = 21.4 mS/m
Max = 111.8 mS/m

Min = 0.5 mS/m
Average = 10.8 mS/m
Max = 42.6 mS/m

- **The increase in salinity is a combination of naturally saline geology as well as land use change**
- **Land use change has resulted in DRYLAND SALINIZATION!**

Aims of the Investigation

- To simulate the hydrology and salinity fluxes in the Sandspruit catchment with the JAMS/J2000 – NaCl semi-distributed hydrosalinity model
  - Model Parameterisation
  - Model Calibration (Manual and Automatic)

- Identify land use/management scenarios that would minimise the impacts of dryland salinisation on water resources in the Sandspruit catchment.

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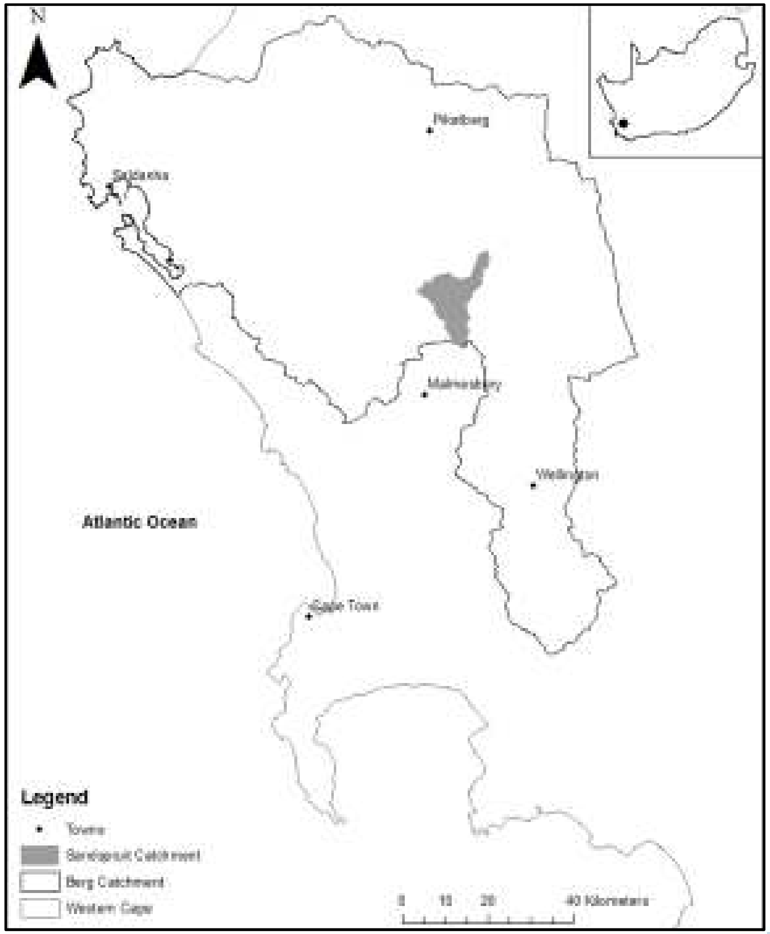
Description of the Sandspruit Catchment

- The Sandspruit river is a seasonal tributary of the Berg River
- It is located approximately 80 km north-east of Cape Town
- Land use is dominated by wheat cultivation (3 year land rotation)
- Man-made anti-erosion contours are evident throughout the catchment
- Semi-Arid climate (precipitation = 400 - 450 mm a^{-1})
- Catchment actual evapotranspiration amounts to approximately 94% of precipitation
- Large quantities of soluble inorganic salts are stored in the regolith



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Model Description

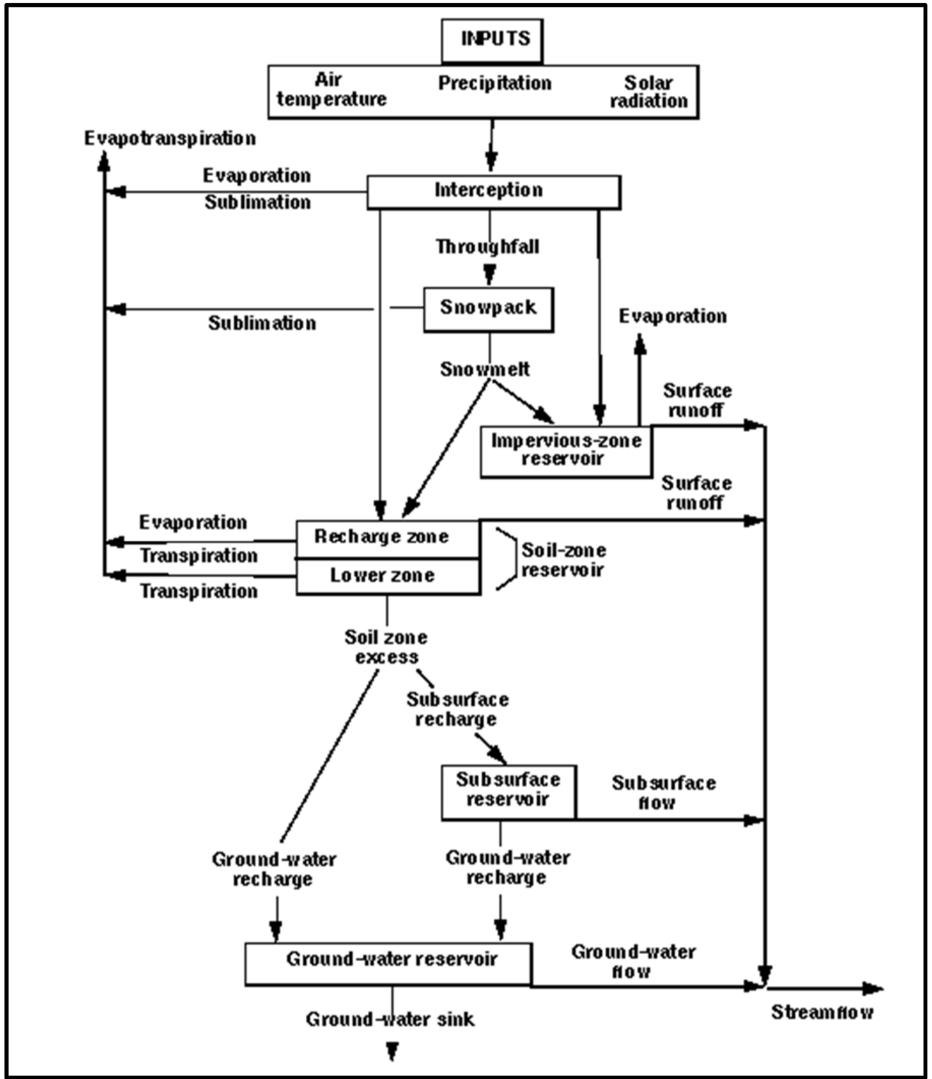
JAMS/J2000

- Simulates the water balance in large catchments.
- Hydrological Response Unit concept (overlay land use, geology and soils)
- Input Data: precipitation, temperature, wind speed, relative humidity, solar radiation and sunshine hours

JAMS/J2000 – NaCl

- Salinity modelling capability adopted from SWAT
- Additional land use and land management options (SWAT)
- Incorporates the effects of contour banks on the catchment hydrology

JAMS/J2000 Flow Chart



Model Set-Up

- The model was run for the period 2006 – 2011
- 2006 – 2008 = model initialisation
- 2009 – 2010 = model calibration
    - Manual calibration
    - Automatic calibration (OPTAS)
- 2011 = model validation

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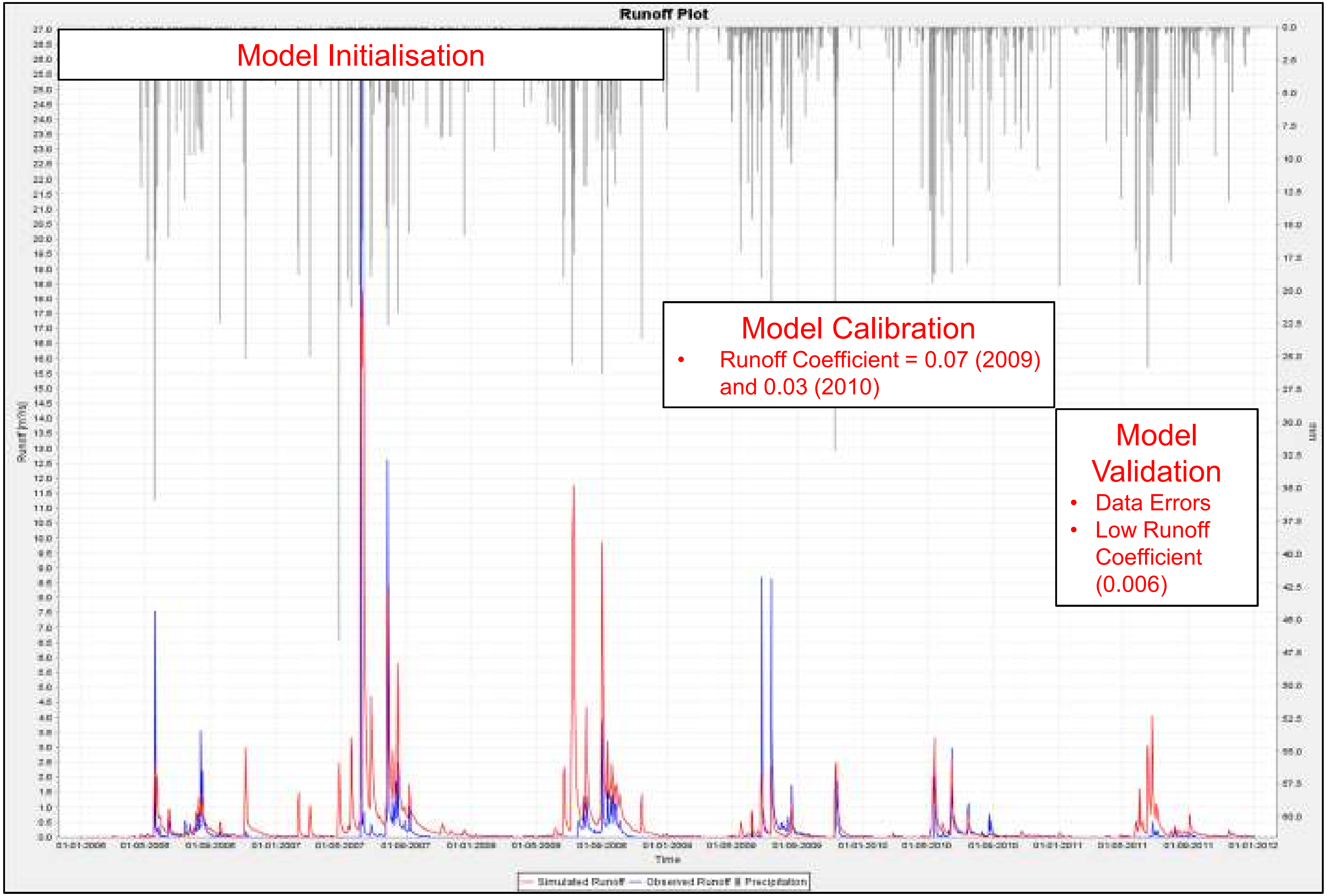
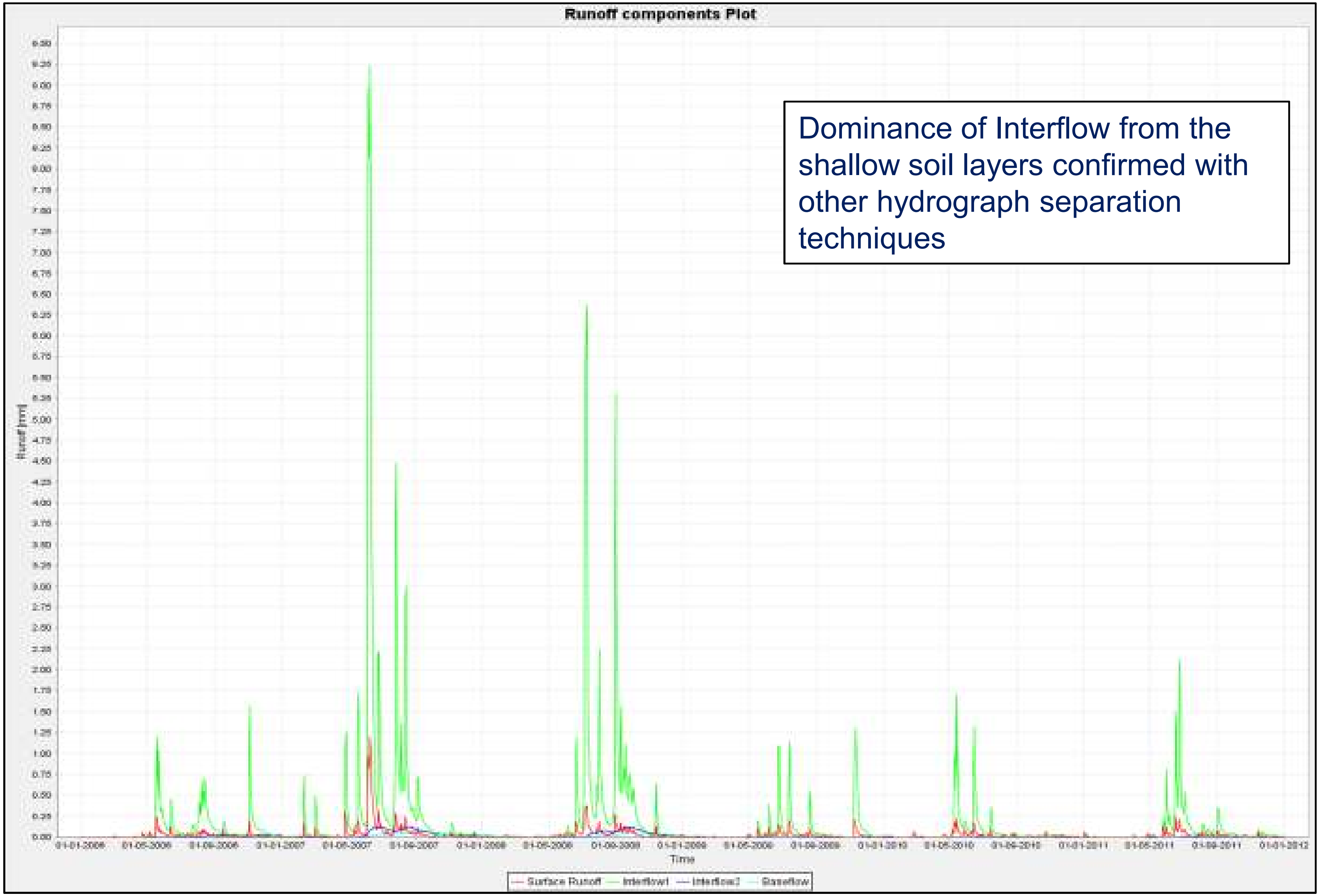
Model Results



Model Results (cont)



Dominance of Interflow from the shallow soil layers confirmed with other hydrograph separation techniques

Model Results (cont)

Simulated and Observed Annual Totals of Various Components of the Hydrological Cycle and Salt Balance							
Year	Simulated				Observed		
	Precipitation (mm a^{-1})	Actual Evapotranspiration (mm a^{-1})	Runoff (mm a^{-1})	Salt Output (t a^{-1})	Precipitation (mm a^{-1})	Runoff (mm a^{-1})	Salt Output (t a^{-1})
2009	410.68	374.36	32.67	22 106	454.44	36.87	21 409
2010	409.78	388.57	30.07	7 279	424.17	15.88	14 599
2011	411.18	343.87	36.61	8 702	397.70	2.50	3 259

- The simulated and observed catchment precipitation was generally of the same order of magnitude
- Simulated catchment actual evapotranspiration ranged between 84 – 95% of the simulated precipitation
- Discrepancies in the magnitude were observed between the annual simulated and observed runoff in 2010 and 2011 which may be a function of the low runoff coefficient and errors in the observed dataset
- There was a good correlation between the annual simulated and observed salt output in 2009

Scenario Simulations

- Recharge control has been identified as the dominant approach to mitigate the impacts of and control dryland salinisation, i.e. land use change from annual agricultural cropping systems to perennial vegetation
- Reduces groundwater recharge/infiltration and the subsequent mobilisation of stored salts
- Hydrological models have been the main tool with which to evaluate the effects of land use change scenarios
- A scenario may represent a land use option, a land management change or an engineering solution
- Each scenario is modelled over a fixed period of climatic data, with the differences between each being used to quantify the impacts of the scenario on the water balance, catchment hydrology and salinity

Selected Crop Parameters				
Crop Name	Classification	Rooting Depth (m)	Maximum Canopy Height (m)	Optimal Temp. for Plant Growth (^{o}C)
Mixed Forest	Tree	2	24	15
Evergreen Forest	Tree	2.5	25	15
Range Brush	Tree	2	1	25
Pasture	Perennial Vegetation	0.8	0.9	21

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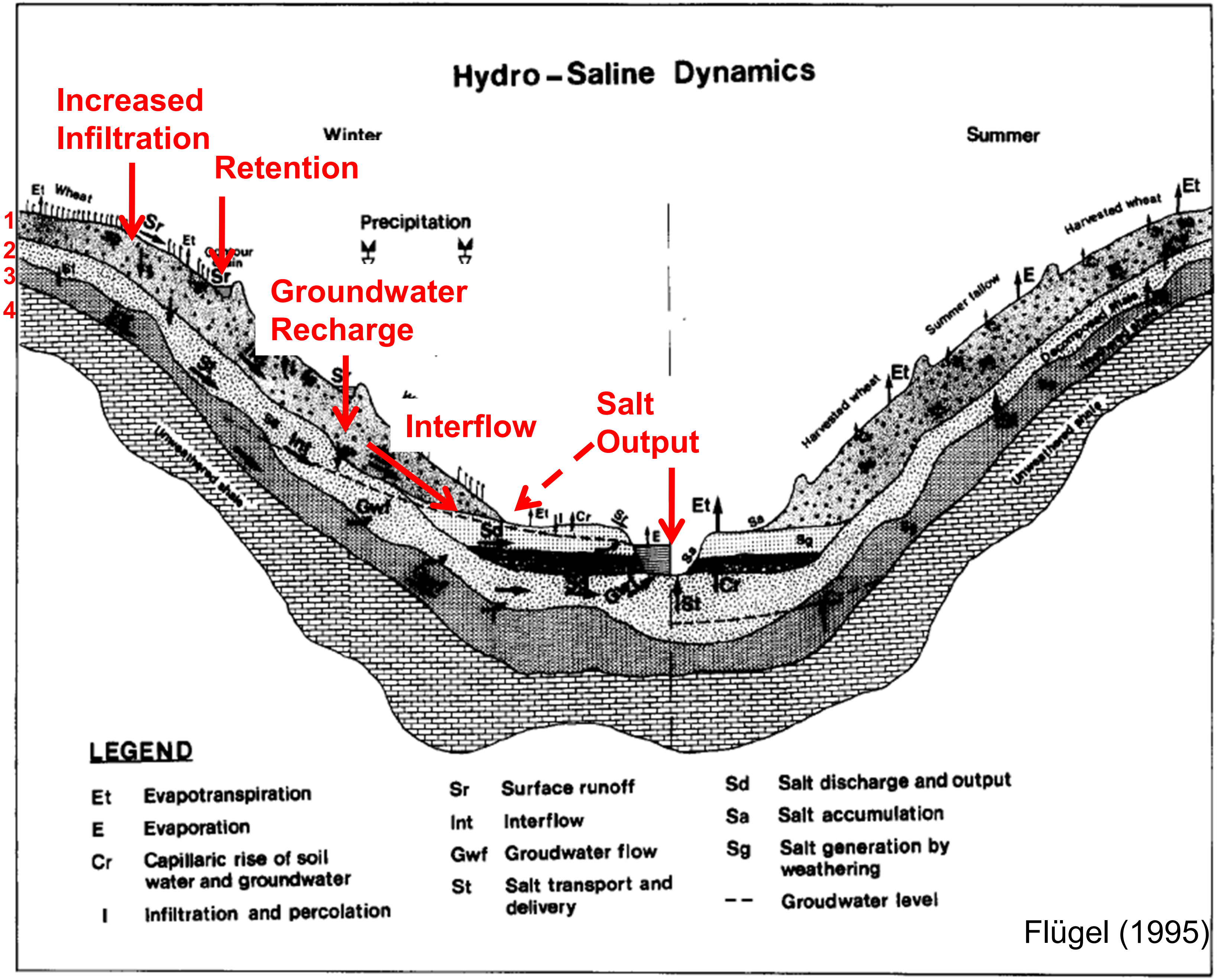
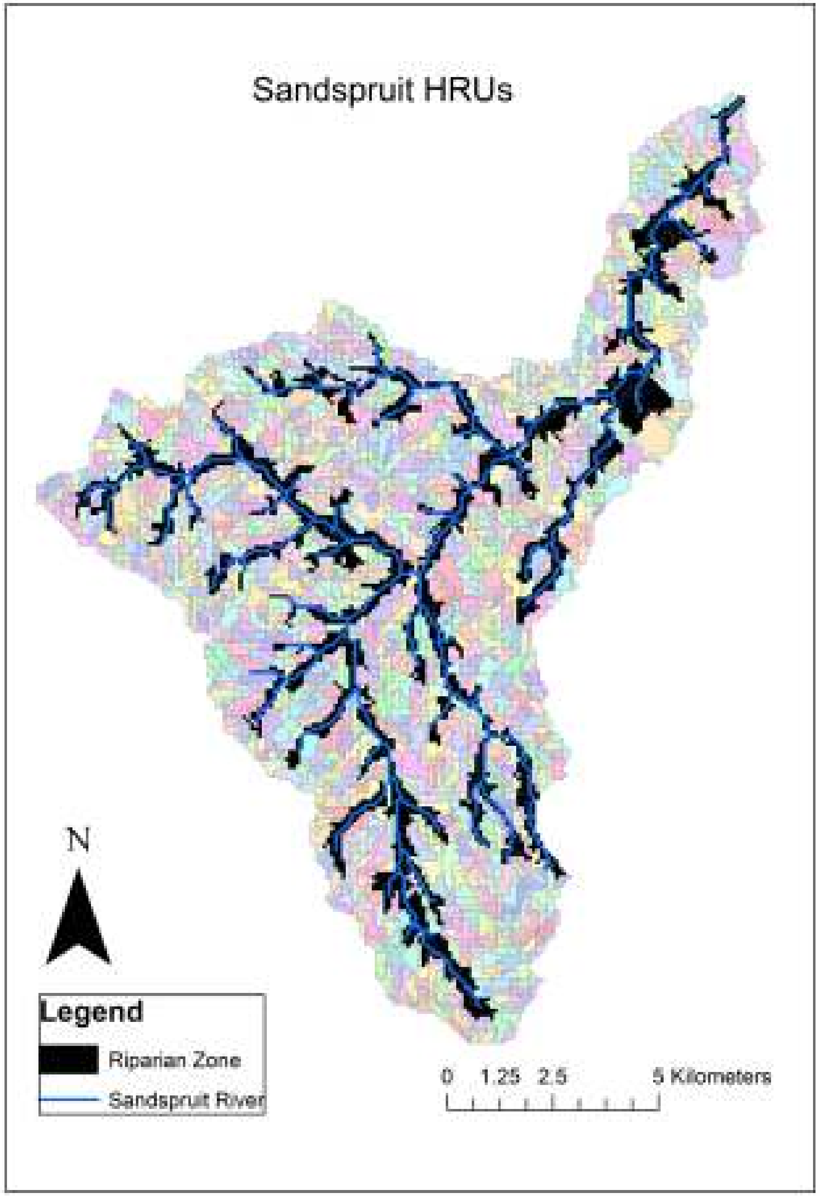
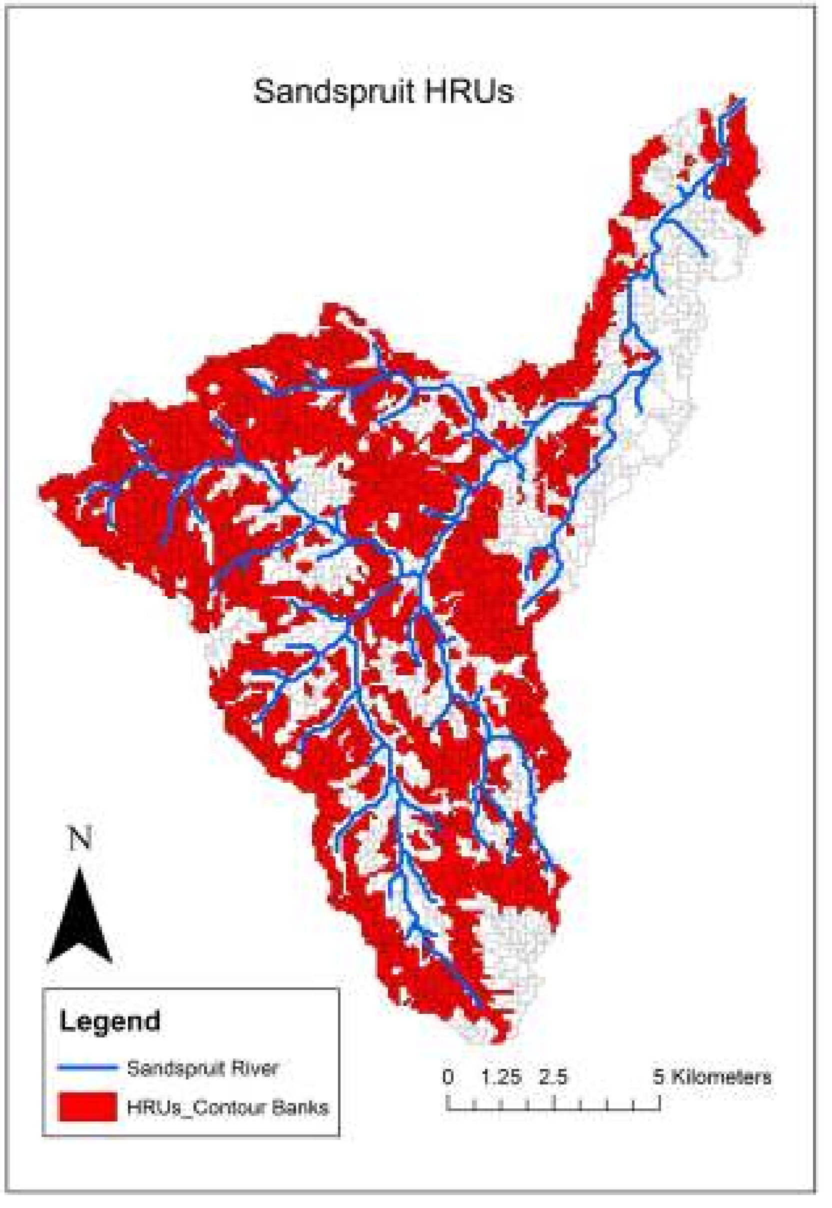

Hydro – Saline Dynamics
Increased Infiltration
Retention
Winter
Summer
Precipitation
Groundwater Recharge
Interflow
Salt Output
1
2
3
4
Et
Wheat
Sr
Harvested wheat
Summer fallow
Unweathered shale
Gwf
Int
Sd
Cr
St
E
Sa
Sg
LEGEND
Et Evapotranspiration
E Evaporation
Cr Capillaric rise of soil water and groundwater
I Infiltration and percolation
Sr Surface runoff
Int Interflow
Gwf Groudwater flow
St Salt transport and delivery
Sd Salt discharge and output
Sa Salt accumulation
Sg Salt generation by weathering
-- Groudwater level
Flügel (1995)

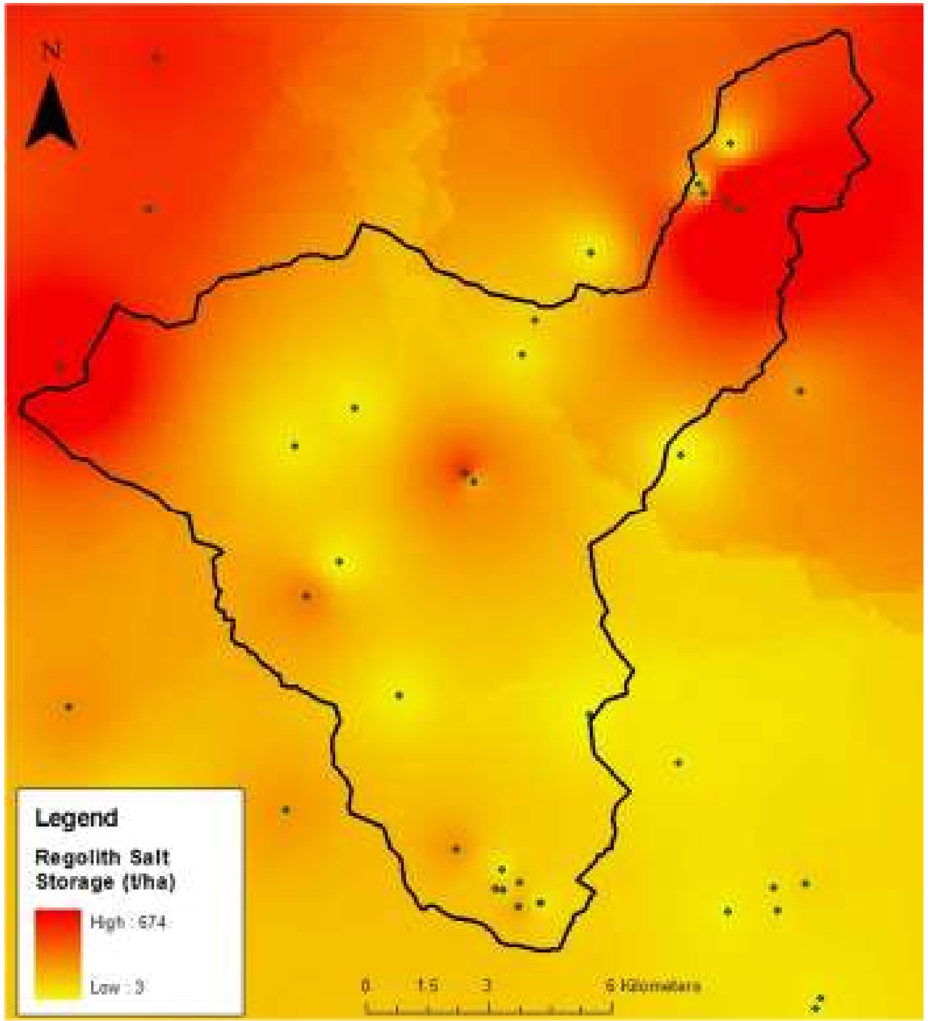
Scenario1: Simulating the effects of alternative land use/vegetation types in riparian zones

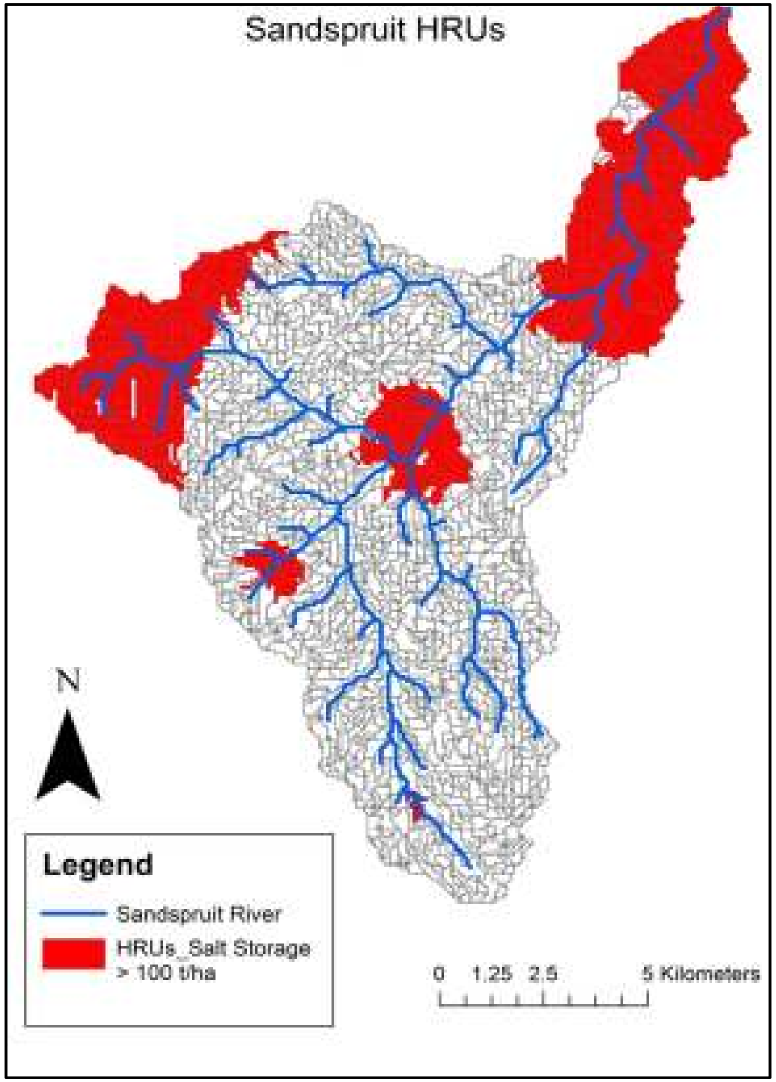


Scenario 2: Simulating the effects of alternative land use/vegetation types along contour banks

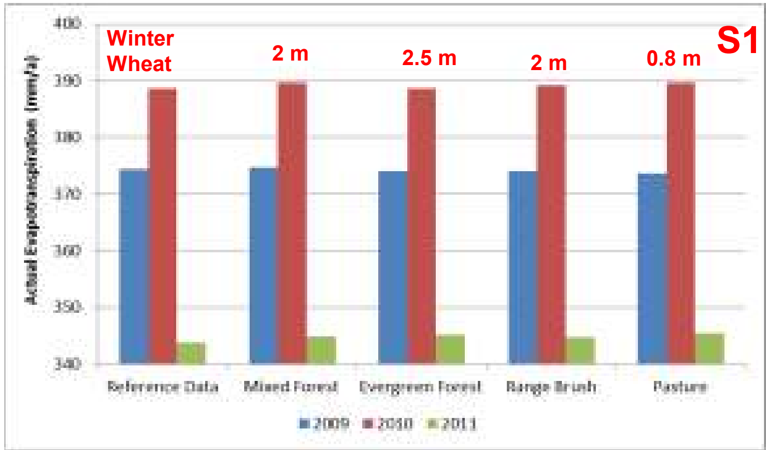


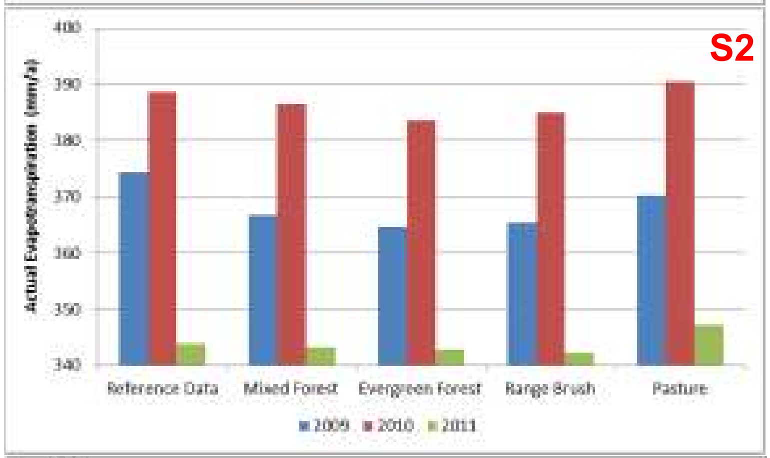
Scenario 3: Simulating the effects of alternative land use/vegetation types in areas which exhibit a high salt storage in the regolith zone

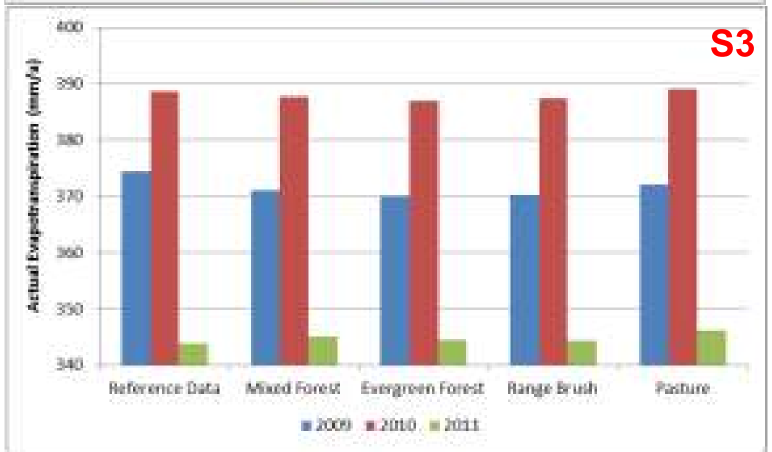




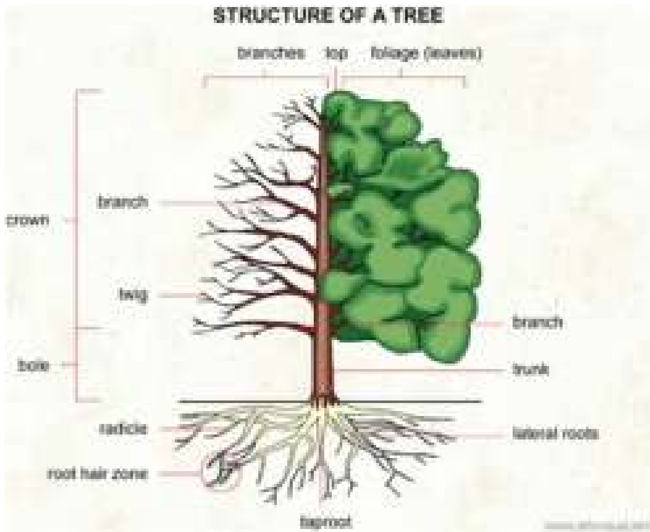
Scenario Simulation Results (Actual ET)







- The sensitivity of JAMS/J2000-NaCl is evident
  - different crop types (with rooting depth being the dominant factor)
  - different spatial distribution of the crops
- The shallower rooted crop types exhibited higher annual evapotranspiration rates (reduced annual runoff) when compared to deeper rooted species
  - Model does not have functionality to incorporate root water uptake from both shallow and deep soil layers



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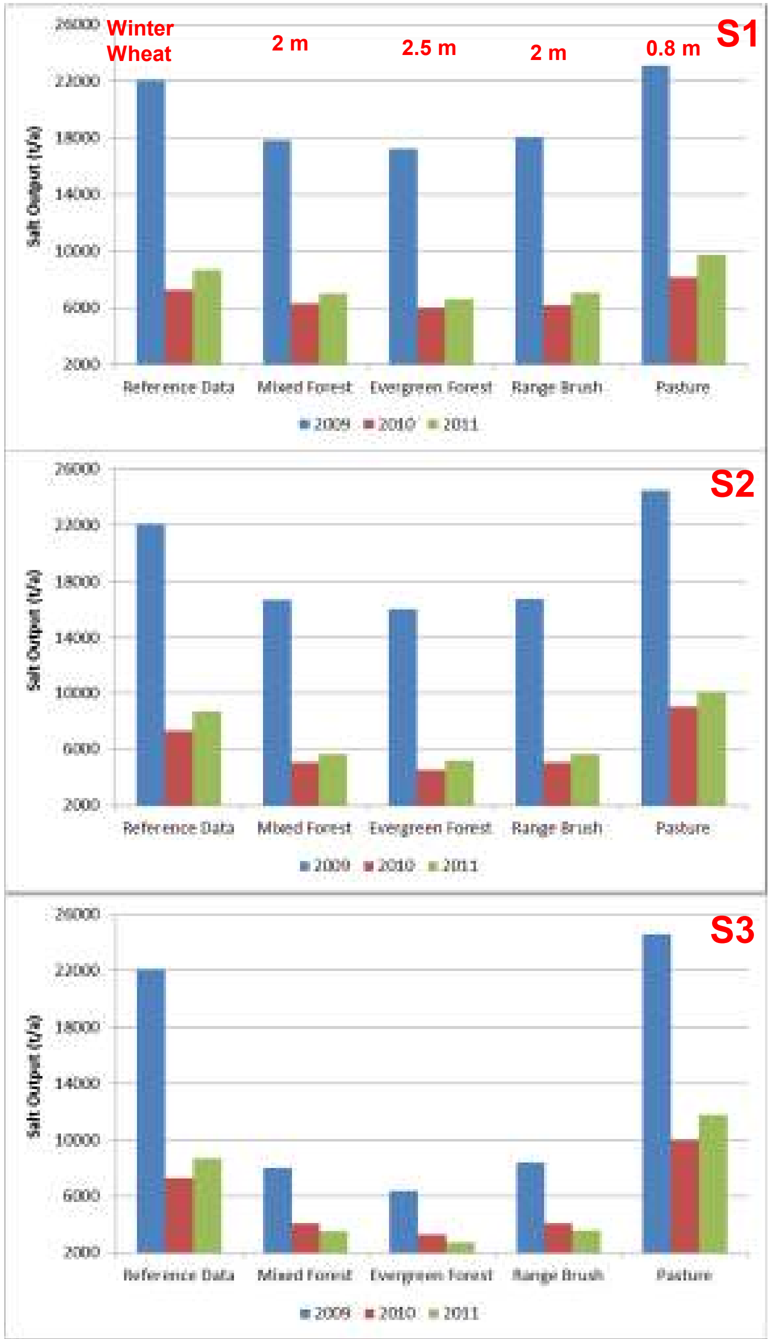
Scenario Simulation Results (Salt Output)



- The deeper root species exert a greater influence, i.e. reduction, on the catchment salt balance
- These crop types abstract water from the soil horizons where salt mobilization dominantly occurs
- The Evergreen Forest exerts the greater influence on the catchment water and salt balance. This species is most effective in minimising salt mobilisation when the lower more saline parts of the catchment are re-vegetated (Scenario 3)
  - 70% reduction in the catchment salt output in 2009

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Conclusions

- The sensitivity of JAMS/J2000-NaCl semi-distributed hydrological model to different land uses and different spatial distributions of vegetation is evident
- Of the vegetation types tested an Evergreen Forestry species (2.5 m rooting depth) exerted the greatest influence on the simulated hydrosalinity balance
- This species was most effective in minimising salt leaching when the lower more saline parts of the Sandspruit catchment were re-vegetated (Scenario 3)
- This investigation provides evidence of the potential to use deep rooted perennial species to mitigate the impacts of dryland salinity
- The importance of quantifying the spatially distributed catchment salt storage has been highlighted

The landscape in the Sandspruit Catchment

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Thank you for your attention!

Acknowledgements

- National Research Foundation (South Africa)
- Water Research Commission (South Africa)
- Federal Ministry of Education and Research (BMBF, Germany)
- Department of Water Affairs (South Africa)

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