Dryland Salinity Management in the Semi-Arid Western Cape (South Africa)

XXV IUGG General Assembly (Melbourne, Australia)
Earth on the Edge: Science for a Sustainable Planet
28 June 2011 – 7 July 2011

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Background and Motivation

- The Berg River, an important source of water to the city of Cape Town in the Western Cape Province of South Africa has over the past decades been exhibiting and increasing trend in inorganic salt levels
- The results from, a cycle of research projects, attribute the cause of the salinity increase to **Dryland Salinization**, a result of land use change

Aim

- This investigation aims to quantify the salinity input, storage and output of the Sandspruit catchment, a tributary of the Berg River
- The investigation was conducted on an annual scale for the period 2007 – 2010

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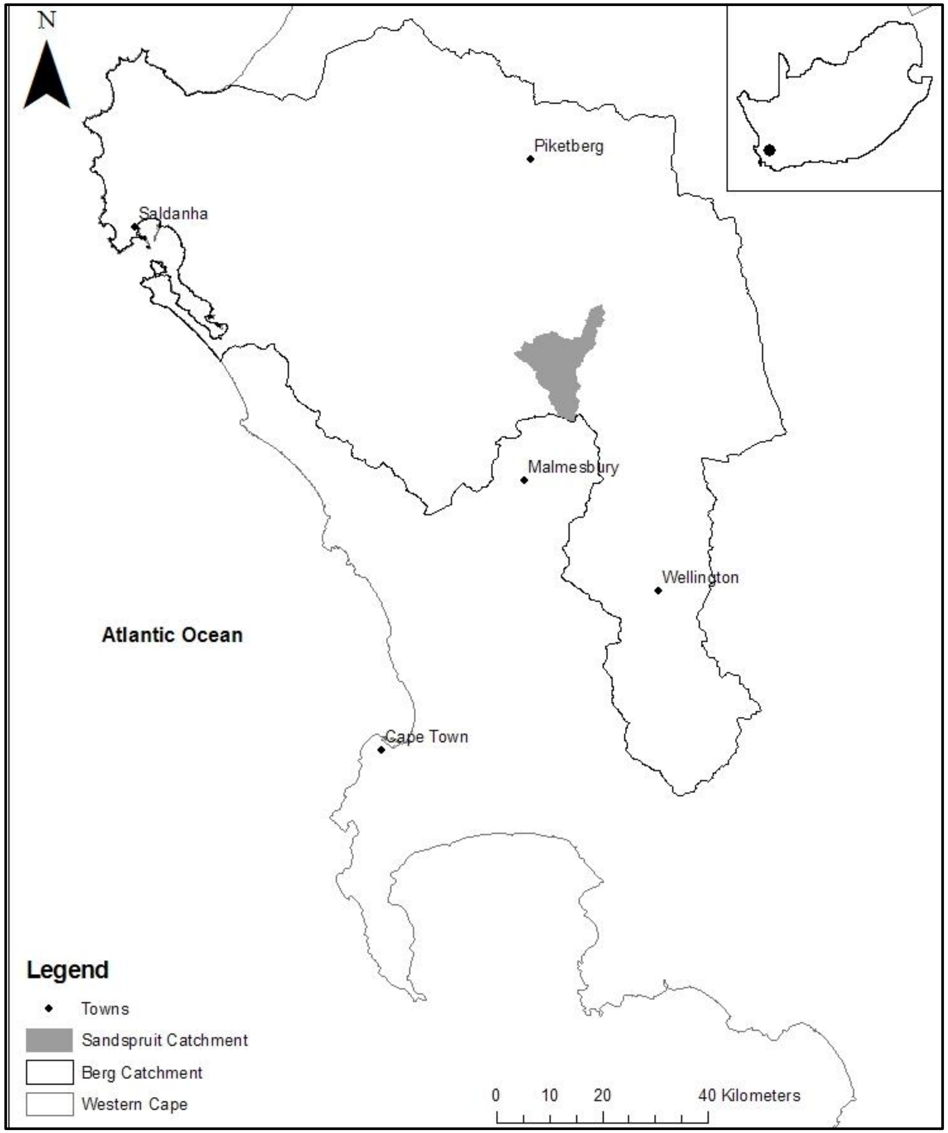
Description of the Sandspruit Catchment

- 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



Salt Input

- The main source of salt input is rainfall (atmospheric deposition)
- Total Salt Input (kg Catchment $^{-1}$) = Rainfall (mm) * catchment area (km^2) * Salt Fall Concentration (mg L^{-1})
- Salt Fall Concentration = 37 mg L^{-1} (average, Flügel 1995)
- Total Salt input ranged between 1700 and 3600 t catchment^{-1}

Total Salt Input (TSI) to the Sandspruit Catchment.			
Year	Rainfall (mm a^{-1})	TSI (t CA^{-1})	TSI (t ha^{-1})
2007	655	3684	0.24
2008	519	2919	0.19
2009	444	2497	0.16
2010	307 *	1727	0.11

* Data is only available up to 05/09/2010

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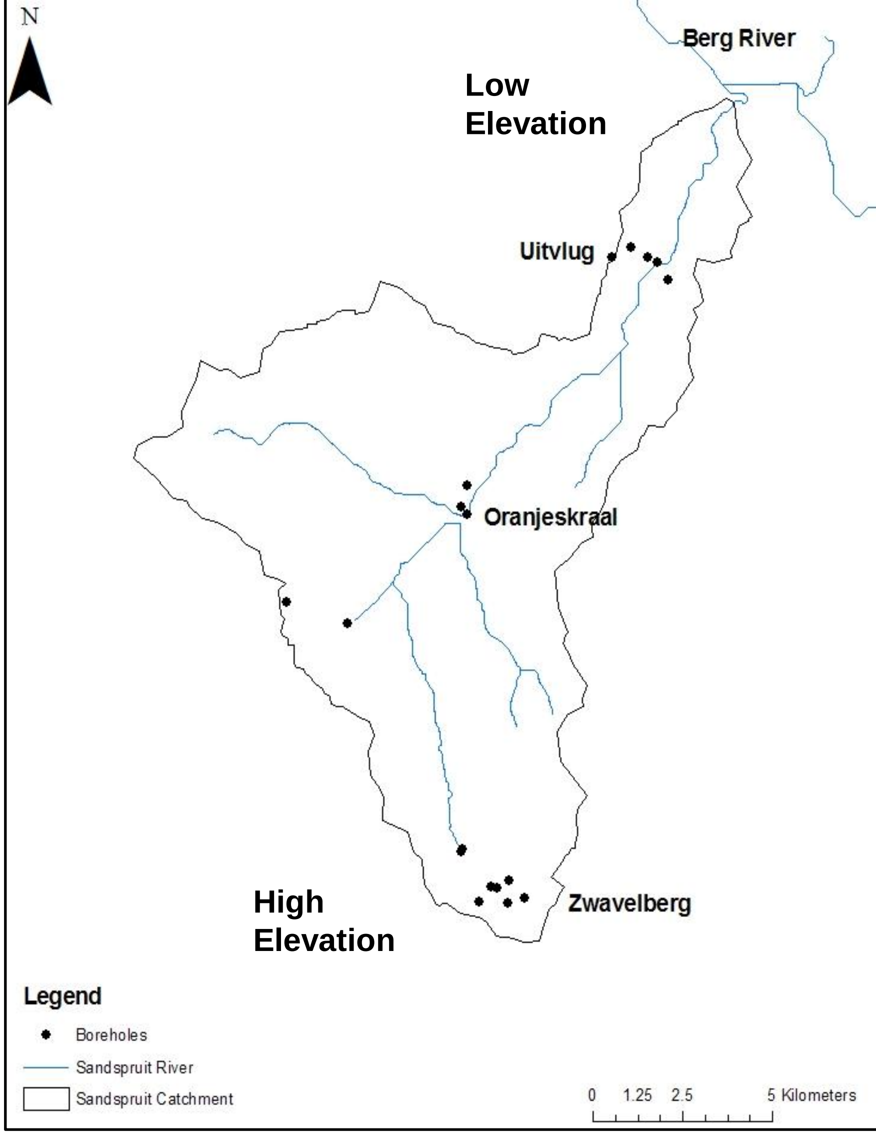
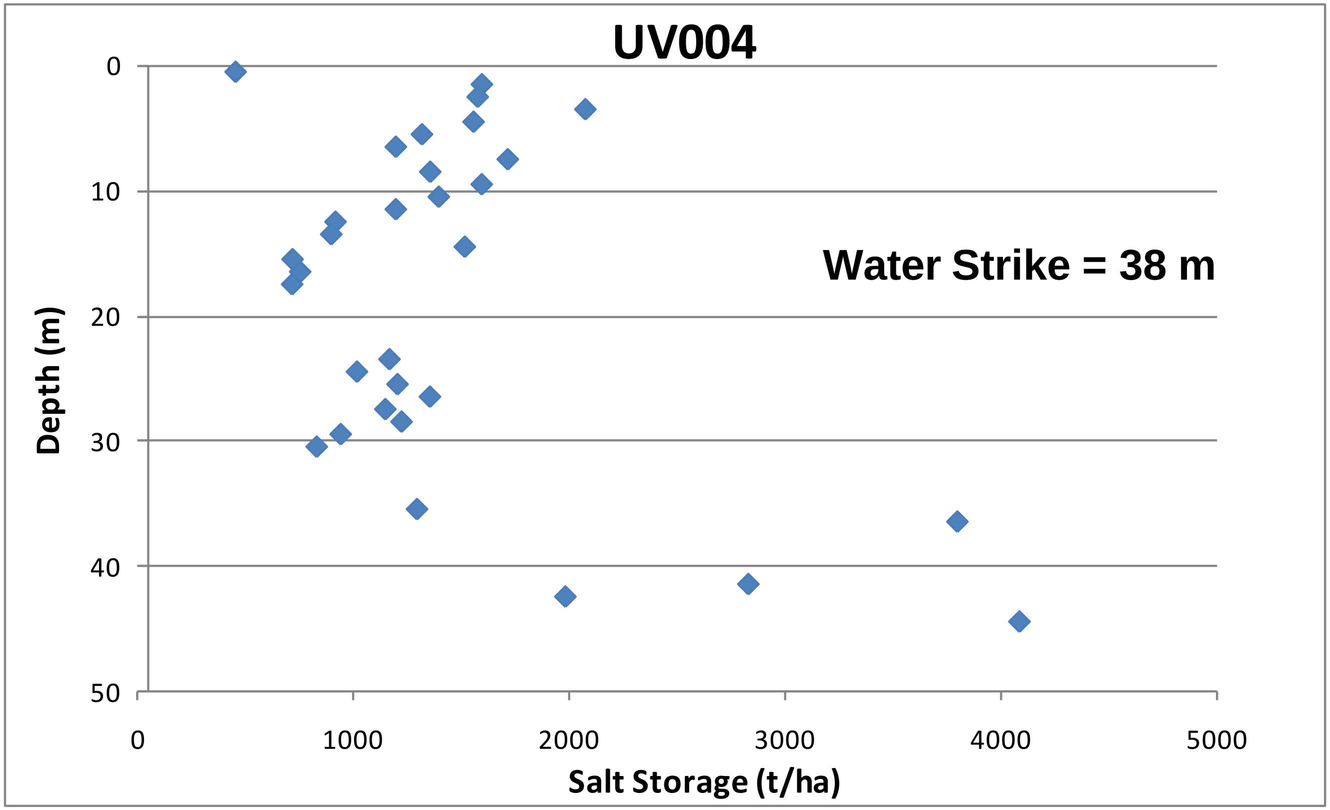
Salt Storage

- To facilitate the quantification of salt storage within the regolith 17 boreholes were drilled throughout the Sandspruit Catchment
- Drilling sites were spatially distributed so as to be representative of geological and topographic variation within the catchment
- The depth of drilling was determined by the depth to groundwater and the depth to bedrock



Salt Storage (cont)

- During drilling samples were collected at 1 m intervals
- Samples were used to prepare 1:5 solid:solution extracts
- The Total Dissolved Salts was inferred from the electrical conductivity using the equation: TDS (mg L^{-1}) = 534.91 * EC (dS m^{-1}) – 12.655 (r^2 = 0.90).
- The TDS concentrations of the sediment solution was used to calculate the salt storage in t ha^{-1} using a series of equations



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Salt Storage (cont)

Salt storage ($t\ ha^{-1}$) in the Sandspruit Catchment.					
Site	Borehole No	Soil Zone Salt Storage ($t\ ha^{-1}$)	Soil Zone Profile Depth (m)	Regolith Salt Storage ($t\ ha^{-1}$)	Regolith Profile Depth (m)
Zwavelberg	ZB001	791	3	2803	11
	ZB002	1353	4	2260	9
	ZB003	837	2	5168	11
	ZB004	384	4	1459	19
	ZB005	355	4	1576	13
	ZB006	2199	5	3959	16
	ZB006A	478	3	2063	11
	ZB007	367	2	7465	15
	ZB007A	766	2	9732	12
Oranjeskraal	OK001	433	2	1754	8
	OK002	444	3	7902	29
	OK003	986	4	3890	29
Uitvlug	UV001	792	3	34923	69
	UV002	16827	3	92246	15
	UV003	5498	2	51912	22
	UV004	3623	3	34147	30
	UV005	501	3	9653	53

Spatial Variability in Salt Storage

- Salt stores occur in areas which are conducive to the accumulation of water and salts (topographic setting, soil conditions, vegetation,etc)
- Results from previous investigations suggest that the spatial variability in salt storage is dominantly a function of elevation (e.g. Flügel, 1995)
- Correlations between elevation (mamsl), the Topographic Wetness Index (TWI) and interpolated (IDW) groundwater salinity (mS m^{-1}) and regolith salt storage were investigated. The coefficient of determination and the Spearman's rank correlation coefficient (Rs) were used to evaluate the results.

Correlation of regolith salt storage (t ha^{-1}) with catchment variables.			
	Groundwater EC (mS m^{-1}) *	**Ground Elevation (mamsl)**	**TWI**
r^2	0.75	0.41	0.07
Rs	0.72	-0.76	-0.21

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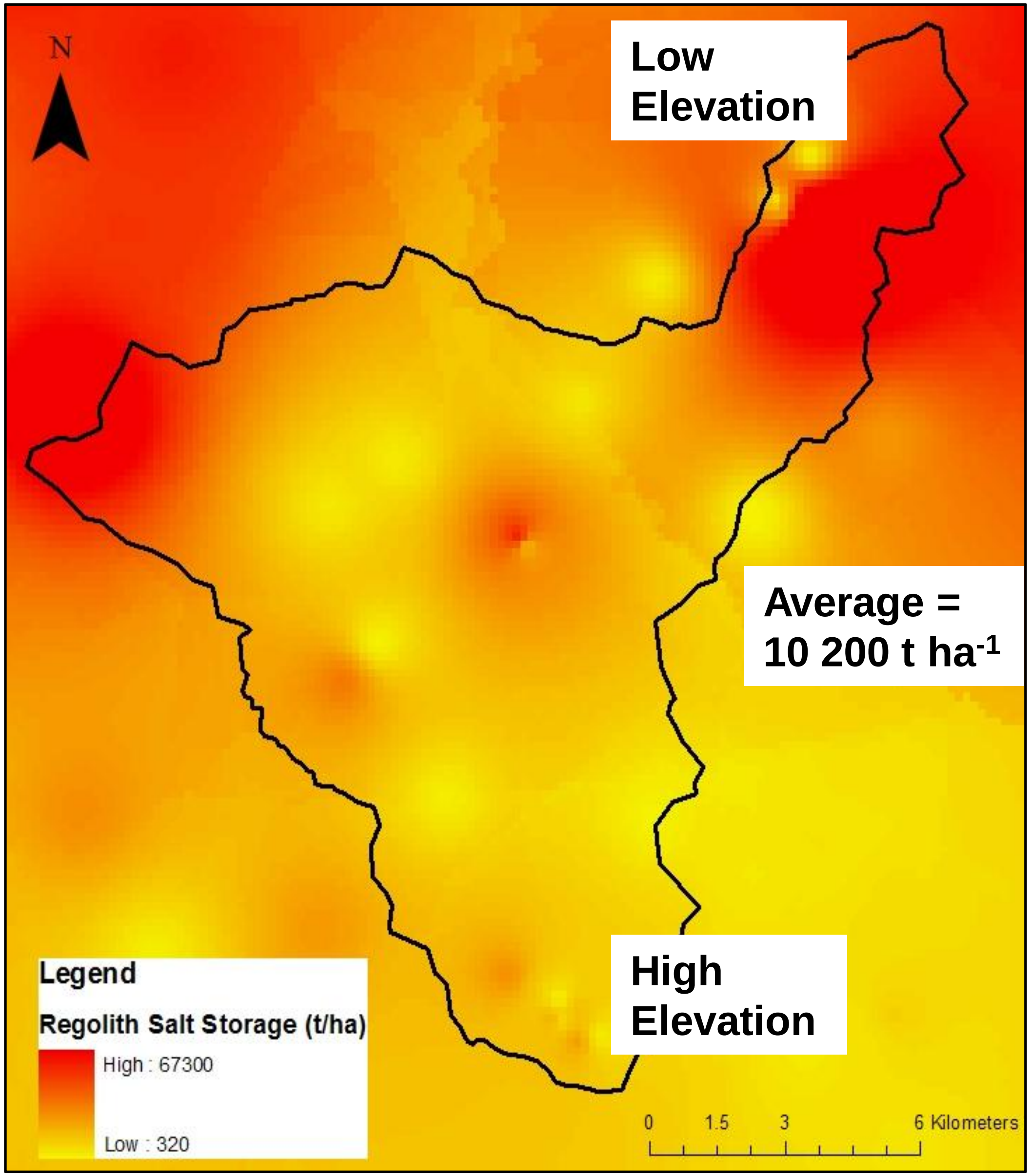
Spatial Variability in Salt Storage (cont)



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Salt Output

- The total salt output from a catchment may be quantified using streamflow quantity and salinity datasets, i.e. the salt load is equal to the product of the streamflow ($m^3\ s^{-1}$) and the corresponding stream water salinity (TDS, mg L^{-1})
- The salinity of the Sandspruit River is being monitored hourly with an electronic EC sensor
- The electronic EC sensor produces readings in mV, which are calibrated using streamflow EC readings recorded with a hand-held EC meter during field visits and grab samples
- EC is deduced from the mV reading using the equation: EC (mS m^{-1}) = 0.886* daily average mV - 218.99; $r^2 = 0.72$
- Salt Load (kg s^{-1}) = Total Dissolved Salts (mg L^{-1}) * Discharge ($m^3\ s^{-1}$) * 1000 L m^{-3} / 1×10^6 mg kg^{-1}
- Salt output ranged between 12 600 t a^{-1} and 21 400 t a^{-1}

Total salt output from the Sandspruit Catchment .			
Year	**Rainfall (mm)**	**Discharge (mm)**	**Salt Output (t a^{-1})**
2007	655	32	16 890
2008	519	27	12 671
2009	444	37	21 409
2010	307 *	15*	14 217 *

* Data is only available up to 5/09/ 2010

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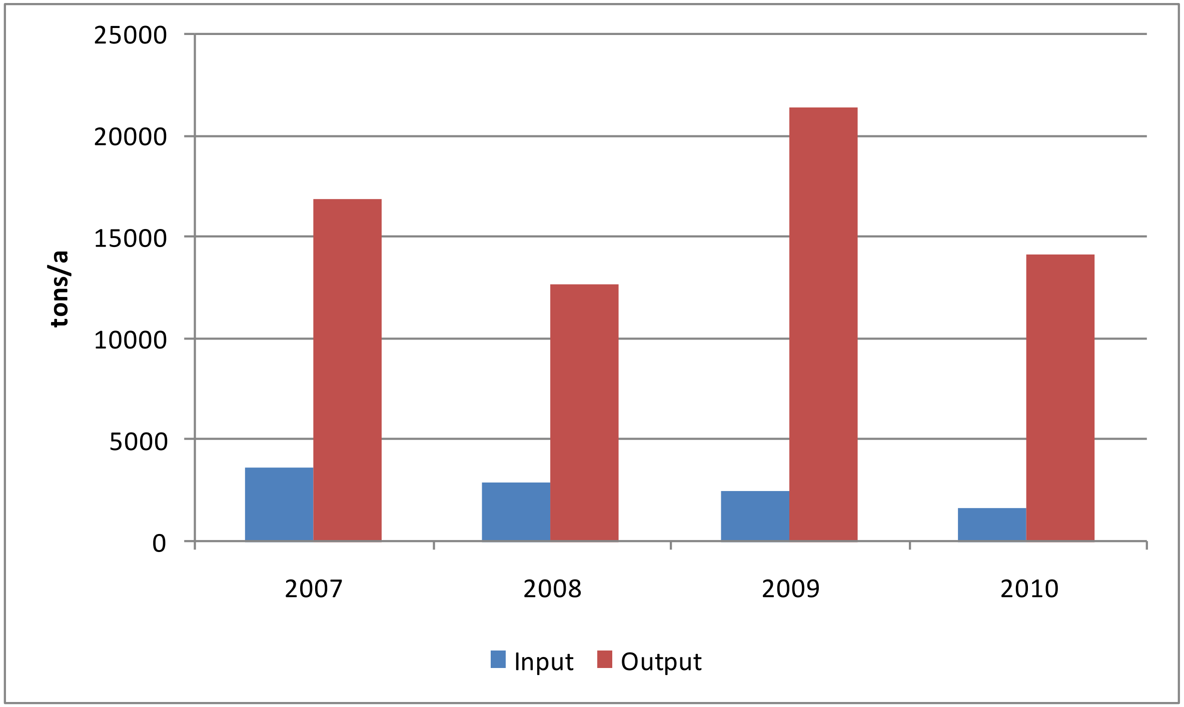
Salt Balance Index

- The catchment salt balance, i.e. salt output/input (O/I) ratio, is a key indicator for a catchment that is undergoing salinisation
- Prior to the clearing of indigenous vegetation, the O/I ratio is of the same order of magnitude, which is indicative of a state of salt equilibrium. Subsequent to clearing, output exceeds input with the rate of migration back to a state of equilibrium dependant on the leaching rate and the magnitude of the salt stores
- The Salt Balance Index (SBI) is commonly used to describe the catchment salt balance



The SBI of the Sandspruit Catchment

Year	SBI
2007	4.6
2008	4.3
2009	8.6
2010	8.2

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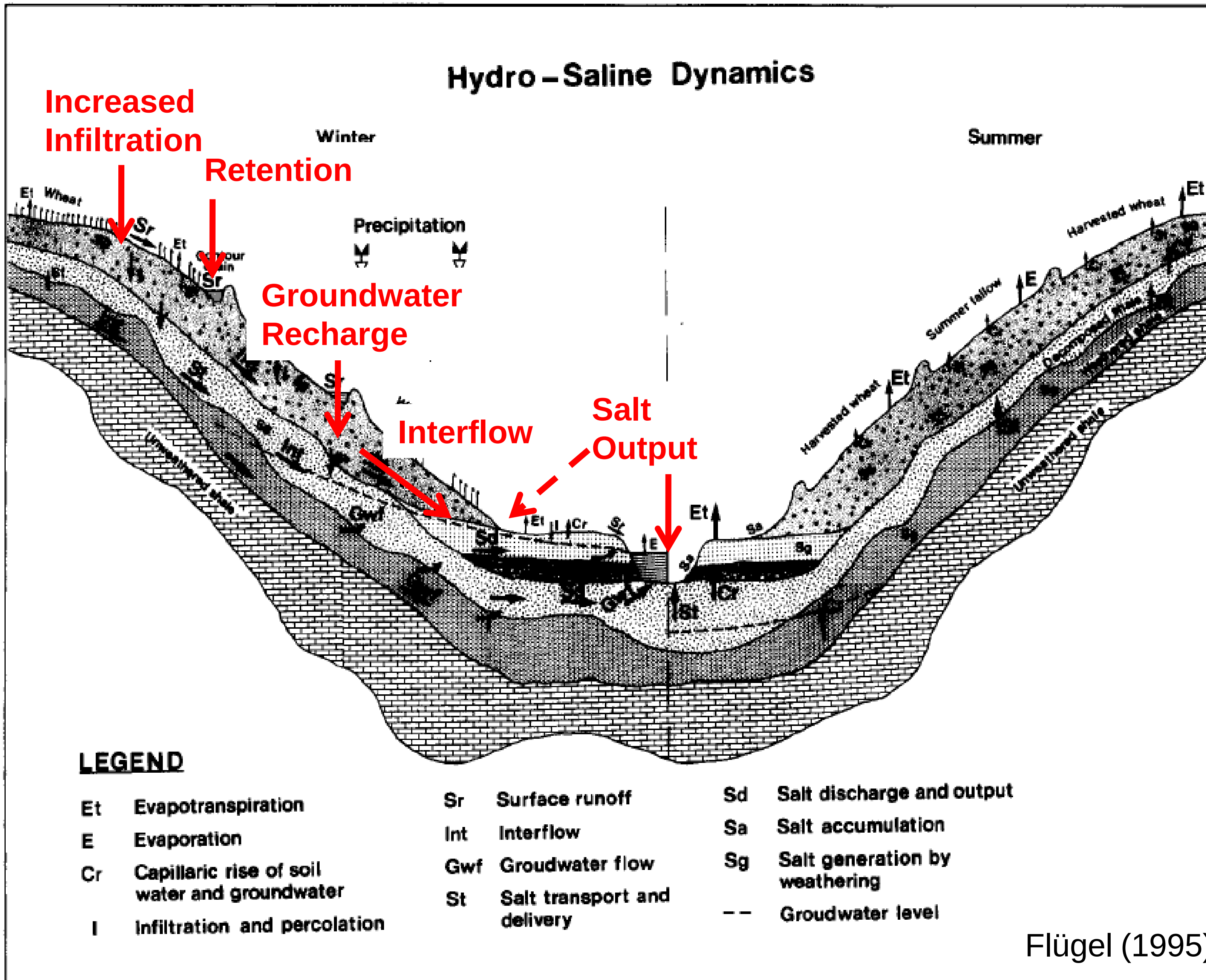
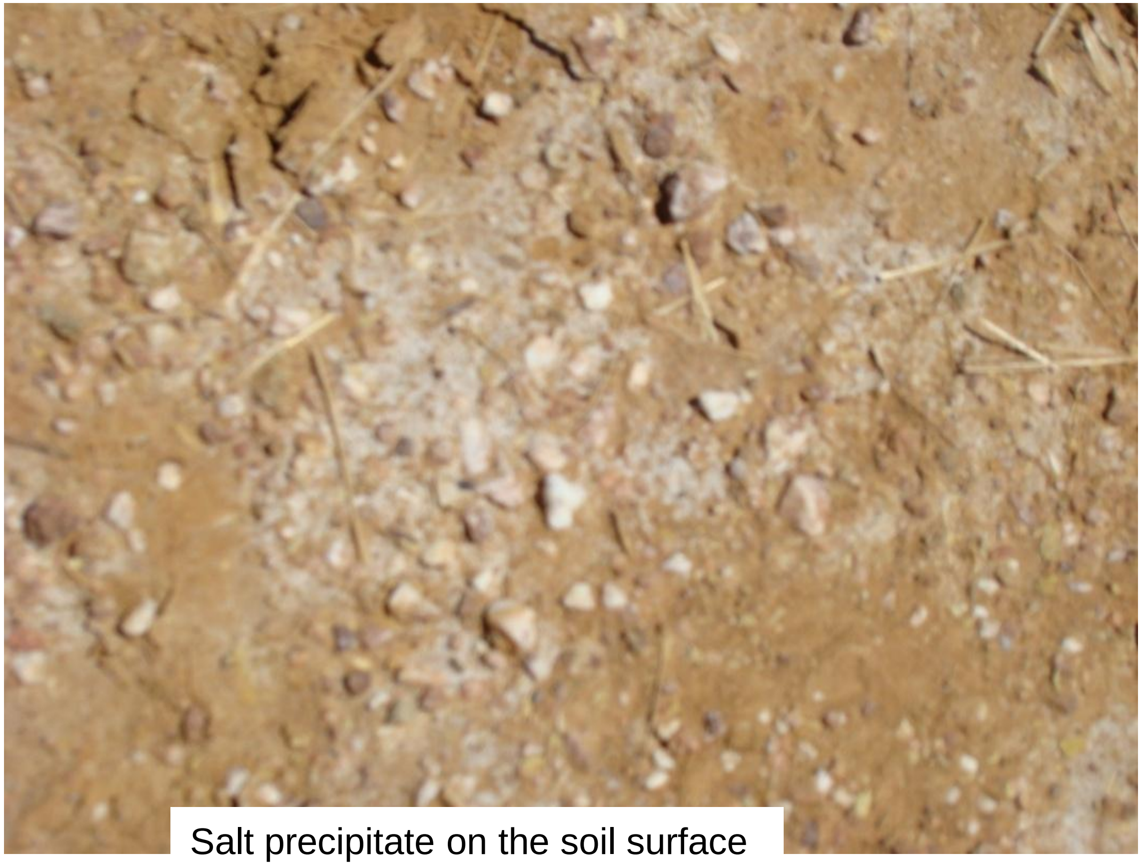
Conceptualization of Salt Movement



Flügel (1995)

Summary

- The SBI indicates that the Sandspruit catchment is in a state of salt depletion. Salt input, as a percentage of output, ranged between 11 and 23%
- Salt storage is higher in the lower elevation areas in the landscape
- Conceptually, salt movement in the landscape mainly occurs via infiltration, groundwater recharge and interflow



Salt precipitate on the soil surface

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The Way Forward

- Monitor the chemistry of rainfall
- Use the results from this and previous investigations to set-up a physically based and distributed salinity model for the Sandspruit catchment
- A salinity module will be developed for the J2000 distributed hydrological model
- Identify suitable land use and management practices to mitigate the release of stored salts into surface water resources

The landscape in the Sandspruit Catchment

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Thank you for your attention!

Acknowledgements

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

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