AN OPPORTUNITY TO MANAGE VAAL BASIN SALT LOADING: IRRIGATION WITH GOLD MINE WATER

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SANCID Symposium
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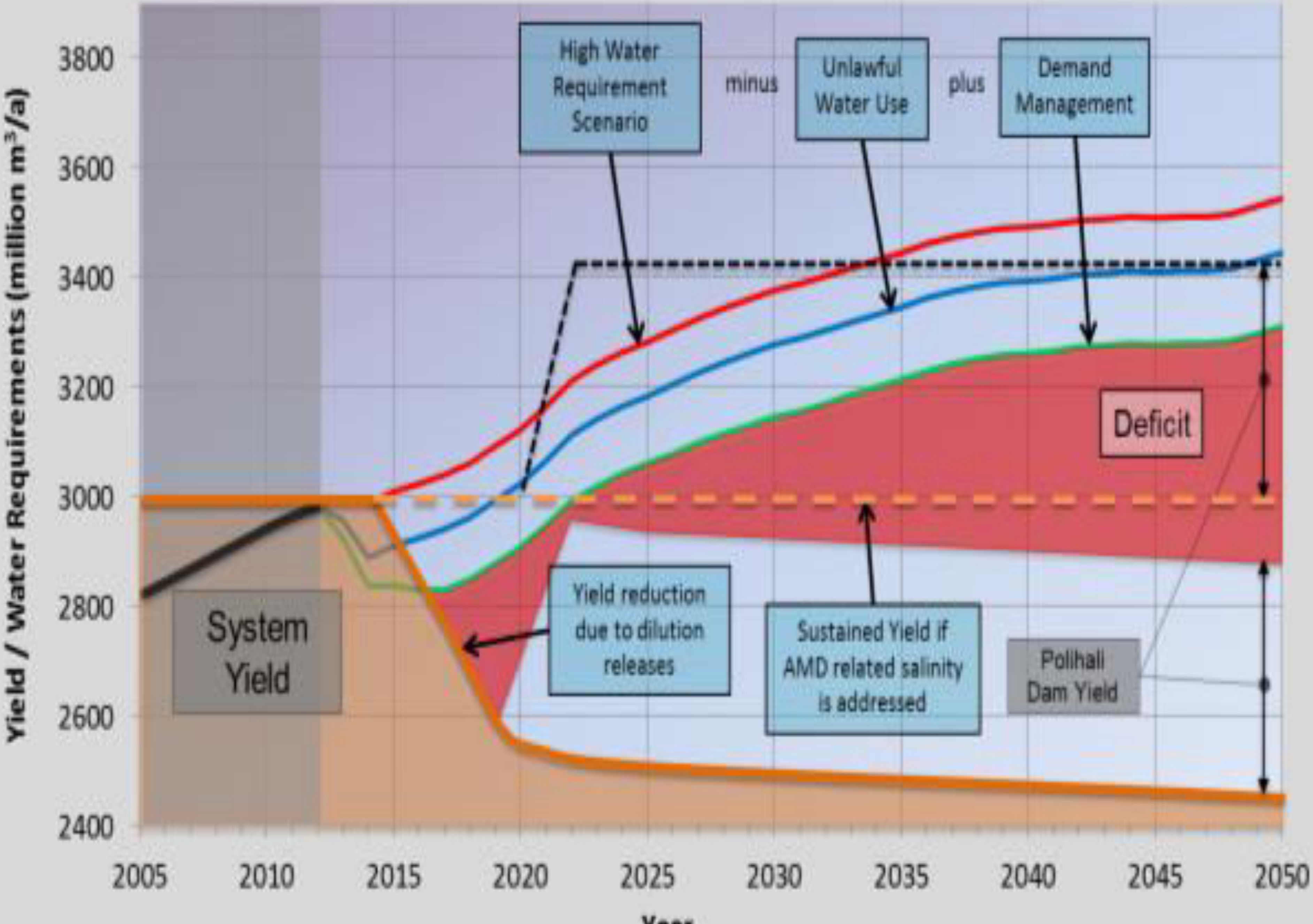
UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
Water Institute

WATER RESEARCH COMMISSION

Problem Statement

- Mine water rising rapidly in the Gauteng Gold Fields
  - Already decanting in the Western Basin
- Expected volumes of Acid Mine Drainage
  - Western Basin – 23 Ml per day
  - Central Basin – 84 Ml per day
  - Eastern Basin – 110 Ml per day
- Water is saline (280 – 450 mS/m), can be quite acidic (pH 2.4 to 6.5) – neutralised with HDS
- Release to surface waters requires dilution capacity to meet water quality objectives (600 mg/l TDS)
- Really a salt problem



Yield / Water Requirements (million m³/a)
3800
3600
3400
3200
3000
2800
2600
2400
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Year
High Water Requirement Scenario
minus
Unlawful Water Use
plus
Demand Management
Deficit
System Yield
Yield reduction due to dilution releases
Sustained Yield if AMD related salinity is addressed
Polihali Dam Yield

Water Resource Planning Systems Series

Water Quality Planning

Feasibility Study for a Long-Term Solution to address the Acid Mine Drainage associated with the East, Central and West Rand underground mining basins

Options for the Sustainable Management and Use of Residue Products from the Treatment of AMD

Study Report No. 5.5

P RSA 000/00/16512/5

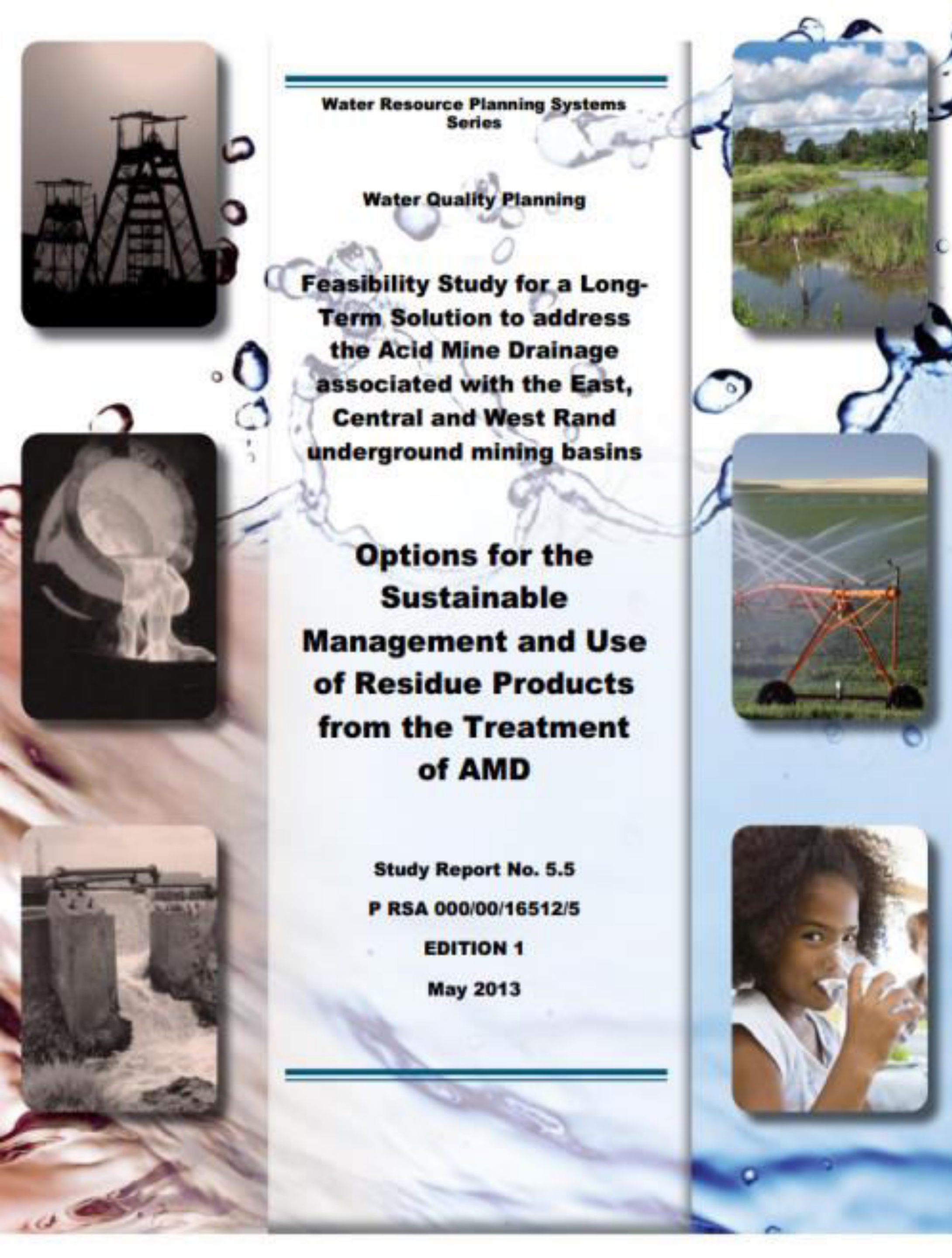
EDITION 1

May 2013

‘The Feasibility Study should investigate a wide range of possible solutions and disqualify those found to be not suitable’.

‘If AMD, which has not been desalinated, is discharged into the Vaal River System, the high salt load will require large dilution releases to be made from the Vaal Dam to achieve the fitness-for-use objectives set for the Vaal Barrage and further downstream.’

‘Irrigation and potential cultivation of salt-resistant plants – associated risks too high (salts might leach to groundwater and eventually end up in surface water resources)’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Recommendation:

Conventional Reverse Osmosis

Capital costs:
R 6.66 billion

Running costs:
R 990 million/yr

The irrigation option:

Advantages	Concerns
Inexpensive and no RO brine disposal	Not all salts removed
Beneficial use of water	Seasonal water demand not constant – storage required
Contributes to food security, job creation	Land availability
Potentially lower environmental impact	Potential cost of treating salts downstream

WRC project – Jo Burgess

‘Feasibility study on the use of irrigation as part of a long-term neutralised acid mine drainage management strategy in the Vaal Basin’

WRC Project no. K5/2233

1 April 2013 – 15 December 2014

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USING LIME TREATED ACID MINE WATER FOR IRRIGATION

H. M. du Plessis

Soil and Irrigation Research Institute, Department of Agriculture and Fisheries, Private Bag X79, Pretoria, 0001, South Africa

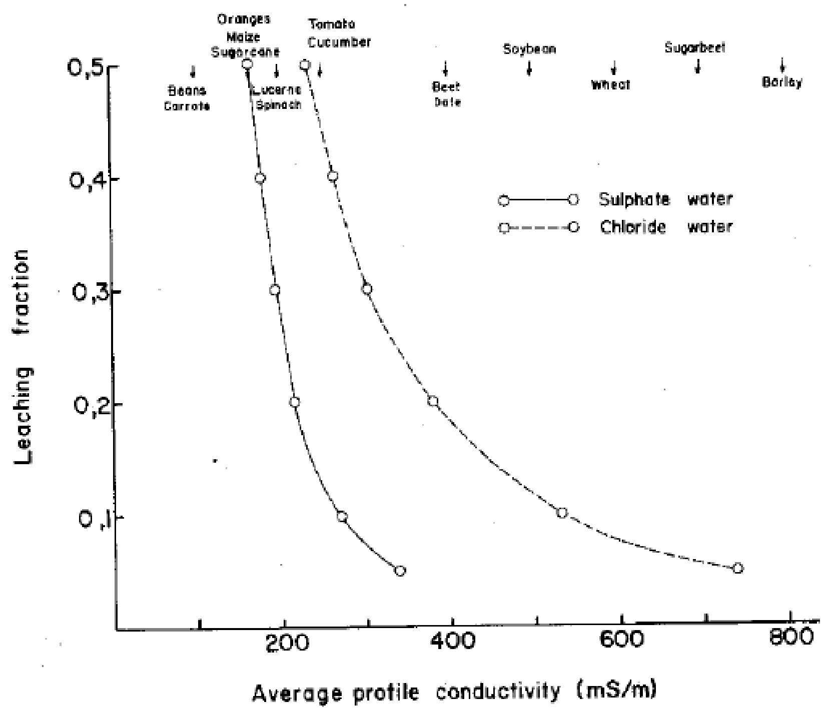


Fig 2 Profile average saturation extract conductivities (mS/m) for the sulphate and chloride waters at different leaching fractions with an indication of threshold conductivities for various crops.

The irrigation option: Technology principle

Irrigation with $CaSO_4$ rich mine water

⬇

Roots take up water and concentrate the salt
Precipitation of gypsum in the soil profile ('infinite' capacity)

⬇

Salts therefore removed from the water

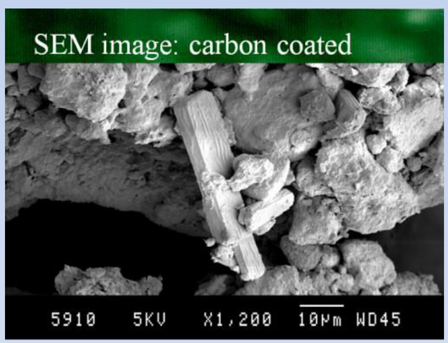
➡ Soluble salts will still be exported via irrigation return flows

➡ Surface water and groundwater impact needs to be acceptable

Naturally gypsiferous soil – Ebro Basin Spain – 15 t ha^{-1} maize from these fields

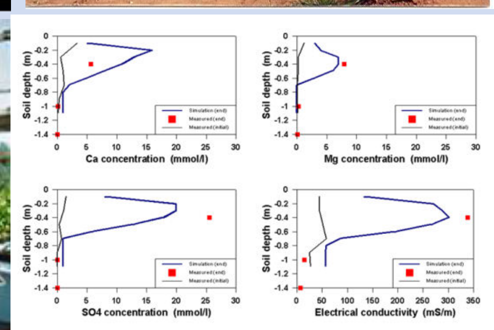
Previous research – University of Pretoria

- Laboratory incubation trials
- Glasshouse trials
- Mpumalanga coalfields – field trials and commercial production of crops



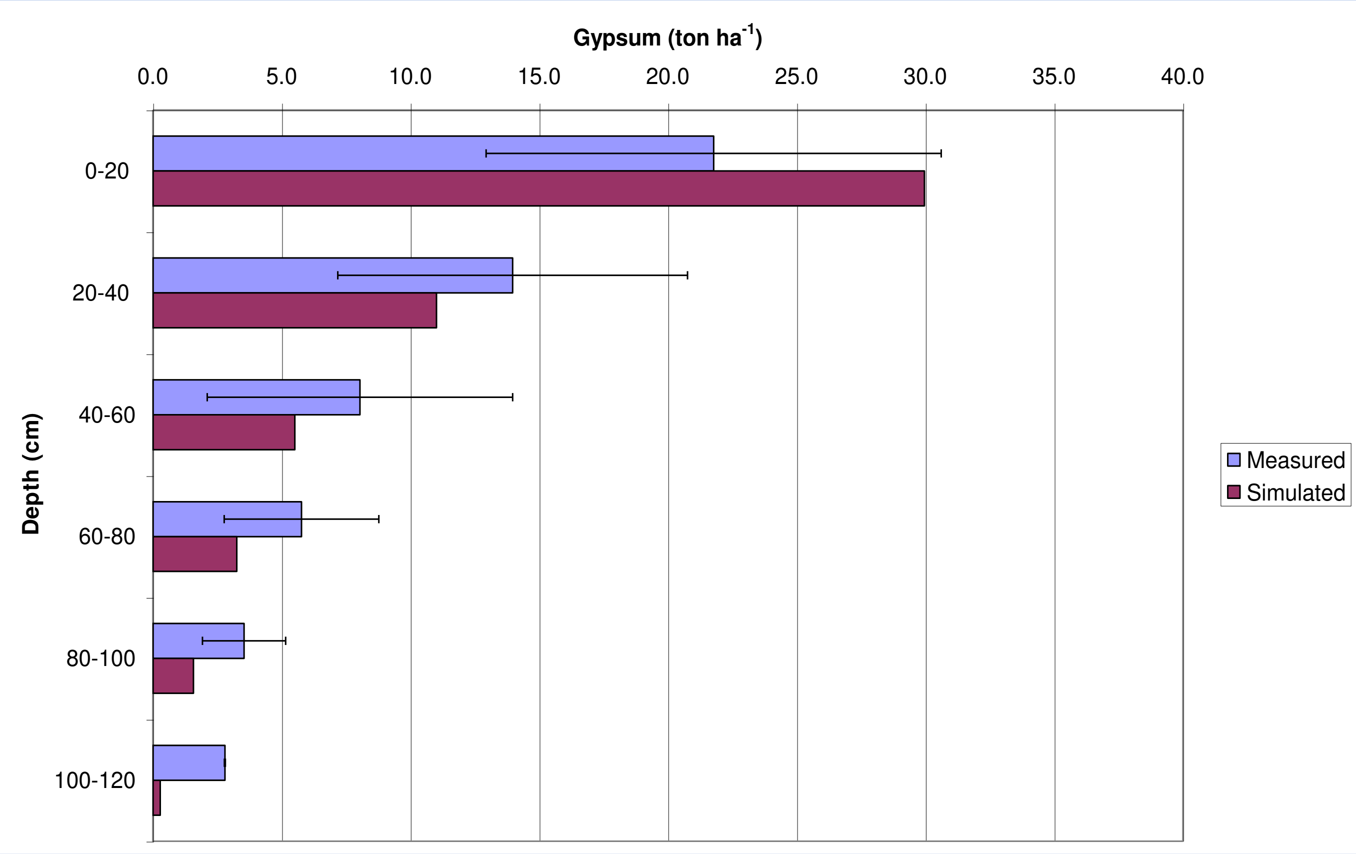




Previous research – University of Pretoria

- Long-term chemical equilibrium modelling (SWB)
- Soil salinity increased, stabilized with EC_e

~ 200 mS m^{-1}



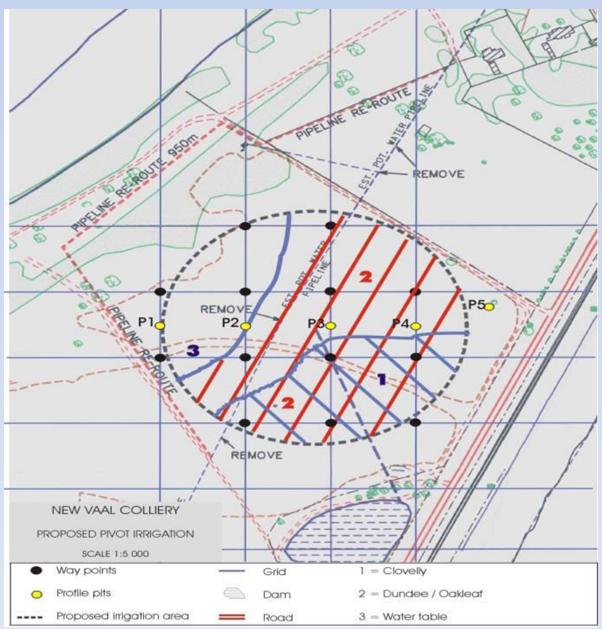

Sugar beans: 1.2 to 3.2 t ha-1


Yield of wheat: 5.0 to 8.1 t ha-1


Yield of maize: 8.0 to 10.0 t ha-1

Previous research – environmental impact

- Institute for Groundwater Studies involved - groundwater impact
- ….'Impact of gypsiferous irrigation on crops and soils minimal and manageable'



Mine Water Irrigation

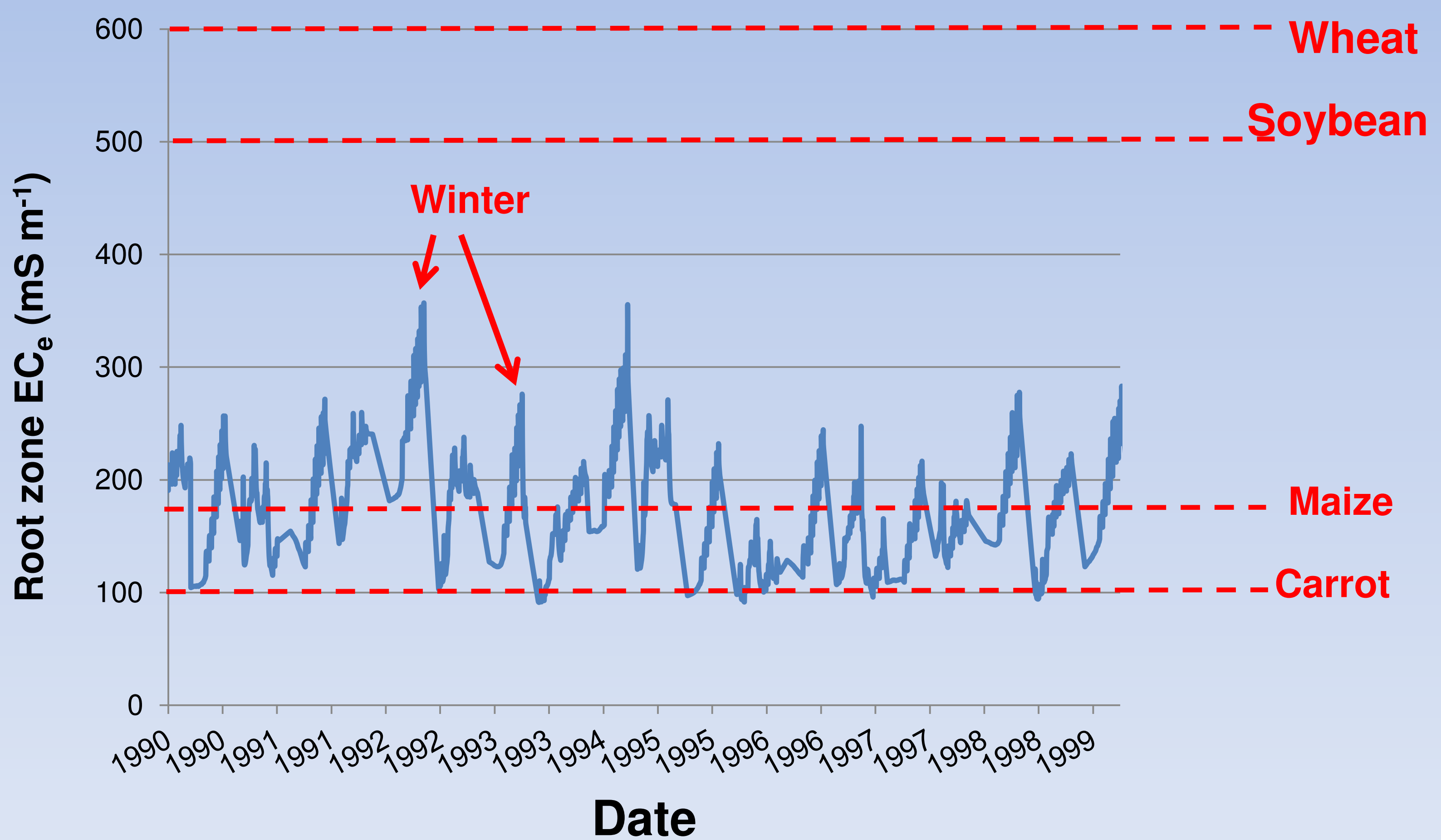
- Have a lot of confidence that crops can be grown with neutralised mine waters
- Investigated other options to treat mine water to increase the opportunity to precipitate as large a fraction of the salts possible
  - Mn wad
  - Aluminium sulphate
- Simulated water and salt balances to do some economic and environmental analyses

Mine water qualities used for SWB-Sci simulations

Basin / Treatment	Ca	Mg	Na	SO_4	Cl		Ca	Mg	Na	SO_4	Cl
			mol l^{-1}						mg l^{-1}		
Western - limestone + lime*	0.019	0.006	0.002	0.024	0.001		760	147	50	2285	37
Western - limed Al	0.024	0.008	0.003	0.031	0.003		960	192	69	2976	105
Western - limestone‡	0.012	0.004	0.006	0.017	0.001		480	96	138	1632	35
Central - limestone‡	0.012	0.005	0.007	0.017	0.004		480	120	161	1632	140
Eastern - limestone‡	0.012	0.005	0.01	0.017	0.005		480	120	230	1632	175
Eastern - Grootvlei HDS#	0.011	0.006	0.011	0.017	0.006		421	134	244	1667	205

*Taken from Maree et al. (2013)
‡Estimated using stoichiometric calculations
#DWAF monitoring data

Western Basin
Root zone saturated paste EC



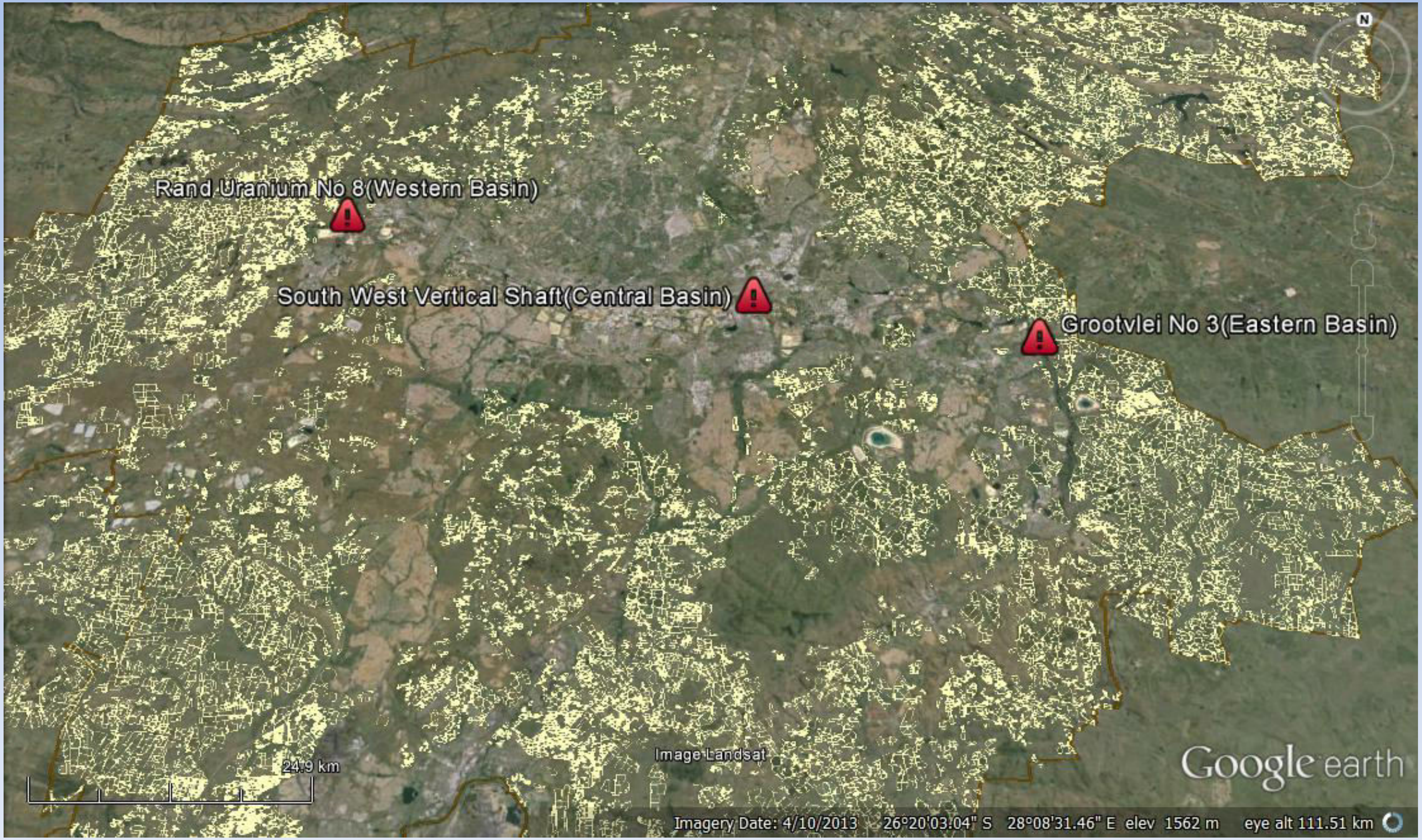
Wheat / soybean rotation
Water use and area
estimated using SWB-Sci

Basin	Ml / day	Water use mm / a	Area ha
Western	23	618	1400
Central	46	535	3200
Eastern	110	540	5600

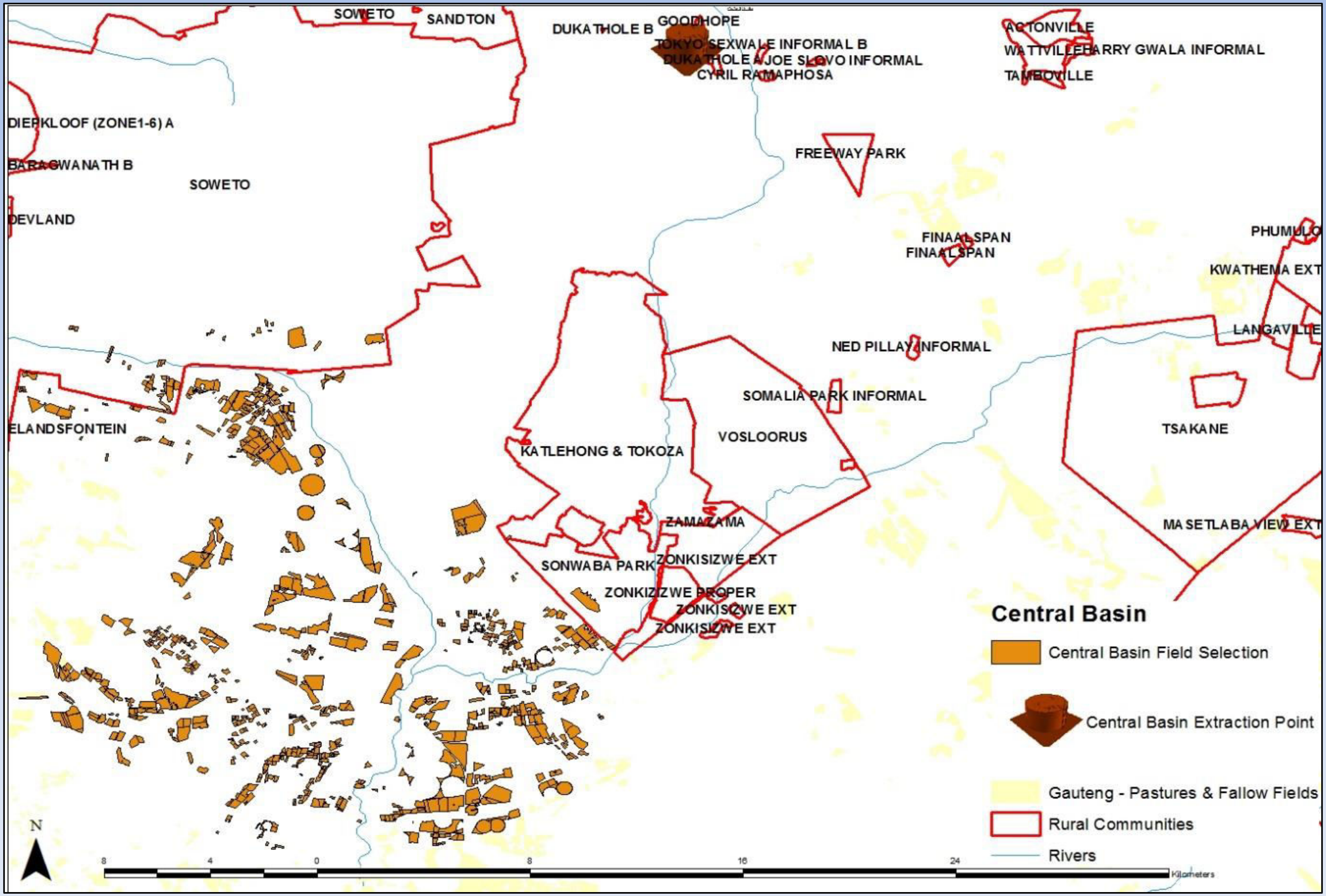
Summary of selected (best and worst) soybean-wheat cropping system simulation results for the Western, Central and Eastern Basins

Basin / Treatment	Irrigation /annum (mm)	Drainage /annum (mm)	Percentage salts precipitated (%)	Salt load added (t ha^{-1} a^{-1})	Gypsum precipitated (t $ha^{-1}a^{-1}$)	Ave root zone EC_e (mS m^{-1})	Ave leachate TDS (mg l^{-1})
Western - limestone + lime	600	142	69	19.7	13.7	183	4225
Western - limed Al	595	144	69	25.8	17.9	217	5486
Eastern - Grootvlei HDS	531	169	39	14.3	5.6	232	5148

Agricultural land availability in proximity to treatment plants



Central Basin



Land Availability (fallow, old lands, pastures)

Basin	Pipeline km	Land available ha	Area required ha
Western	17	2000	1400
Central	30	3800	3200
Eastern	20	6900	5600

Economic Feasibility

SA a net importer of wheat and soybean oilcake

Current crushing capacity of soybeans currently underutilized

Average production expenditure

R19 900 per ha – pay for water but no capex/opex

R23 300 – includes infrastructure and maintenance

Worst case scenario

From a 40 ha pivot – R240 000 per year net income

Opportunity to establish about 300 such farmers

Life cycle assessment
Conventional RO vs irrigation

- RO desalination LCAs have shown the main environmental impact comes from the operation of the plant, with the construction and disposal phases being almost negligible in comparison (Buckley et al, 2011, Raluy et al, 2004).
- >> For this reason the main focus was on the impacts resulting from electricity consumption for the two activities
- Functional unit (FU) is '**one metric tonne of salt removed from neutralised mine water**'

Life Cycle Assessment

- Mid-point impact categories:
- **Global warming potential -** carbon dioxide equivalent (CO2-e) emissions as a result of generating the electricity to power both processes
- **Non-renewable energy consumption -** use of coal fossil fuel to generate the electricity required for RO or irrigation
- **Acidification potential -** from the burning of sulphur containing fuels
- **Blue water consumption**

Environmental impact indicators per ton of salt removed – Western Basin

Impact	RO	Irrigation	Irrig RO return flow
Global Warming kg CO2-e	696	78	207
Acidification kg SO2-e	5749	648	1712
Non renewable energy MJ/FU	2555	288	761
Blue water consumption Litres/FU	958	108	285

Where to next?

Conclusions

- Irrigation will be able to immobilize a large fraction of salts and keep these from surface water bodies for a very long time
- Crop production will be possible, and water can be used beneficially and productively, thereby creating jobs
- Considering the enormous cost and energy requirement of RO, and the fact that water quality may start improving in a few years, serious consideration should be given to the irrigation option.

Future Research

- Innovative water treatment options should be tested on pilot scale – significant savings may be possible with the HDS process
- Irrigation with neutralised, unclarified mine water should be tested – this would reduce the need for settling during treatment, and the need to dispose of “yellow boy”. Physical soil benefits are expected, but plant nutritional problems may arise

Future Research

- With the irrigation option we need to do a risk analysis, as well as an opportunity analysis
- WATCH THIS SPACE! (Jo Burgess – parliamentary brief)

Acknowledgements

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Conclusions

- Land treatment of raw mine water shows real promise because solids sequestration is very high yet there is little sign of serious degradation from the solids enrichment. This is worth pursuing further.
- Al sulfate is considerably more effective than the Fe-Mn wad in removing metals and producing water of acceptable quality for irrigating crops. Quite likely neither may prove economically attractive but there are advantages such as efficient removal of metals including Mg and also settling characteristics (rate and volume) which suggest that tests would be worth conducting at pilot plant scale before costing is attempted. Also combination of Al sulfate with lime for amending soil or tailings in land treatment of raw mine water could be worth exploring.
- Black clay soils with montmorillonite are common in the vicinity of decant points and are exceptionally well suited to receiving and neutralising sulfuric mine water while remaining potentially productive substrates for plant growth.

Where to next?

- Investigate more quantitatively and on a larger scale the economic feasibility of using Al sulfate and Fe-Mn wad as supplementary ameliorants for mine water treatment.
- Carry out field trials to quantify the effects of direct application of raw mine water to agricultural soils and mine tailings, selected for their buffer capacity and/or availability at each of the decant locations.
- Establish a pilot plant in the Western Basin to investigate salt dynamics in a neutralised mine water wheat-soybean (or other suitable crop) irrigation system.

Where to next?

- Find out, based on expected leaching loads and concentrations, whether there is assimilative capacity in the rivers of the Western, Central and Eastern Basins.
- Conduct geo-hydrological studies to identify sites where neutralised mine water irrigation schemes can be located so as to have minimal impact on the environment (for example, above an already contaminated aquifer).
- Improve the SWB-Sci model's capacity to simulate bypass flow (incomplete solute mixing) and crop response to soil salinity. The latter should be informed by local field trials irrigating crops with brackish water.

Outputs

- Van der Laan, M; Annandale, JG; Fey, MV; de Jager, PC; du Plessis, HM (2014) Managing poor quality mine water: Is irrigation part of the solution? Water Institute of Southern Africa Mine Water Division Symposium, 24 October 2014.

- Van der Laan, M; Annandale, JG; Fey, MV; de Jager, PC; du Plessis, HM (2014) Is irrigation part of the solution to managing highly saline neutralized acid mine drainage in the Vaal Basin, South Africa? Third International Salinity Forum, Riverside, California, 16-18 June 2014.

In the Vaal Basin….its really a salt problem….

Impact reduction of irrigation and irrigation plus RO of return flows compared to conventional RO