ADAPTIVE MANAGEMENT STRATEGIES AND OPTIONS FOR WATER RESOURCES SECTORS IN THE CONTEXT OF CLIMATE CHANGE

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WHY A FOCUS ON WATER IN CLIMATE CHANGE IMPACT STUDIES IN S.A.?

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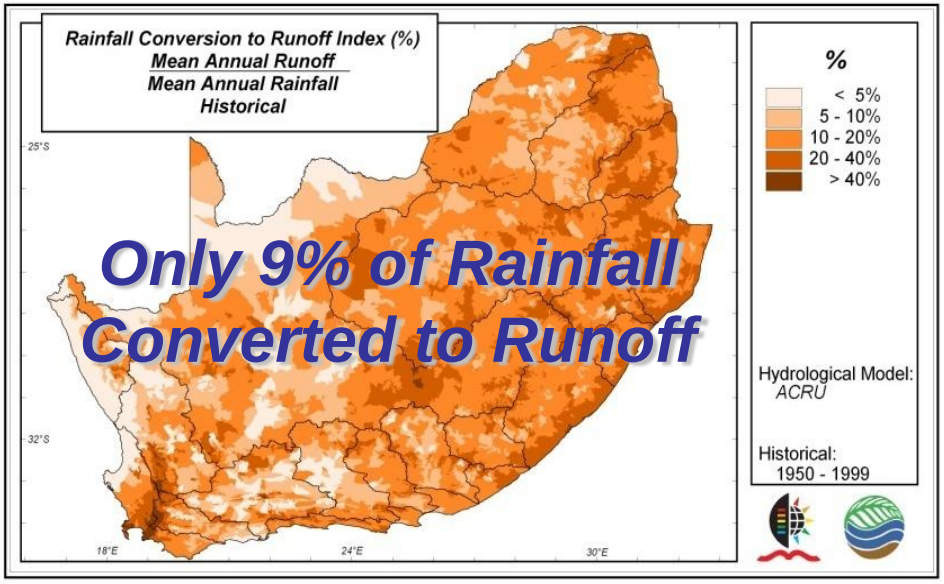
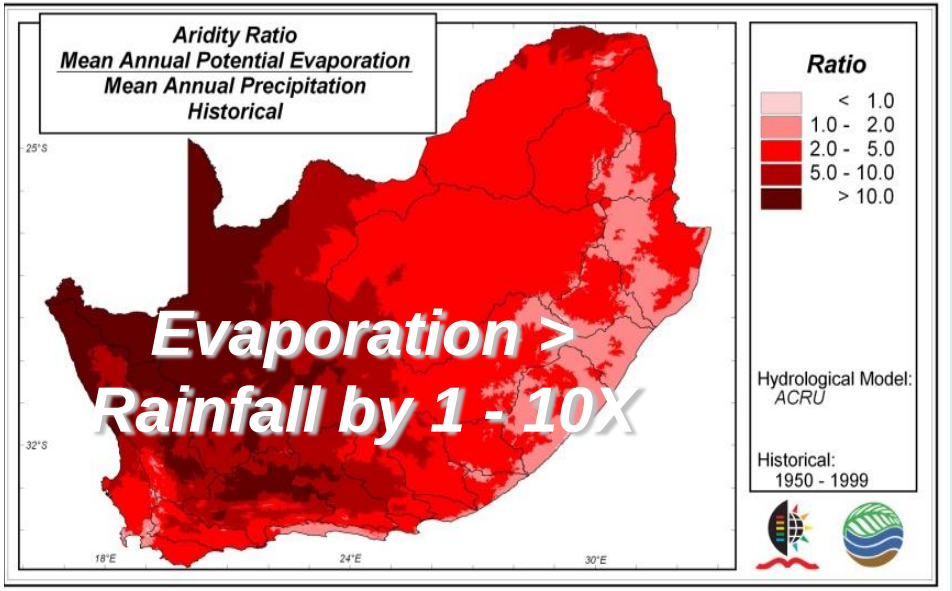
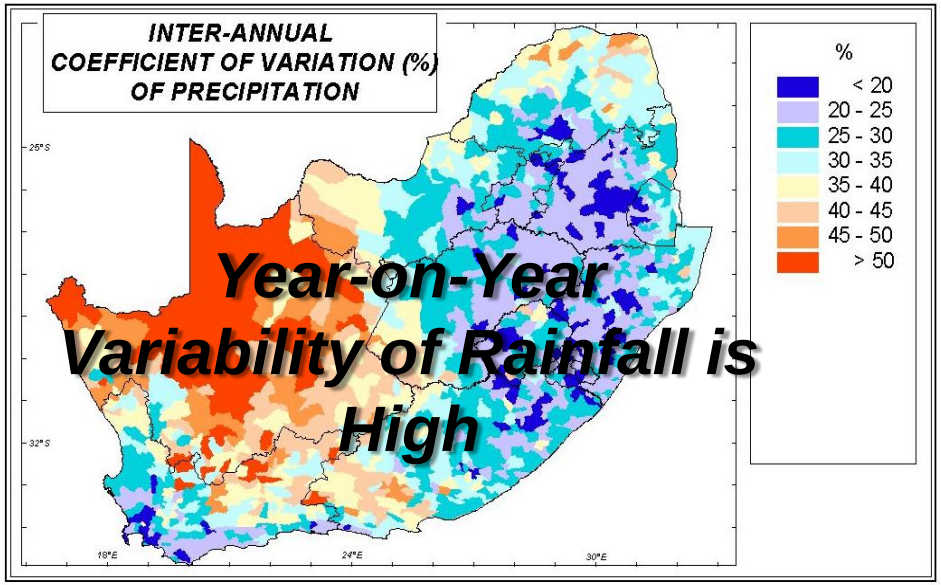
1. SA is Already Exposed to a High Risk Climate



Only 9% of Rainfall Converted to Runoff



Evaporation > Rainfall by 1 - 10X



Year-on-Year Variability of Rainfall is High

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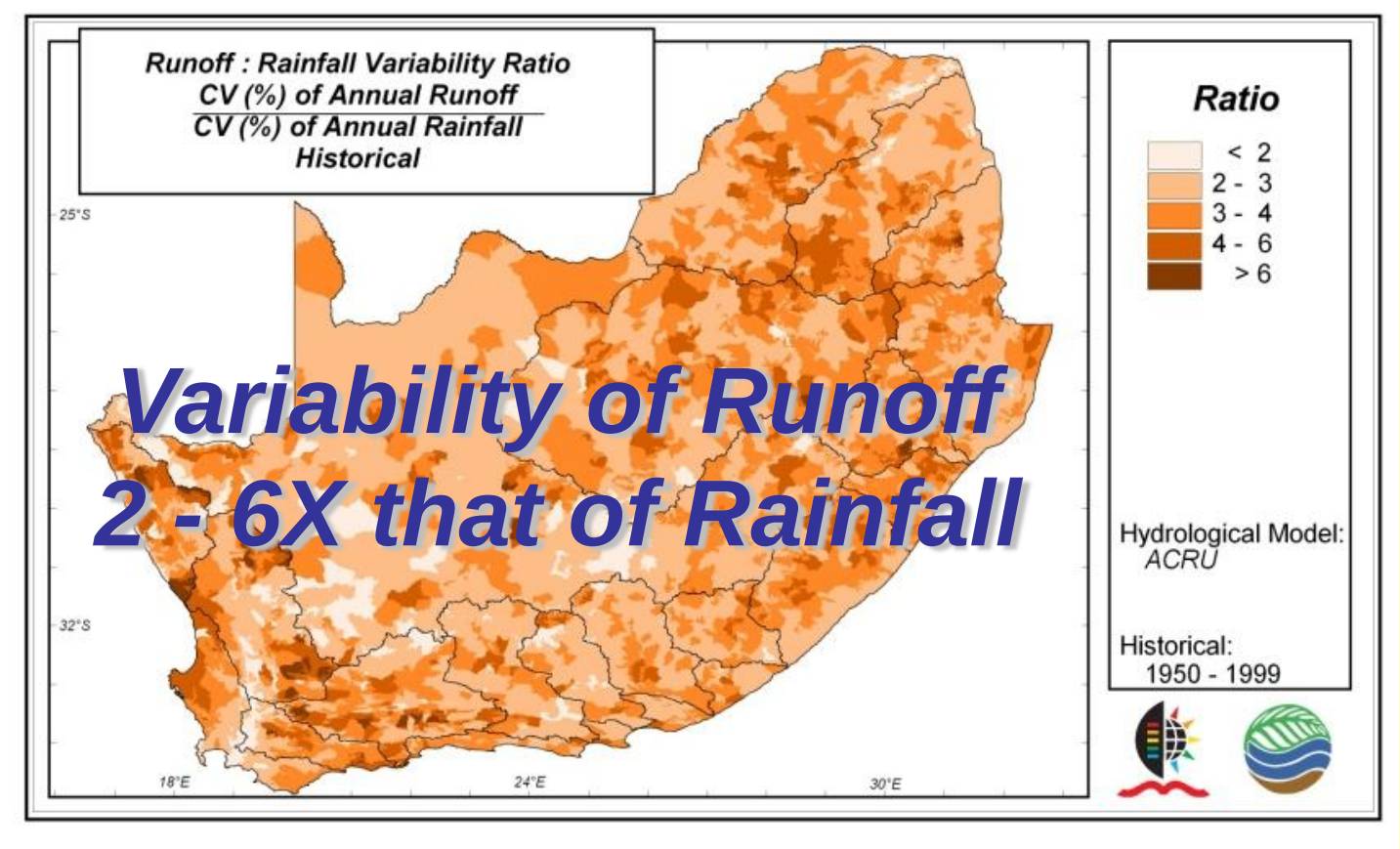
2. Any Changes in Rainfall are Amplified in their Hydrological Responses



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3. Many Fragile Ecosystems, Both Aquatic and Terrestrial, are Implicitly / Explicitly Water Dependent

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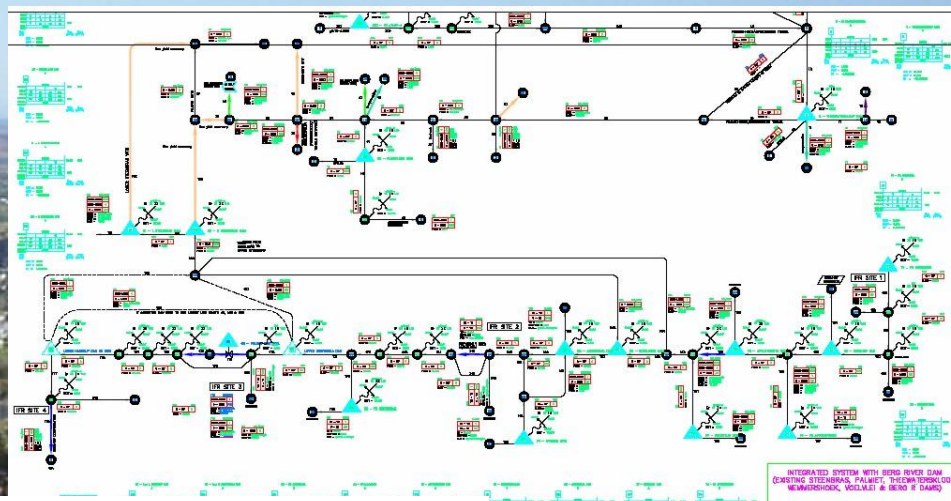
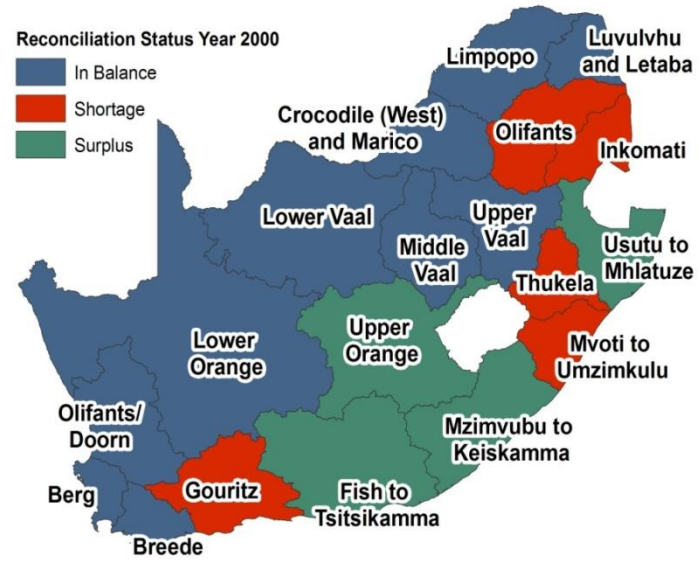
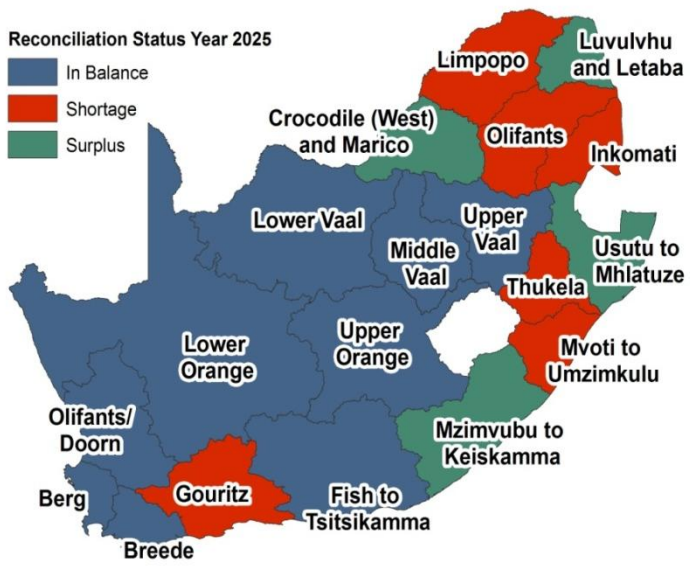
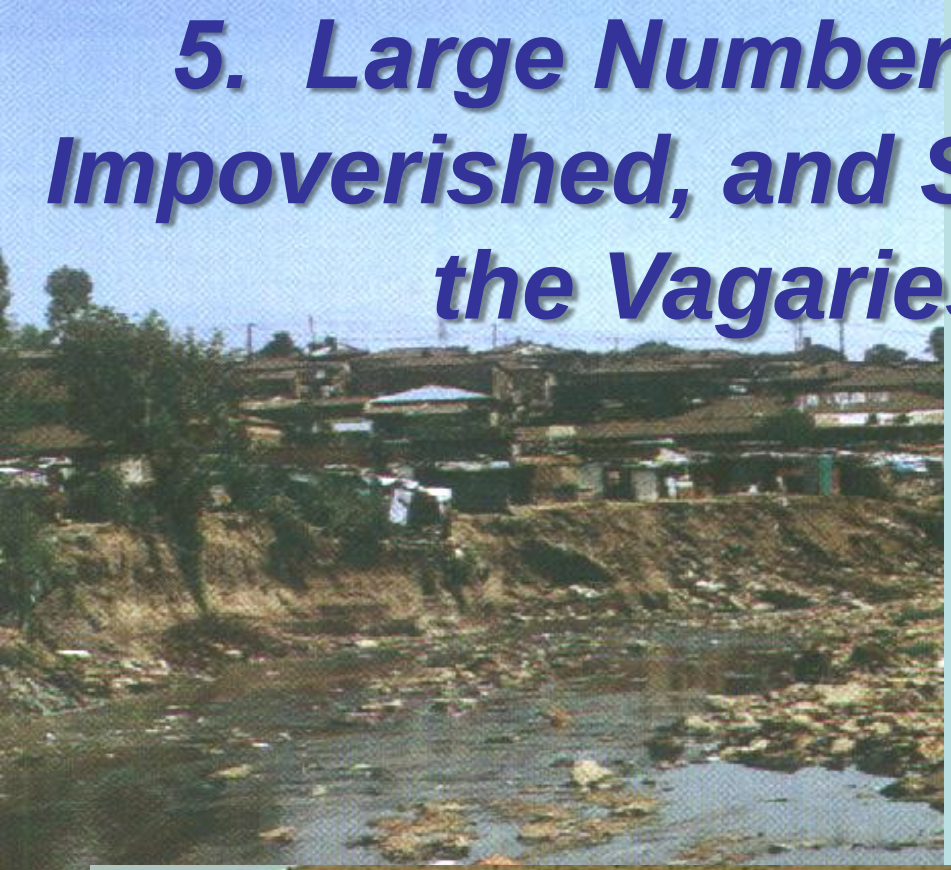
4. CC is NOT Experienced over Virgin Catchments, but is SUPERIMPOSED over ALREADY STRESSED Operational Catchments

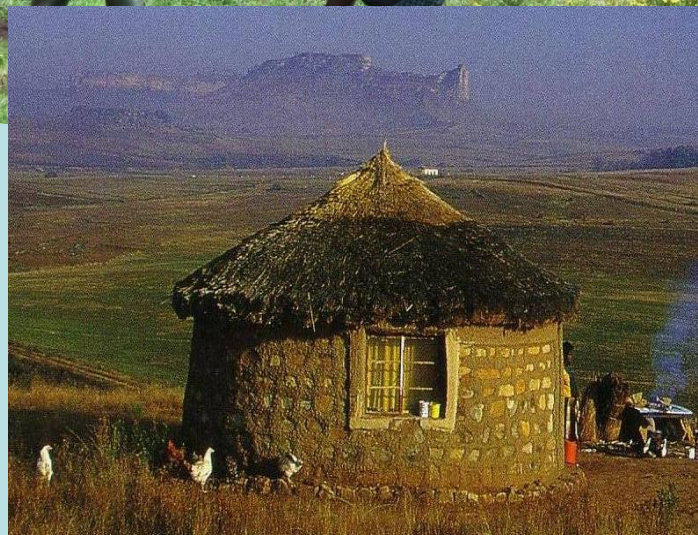






5. Large Numbers SA's People are Impoverished, and Subjected Directly to the Vagaries of Climate





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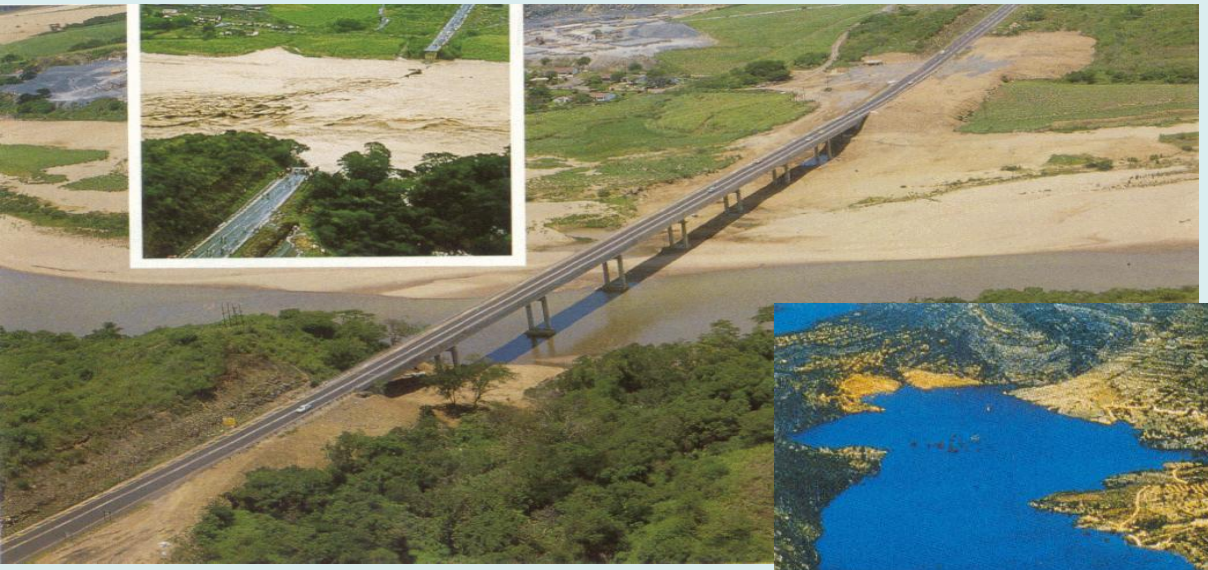
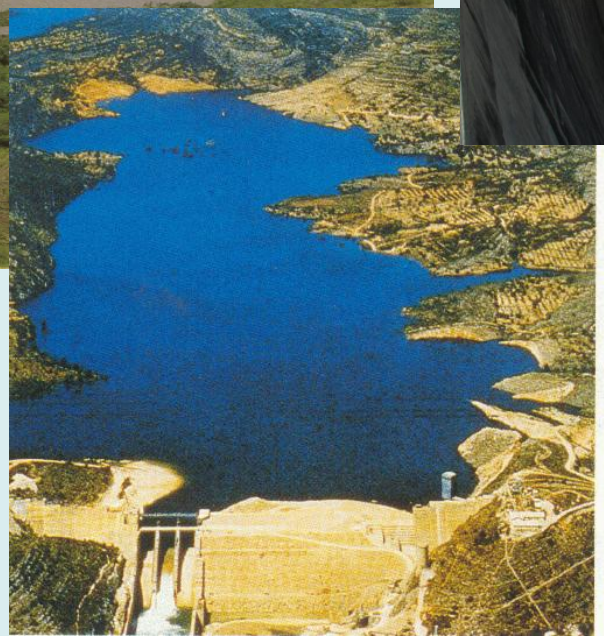
6. Water Related Infrastructure Typically has a Design Life of 50-100 Years (well into the era of CC), is Expensive and Essentially Irreversible



SEPTEMBER 1987 FLOODS - THUKELA



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7. SA's Water Quality is Generally Poor, and Getting Poorer. Note that a 2-3°C Increase in Temperature Speeds up most Chemical Reactions

(Source: O-

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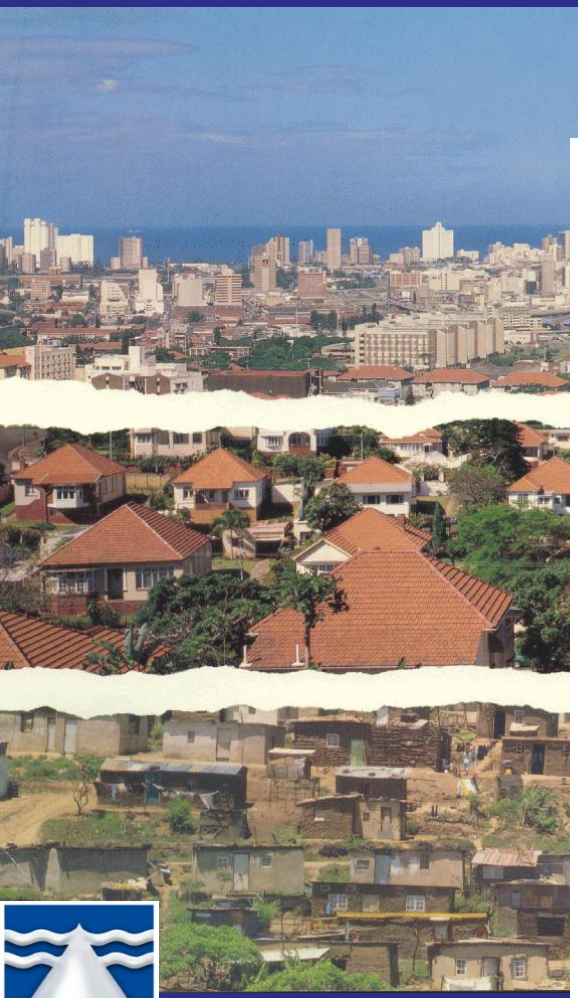
8. CC Plays Itself Out Very Differently at Local Level; Hence Adaptation is Also a Local Issue



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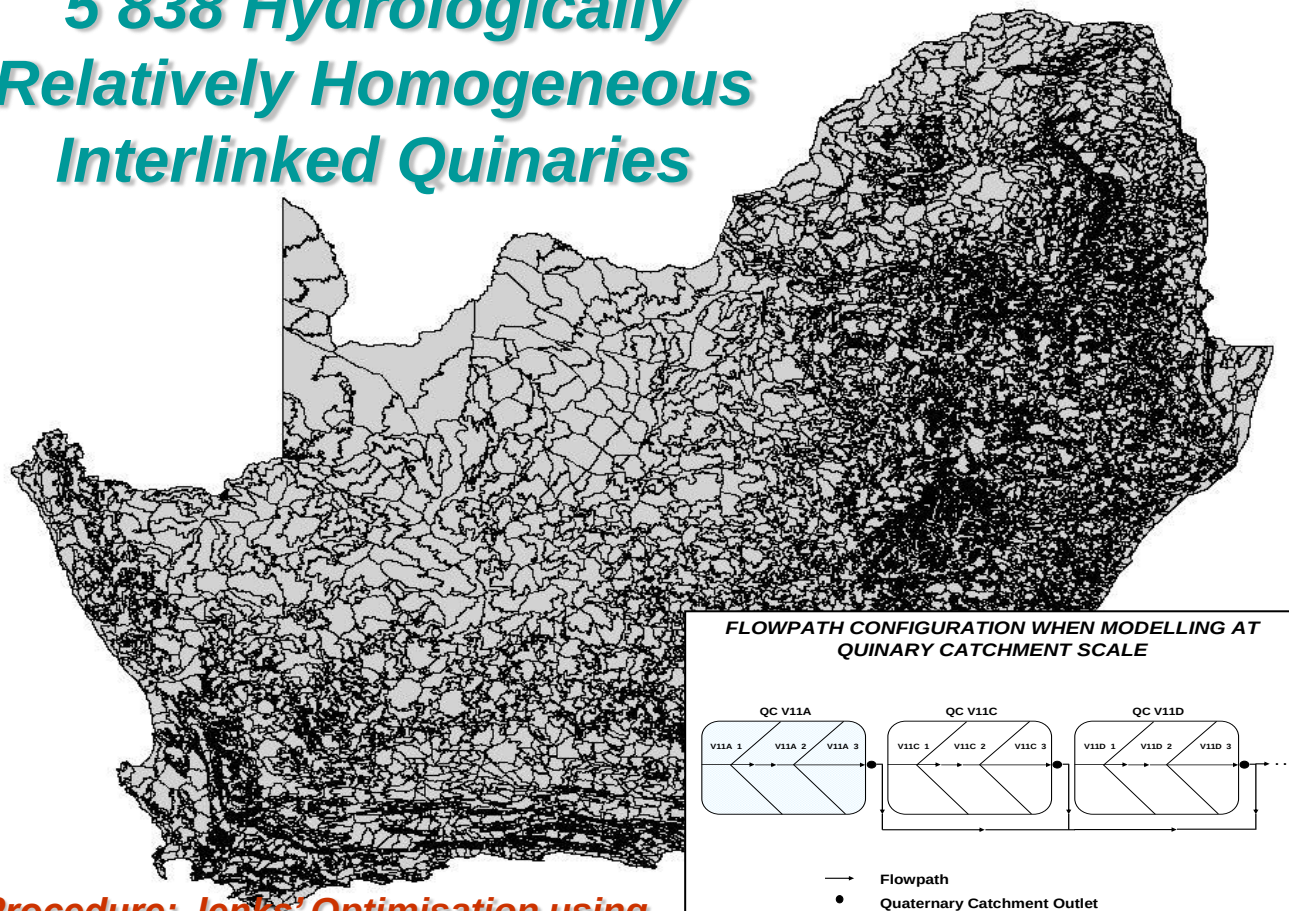
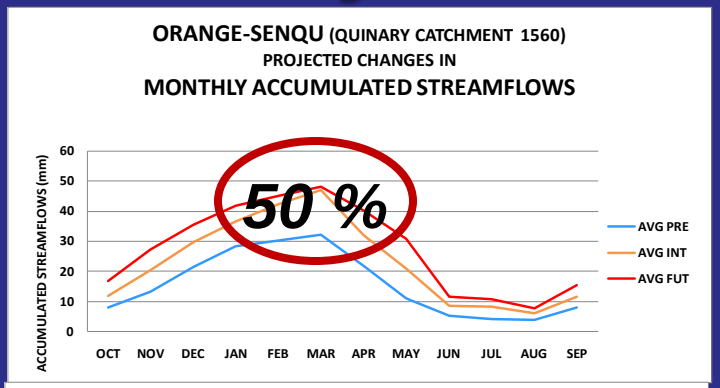
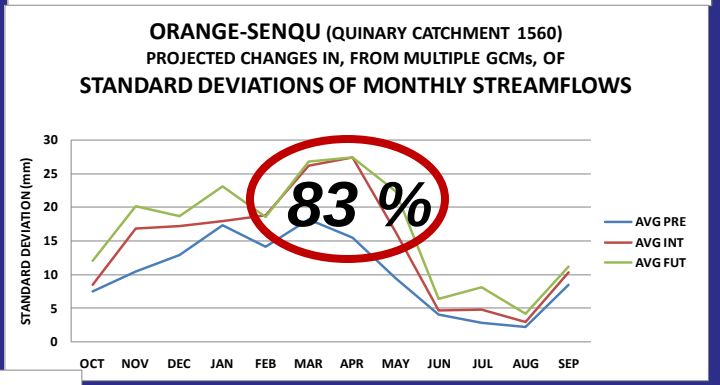
5 838 Hydrologically Relatively Homogeneous Interlinked Quinaries

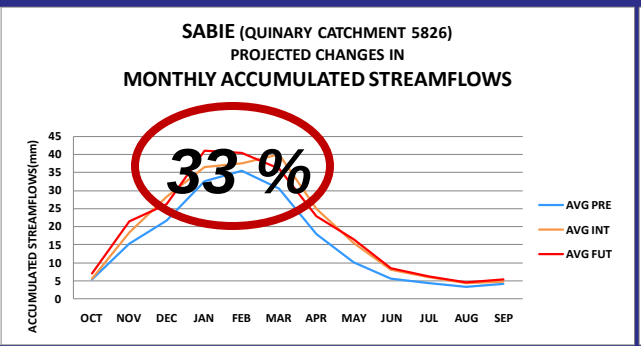


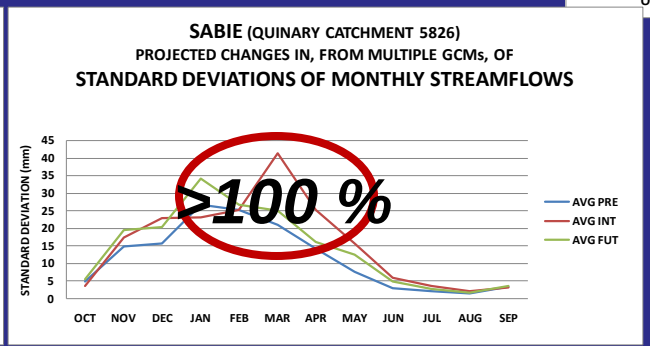
Procedure: Jenks' Optimisation using Natural Breaks in Altitude

9. Many of Our Rivers are Transboundary (from, to, border)…What About Changes in Flows, Timing and Quality?









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WHAT'S NEW ON THE SOUTH AFRICAN RESEARCH FRONT?

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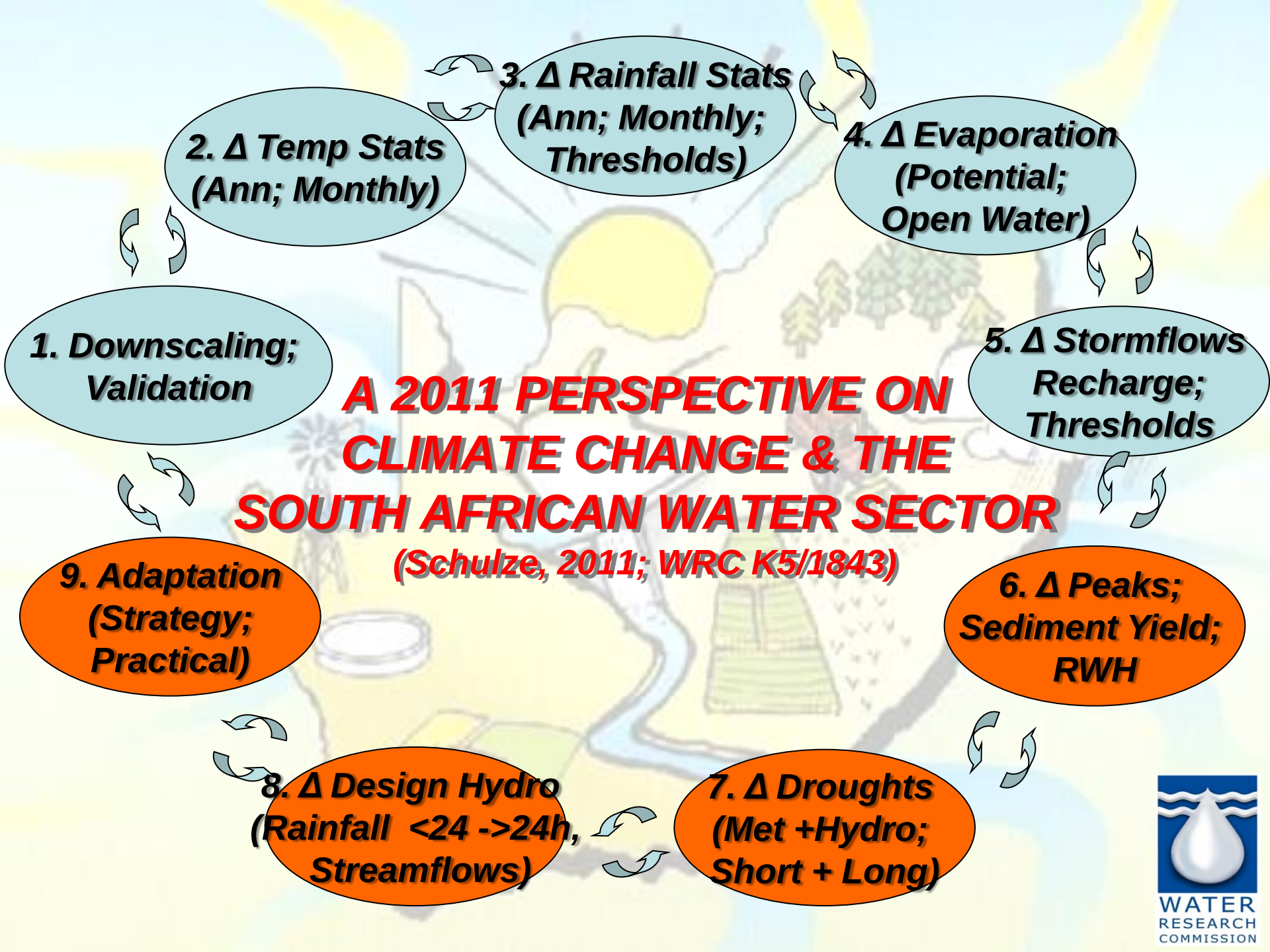
3. Δ Rainfall Stats (Ann; Monthly; Thresholds)
2. Δ Temp Stats (Ann; Monthly)
4. Δ Evaporation (Potential; Open Water)
1. Downscaling; Validation
5. Δ Stormflows Recharge; Thresholds
A 2011 PERSPECTIVE ON CLIMATE CHANGE & THE SOUTH AFRICAN WATER SECTOR
(Schulze, 2011; WRC K5/1843)
9. Adaptation (Strategy; Practical)
6. Δ Peaks; Sediment Yield; RWH
8. Δ Design Hydro (Rainfall <24 ->24h, Streamflows)
7. Δ Droughts (Met +Hydro; Short + Long)
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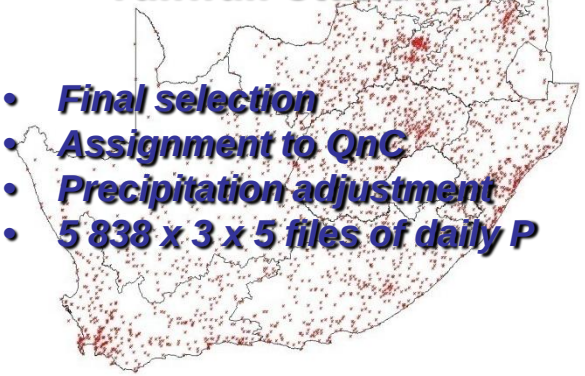
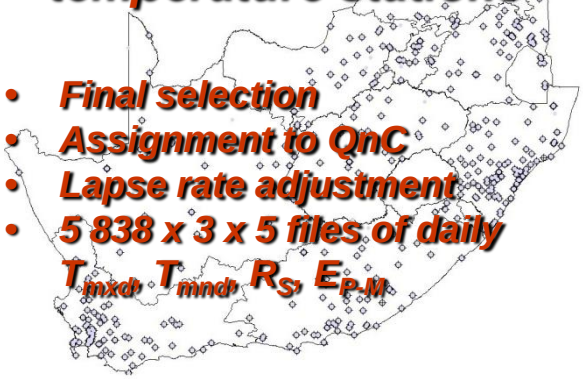
METHODOLOGY

Downscaling to > 2 600 rainfall stations

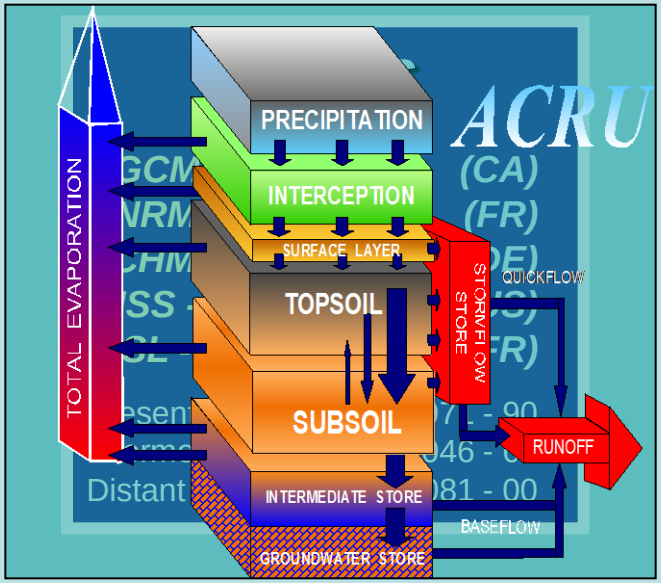


- Final selection
- Assignment to QnC
- Precipitation adjustment
- 5 838 x 3 x 5 files of daily P

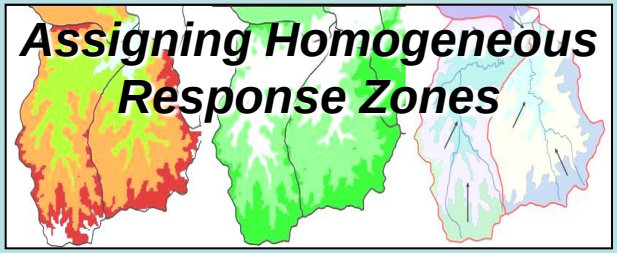
Downscaling to > 400 temperature stations

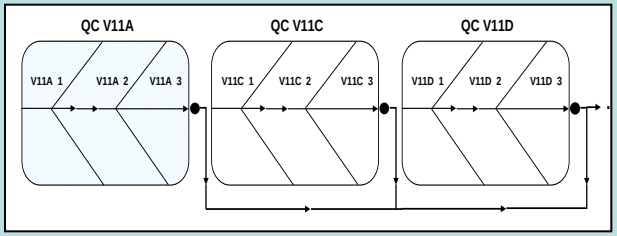


- Final selection
- Assignment to QnC
- Lapse rate adjustment
- 5 838 x 3 x 5 files of daily T_{mxd}, T_{mnd}, R_S, E_{P-M}



Assigning Homogeneous Response Zones





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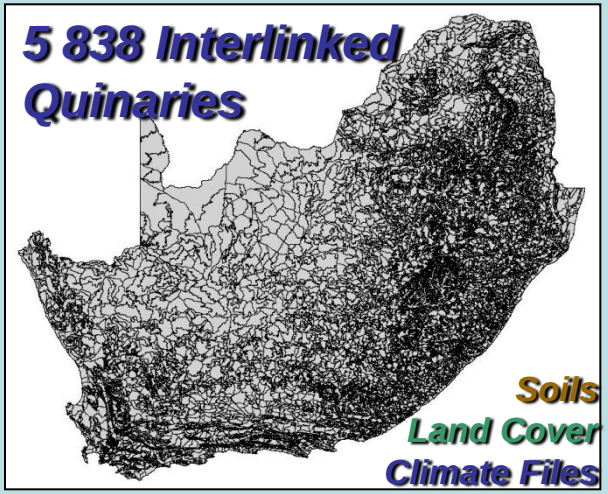
5 838 Interlinked Quinaries



ANALYSES

Temperature Analyses

- Annual Temperature Stats
- Cardinal Month (Ja, Ap, Ju, Oc) Stats
- Frost Days
- Cold Spells
- Heat Waves
- Climate Zones
- Validation Studies

Rainfall Analyses

- Annual Rainfall Stats
- Cardinal Month Stats
- Seasonality and Concentration
- Threshold Rainfalls Exceeded
- Shifts in Timing of Rains > Thresholds
- Short and Long Duration Design P
- Meteorological Droughts (S, M, M, / A, M)
- Validation Studies

GCMs

CGCM3/T47(no DF)	(CA)
CNRM - CM3	(FR)
ECHMA5/MPI - OM	(DE)
GISS - ER	(US)
IPSL - CM4	(FR)

Present	1971 - 90
Intermediate	2046 - 65
Distant Future	2081 - 00

Hydrological/Hydro-Ecological Analyses

- Annual Runoff/Streamflow Stats
- Cardinal Month Stats
- Thresholds of Streamflows Exceeded
- Potential Evaporation
- Soil Moisture
- Peak Discharge; Sediment Yield
- Hydrological Droughts (Sev, Mod, Mld, / An, Mo)
- Shifts in Timing of Streamflows > Thresholds
- 1 - 7 Day Design Stormflows (2, 5, 10, 20, 50, 100 yr RP)
- Env Flows: Indicators of Hydrological Alteration
- Env flows: Water Temperature
- Estuarine Responses
- Land Use/ CC Dynamics: Mgeni Catchment
- Case Studies: Durban; Cape Town

Agricultural Analyses

- 2nd Order Analyses
  - Heat Units - Chill Units
- 3rd Order Analyses
  - Pests /Diseases (Ch/CM/El/Ea/SbR/OF)
  - Crops (Mz, Wh, So, Sb Sc)
  - Pastures (Ec, Kik)
  - Crops - Horticulture
  - Production Forestry (Am, Eg, Pp)
  - Primary Production
  - Irrigation Requirements
- Vegetation Dynamics

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TAKE-HOME MESSAGES FROM THAT RESEARCH

10 Key Messages

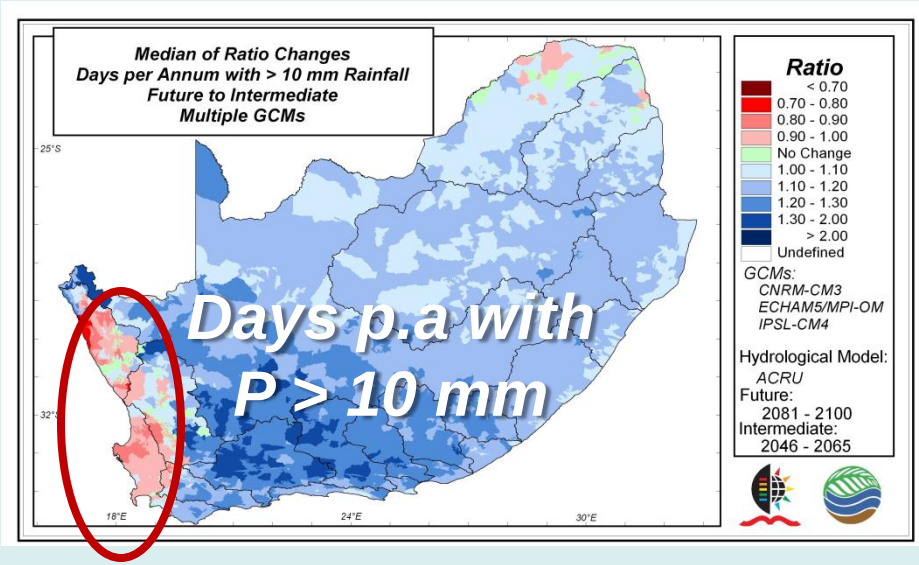
Take-Home Message 1

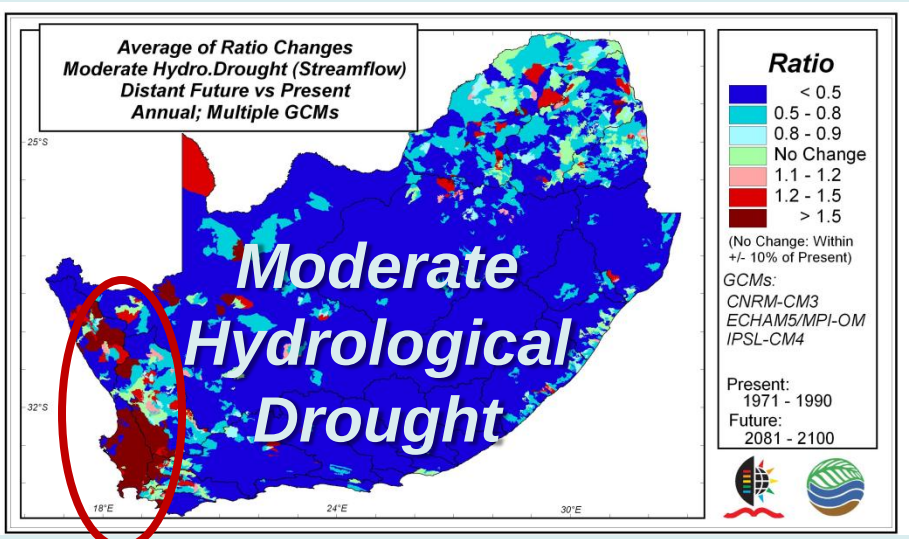
Some Areas will be Winners

(with new opportunities)

Others will be 'Hot-Spots of Concern'

(especially in distant future, with added stresses)



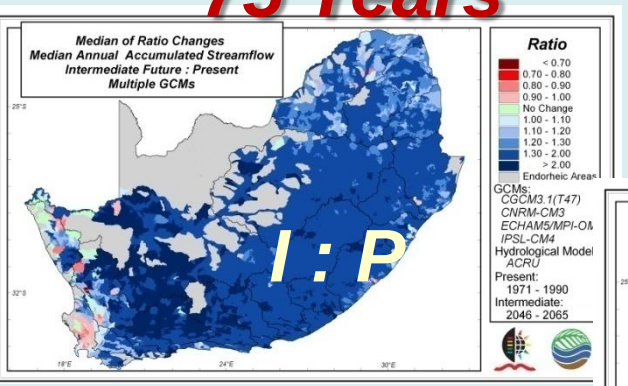


Take-Home Message 2

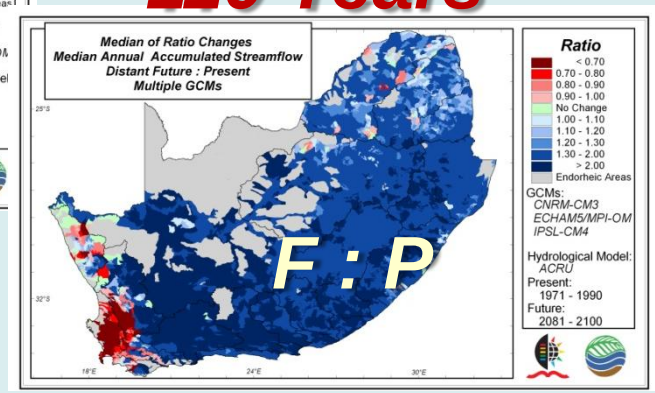
An Intensification of Change is Projected in the Latter Part of the Century

e.g. Projected Changes in Streamflows from Multiple GCMs

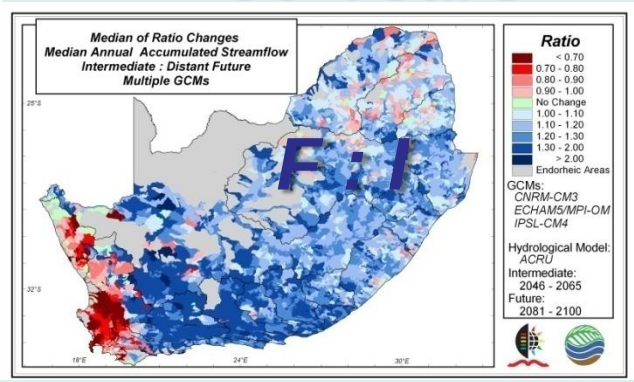
75 Years



110 Years



35 Years



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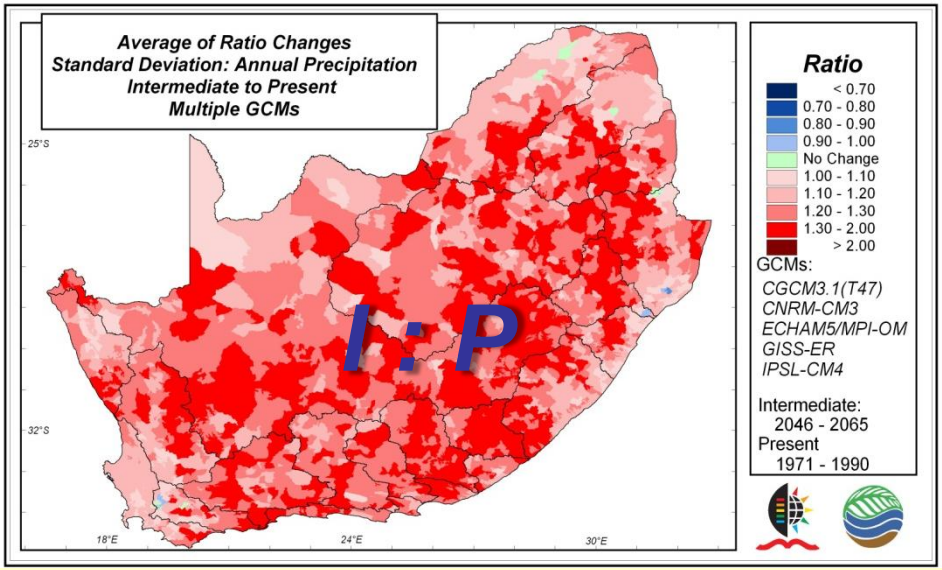
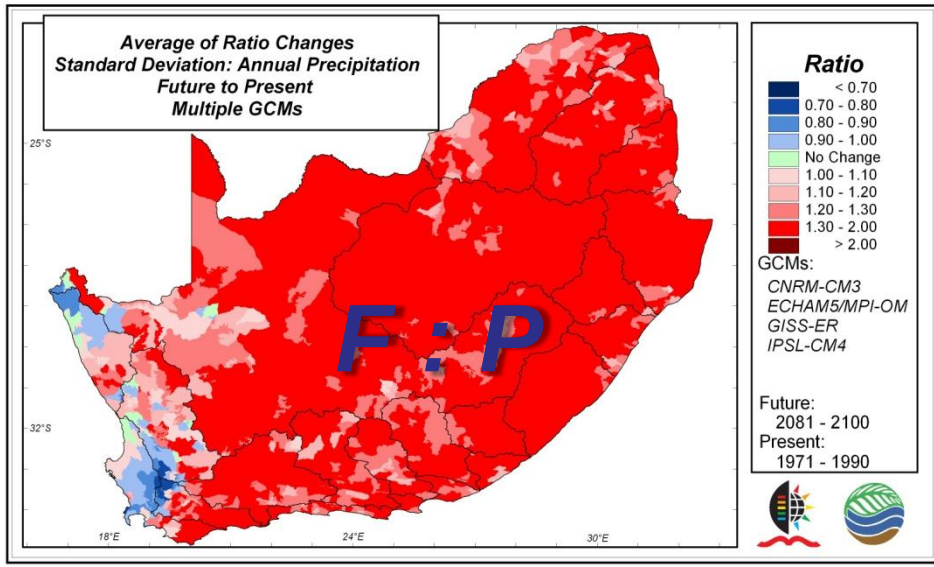
Take-Home Message 3

Variability is Projected to Increase …More so Over Time

Projected Increases in Standard Deviation of Annual Temperatures from Multiple GCMs



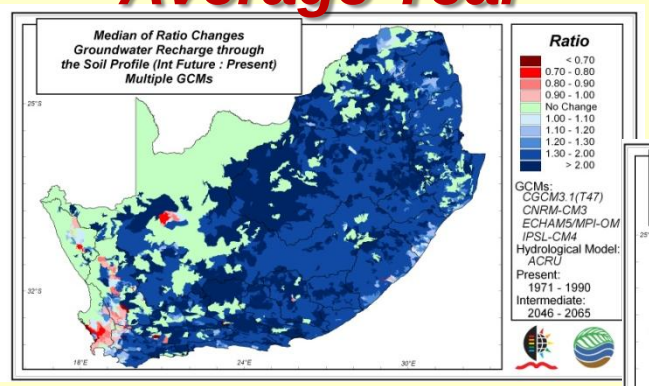


Take-Home Message 4

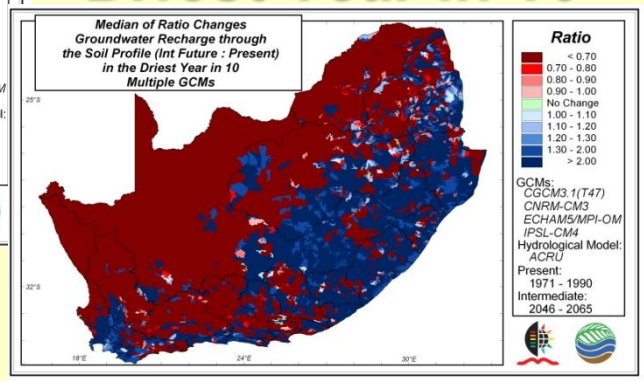
Patterns of Projected Change Differ Between Future Average, Wet and Dry Years

The Case of Changes in Recharge into the Groundwater Store

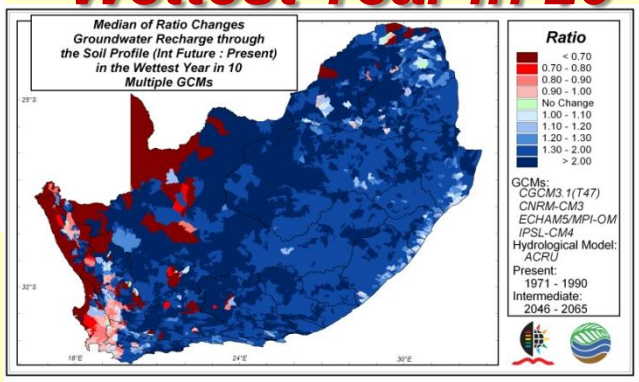
Average Year



Driest Year in 10



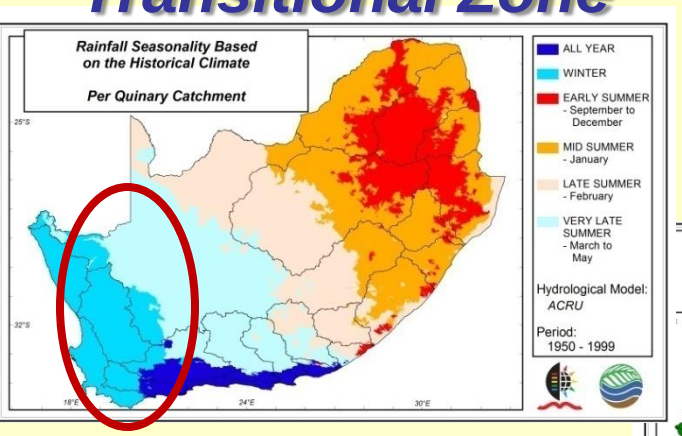
Wettest Year in 10



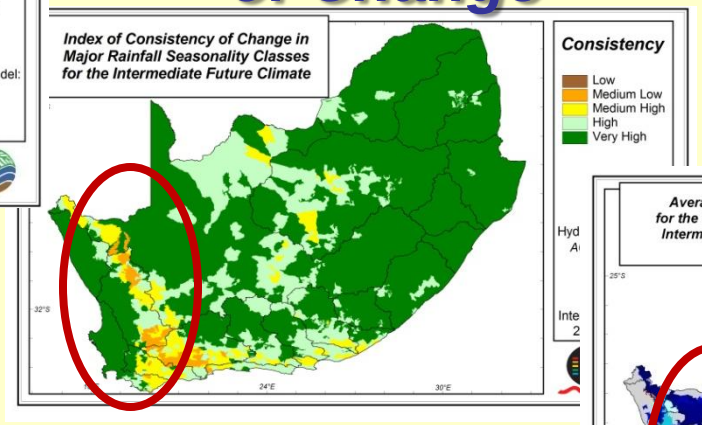
Take-Home Message 5

The Transitional Zone Between the Summer and Winter Rainfall Zones is Often Highly Sensitive to Change

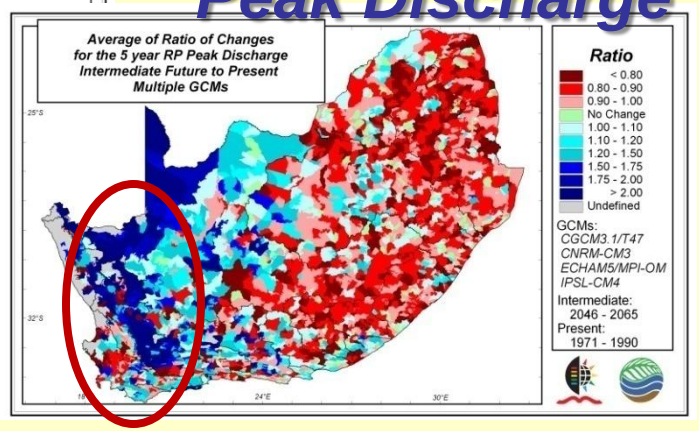
Transitional Zone



Index of Consistency of Change



Δ in 5 Year RP Peak Discharge



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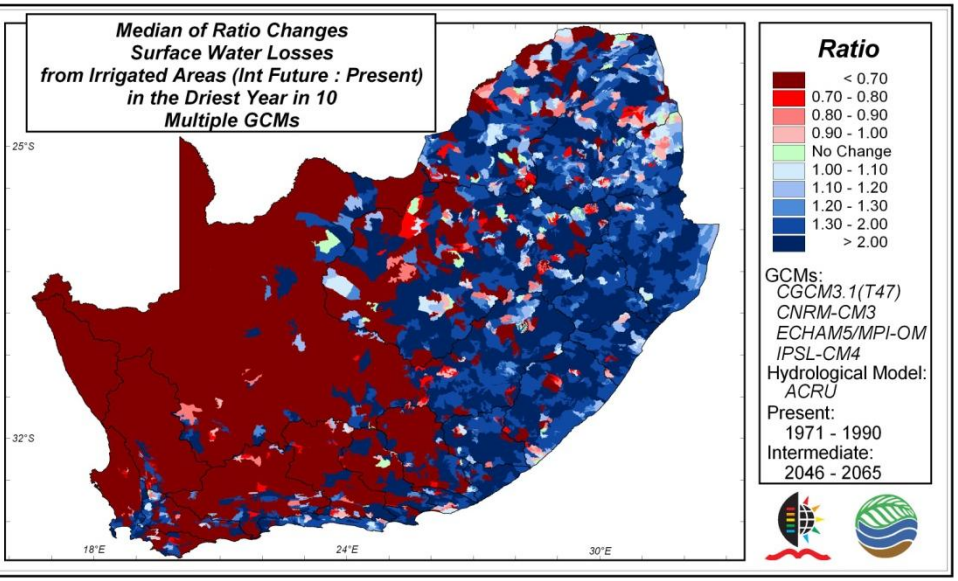
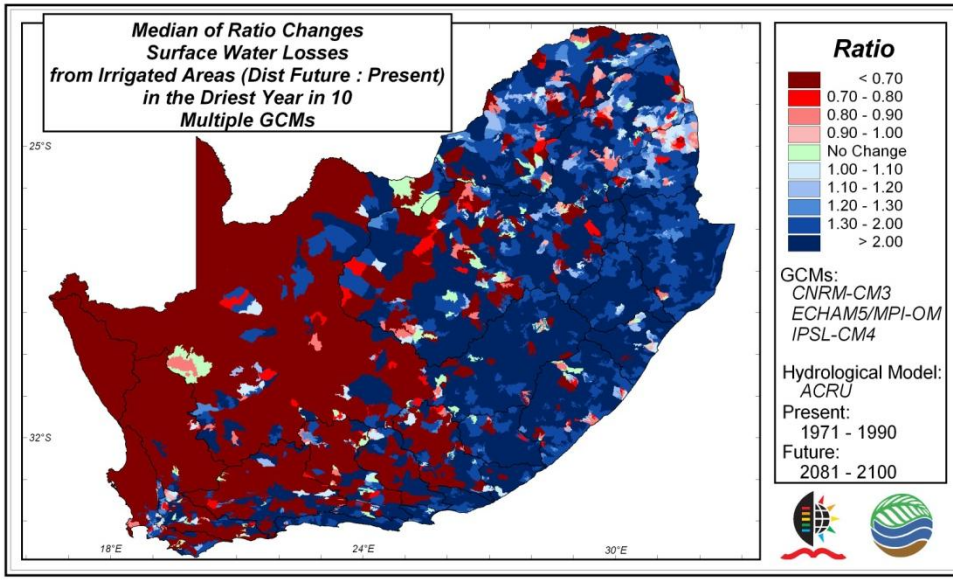
Take-Home Messages 6 and 7

Projected Patterns Often Display Abrupt Change of Sign and Strong Gradients

Some Components of the Hydrological System are More Sensitive than Others

Example: Changes in Surface Water Losses from Irrigated Lands

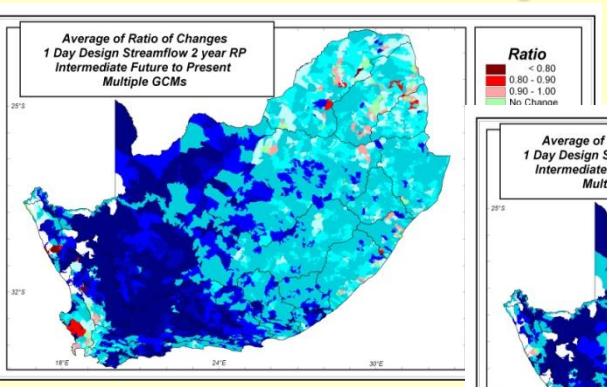




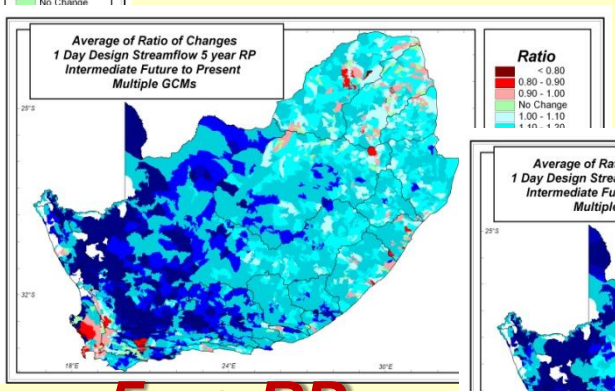
Take-Home Message 8

Projected Changes in Design Rainfall & Runoff Vary with Return Period Rather than with Critical Duration

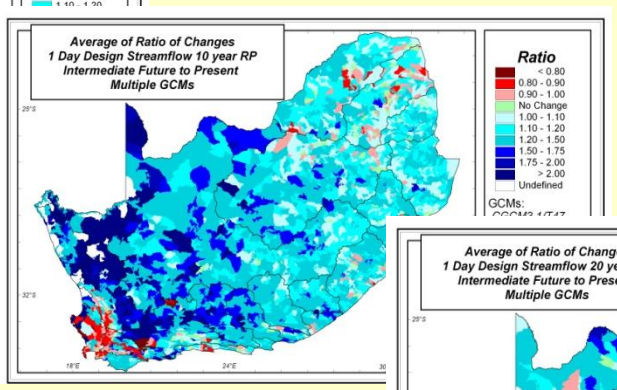
Example: 1 Day Design Streamflows



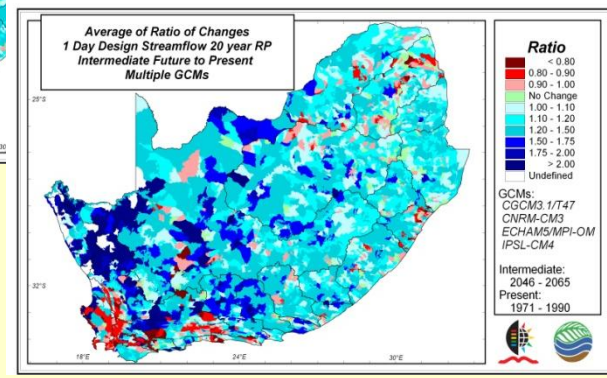
2 yr RP



5 yr RP



10 yr RP



20 yr RP

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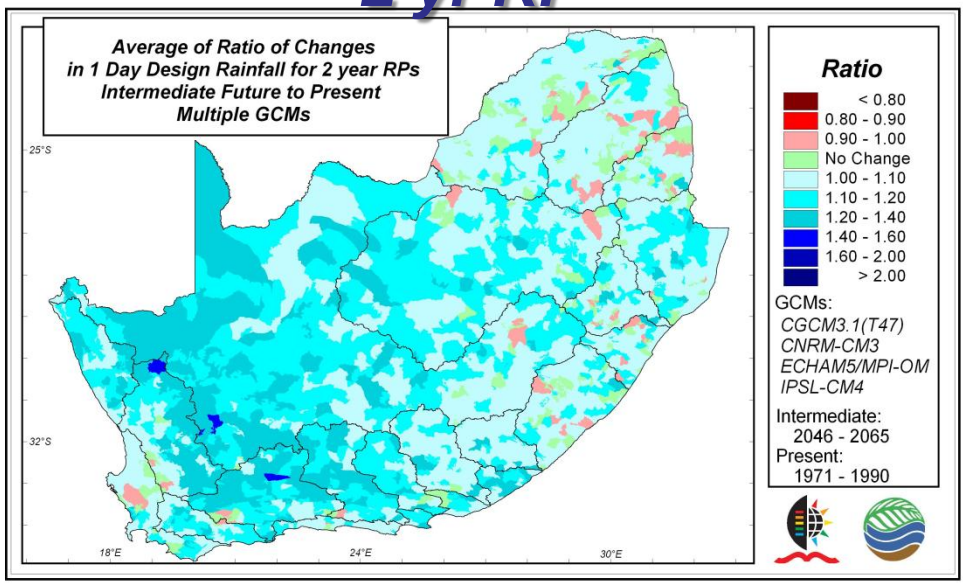
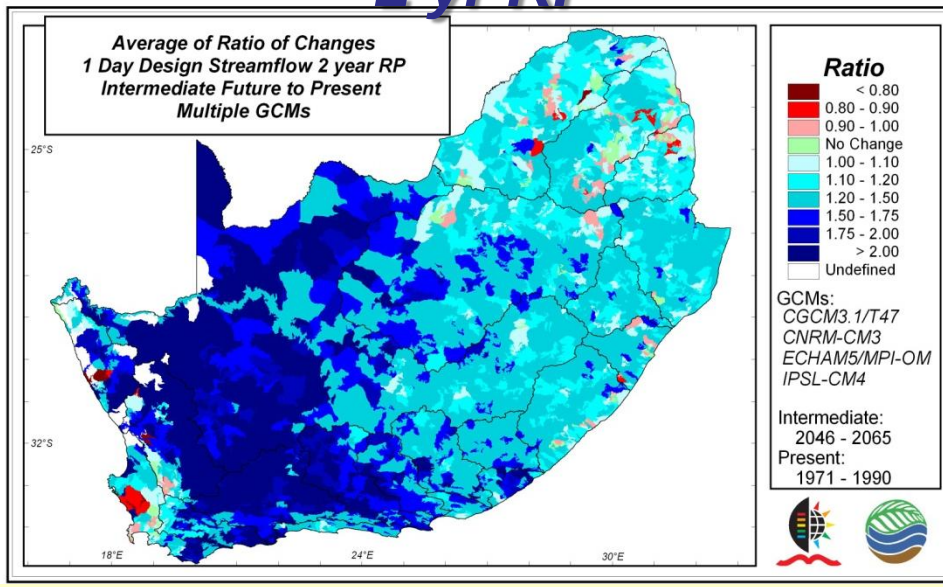
Take-Home Message 9

A Strong Amplification / Intensification is Projected when Changes in Rainfall Parameters are Compared with their Equivalent Runoff Responses

Δ in 1 Day Design Rainfall, 2 yr RP

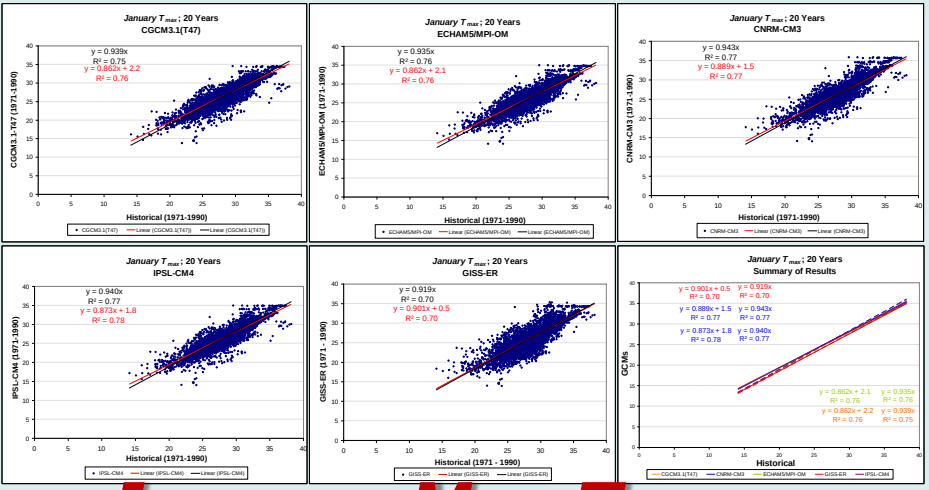


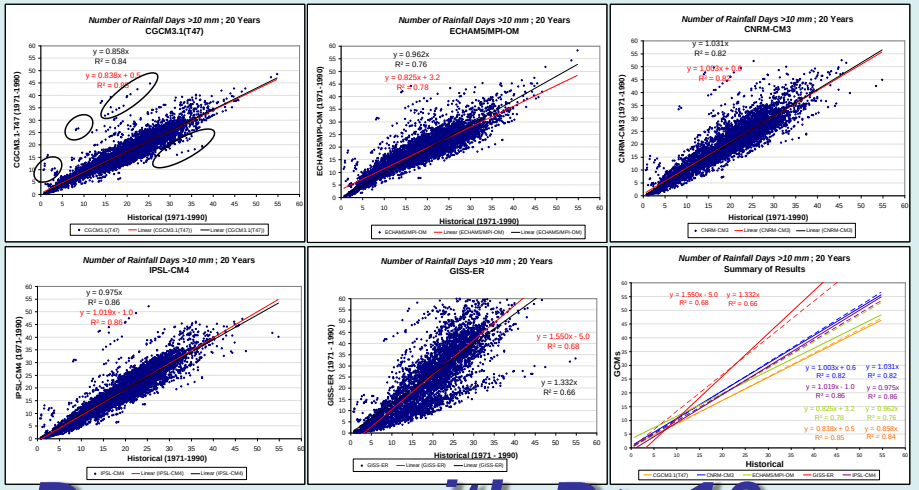
Δ in 1 Day Design Runoff, 2 yr RP



Take-Home Message 10

We Need to Validate Critical GCM Output and Use Output from Multiple GCMs

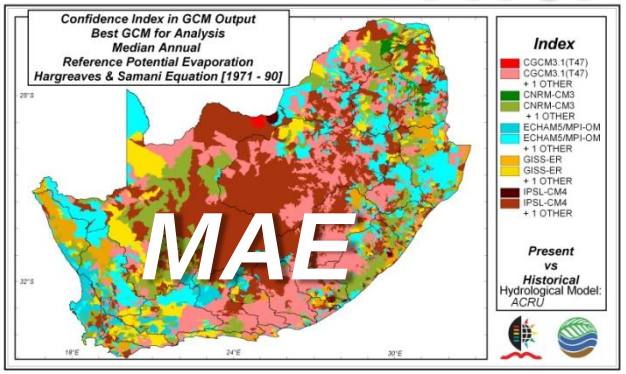


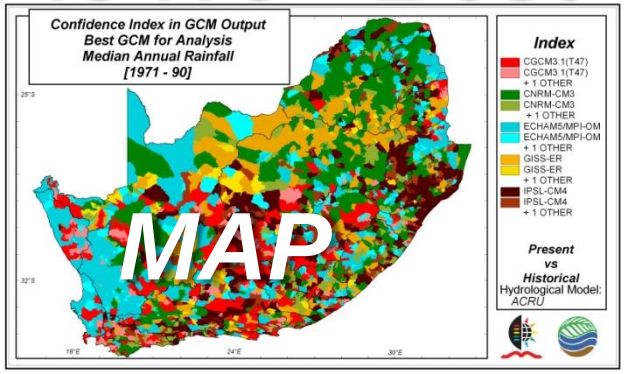


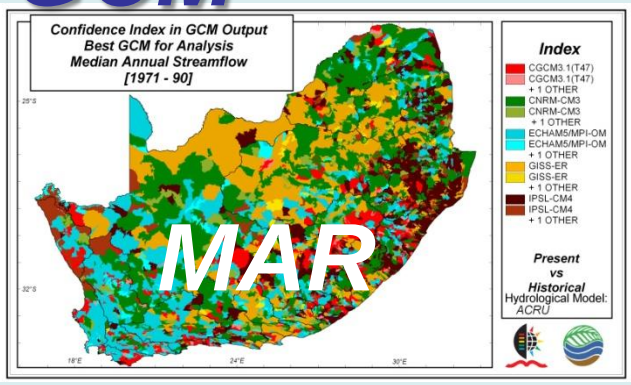
January Max Temps

Days p.a. with P > 10mm

There is NO "Best" GCM







The Key Messages from the Take-Home Messages

1. CC poses new challenges to WRM in SA

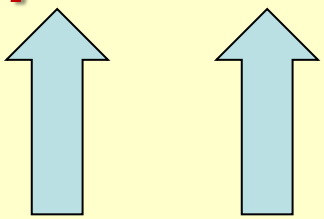
a. Neither is CC all 'gloom and doom'

b. Nor is it 'business as usual' as 'everything under control'

2. There is a need to adapt, by way of

a. A strategy for the water related sector

b. Some practical approaches to adaptation



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WRM Requires an Integrated Approach

ENGINEERING PERSPECTIVE

Existing

- Delivery
- Treatment
  - Pre-treatment
  - Post-treatment
- Allocation
- Regulation
- Efficiencies
- Equity
- Vulnerability
- Climate variability
- Infrastructure
- Rural water
- International obligations
- Water poverty
- Modelling

Future

- Population change
- Expectations
- Catchment change
- Channel change
- Climate change
- Infrastructure
- Sustainable use
- Climate variability
- Flow forecasting
- International obligations
- Millennium Dev Goals
- Modelling

ECOLOGICAL PERSPECTIVE

In-stream

- Navigation
- Hydro-power
- Ecological Integrity
  - EnFlo
  - BioDi
- Renaturalisation
- Recreation
- Flood control
- Quality control
  - Phy
  - Che
  - Bio
- Climate change
- Health & Water
- Disaster Management
- Modelling

Off-stream

- Irrigation
- Power cooling
- Municipalities
- Land use
  - LU for water
  - Water for LU
- Climate change
- Rehabilitation
- Disaster Management
- Food Security
- Modelling

GOVERNANCE PERSPECTIVE

Institutional

- Government
  - National
  - Provincial
  - Local
- CMAs
- Bulk suppliers
- Irrigation Boards

Individual

- Household
  - With water
  - Without
- Farmer
  - Irrigation
    - Commercial
    - Community
  - Dryland
    - Commercial
    - Emerging
    - Subsistence
- Community

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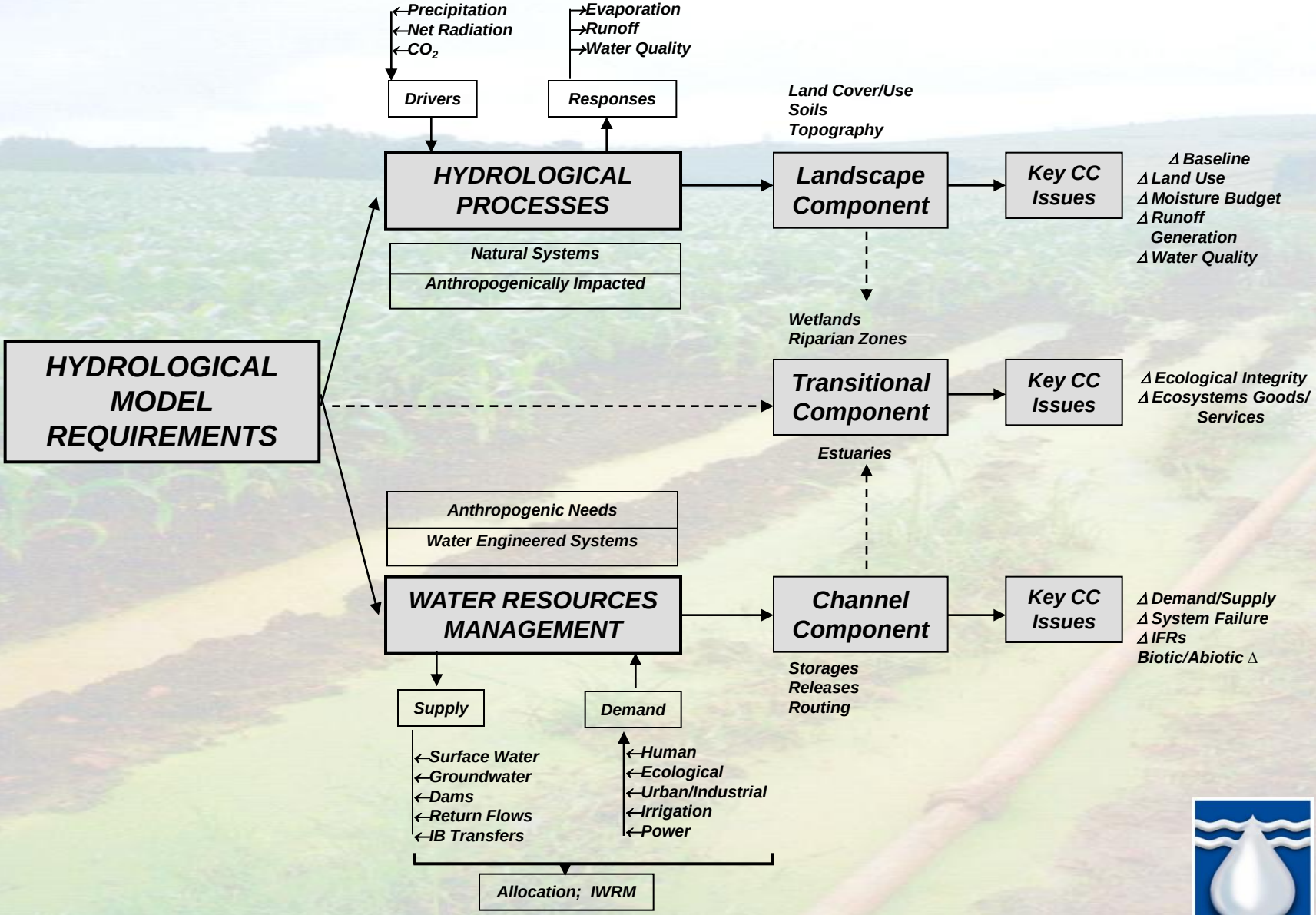
…on a Complex System

MODELLING IMPACTS OF LAND USE AND CLIMATE CHANGE ON HYDROLOGICAL RESPONSES AND WATER RESOURCES



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On Practical Adaptation…1

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Categories to be Considered in Enhancing Adaptive Capacity to CC in the Water Sector

1. Knowledge and Skills Participation
2. Policy Instruments
3. Risk Sharing / Spreading
4. Enhancing Adaptive Capacity via Technological and Structural Change
5. Changes in Uses/Activities/Location

On Practical Adaptation…2 Categories to be Considered…

1. Enhancing Adaptive Capacity via Technology / Structures

a. Storage & Reticulation *(e.g. Surface; Groundwater; System Maintenance; Rainwater Harvesting; Re-Use)*
b. Desalination
c. Flood / Storm Surge Control *(e.g. levees, wave breaks)*
d. Early Warning Systems *(near real-time; medium and long term)*
e. Communication of Forecasts to End Users
f. Operations / Systems Improvements *(e.g. ops rules; retrofitting; wastewater treatment works; sanitation)*
g. Water Demand Management
h. Indigenous Coping
i. Precipitation Enhancement
j. Water Quality / Quantity Monitoring Systems

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On Practical Adaptation…3 Categories to be Considered…

2. Knowledge, Skills and Participation

a. Research and Development

i. Efficient technologies
ii. Upgrading of climate modelling
iii. Improvements to downscaling / RCMs
iv. Fine scale info provision relevant to local managers
v. Improve forecasting skills / dissemination
vi. Development of drought resistant crops

b. Development of Risk Maps / Floodlines

c. Communication / Training / Dissemination

i. Awareness creation at higher decision making level
ii. Awareness creation at operational level
iii. Training at mid-management and local levels

d. Participatory Approach in Decision-Making

i. Establishment of interdepartmental learning platforms
ii. Establishment of an integrated communications system
iii. Creation of ongoing learning platforms btw water users

On Practical Adaptation…4 Categories to be Considered…

3. Policy Instruments

a. International Conventions

b. International Water Agreements

c. International Trade

d. National Water Master Plans

i. National Water Act of 1998
ii. Water Services Act of 1997
iii. National Water Resource Strategy of 2004, 2011
iv. Water for Growth and Development Framework of 2009
v. Catchment Management Strategies
vi. Estuary Management Plans

c. Other National Master Plans

i. National Environmental Management Act
ii. Conservation of Agricultural Resources Act

d. Provincial Strategies

i. Provincial Growth and Development Strategies
ii. Provincial Water Reconciliation Strategies

e. Local Strategies

i. Municipal Bye-Laws

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On Practical Adaptation…5 Categories to be Considered…

3. Risk Sharing / Spreading

a. Private Sector Strategies

i. Insurance

* Primary insurance
* Re-insurance
* Micro-insurance

ii. Banks

* Development Banks
* Private Banks
* Micro-lenders

b. Public Sector Strategies

* Flood and Drought Relief

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On Practical Adaptation…6

Role Players in the SA Water Sector for whom Climate Change Adaptation is Important

1. National Water Planners (e.g. DWA)
2. Regional Water Planners (e.g. CMAs)
3. Bulk Water Suppliers (e.g. Umgeni Water)
4. Water User Associations / Irrigation Boards
5. Municipalities (e.g. eThekwini-Durban)
6. Disaster Risk Management (Nat / Prov / Local)
7. Insurance Industry (e.g. Santam)
8. Irrigated Agriculture (e.g. Pongola Irrig Board)
9. Rainfed Agriculture, incl. Forestry, Livestock
10. Poor Rural Communities
11. Informal Urban Settlements (e.g. Khayalitsha)
12. Individual Households
13. Thermal Electric Power Utilities (e.g. Eskom)
14. Hydro-Electric Power (e.g. Gariep Dam, LHDA)
15. Transport Sector (e.g. SANRAL, Provincial)
16. Aquatic Ecosystems (e.g. Wetlands, estuaries, environmental flows)
17. Terrestrial Ecosystems (e.g. Biodiversity, buffers)

On Practical Adaptation…7

What are we Adapting to in the SA Water Related Sector? Changes in…

1. Flash Floods
2. Regional Floods
3. Agricultural Droughts
4. Hydrological Droughts
5. Heat Waves
6. Surface Water Supply
7. Groundwater Supply
8. Water Quality Deterioration – Seds; Chemical; Biological
9. Water Temperature
10. Design Precipitation
11. Design Hydrology (peaks, hydrographs)
12. Sea Level Rise
13. Storm Surges
14. Environmental Degradation

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Adaptation Options for National Water Planners

ENHANCING ADAPTIVE CAPACITY TECHNOLOGICAL AND STRUCTURAL	ADAPTING TO CHANGES IN . . .	CROSS REFERENCES TO SCHULZE (2011)
• Storage and Reticulation		
- Surface water		
▫ Large Reservoirs	• Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Storm Surges	Not in Report
	Transboundary Flows	Ch 5.4, 5.5, 5.7, 6.2, 7.3, 8.2, 8.3
	Environmental Flows	See Barichievy *et al*. (2010b)
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Enhanced Evaporation	Ch 4.1, 4.2, 8.1
	Threshold Streamflows	Ch 5.5
• Early Warning Systems		
- Short-Term (Days to Weeks)	• Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Water Quality - Chem	Ch 8.3
	Water Quality - Biol	Not in Report
- Medium-Term (Month to Season)	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Recharge	Ch 5.3
	Regional Floods	Ch 7.2, 7.3
- Long-Term (Years to Decades)	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Recharge	Ch 5.3
	Water Quality - Seds	Ch 5.7
	Water Quality - Chem	Ch 8.3
• Operations / System Improvements		
- Reservoir Operations Rules	• Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	DDF - Peak Discharge	Ch 5.6
	DDF - Streamflows	Ch 7.3
	Water Temperature	See Barichievy *et al*. (2010a)
	Water Quality - Chem	Ch 8.3
	Water Quality - Biol	Not in Report
• Water Demand Management	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Recharge	Ch 5.3
	Water Quality - All	Ch 5.7, 8.3
KNOWLEDGE / SKILLS / PARTICIPATION	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Research and Development		
- Efficient Technologies	• All	
- Upgrading of Climate Models	• All	
▫ Improvements to Downscaling / RCMs	• All	
- Improvement of Forecast Skill / Dissemination	• All	
• Development of Risk Maps / Floodlines	• Regional Floods	Ch 7.2, 7.3
	Flash Floods	Ch 5.6, 7.1
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	7.2
	DDF - Discharge	5.6
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
• Communication / Training / Dissemination		
- Awareness Creation at Higher-Decision Making Level	• All	
• Participatory Approach in Decision-Making		
- Establishment of Inter-Departmental Learning Platforms	• All	
- Establishment of Integrated Communication Systems	• All	

POLICY INSTRUMENTS	ADAPTING TO CHANGES IN . . .	CROSS REFERENCES
• International Conventions (e.g. UNFCCC)	• All	
• International Water Agreements		
• National Water Master Plans		
- National Water Act of 1998	• All	
- National Water Resource Strategy	• All	
• Other National Master Plans		
- National Environmental Management Act	• Environmental Flows	See Barichievy *et al*. (2010b)
- Conservation of Agricultural Resources Act	• Water Quality - Seds	Ch 5.7
	Water Quality - Chem	Ch 8.3
• Disaster Management Policies / Plans	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 5.2, 5.4, 7.3
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
RISK SHARING / SPREADING	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Private Sector Strategies		
- Banks		
▫ Development	• All	
CHANGE OF USE / ACTIVITY / LOCATION	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Land Use Measures		
- Adaptive Spatial Planning	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Streamflows	Ch 7.3
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Water Quality - Seds	Ch 5.7
	Water Quality - Chem	Ch 8.3
	Water Quality - Biol	Not in Report
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report

WATER RESEARCH COMMISSION

Adaptation Options for the Insurance Industry (Water related)

ENHANCING ADAPTIVE CAPACITY TECHNOLOGICAL AND STRUCTURAL	ADAPTING TO CHANGES IN . . .	CROSS REFERENCES TO SCHULZE (2011)
• Early Warning Systems		
- Near Real-Time (Hours to Days)	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Rainfall: Short	Ch 7.1
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Heat Waves	See Schulze and Kunz (2010)
	Threshold Rainfalls	Ch 3.6
	Threshold Streamflows	Ch 5.5
- Short-Term (Days to Weeks)	• Regional Floods	Ch 7.2, 7.3
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Heat Waves	See Schulze and Kunz (2010)
	Threshold Rainfalls	Ch 3.6
	Threshold Streamflows	Ch 5.5
- Medium-Term (Month to Season)	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
- Long-Term (Years to Decades)	• Regional Floods	Ch 7.2, 7.3
• Communication of Forecasts to End Users	• Flash Floods	Ch 5.6, 7.1
	Threshold Rainfalls	Ch 3.6
	Threshold Streamflows	Ch 5.5
	Heat Waves	See Schulze and Kunz (2010)
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	Ch 7.2
	DDF - Peak Discharge	Ch 5.6
	Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
• Operations / System Improvements		
- Retrofitting Existing Structures	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
- Precipitation Enhancement	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
KNOWLEDGE / SKILLS / PARTICIPATION	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCE**
• Research and Development		
- Efficient Technologies	• All	
- Upgrading Climate Models		
▫ Fine Scale Information Provision Relevant to Local Water Managers	• All	
- Improvement of Forecast Skill / Dissemination	• All	
• Development of Risk Maps / Floodlines	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
• Communication. Training , Dissemination		
- Awareness Creation at Higher Decision-Making Level	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Heat Waves	See Schulze and Kunz (2010)
POLICY INSTRUMENTS	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Disaster Management Policies / Plans	• All	
RISK SHARING / SPREADING	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Private Sector Strategies		
- Insurance		
▫ Primary Insurers	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
▫ Re-Insurance	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Rainfall: Short	Ch 7.1
	DDF - Rainfall: Long	Ch 7.2
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
▫ Micro-Insurance	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
CHANGE OF USE / ACTIVITY / LOCATION	**ADAPTING TO CHANGES IN . . .**	**CROSS REFERENCES**
• Land Use Measures		
- Conservation Structures	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	DDF - Rainfall: Short	Ch 7.1
	DDF - Streamflows	Ch 7.3
	DDF - Peak Discharge	Ch 5.6
	Storm Surges	Not in Report
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2

Adaptation Options for SA Municipalities

ENHANCING ADAPTIVE CAPACITY TECHNOLOGICAL AND STRUCTURAL	COPING WITH / ADAPTING TO?	CROSS REFERENCES TO SCHULZE (2011)
• Storage and Reticulation		
- Surface water		
▫ Large Reservoirs	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Storm Surges	Ch 5.2
- Groundwater		
▫ Artificial Recharge	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Groundwater Supply	Ch 5.3
▫ Sand Dams	• Flash Floods	Ch 5.6, 7.1
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
- System Maintenance		
▫ Supply Leakage Control	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Water Quality	Ch 5.7, 8.3
- Water Re-use / Recycling	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
• Desalination	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
• Flood / Storm Surge Control		
- Structures (i.e. Levees, Sand Bags, Wave Breaks, Planting)	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
• Early Warning Systems		
- Near Real-Time (Hours to Days)	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
- Short-Term (Days to Weeks)	• Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
- Medium-Term (Month to Season)	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
- Long-Term (Years to Decades)	• Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
• Communication of Forecasts to End Users	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
• Water Quality and Quantity Monitoring Systems	• ?	
• Operations / System Improvements		
- Reservoir Operations Rules	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
- Retrofitting Existing Structures	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
• Water Demand Management	• Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
	Hydrological Droughts	Ch 5.5, 6.1, 6.2, 8.1, 8.2
	Sea Level Rise	Not in Report
	Surface Water Supply	Ch 5.2, 5.4, 6.1, 6.2, 8.1, 8.4
	Groundwater Supply	Ch 5.3
	Water Quality	Ch 5.7, 8.3

KNOWLEDGE / SKILLS / PARTICIPATION	COPING WITH / ADAPTING TO?	CROSS REFERENCES
• Research and Development		
- Efficient Technologies	• All	
- Upgrading of Climate Models	• All	
▫ Improvements to Downscaling / RCMs	• All	
▫ Fine Scale Information Provision Relevant to Local Water Managers	• All	
- Improvement of Forecast Skill / DisseminatIon	• All	
• Communication / Training / Dissemination	• All	
- Awareness Creation at Operations Level (e.g. Senior Municipal Officials re. budget allocation and future special planning)		
- Training at Local Level (e.g. Municipal WWT operators)		
• Participatory Approach in Decision-Making		
- Creations of Ongoing Learning and Communication Platforms between Main Water Users (e.g. WRC Reference Group meetings)		

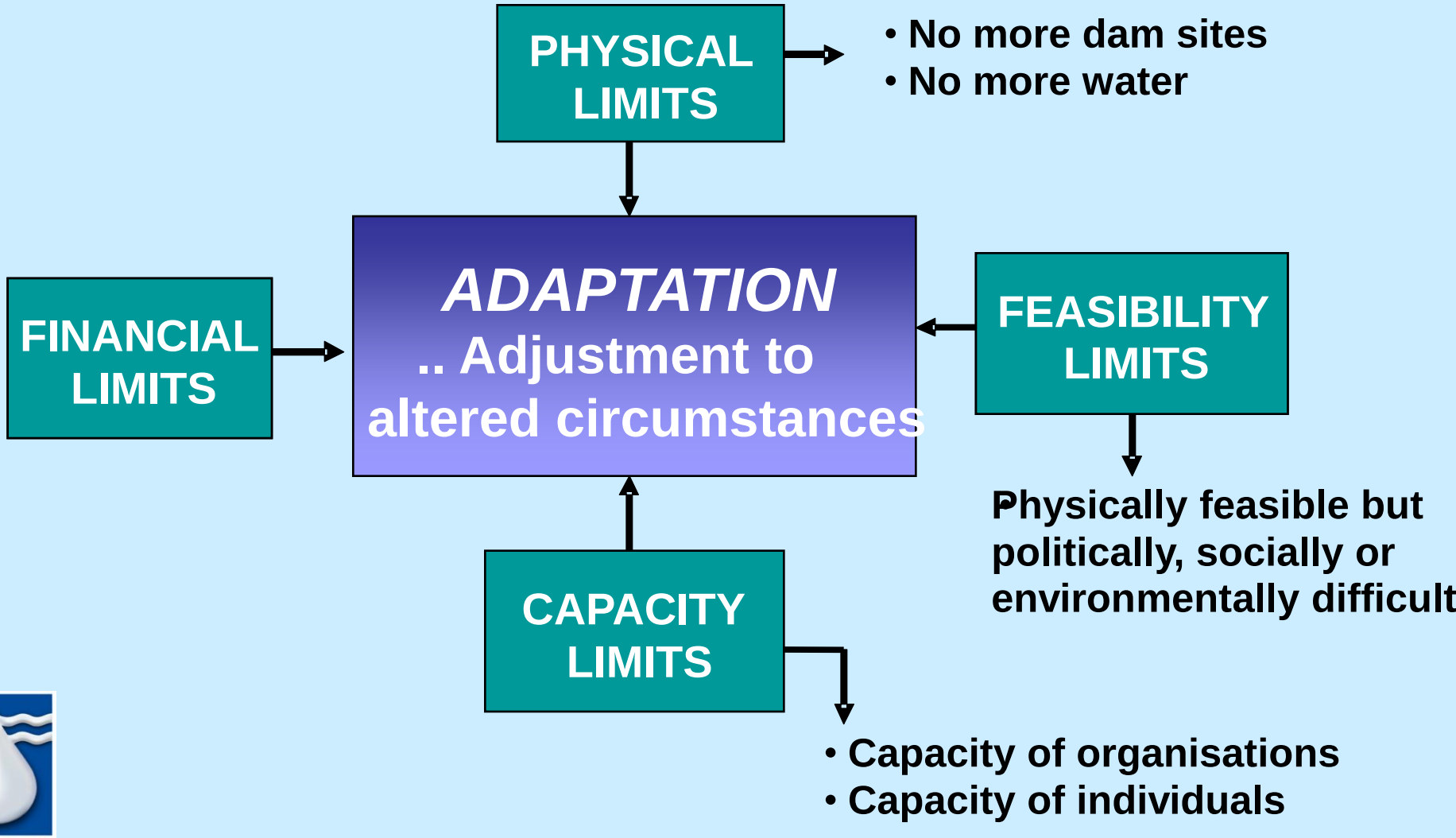
POLICY INSTRUMENTS	COPING WITH / ADAPTING TO?	CROSS REFERENCES
• National Water Strategies		
- Catchment Management Strategies		
- River Management Plans		
• Other National Strategies		
- Integrated Development Plans (IDPs)		
• Provincial Strategies		
- Provincial Growth and Development Strategies		
• Local Strategies		
- Municipal Bye-Laws		
• Disaster Management Policies / Plans		

RISK SHARING / SPREADING	COPING WITH / ADAPTING TO?	CROSS REFERENCES
• Private Sector Strategies		
- Insurance		
▫ Re-Insurance	• Regional Floods	Ch 7.2, 7.3
	Flash Floods	Ch 5.6, 7.1

CHANGE OF USE / ACTIVITY / LOCATION	COPING WITH / ADAPTING TO?	CROSS REFERENCES
• Land Use Measures		
- Conservation Structures	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
	Agricultural Droughts	Ch 4.2, 6.1, 6.2, 8.2
- Adaptive Spatial Planning	• Flash Floods	Ch 5.6, 7.1
	Regional Floods	Ch 7.2, 7.3
	Sea Level Rise	Not in Report
	Storm Surges	Not in Report
- Alien Invasive Clearing Activities		
• Maintaining or Re-establishment of Natural Capital (e.g. wetlands, buffers etc)		

WATER RESEARCH COMMISSION

WE NEED TO RECOGNISE THE COUNTRY'S LIMITS TO ADAPTATION



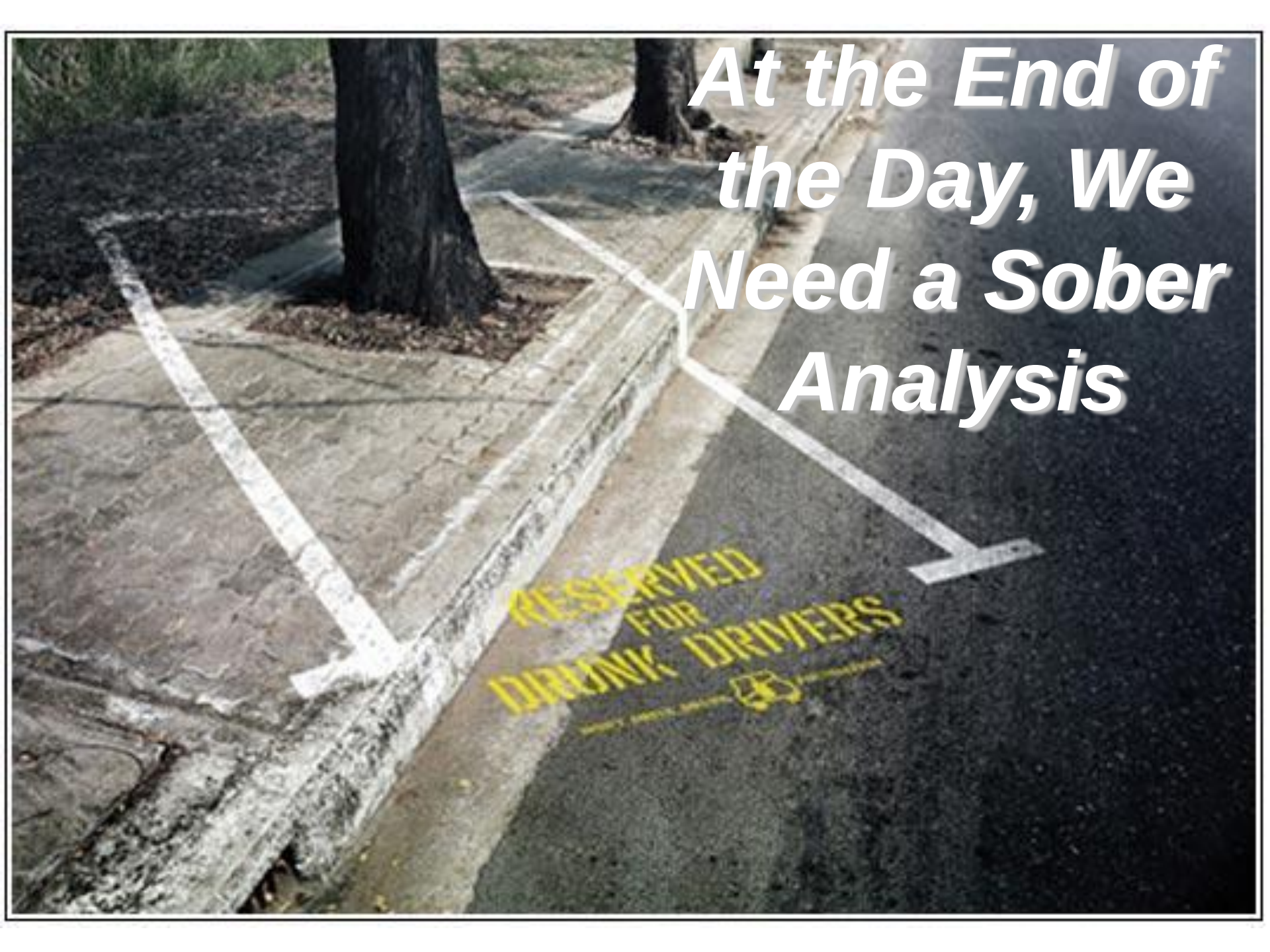
WATER RESEARCH COMMISSION

After Arnell (2005)

Teamwork is what we need

We need sustained DOERS, not only transient CONCEPTUALISERS and MANAGERS

WATER RESEARCH COMMISSION


At the End of the Day, We Need a Sober Analysis
RESERVED FOR DRUNK DRIVERS