Modelling the Economic Impacts of Climate Change in South Africa

aurecon

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Economics of Adaptation to Climate Change

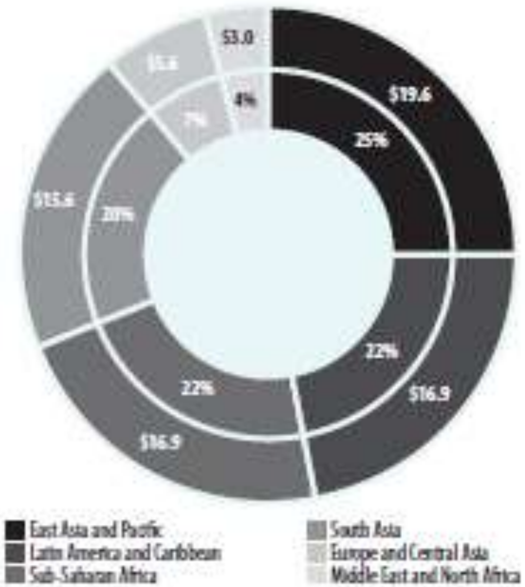
The Costs to Developing Countries of Adapting to Climate Change (WB,2010)

Overall, the study estimates that the ***cost between 2010 and 2050 of adapting to an approximately 2°C warmer world by 2050 is in the range of $75 billion to $100 billion a year*** (table 1). This range is of the same order of magnitude as the foreign aid that developed countries now give developing countries each year, but it is still a very low percentage of the wealth of countries (measured by their GDP).

FIGURE 2

East Asia and Pacific has the highest cost of adaptation in the drier scenario, followed by Latin America and the Caribbean and Sub-Saharan Africa

Total annual cost of adaptation and share of costs for Commonwealth Scientific and Industrial Research Organization (CSIRO) scenario, by region ($ billions at 2005 prices, no discounting)



Source: Economics of Adaptation to Climate Change study team.

Economics of Adaptation to Climate Change

- Key impact/adaptation channels (WB, 2010).

Sector	United Nations Framework Convention on Climate Change (2007)	Economics of Adaptation to Climate Change study: National Centre for Atmospheric Research (NCAR), wettest scenario	Economics of Adaptation to Climate Change study: Commonwealth Scientific and Industrial Research Organization (CSIRO), driest scenario
Infrastructure	2–41	29.5	13.5
Coastal zones	5	30.1	29.6
Water supply and flood protection	9	13.7	19.2
Agriculture, forestry, fisheries	7	7.6	7.3
Human health	5	2	1.6
Extreme weather events	—	6.7	6.5
Total	28–67	89.6	77.7

- Serious gap in coverage of ecosystems services.
  - One estimate puts this at \$12 - \$22 bn/a (Palmer et al, 2009)

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Economics of Adaptation to Climate Change

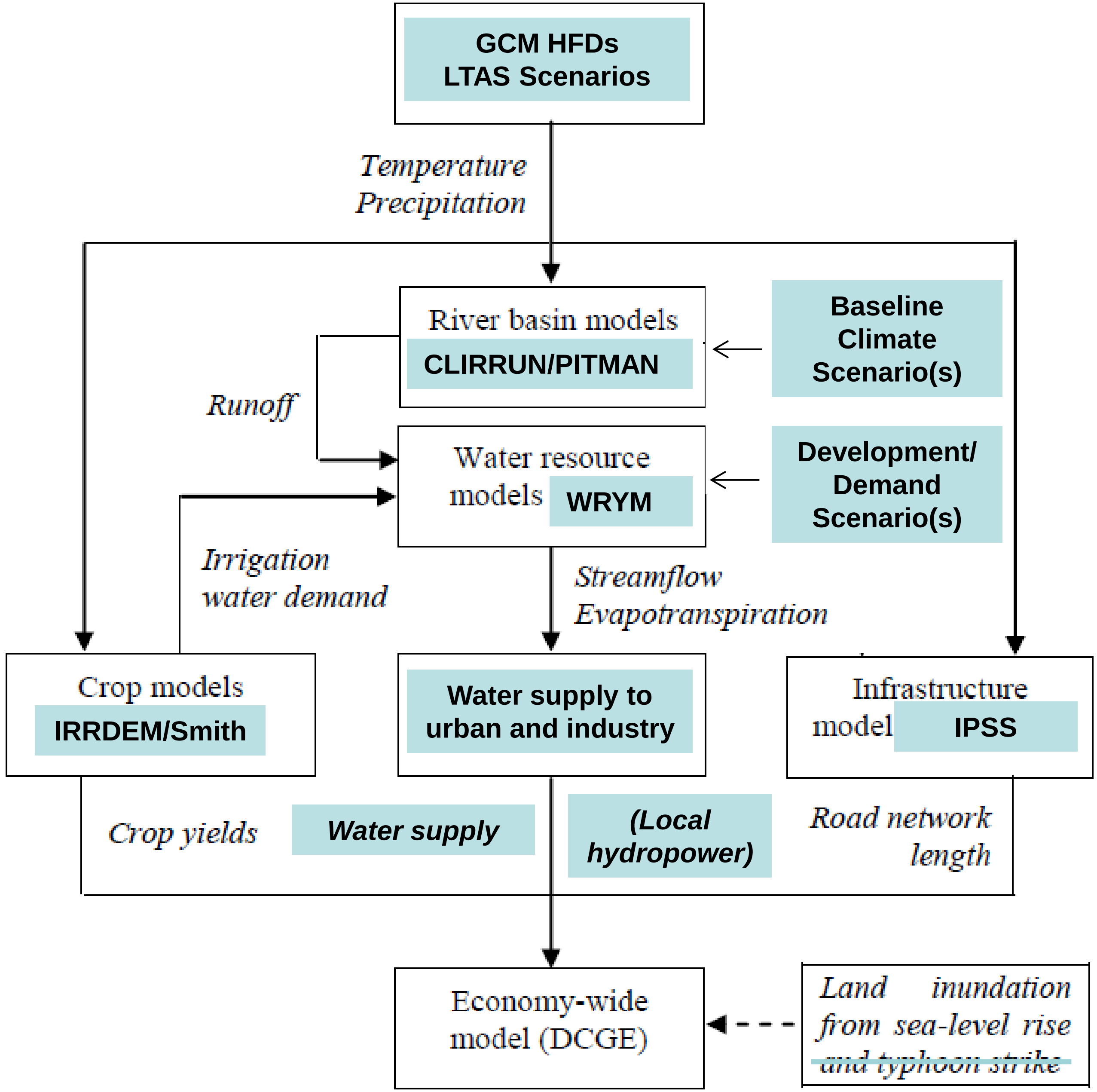
- Key Lessons and Recommendations (WB, 2010)
  1. Adaptation to a 2 C warmer world will be costly (but not impossible, i.e. relatively small % GDP)
  2. The world cannot afford to neglect mitigation. Adaptation minimizes the impacts of CC, but it does not address the causes/drivers of climate change.
  3. Development is imperative (it will address many of the adaptation concerns), but must take a new form.
- Possible additional messages
  1. There are significant spatial/regional variations.
  2. There are likely to be winners and losers from CC

Our Study Objectives

- **High-level, first-order, overview assessment** of the potential economic impacts of climate change on the national economy for South Africa by 2050.
- Integrated modelling:
  - Irrigation, hydropower and water related infrastructure
  - Roads investments and maintenance
  - Agricultural crop yields
  - Sea-level rise on coastal infrastructure
- Integrated through a water based General Equilibrium Model (GEM) for SA at sub-national (WMA) scale.
- Current work for NT/NPC but being extended to LTAS.
- Look at some development and adaptation scenarios.

Integrated Modeling Framework

ADJUSTED FOR RSA MODELS



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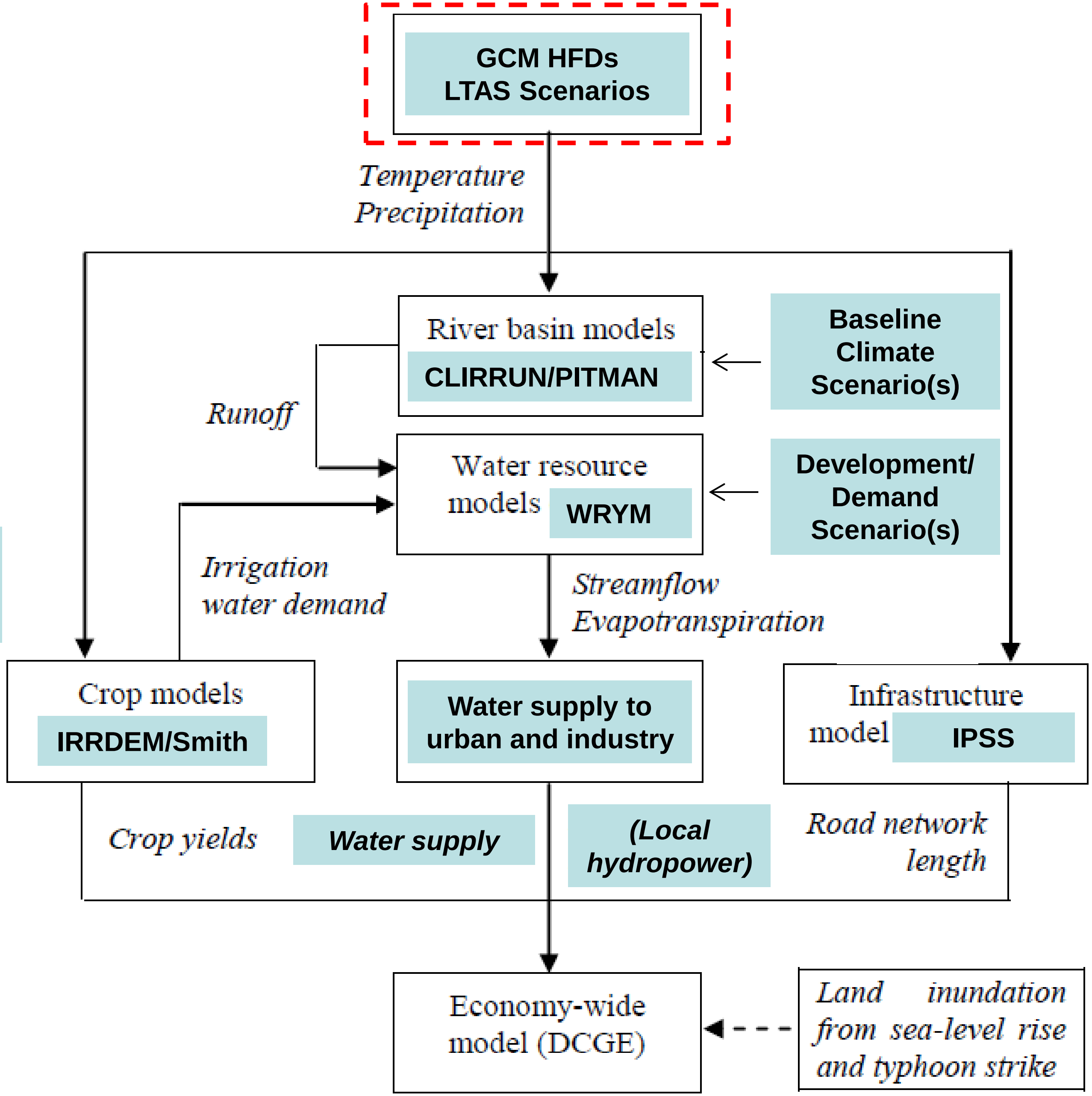

Hybrid Frequency Distributions (HFD)

- The HFDs are outputs from the MIT Integrated Global Systems Model (IGSM) (Sokolov et al, 2009)
- Generates latitudinal impacts under multiple scenarios that are extended through the use of climate change pattern kernals.
- Results in +6800 possible climate futures for the globe.
- These are reduced to 367 through quadrature thinning process.
- Different emissions scenarios including the Unconstrained Emission (UCE) and Level 1 Stablizaition (L1S) scenarios.
- Provides a **probabilistic** estimate of potential climate change impacts and risk that speaks to decision makers.
- Have been used for other similar impacts assessments in Africa.
- The HFDs encompass the range of LTAS future climate scenarios.

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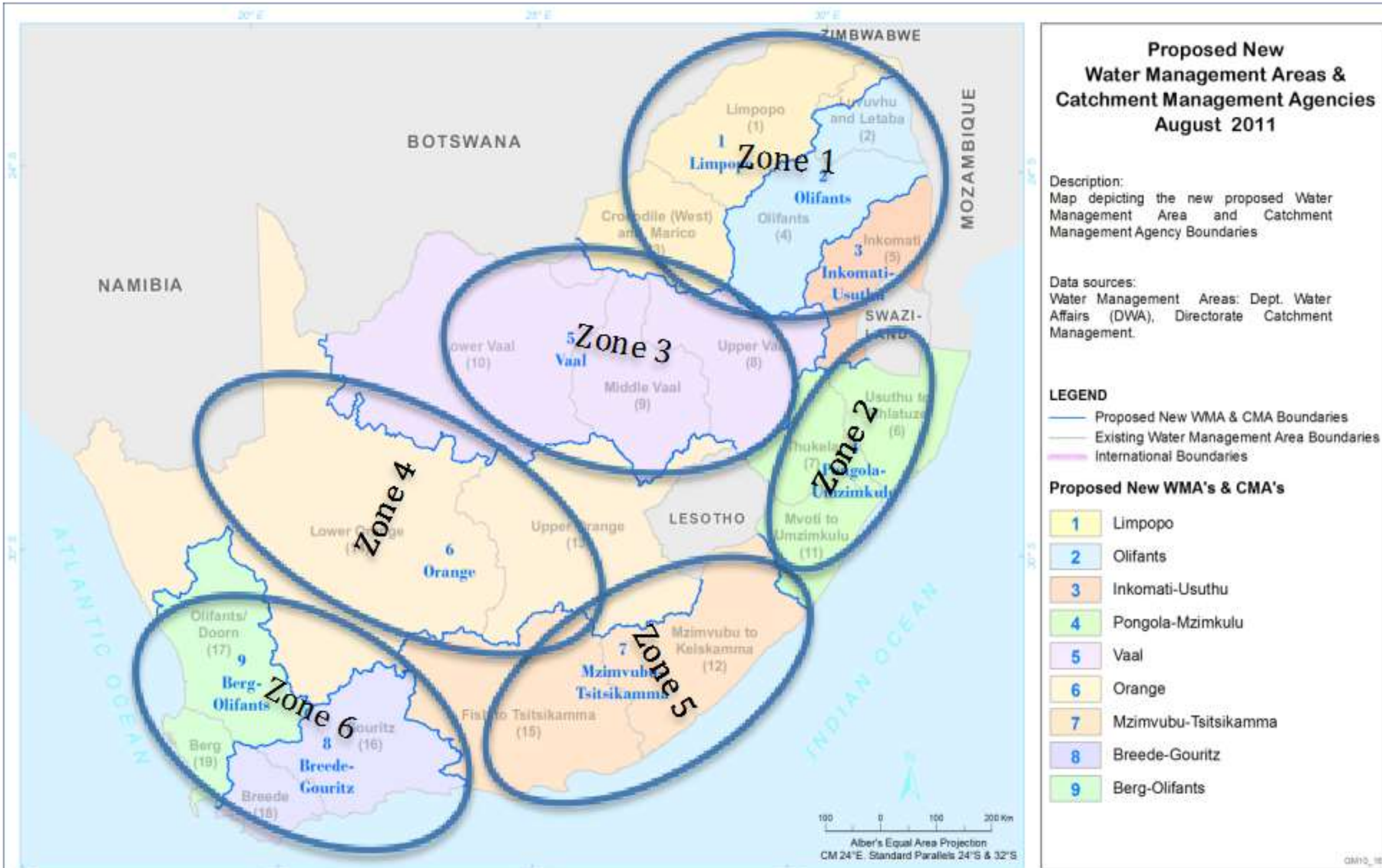
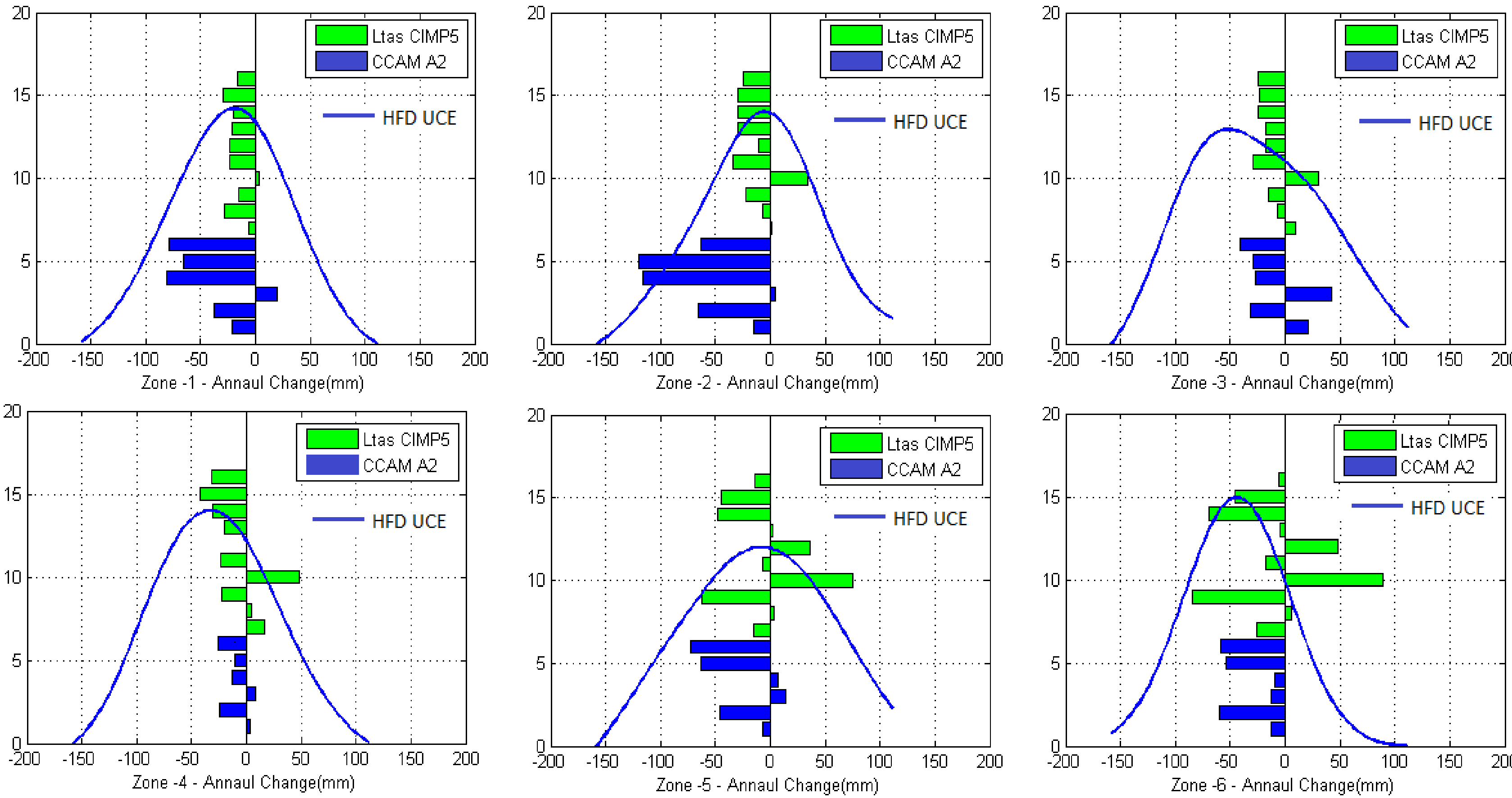


Proposed New
Water Management Areas &
Catchment Management Agencies
August 2011
Description:
Map depicting the new proposed Water Management Area and Catchment Management Agency Boundaries
Data sources:
Water Management Areas: Dept. Water Affairs (DWA), Directorate Catchment Management.
LEGEND
Proposed New WMA & CMA Boundaries
Existing Water Management Area Boundaries
International Boundaries
Proposed New WMA's & CMA's
1 Limpopo
2 Olifants
3 Inkomati-Usuthu
4 Pongola-Mzimkulu
5 Vaal
6 Orange
7 Mzimvubu-Tsitsikamma
8 Breede-Gouritz
9 Berg-Olifants
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
ZIMBABWE
BOTSWANA
NAMIBIA
MOZAMBIQUE
SWAZI-LAND
LESOTHO
ATLANTIC OCEAN
INDIAN OCEAN
Limpopo (1)
Luvuvhu and Letaba (2)
Olifants (4)
Inkomati (5)
Lower Vaal (10)
Upper Vaal (8)
Middle Vaal (9)
Usuthu to Mhlatuze (6)
Thukela (7)
Mvoti to Umzimkulu (11)
Upper Orange (13)
Olifants/ Doorn (17)
Mzimvubu to Keiskamma (12)
Fish to Tsitsikamma (15)
Gouritz (16)
Berg (19)
Breede (18)
Limpopo
Olifants
Inkomati-Usuthu
Vaal
Pongola-Mzimkulu
Orange
Mzimvubu-Tsitsikamma
Berg-Olifants
Breede-Gouritz
100 0 100 200 Km
Alber's Equal Area Projection
CM 24°E. Standard Parallels 24°S & 32°S

Comparison of Hybrid Frequency Distributed (HFD) with the LTAS climate scenarios for the six hydrozones of SA.



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Integrated Modeling Framework

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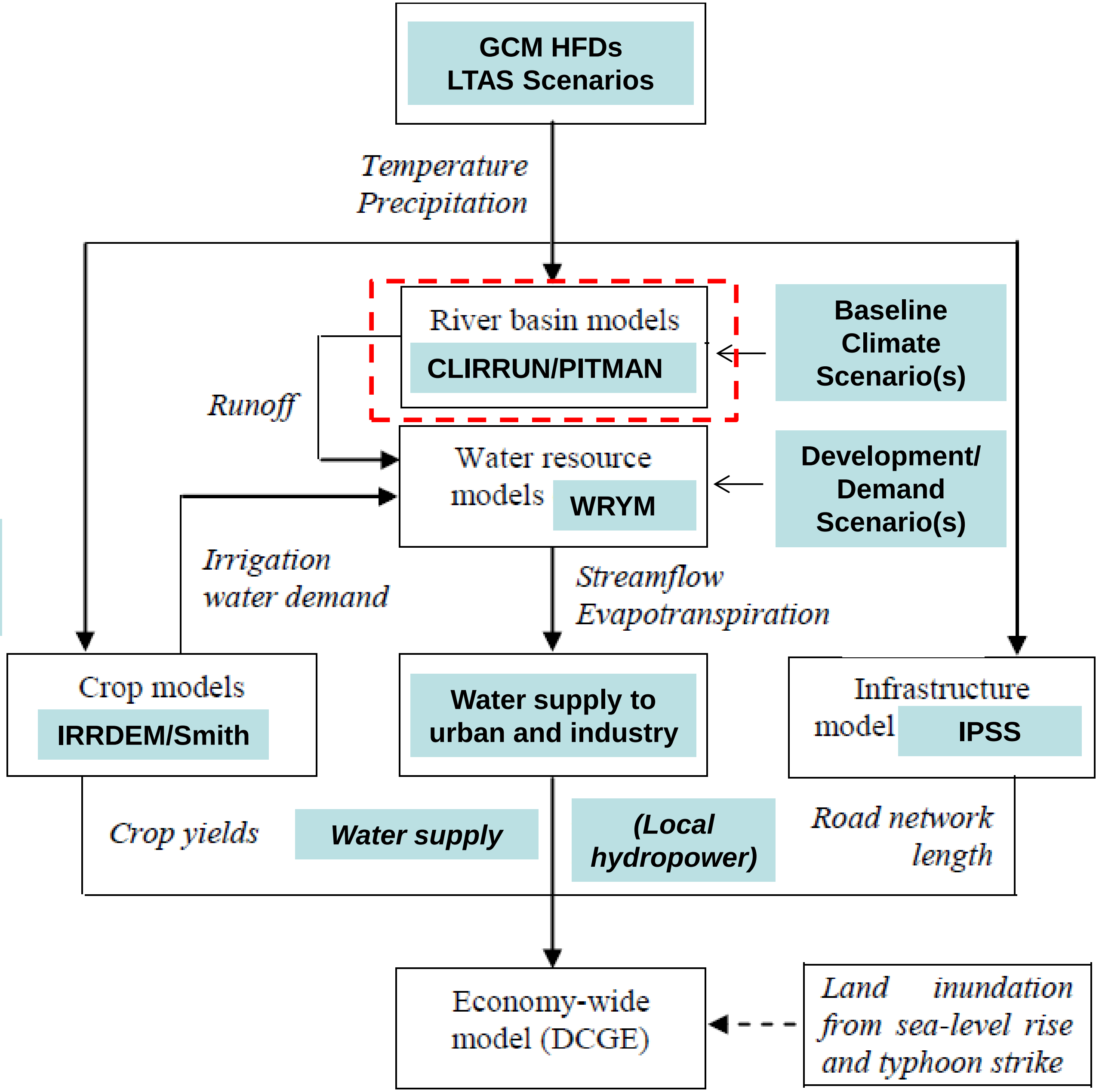
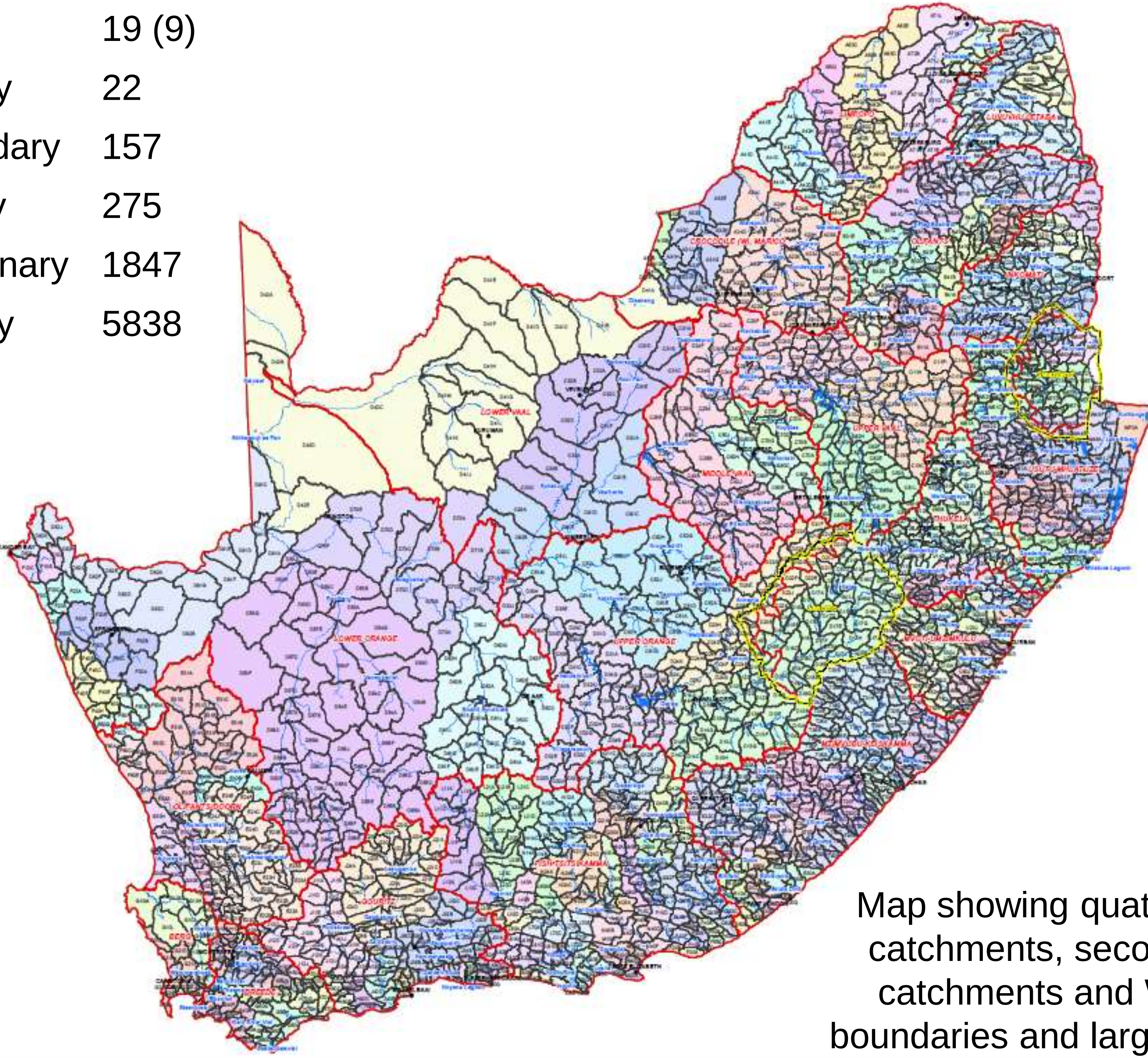


Modelling Impacts on Catchment Runoff

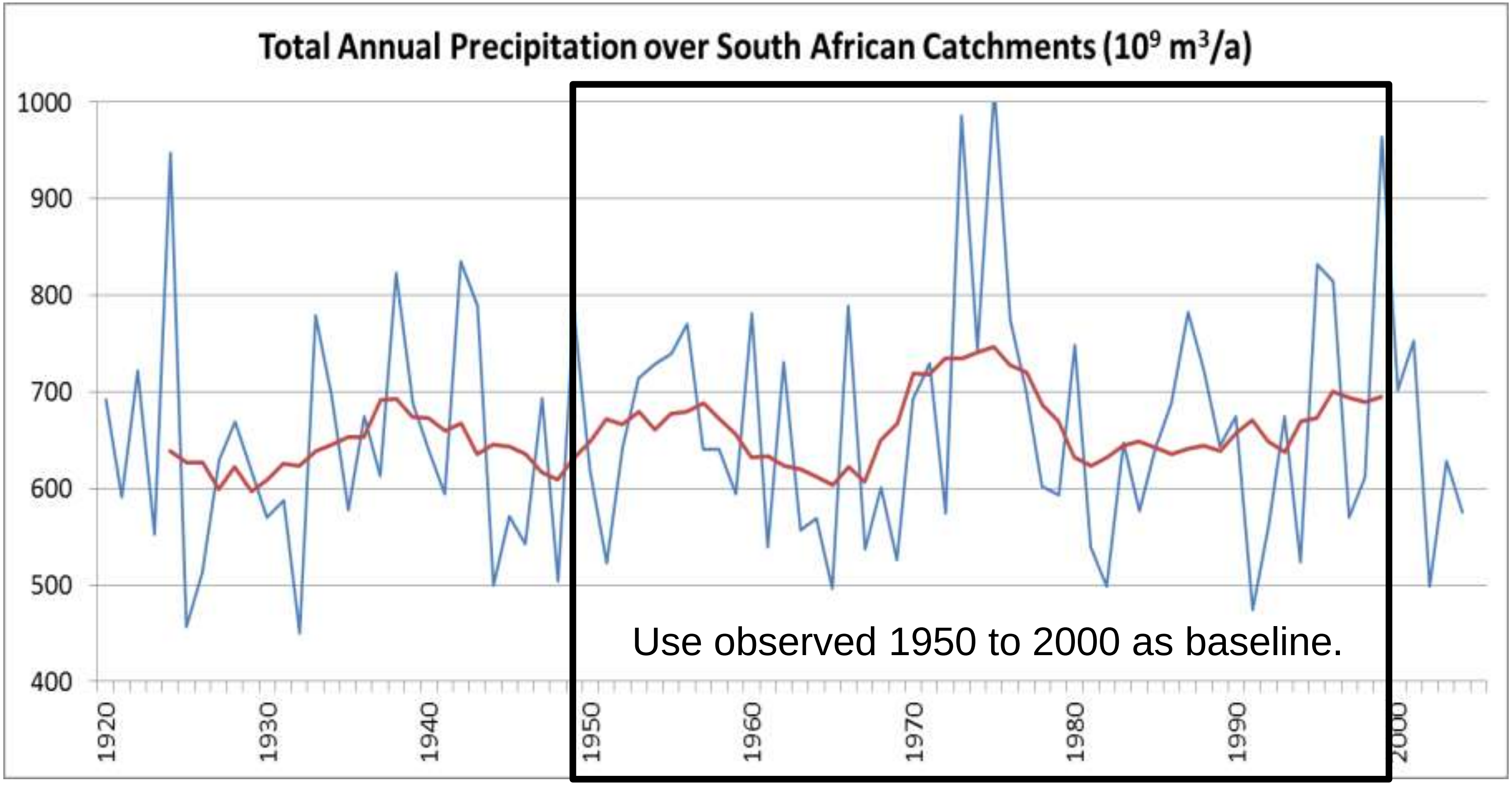
- Incorporate Pitman model in CliRUN framework
  - Monthly rainfall-run off model developed in SA.
  - Standard model still used for water resources in SA.
  - Parameters already calibrated for SA catchments.
  - Generates naturalised runoff at quaternary catchment scale from monthly Precipitation and Evaporation.
  - Model recreates WR90 natural flow sequences.
  - Configured to run multiple climate scenarios (+450) using the CliRUN modelling framework.
  - Aggregate results to secondary catchment scale as inputs to national configuration of WRYM.

WMAs	19 (9)
Primary	22
Secondary	157
Tertiary	275
Quaternary	1847
Quinary	5838

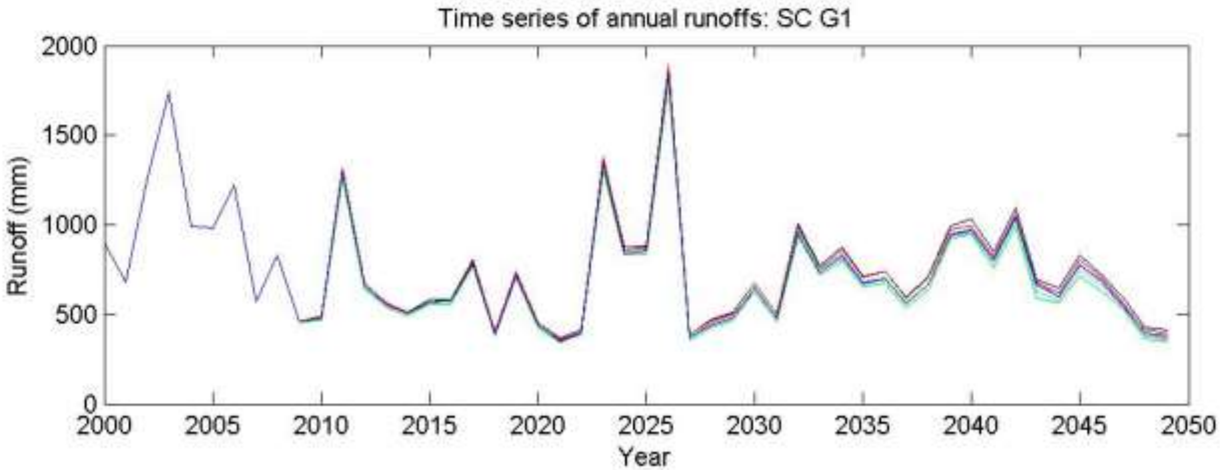


Map showing quaternary catchments, secondary catchments and WMA boundaries and large dams.

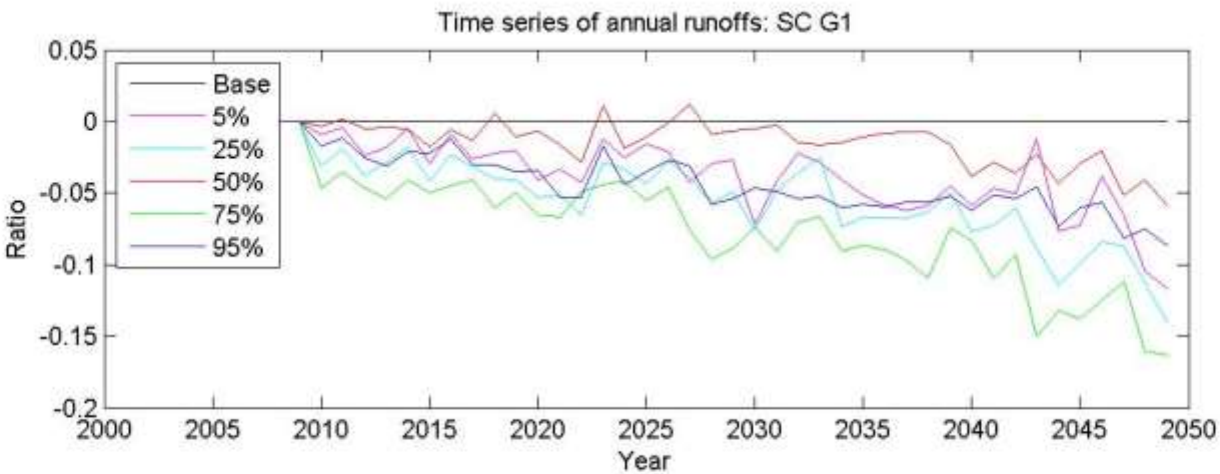
Selection of Baseline Scenario



Model Output: Monthly time series data



- SC G1
- Berg River
- Berg WMA
- Western Cape
- Winter Rainfall
- Hydrozone: 3



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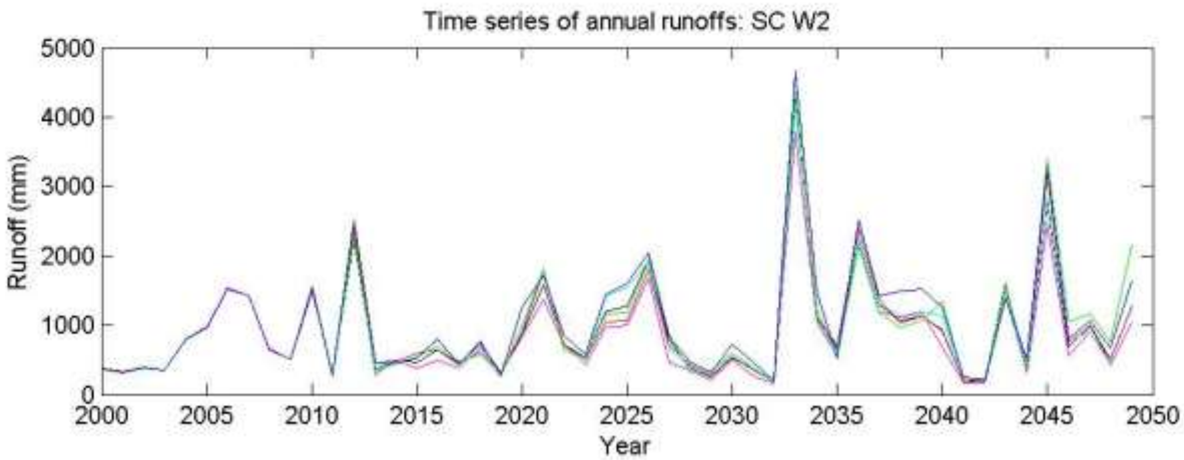
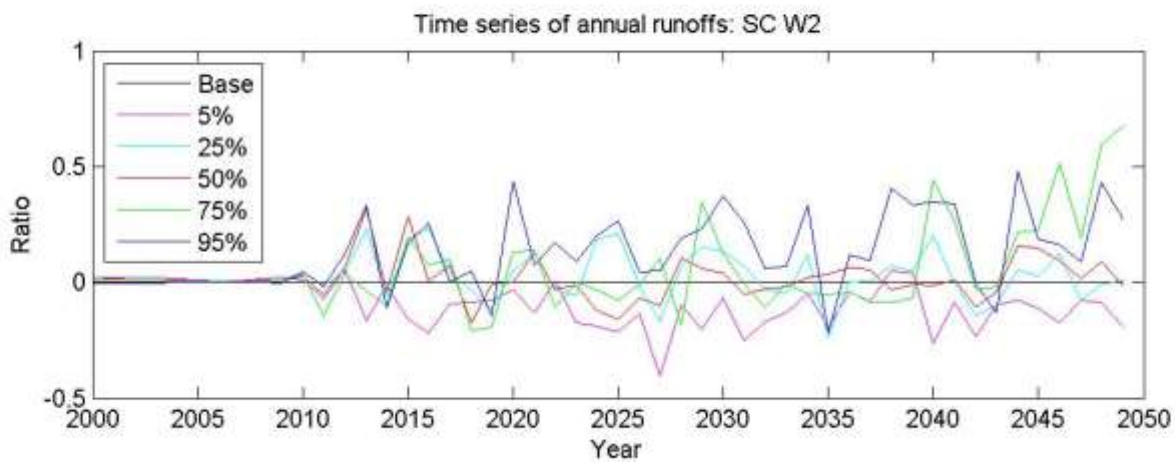


- SC W2
- Black Mfulozi River
- Usutu to Mhlatuze
- KwaZulu Natal
- Summer Rainfall
- Hydrozone: 2



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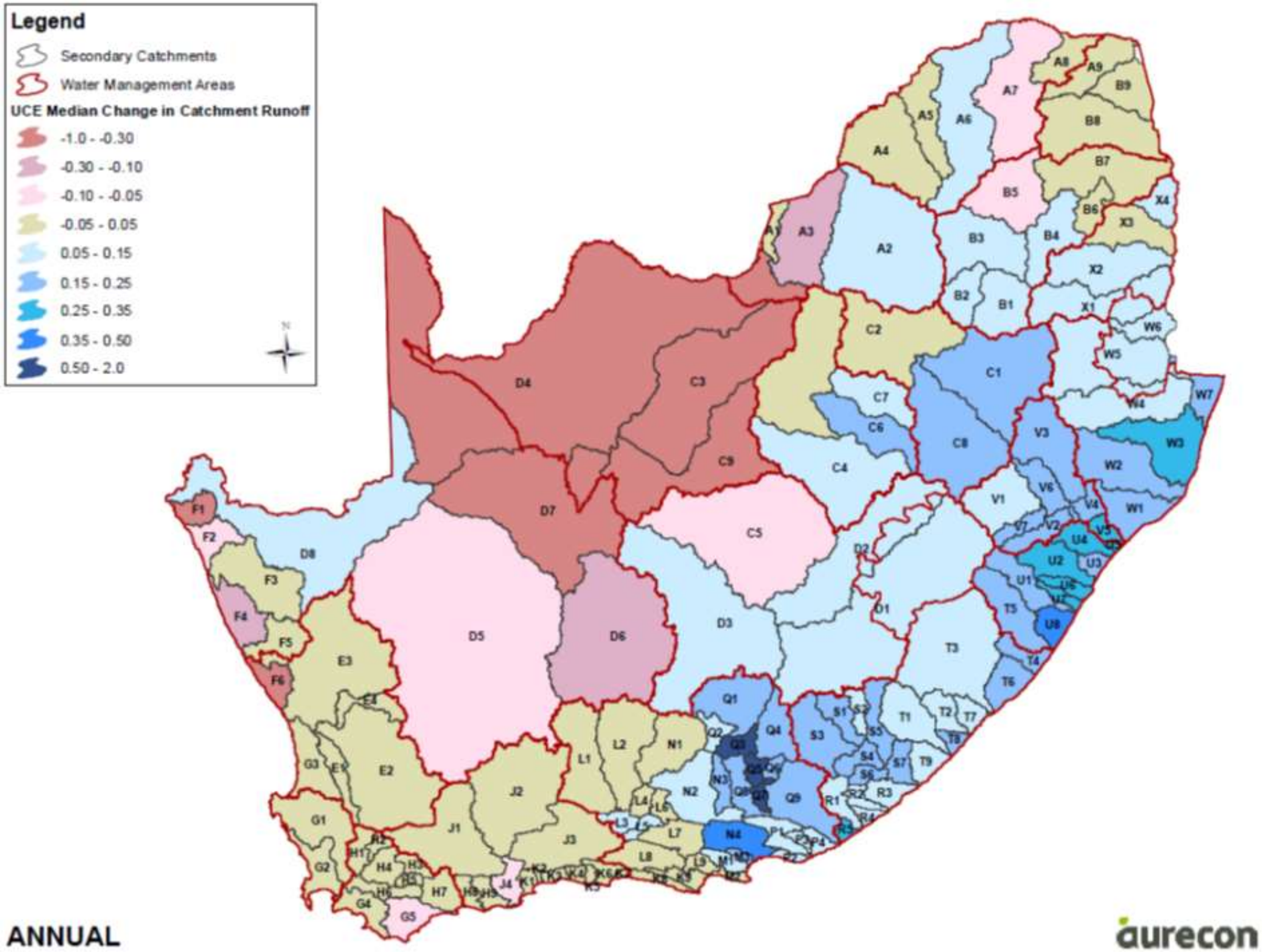
Spatial variation in median impacts of the UCE scenario on Annual Runoff (2040-50)



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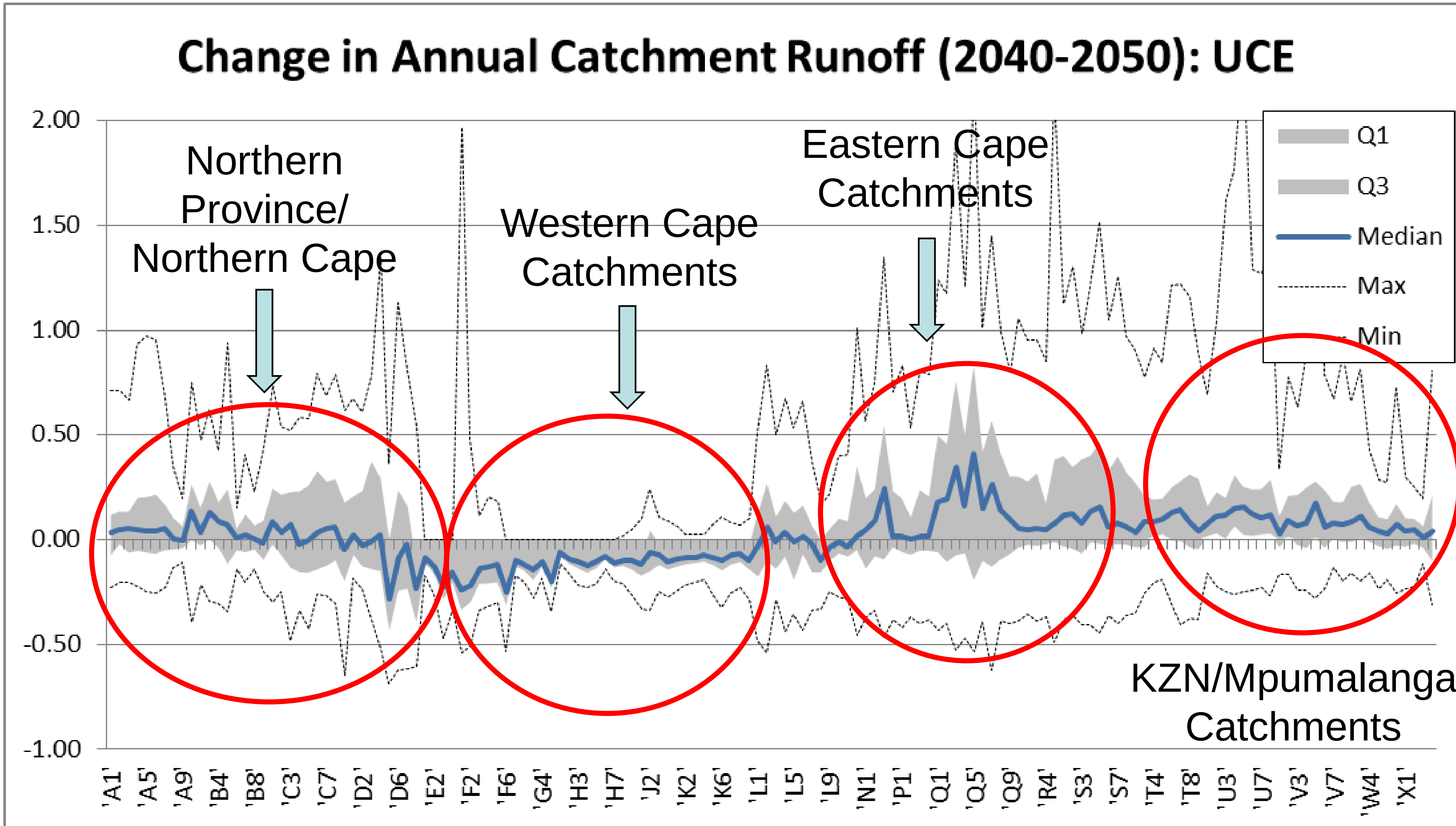
Impacts on MAR for Secondary Catchments: Unconstrained Emissions Scenario (UCE)



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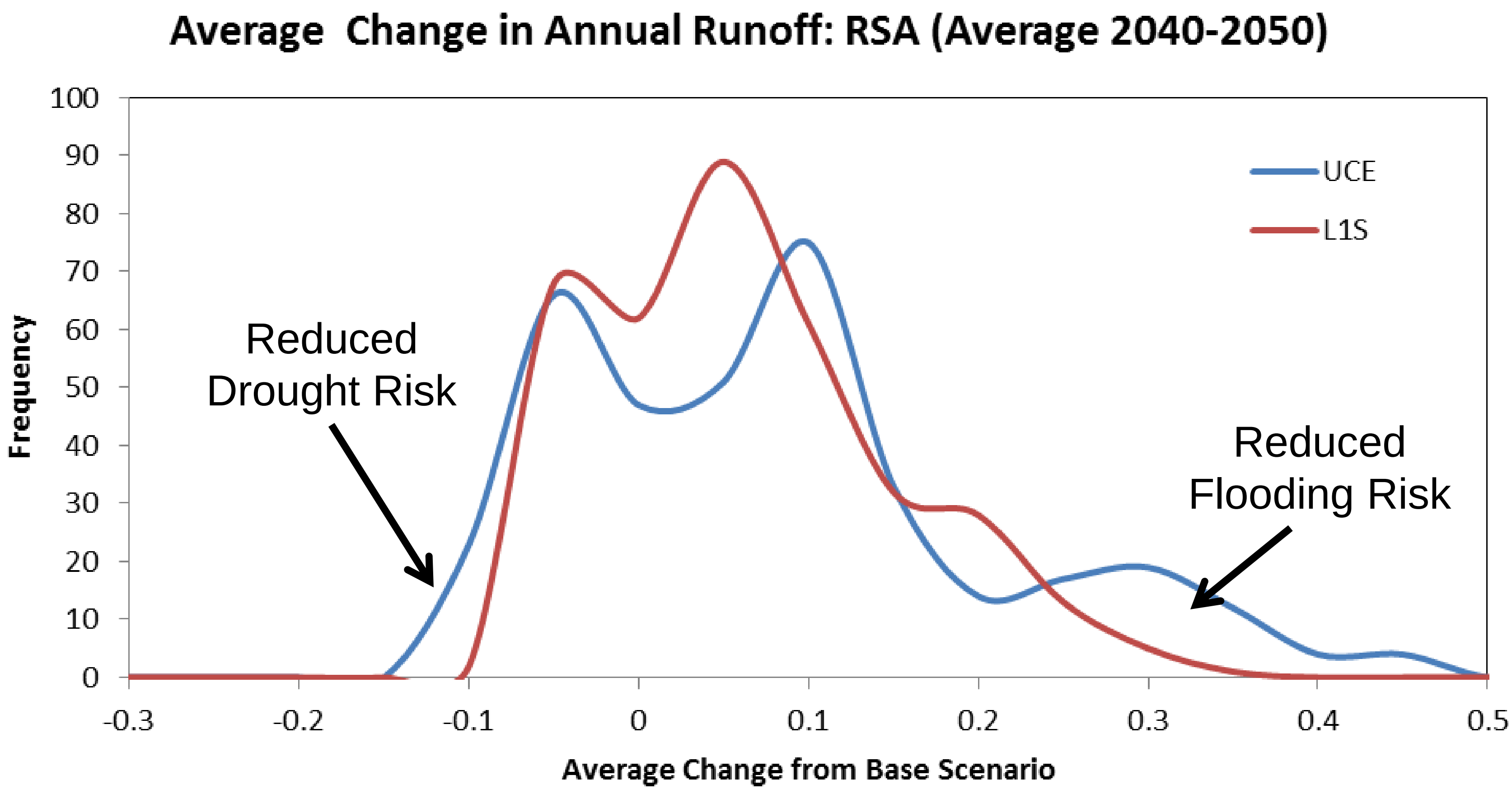
Impact on Annual Runoff for the Country



Integrated Modeling Framework

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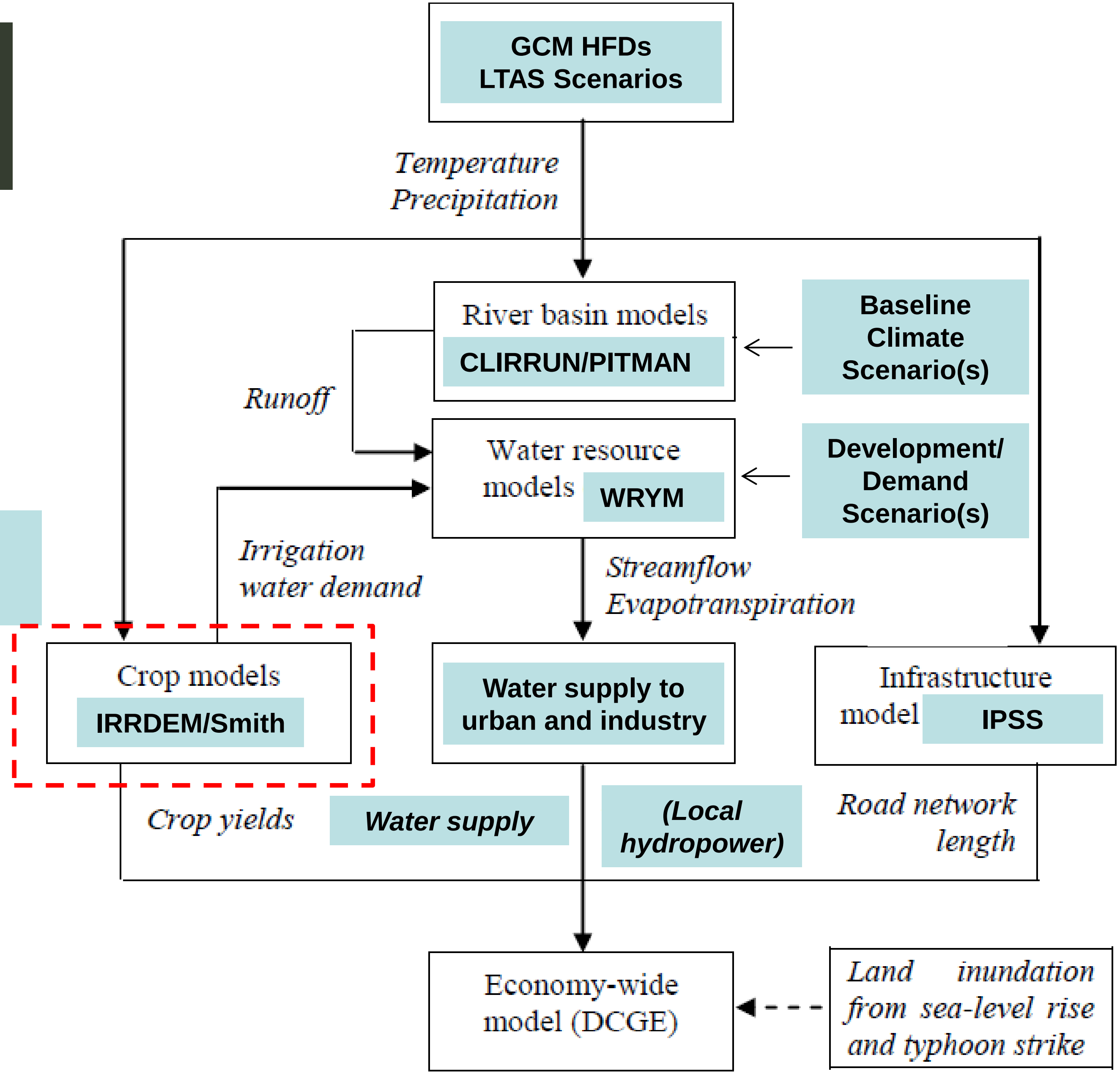
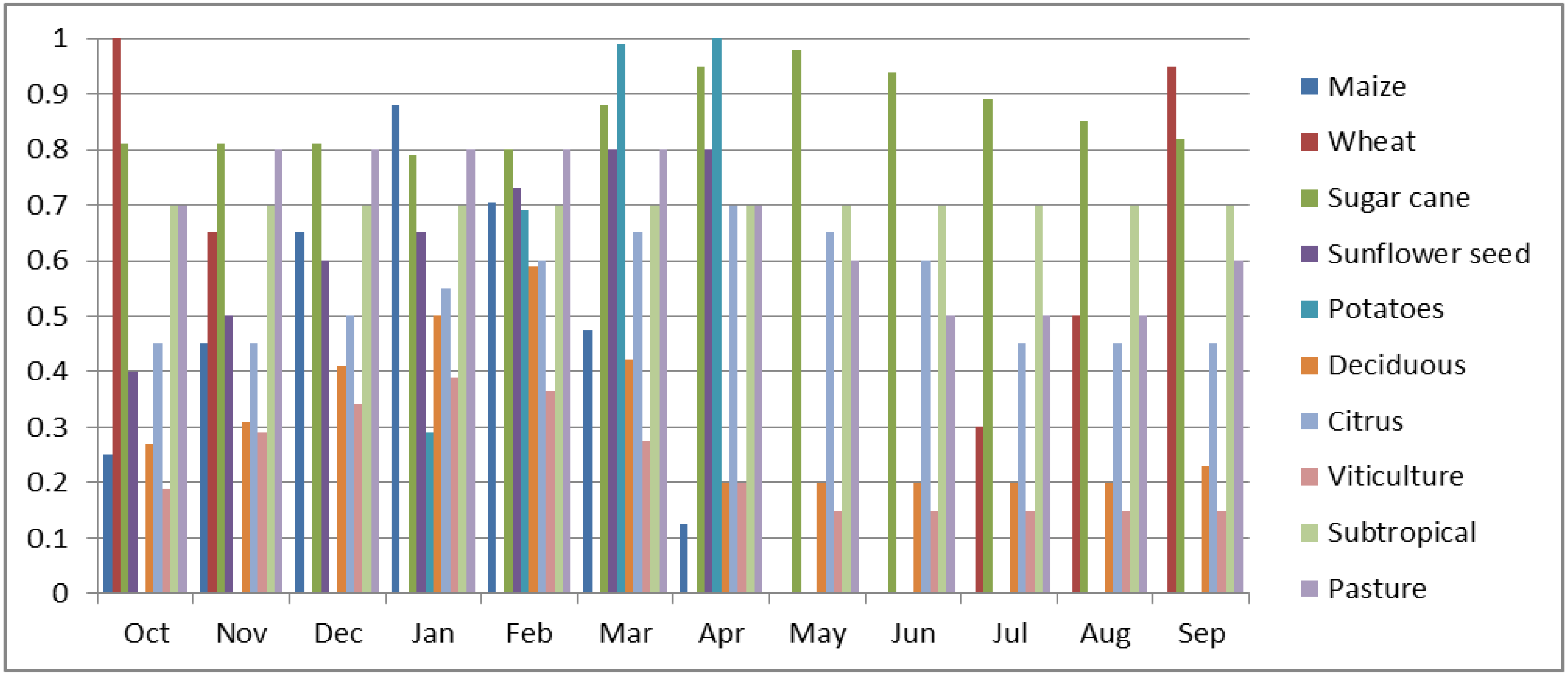


Irrigation Demands

- Use estimate of **CURRENT** crop areas and CURRENT proportional crop mix to get baseline:
  - Current crop mix determine from 2002 Commercial Census of Agriculture (CCA) at Municipal Scale.
  - Reconfigured to QC scale based on National Land Cover Database (NLCD).
  - Used to derive composite crop factors for each QC.
- WR90 average monthly crop factors (K_c)
- Simple water supply deficit model (IRRDEM):
  - Demand (Mm^3) = [(K_c x Evap) – (E_f x Precip)] x Area

General Monthly Crop Factors (WR90)



- Simple water supply deficit model:
  - Demand (Mm^3) = [(K_c x Evap) – (E_f x Precip)] x Area

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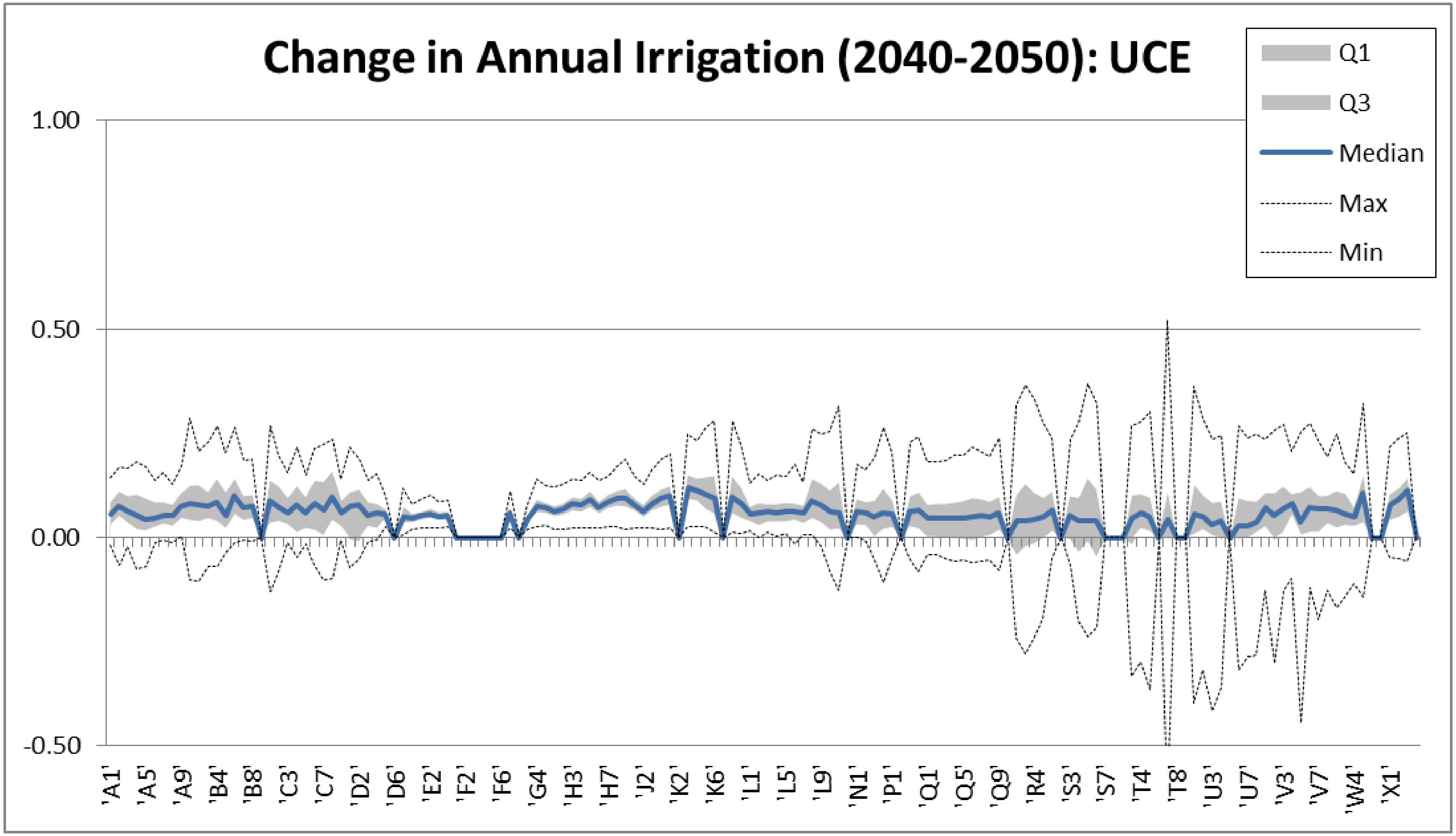
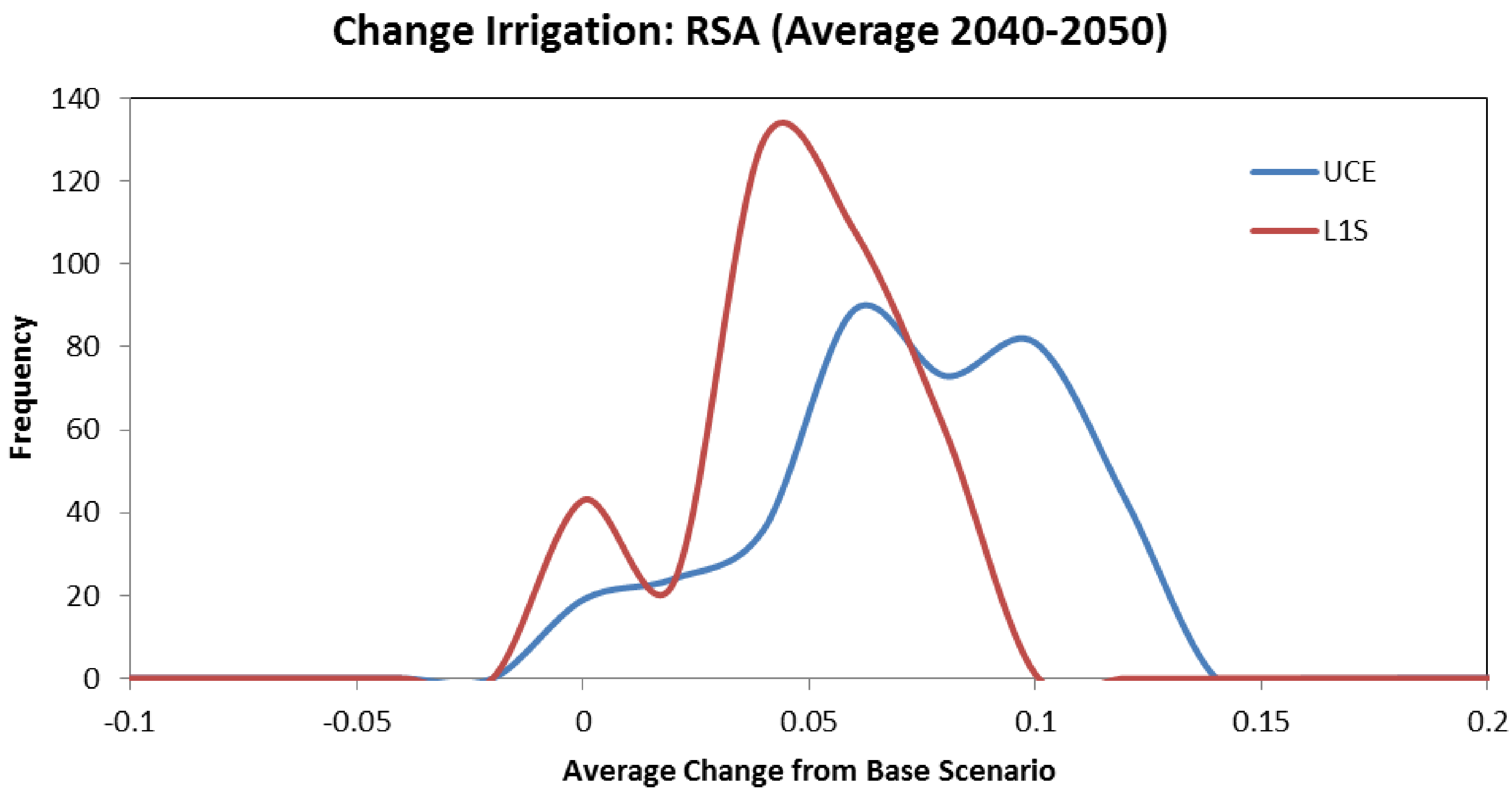
Impacts on Irrigation Demand: UCE



Impacts on Irrigation Demand: UCE v L1S



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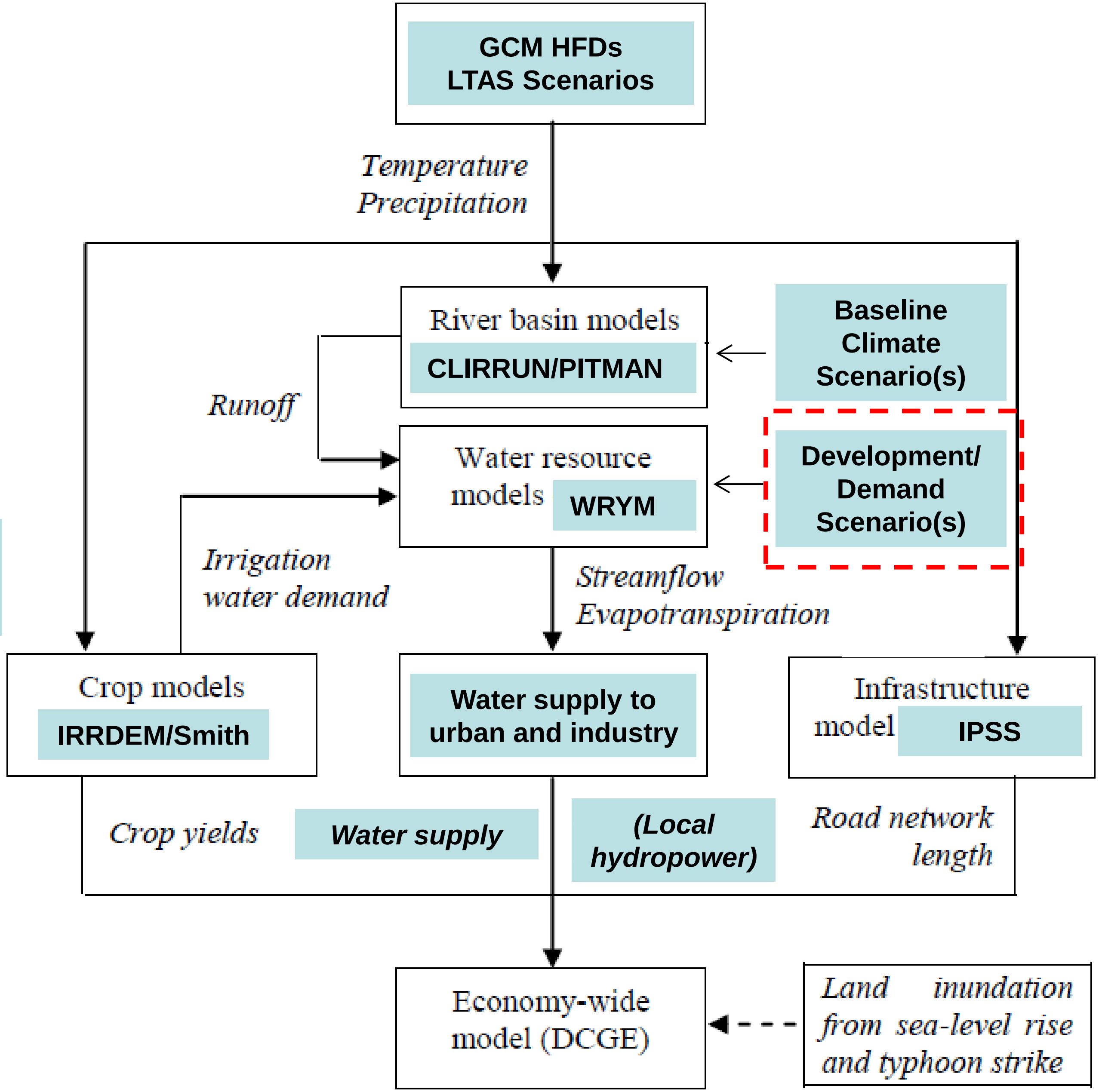

Baseline Scenario Assumptions

- UN median population growth rate to 2050.
- Future growth spatially distributed as observed 2001 to 2010.
- Current estimates of per capita demand – direct and indirect urban use - additional growth met through efficiencies gains.
- Bulk supply (mining, large industry, power) grows at 1% per year in current locations (i.e. disconnect from GDP growth).
- Additional bulk demands in Northern Province to account for new power stations and new mining developments.
- No increase in irrigated area/supply (as per DWA planning).
- Current baseline estimates of SFRA due to forestry and IAPs
- Desktop level Environmental Water Requirement enforced.
- Includes planned future dams (Smithfield, Polihale Dam)

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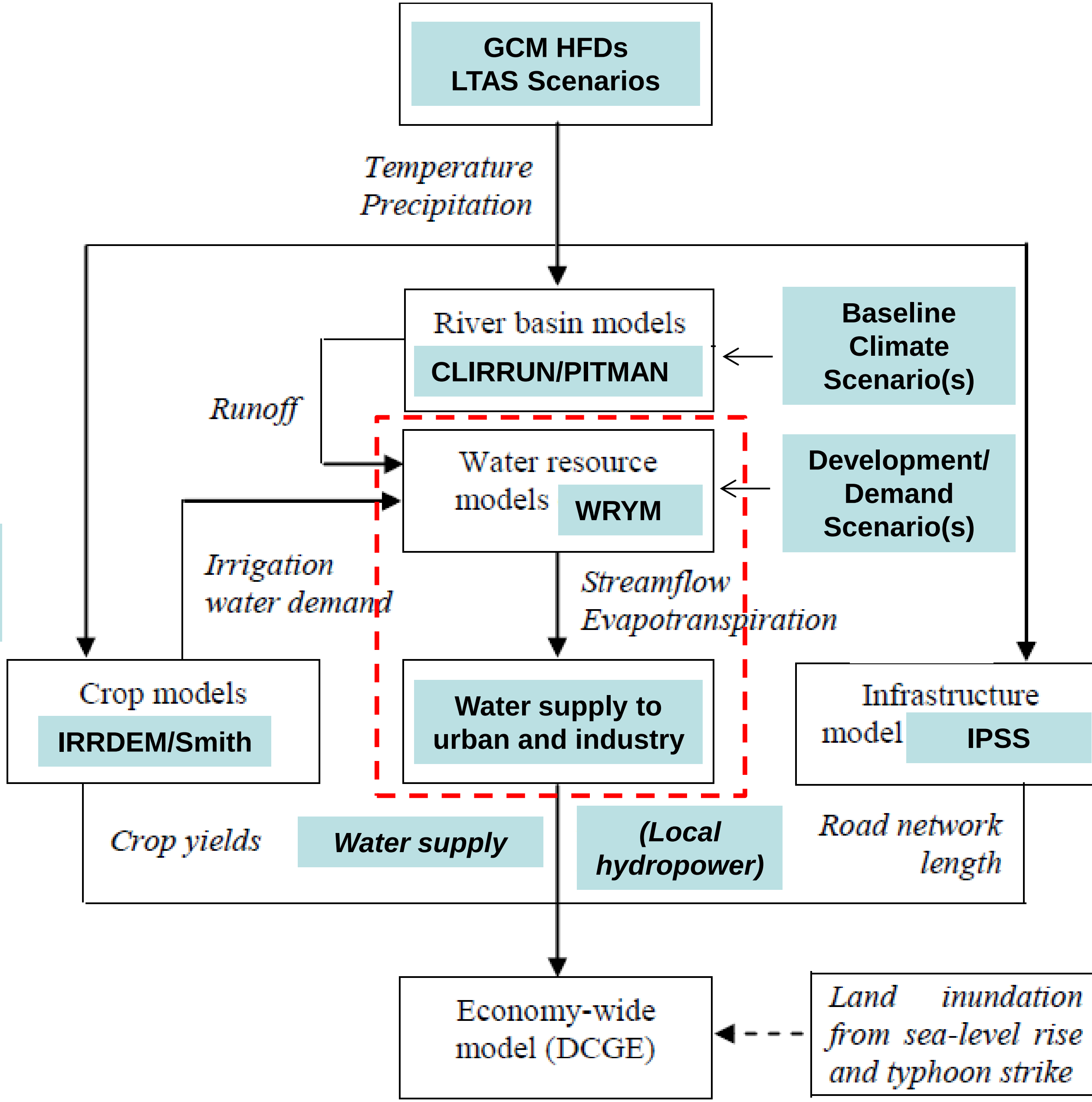

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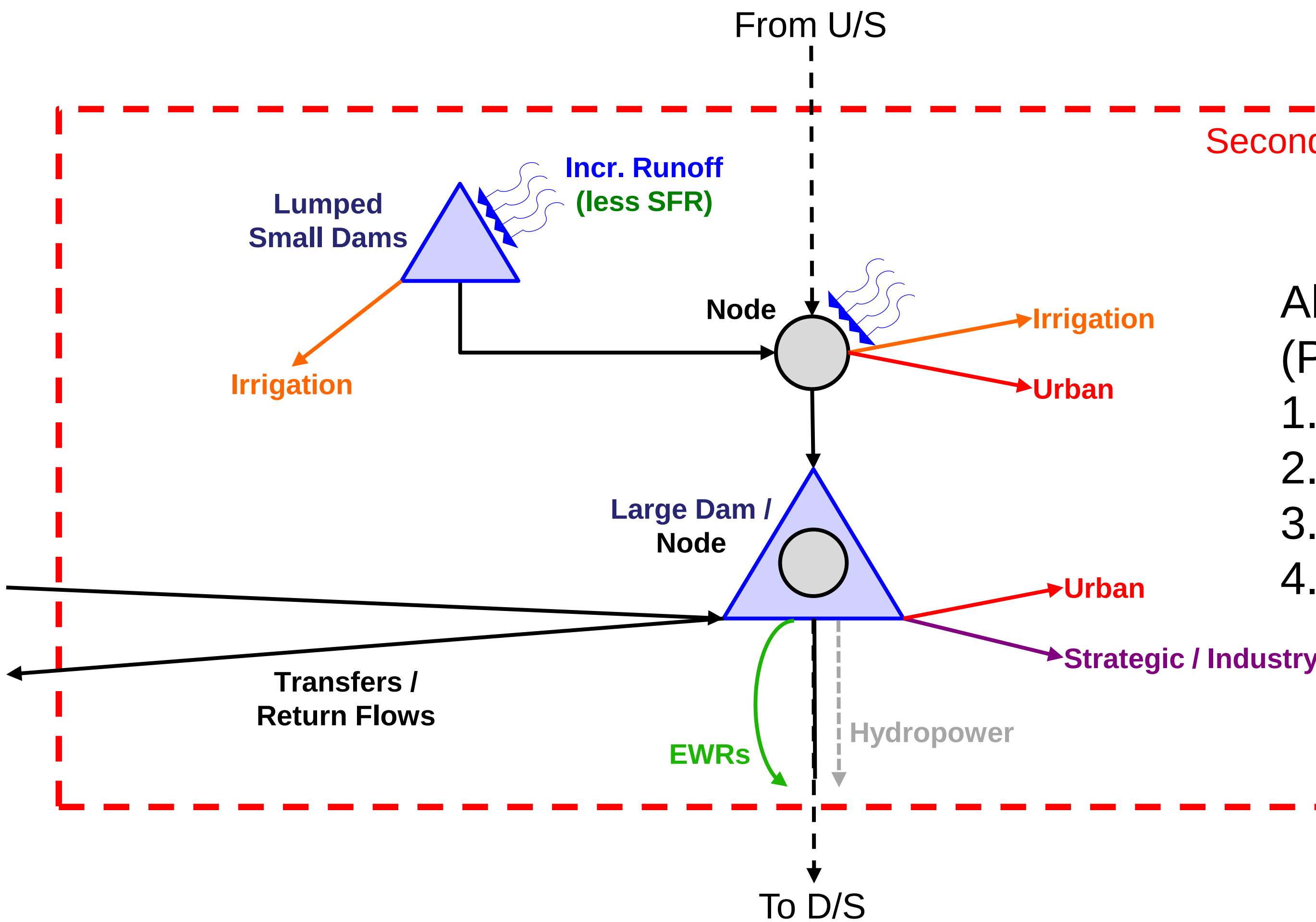
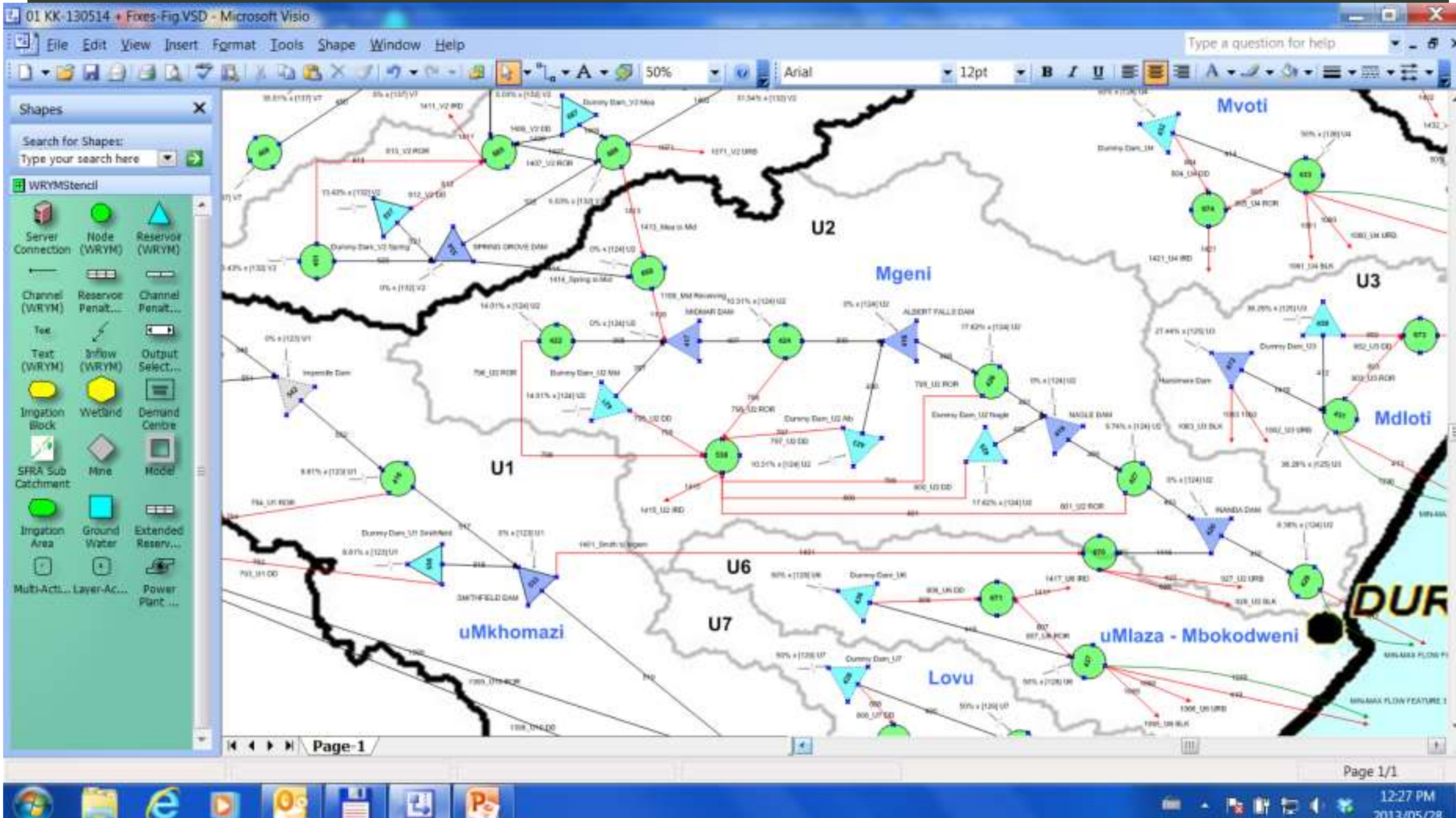
Analysis Unit for National WRYM



Allocation Priorities (Penalty structure):

1. Environmental
2. Strategic & Bulk
3. Urban
4. Irrigation

Water Resources Yield Model (WRYM) - Mgeni



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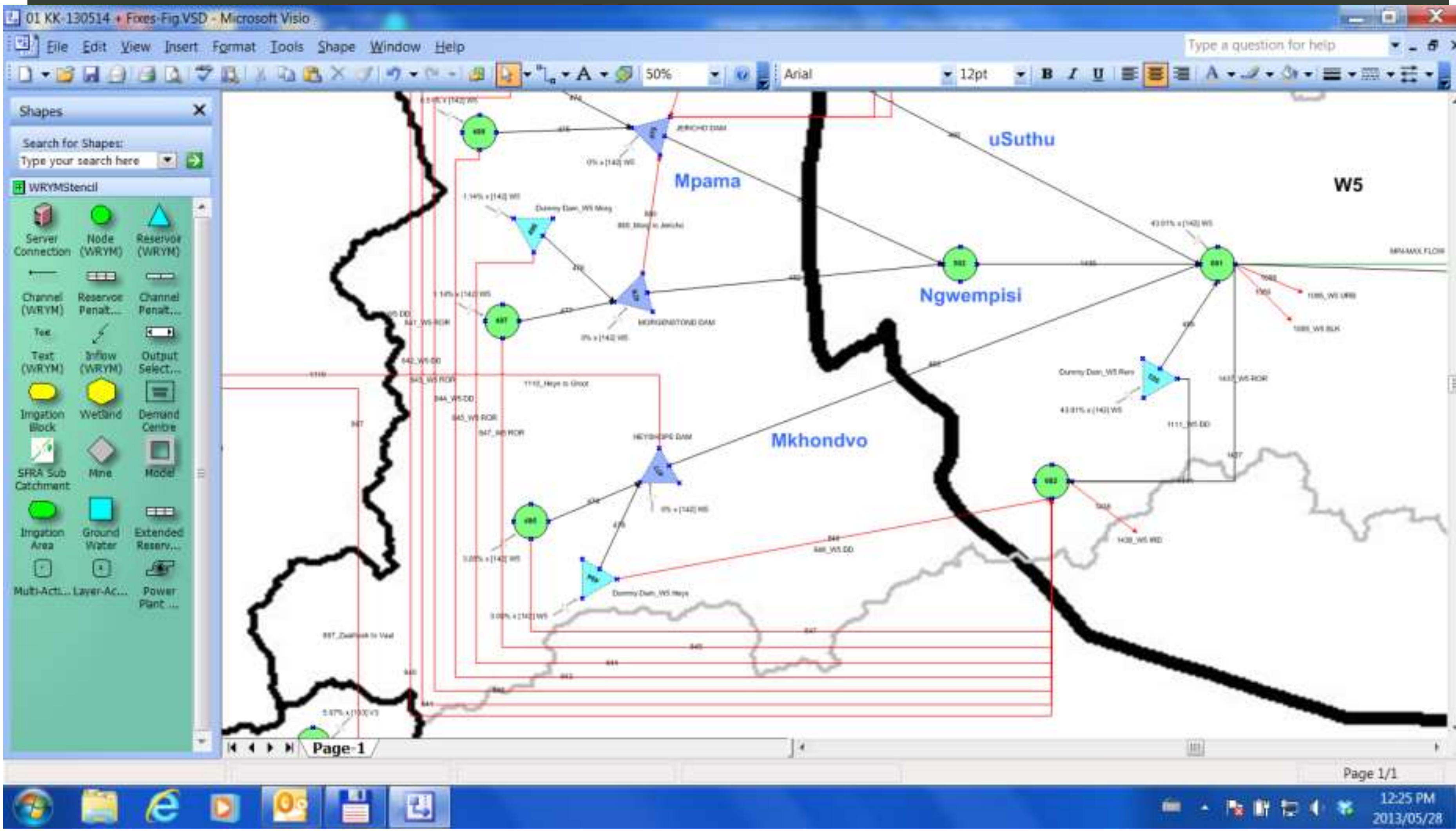
Water Resources Yield Model (WRYM) - uSuthu



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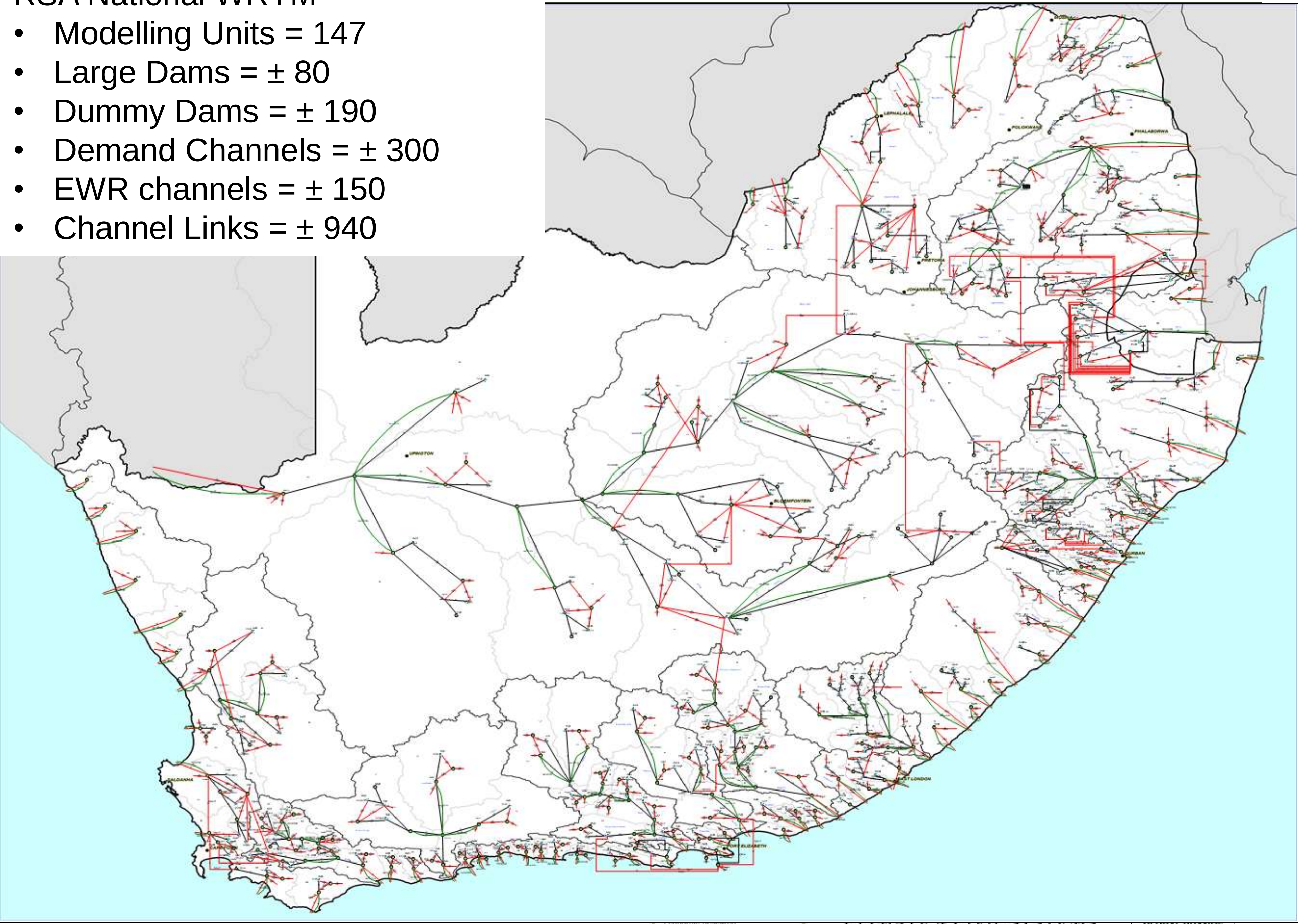
RSA National WRYM

- Modelling Units = 147
- Large Dams = ± 80
- Dummy Dams = ± 190
- Demand Channels = ± 300
- EWR channels = ± 150
- Channel Links = ± 940



Sources of Information

Common sources of Information for all catchments in the Country:

- WSAM – Water demands, transfer capacities
- WR90 – Base hydrology
- WR2005 – Base Rainfall, Dam sizes, afforestation

Catchment specific information

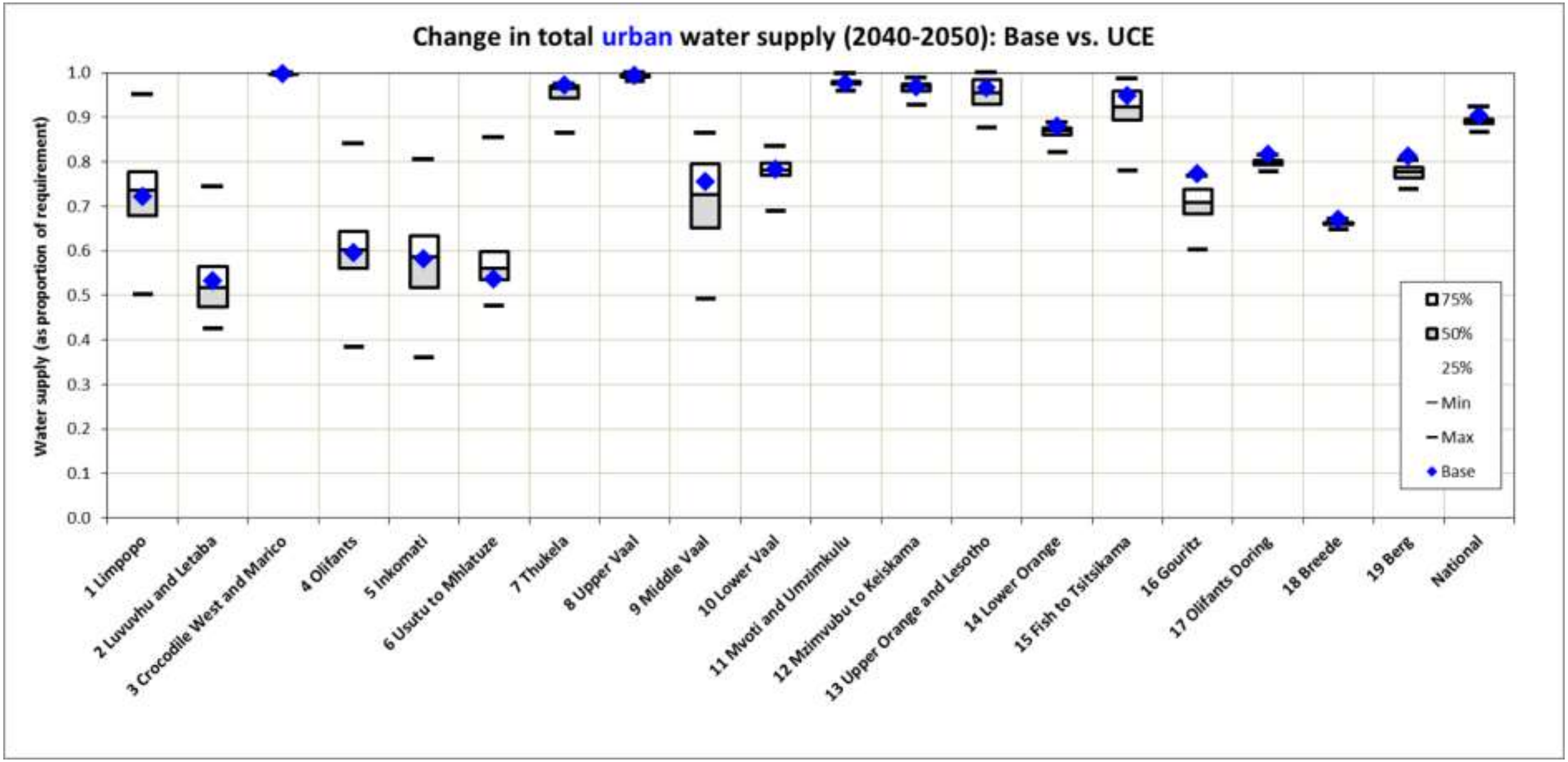
- Reconciliation Strategy Studies
- Experience of study team members

Assumptions

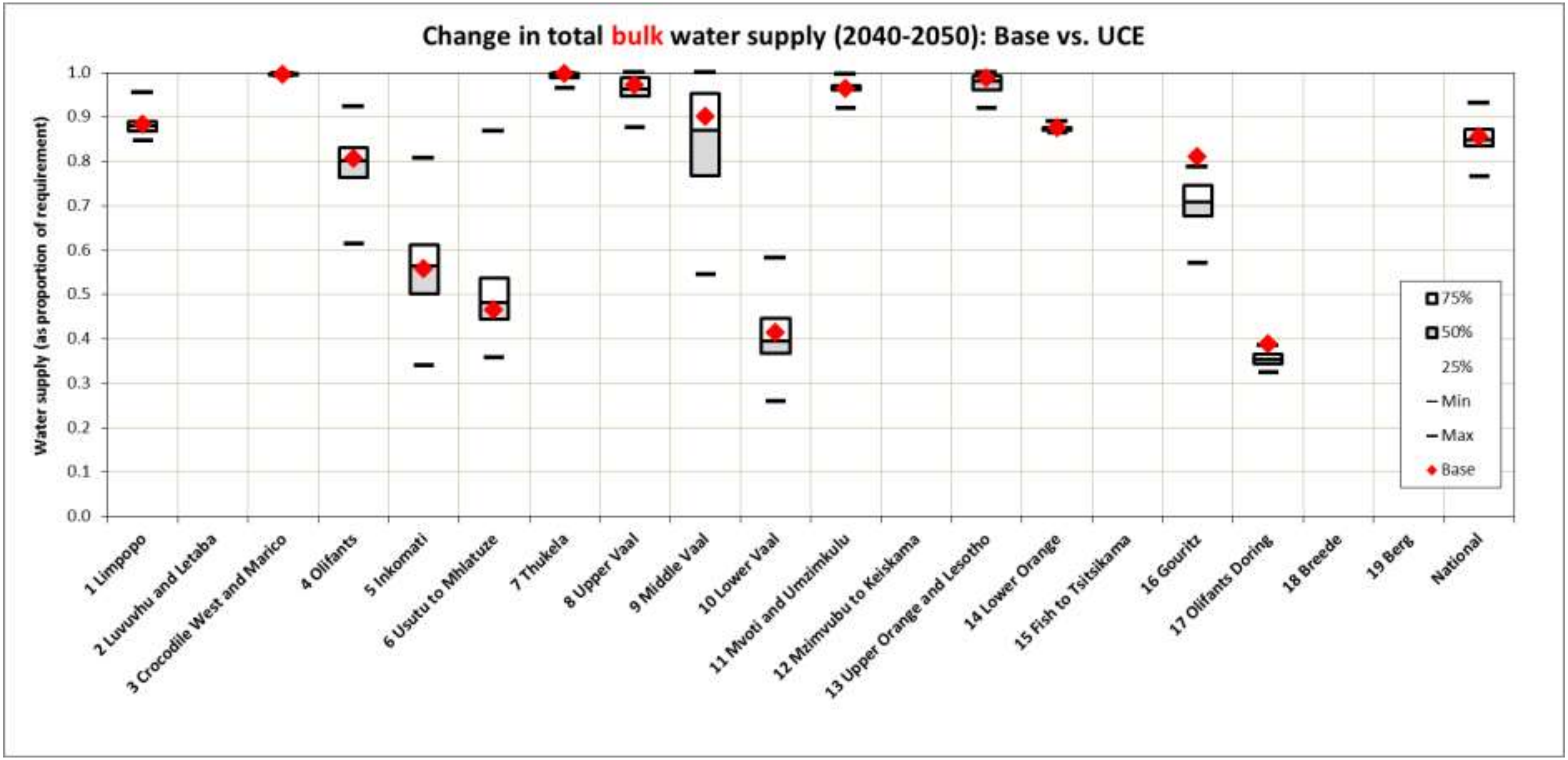
Generic assumptions were applied (unless more detailed info directed otherwise):

- Systems with multiple dams operated to use water from lower dams first and minimise spillage.
- First round system definition included all existing dams and transfer schemes as well as those large known schemes that are likely to be implemented by approx. 2030.
- No additional desalination or re-use of water included for future demands for this first round.

Average water supply 2040-2050: URBAN



Average water supply 2040-2050: BULK



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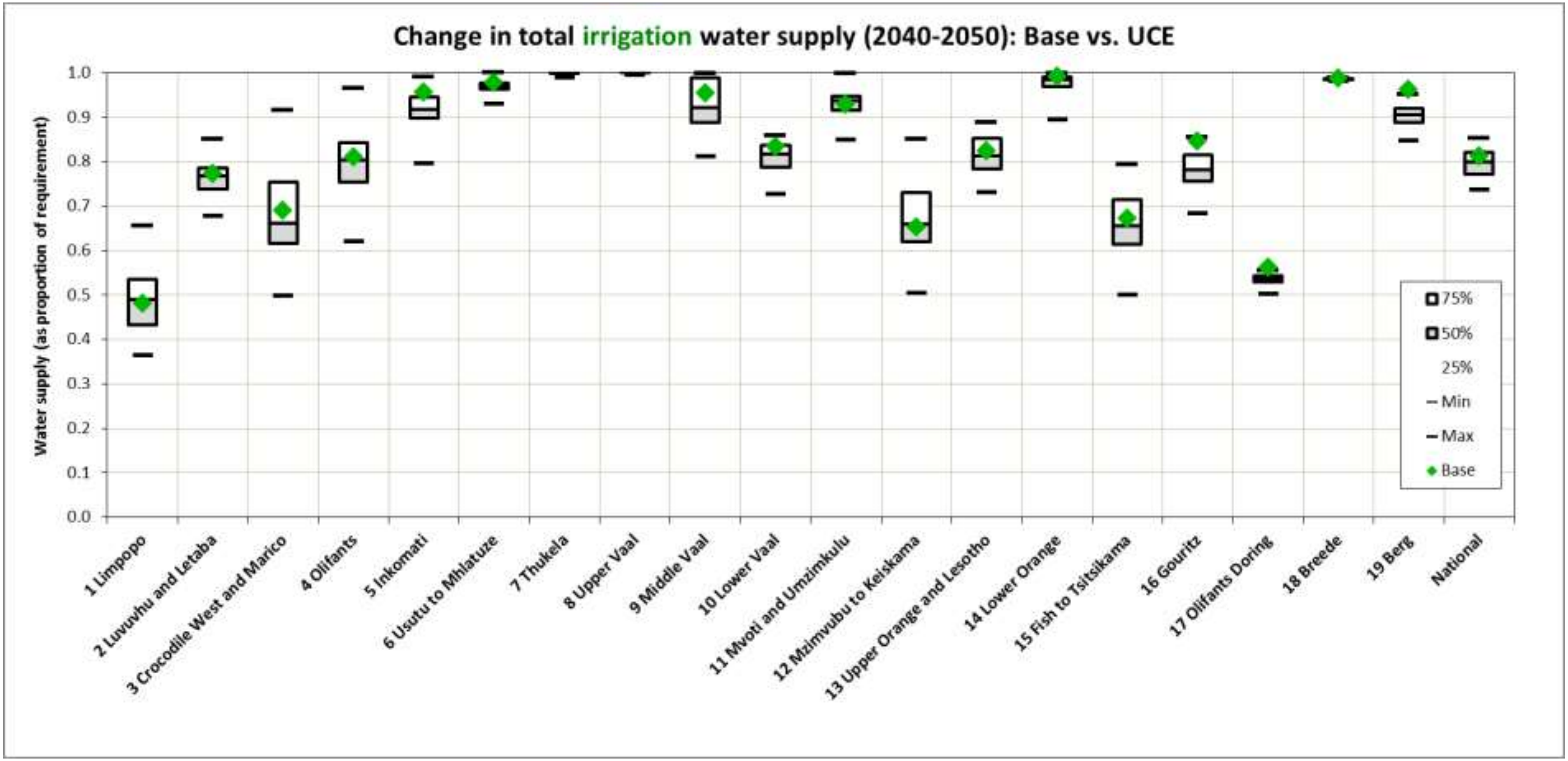
Average water supply 2040-2050: IRRIGATION



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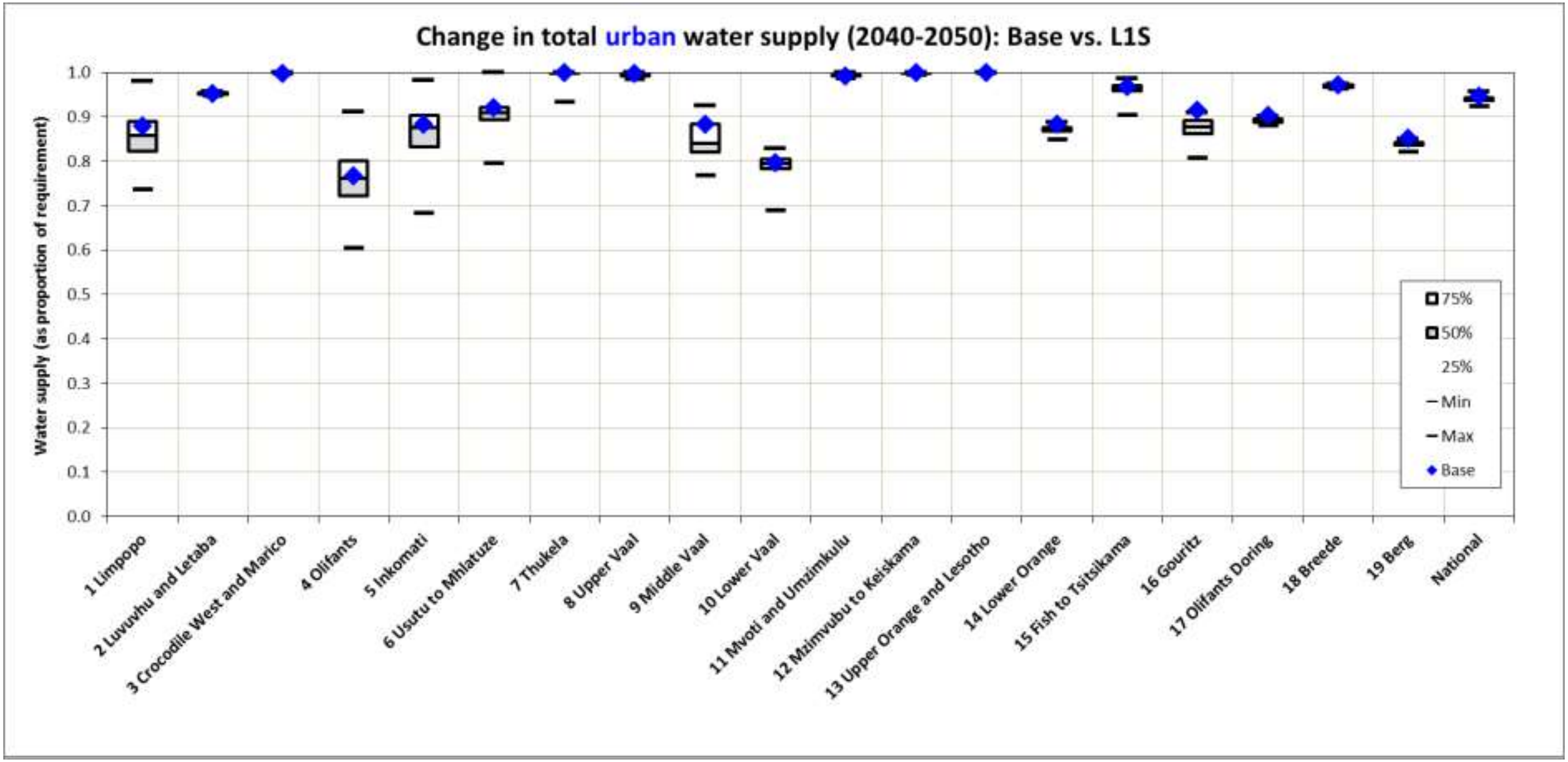
What is the Impact of Meeting the Reserve?



Conclusions

While CC has a significant impact on precipitation and runoff, it does not appear to have as much of an impact on the average ability to supply water.

BUT this is only the average of a 10 year period and for one baseline scenario – i.e. not a proper yield analysis.

There is little difference in the different mitigation scenarios.

The requirements of the Reserve (on potentially increasing IAPs) could be greater than CC …. or compound it.

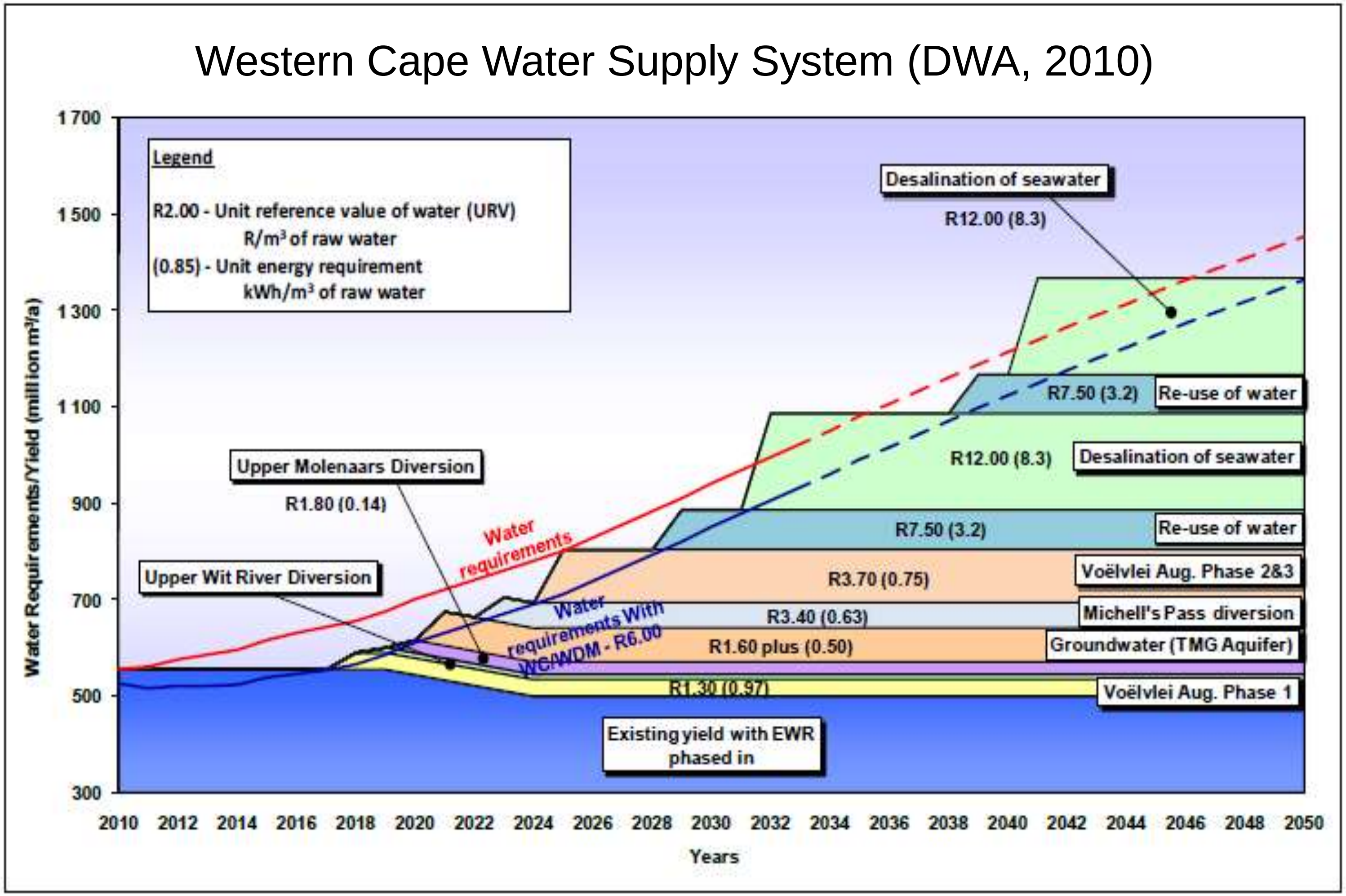
South Africa appears to have a reasonably resilient bulk water supply system, but there are areas of concern.

Incorporating CC into water resources planning is important.

But does this come at a cost?

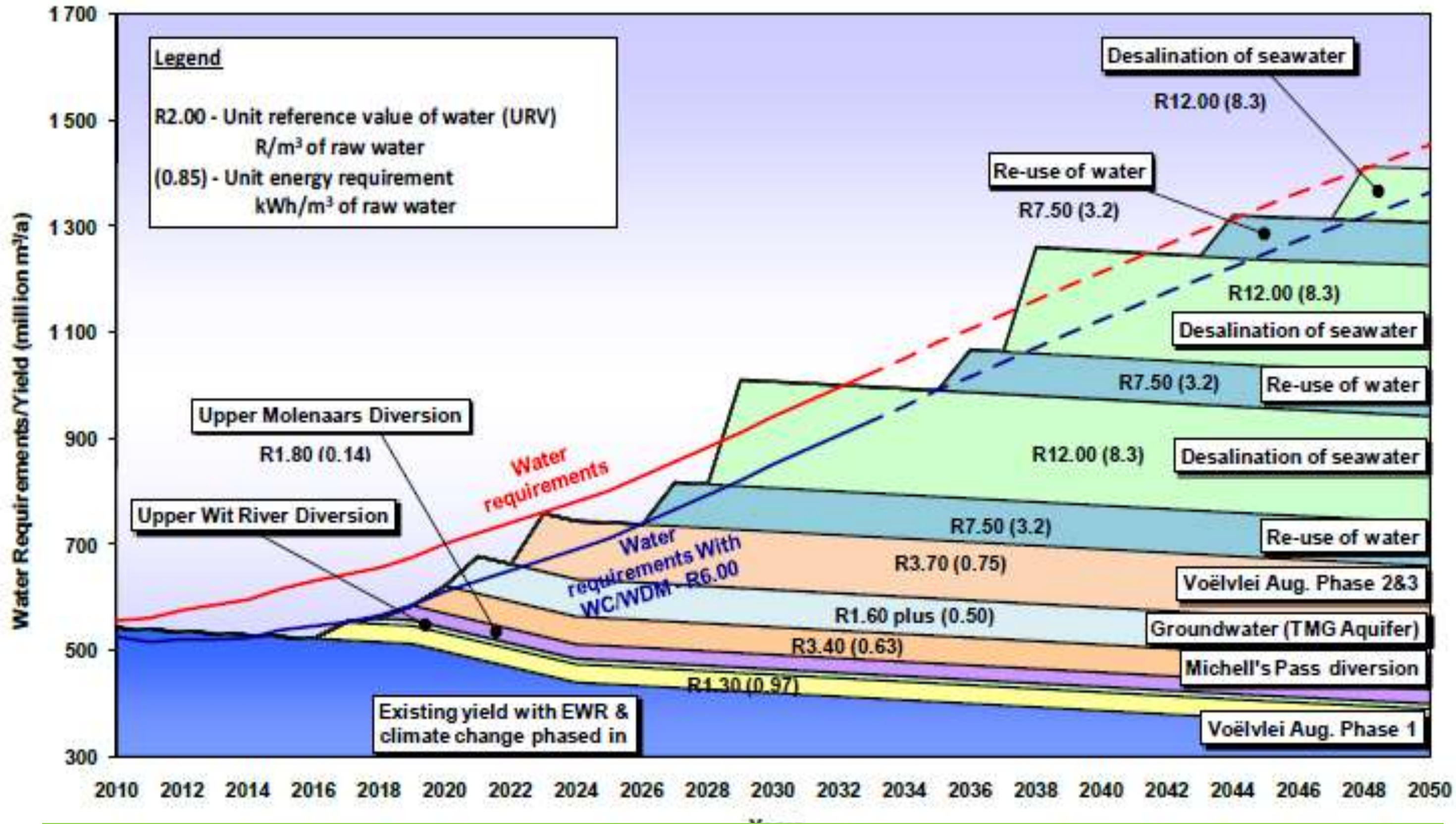
- Increased pumping costs for water transfers?
- Increased ecological impacts?
  - Greater proportion of water being captured.
  - Potential water quality impacts
  - Opportunity costs for reallocation of resources
- Investment cost of early implementation?

WC Reconciliation Study (2007) – No CC



WC Reconciliation Study (2007) – With CC

Western Cape Water Supply System (DWA, 2010)



NPV of early implementation = R417 million (2007)

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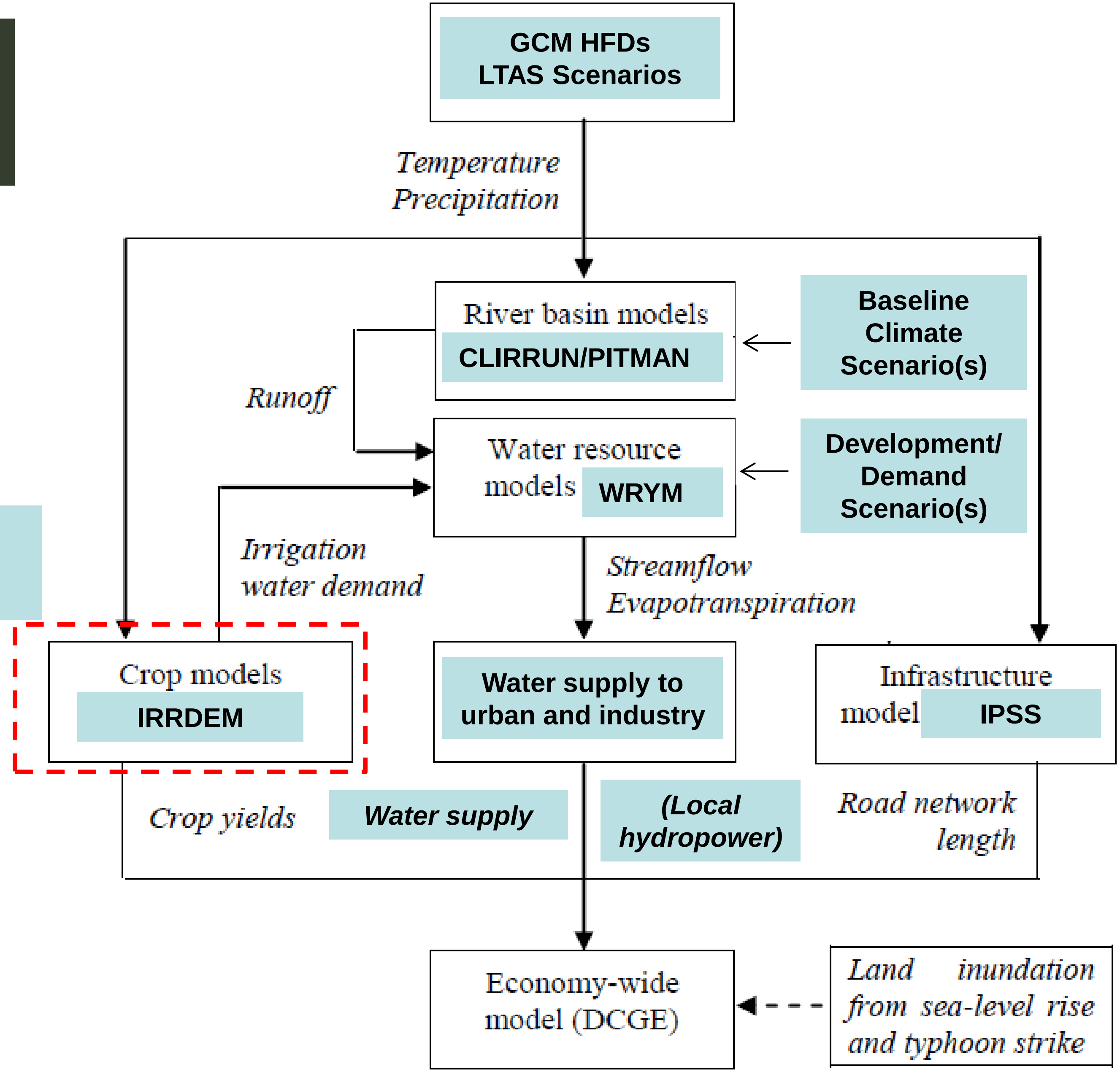
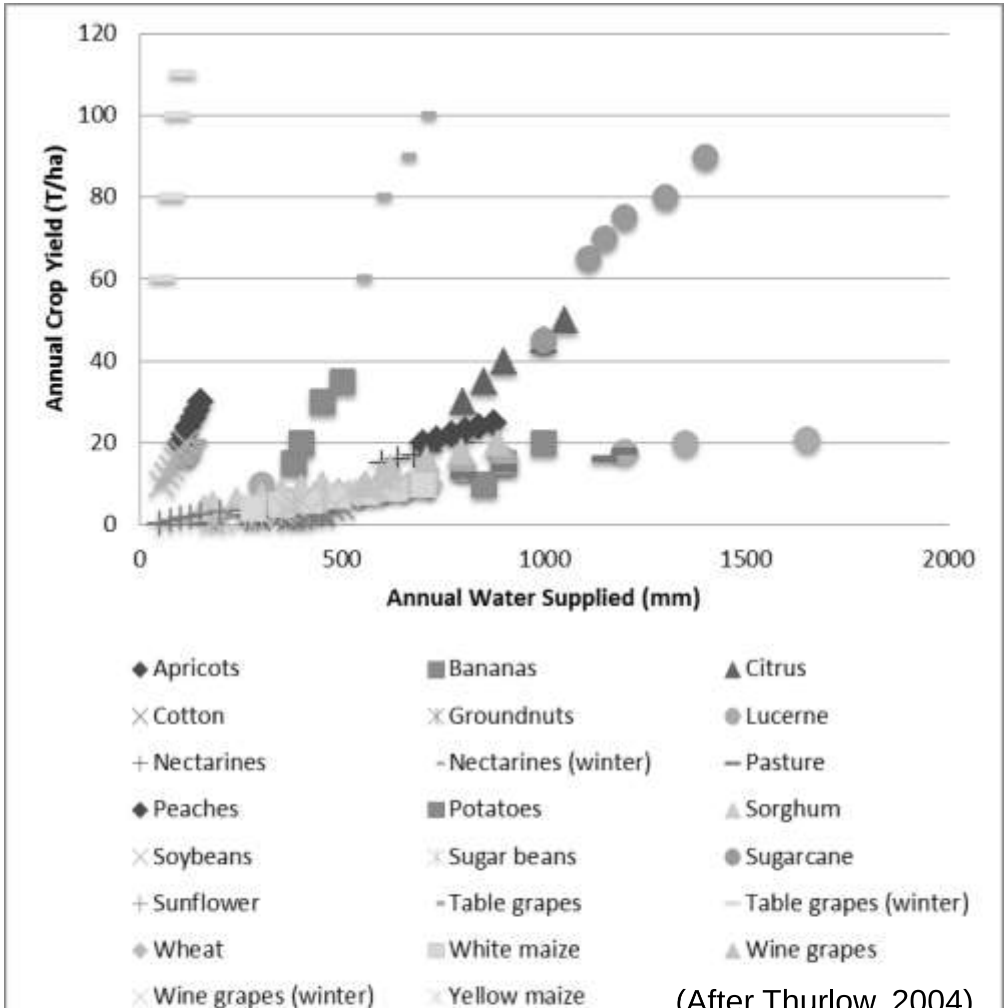


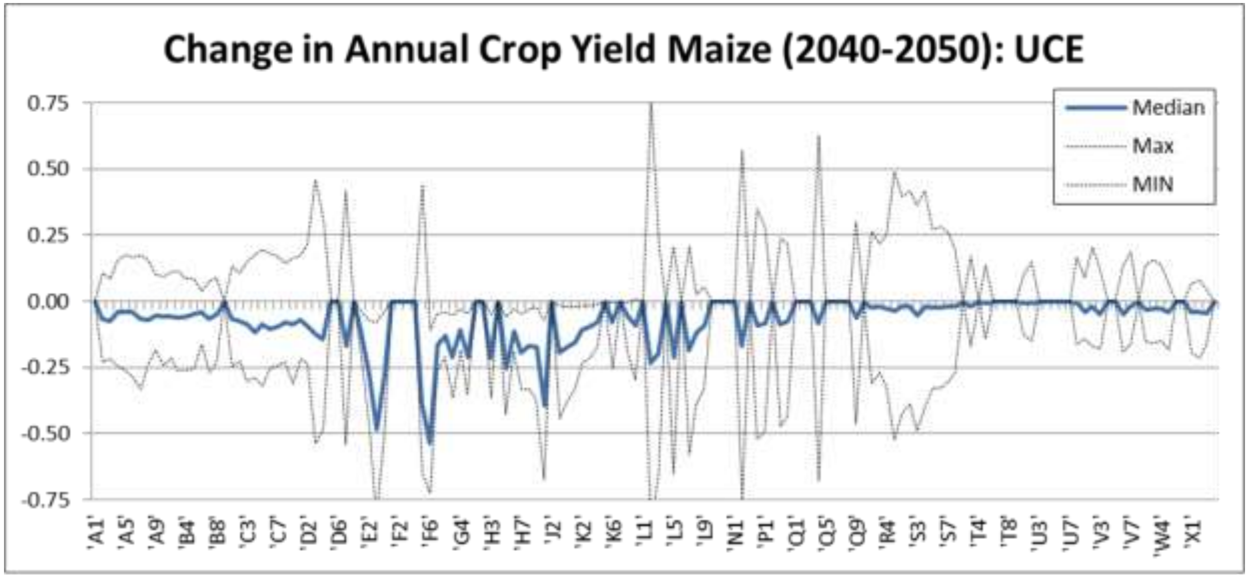
Impact on Agricultural Crop Yields

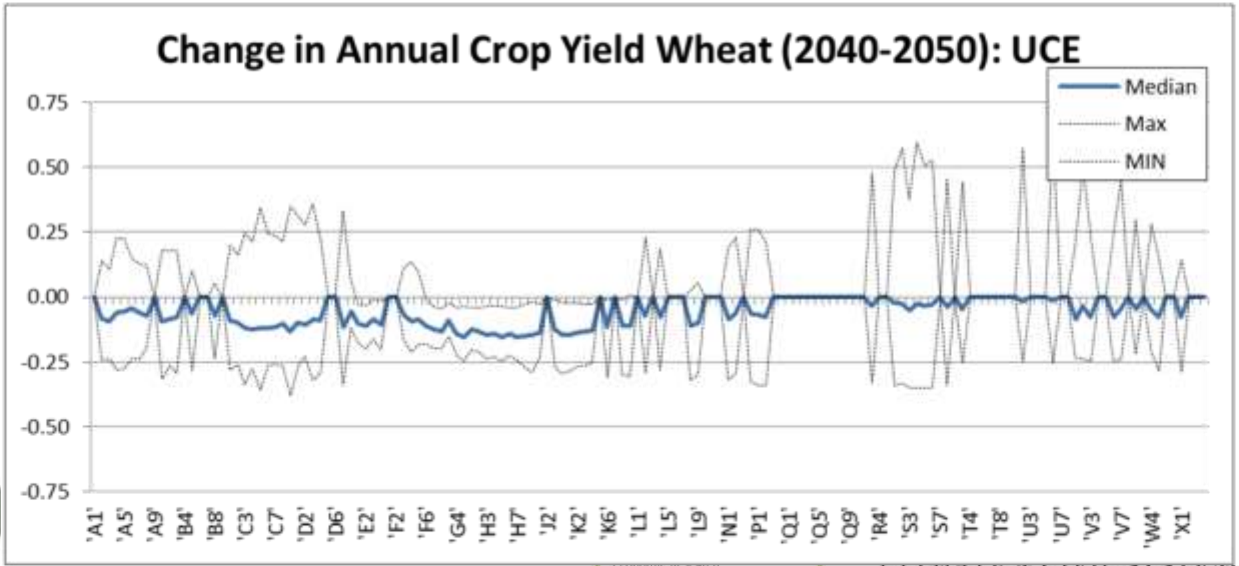
- Use empirical crop yield relationships.
- Consider impact of changes in precip on dry land crop yields
- Irrigation supply as output from WRYM
- Does not included temperature or $C0_2$ fertilization impacts



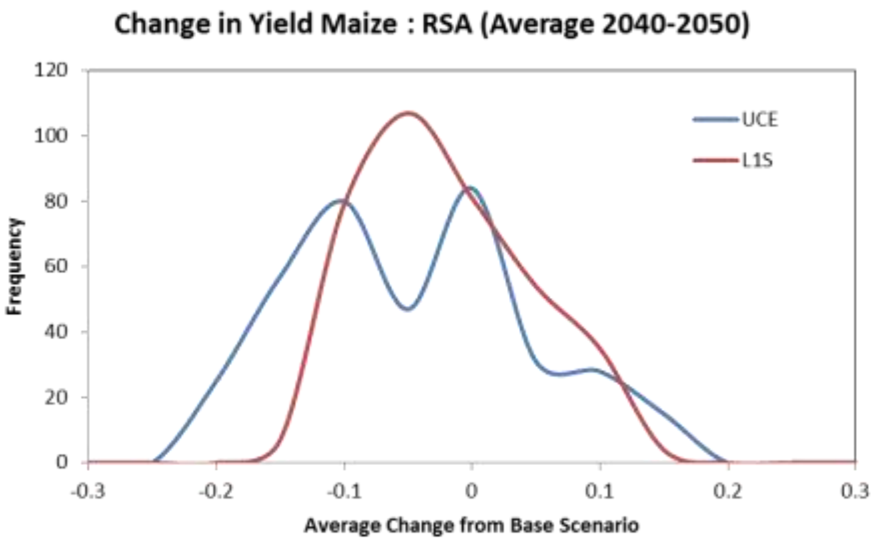
(After Thurlow, 2004)

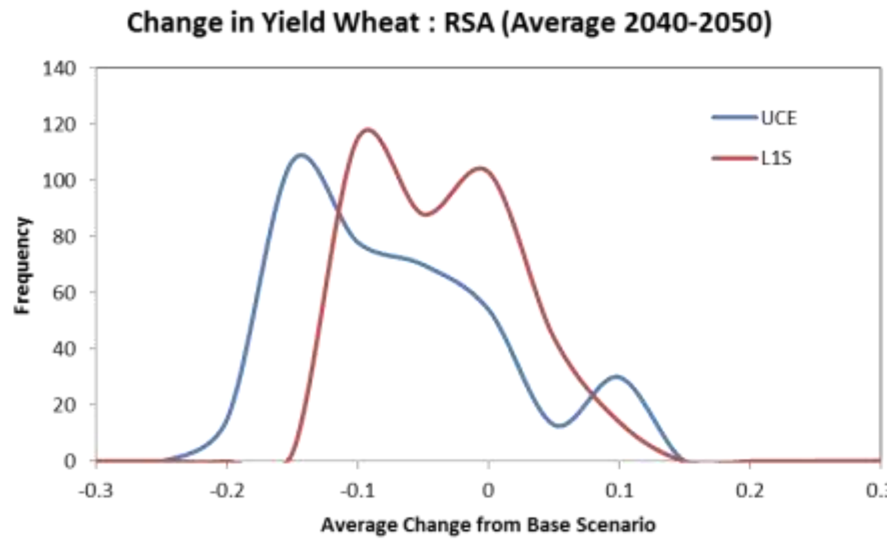
Change in Crop Yields: Secondary Catchment

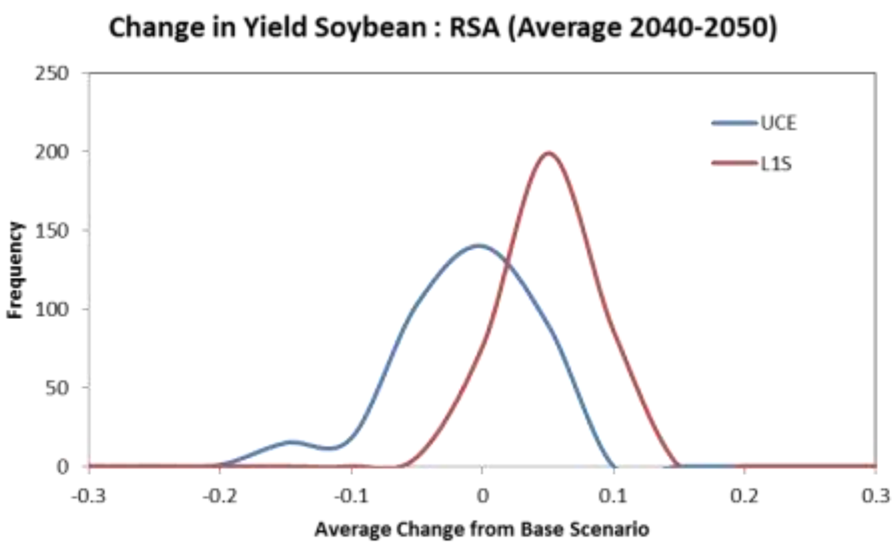


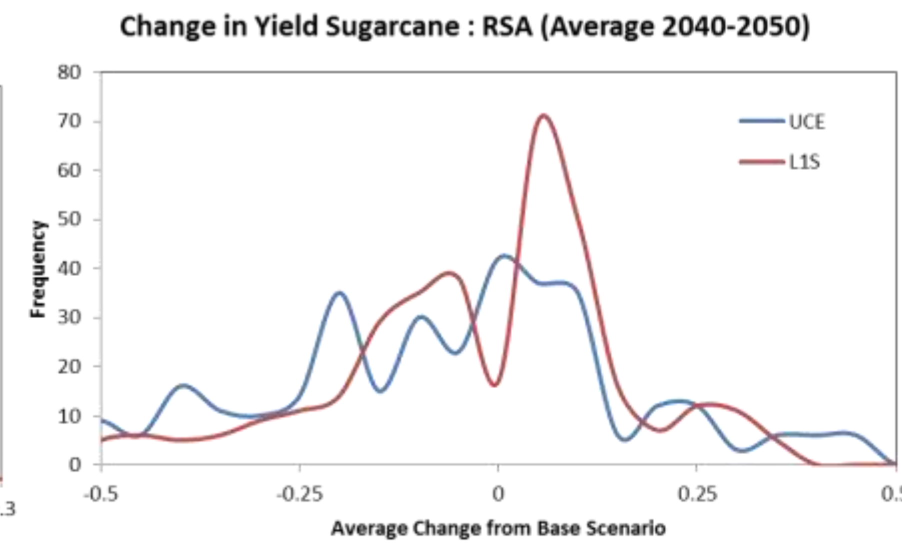


Change in Crop Yields: National









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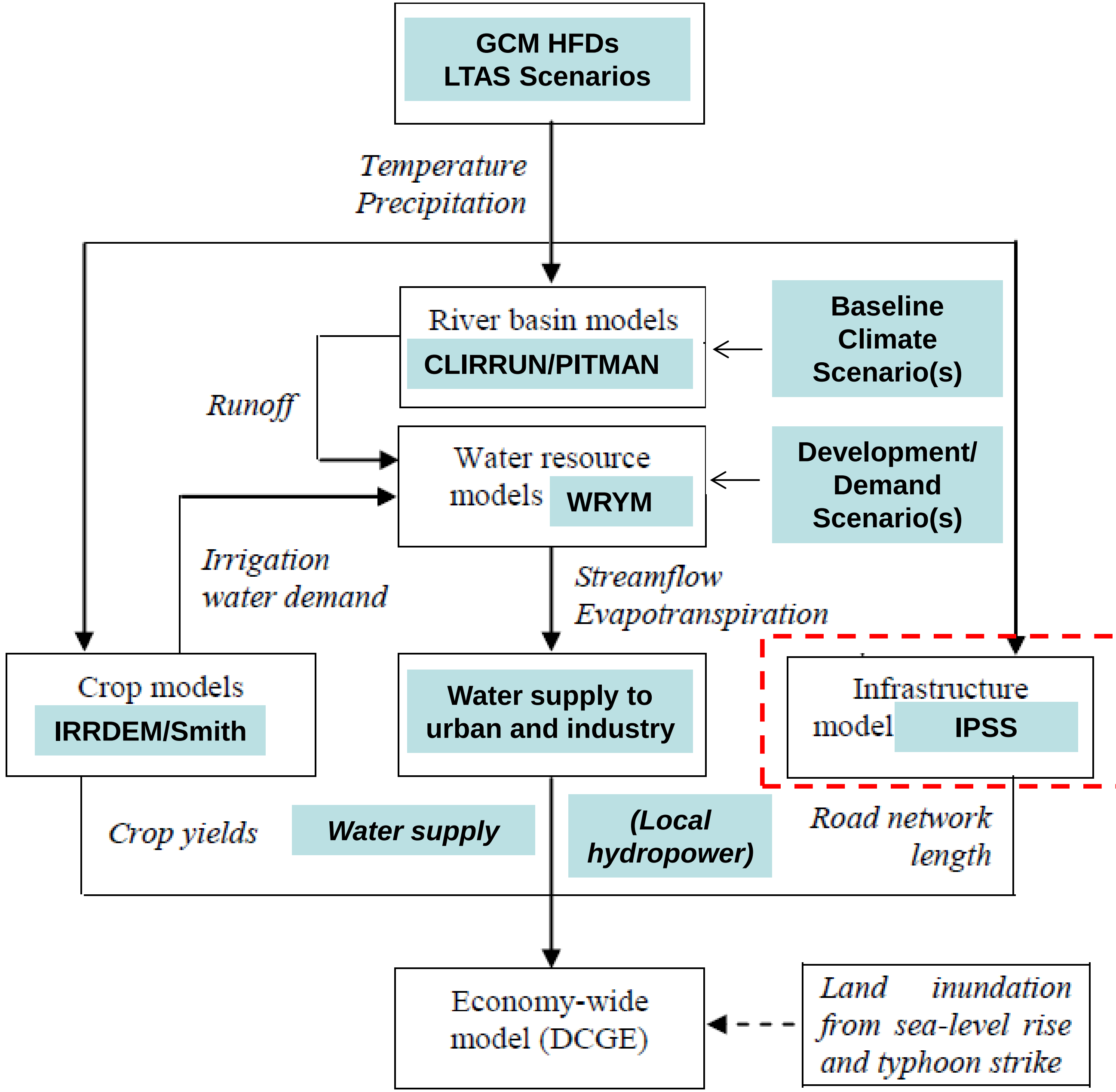

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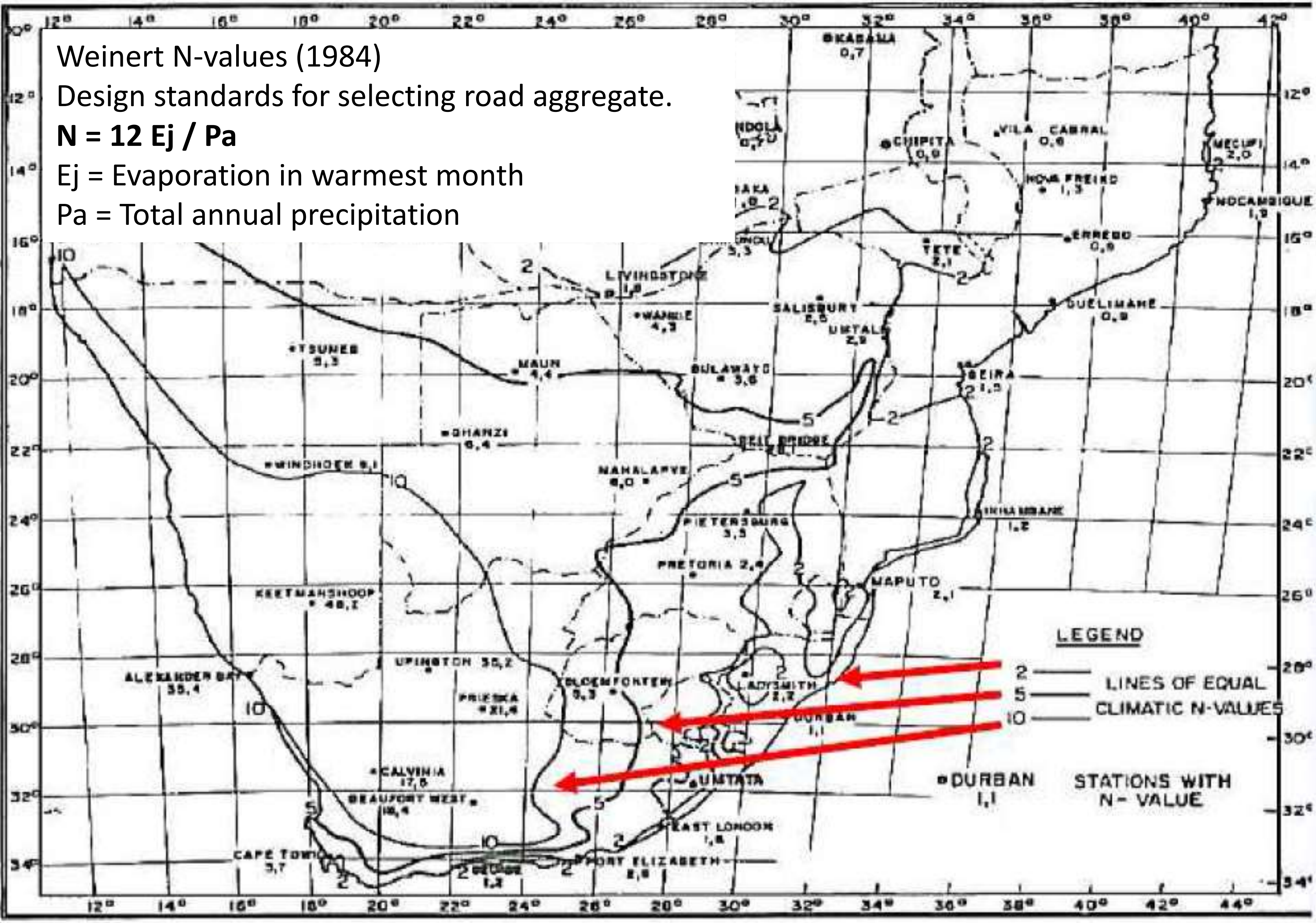
Weinert N-values (1984)

Design standards for selecting road aggregate.

N = 12 Ej / Pa

Ej = Evaporation in warmest month

Pa = Total annual precipitation



Integrated Planning Support System (IPSS) : For Roads Infrastructure Impacts

- Developed by Institute for Civil Systems
- Determines relative life cycle costs for “adapt” and “no-adapt” approach to roads infrastructure.
- Engineering-based focuses on two areas:
  - Maintaining existing road networks
  - Upgrading roads during construction to ensure more resilience for an overall lower life-cycle cost
- Data inputs to IPSS
  - Road stock inventory at administration level
  - Proportional weighting of roads stock to CRU grids
  - Unit cost estimates – construction, maintain, replace.

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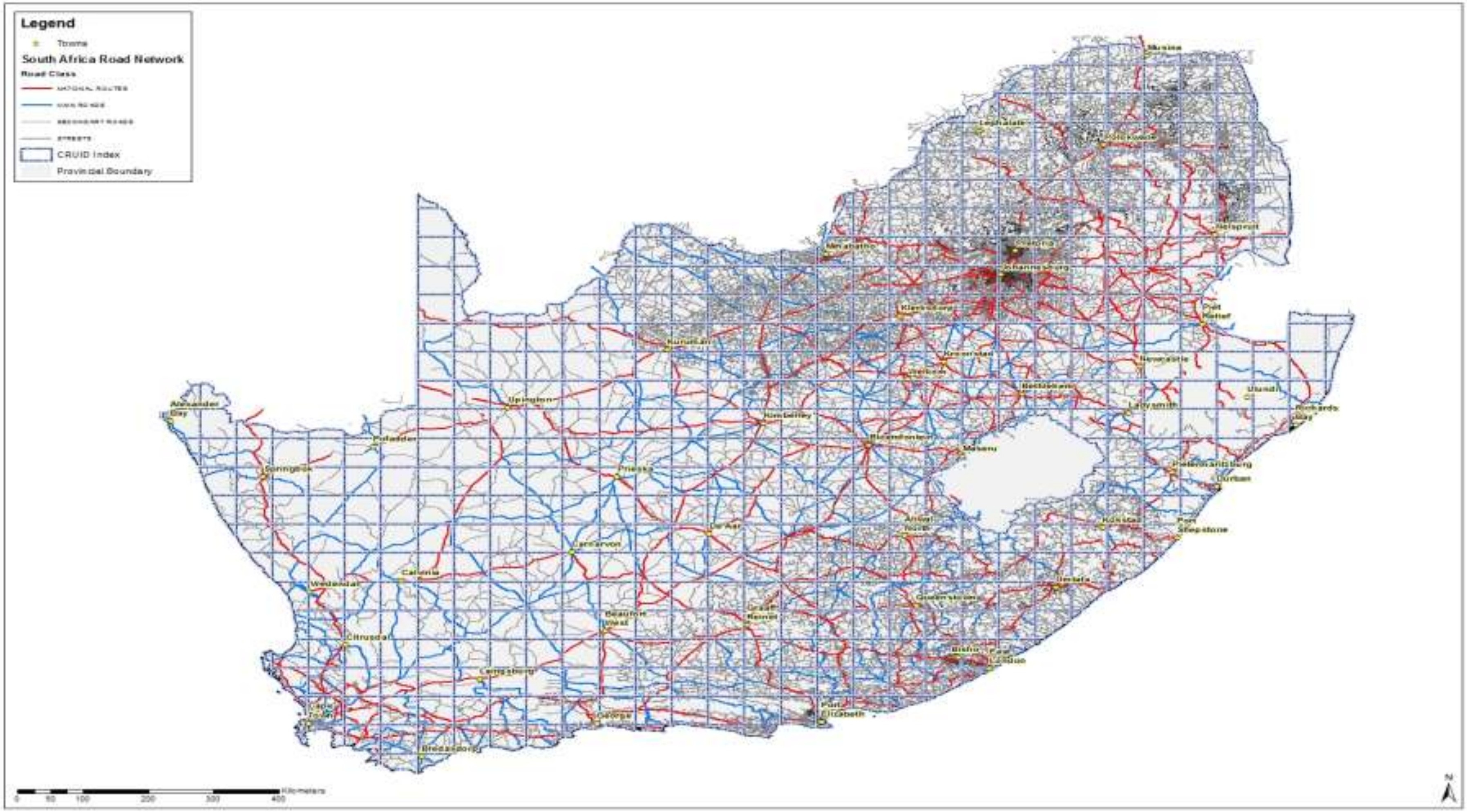
"Adapt" vs "No-Adapt" Policy Approach

Adapt Policy Overview	No Adapt Policy Overview
Assumes foresight with respect to climate change	Assumes no adaptation changes are put in place
Applies these forward-looking climate projections to upgrade new roads as they are re-built and maintained.	Roads are rebuilt according to existing standards
Incurs up-front costs to adapt a road to mitigate future damages that are projected from increases in precipitation or temperature.	The costs incurred are from increased maintenance necessary to retain the design life of the original road as degradation of the road infrastructure occurs from climate change stressors

Examples of Adapt vs No Adapt Costs

Road Type	Adapt Policy	No Adapt Policy
Paved	Upgrade asphalt binder (temp increase) Increase drainage capacity infrastructure	Increased rutting and cracking Increased washout and drainage infrastructure damages
Gravel	Increase sub-base Increase drainage capacity Increase grading	Increased maintenance required from damages

South African Road Network & CRUs



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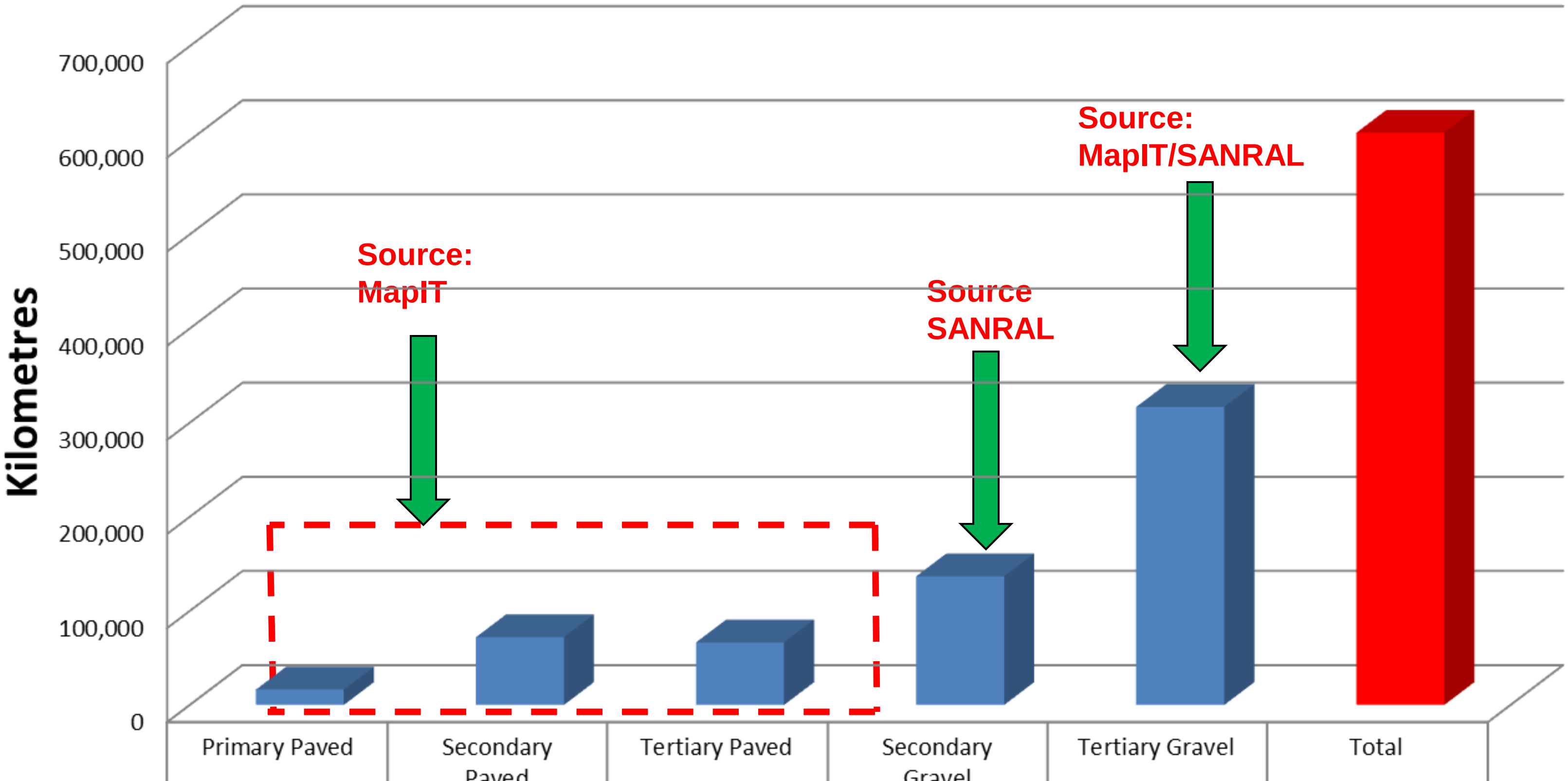
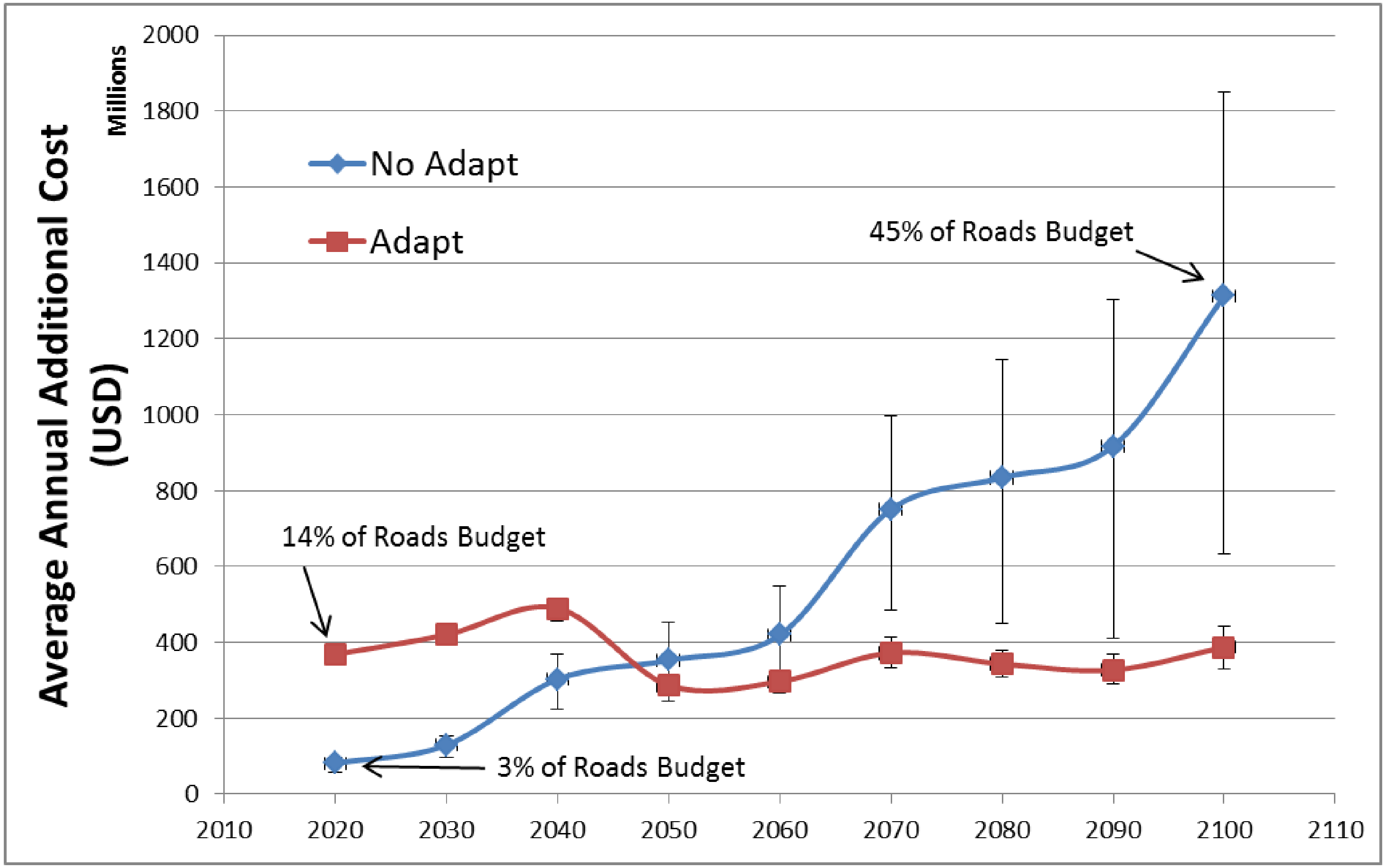
SA Road Network Length

SA's Road Network in KM by road type



	Primary Paved	Secondary Paved	Tertiary Paved	Secondary Gravel	Tertiary Gravel	Total
Grand Total	16,240	71,971	66,512	136,640	316,620	607,983

National Cost and Adaptation Impacts



National Roads Budget (2013/2014) = R28.5 billion

Economic impacts of Climate Change.

- Any questions?

- James Cullis (james.cullis@aurecongroup.com)
- Channing Arndt (channingarndt@gmail.com)