# Application of Bayesian Networks in Integrated Water Resource Management

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AQUATIC ECOSYSTEM RESEARCH

UNIVERSITY OF KWAZULU-NATAL
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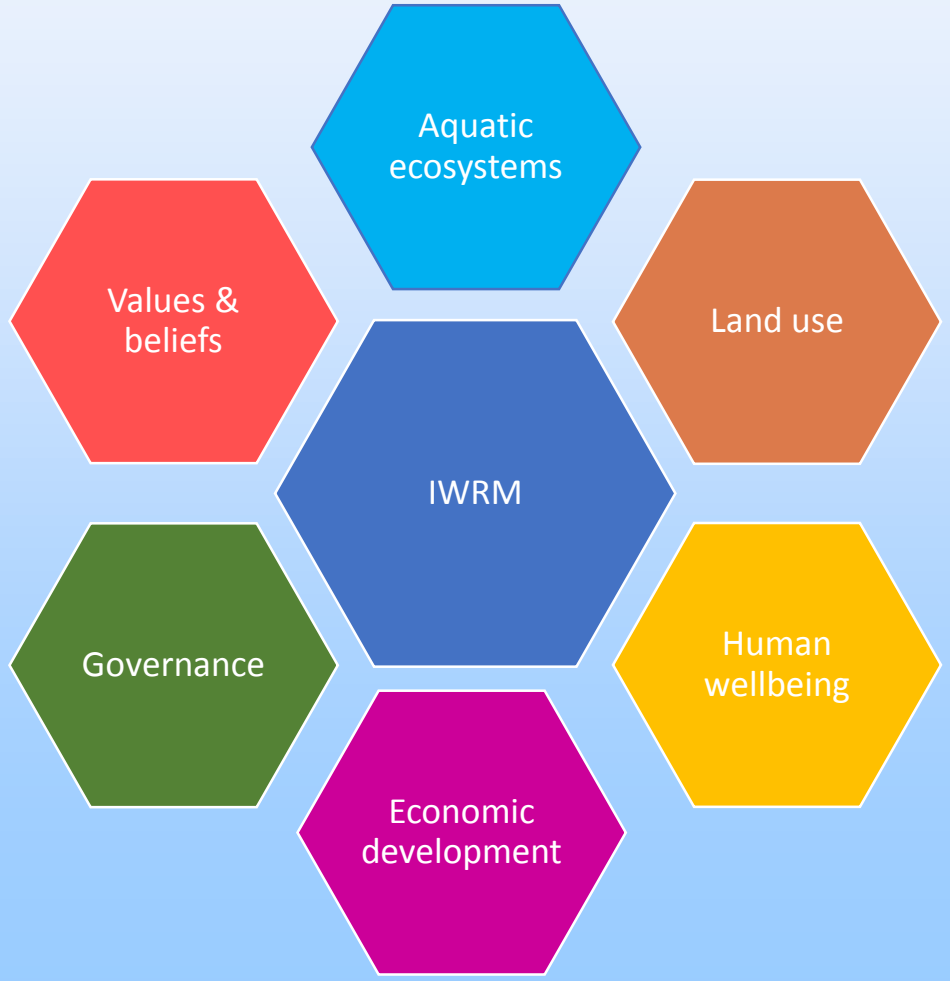
# Integrated water resource management

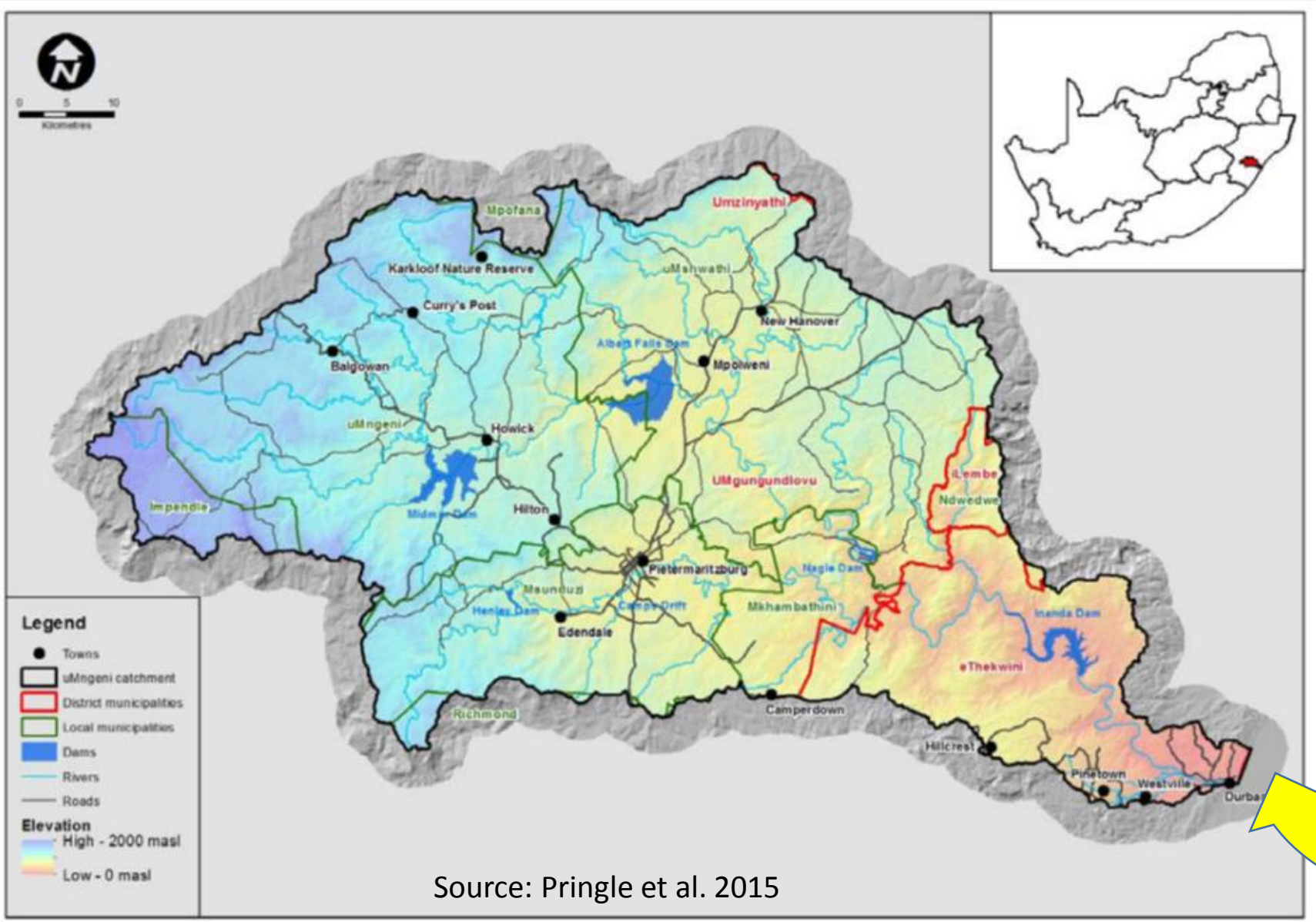
"Is a holistic approach that seeks to integrate the management of the physical environment within the broader socio-economic and political framework" (Claassen, 2013)

**Facilitating water security**

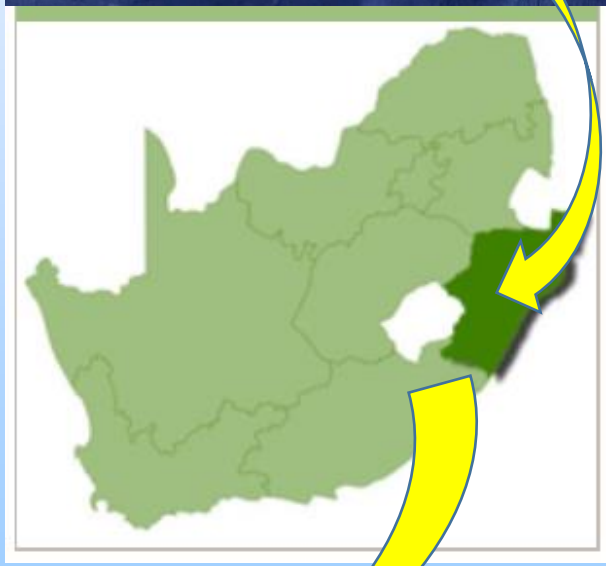



**Promoting development and sustainability**

# The Study Area: The uMngeni River Catchment KwaZulu-Natal, South Africa




Source: Pringle et al. 2015



http://www.roomsforafrica.com/dest/south-africa/kwazulu-natal.jsp

http://www.map-library.com/map-library/maps-of-africa/

# Important catchment

Strengths:

- Economic importance nationally
- Dams
- Labour
- Agriculture
- Forest plantations
- Ecotourism

Challenges:

- Inadequate water & sanitation
- Informal settlements
- Illegal discharges
- Eutrophication of dams
- Alien invasive species


https://www.health-e.org.za/


https://www.health-e.org.za/


http://www.nature-education.org/water-pollution.html

Ecological infrastructure

Ecosystem services

Collaborative research

Increasing water demand

Economic development

# Resource Quality Objectives (RQOs) in South Africa

**Mg_R_EWR1: uMngeni River**

**EIS: LOW**

Highest scoring metrics were diversity of habitat types and features as well as the presence of rare and endangered riparian species.

**PES: C/D**

- The presence of aggressive alien fish species and exotic vegetation species.
- Some decrease in base flows due to abstractions for agriculture.

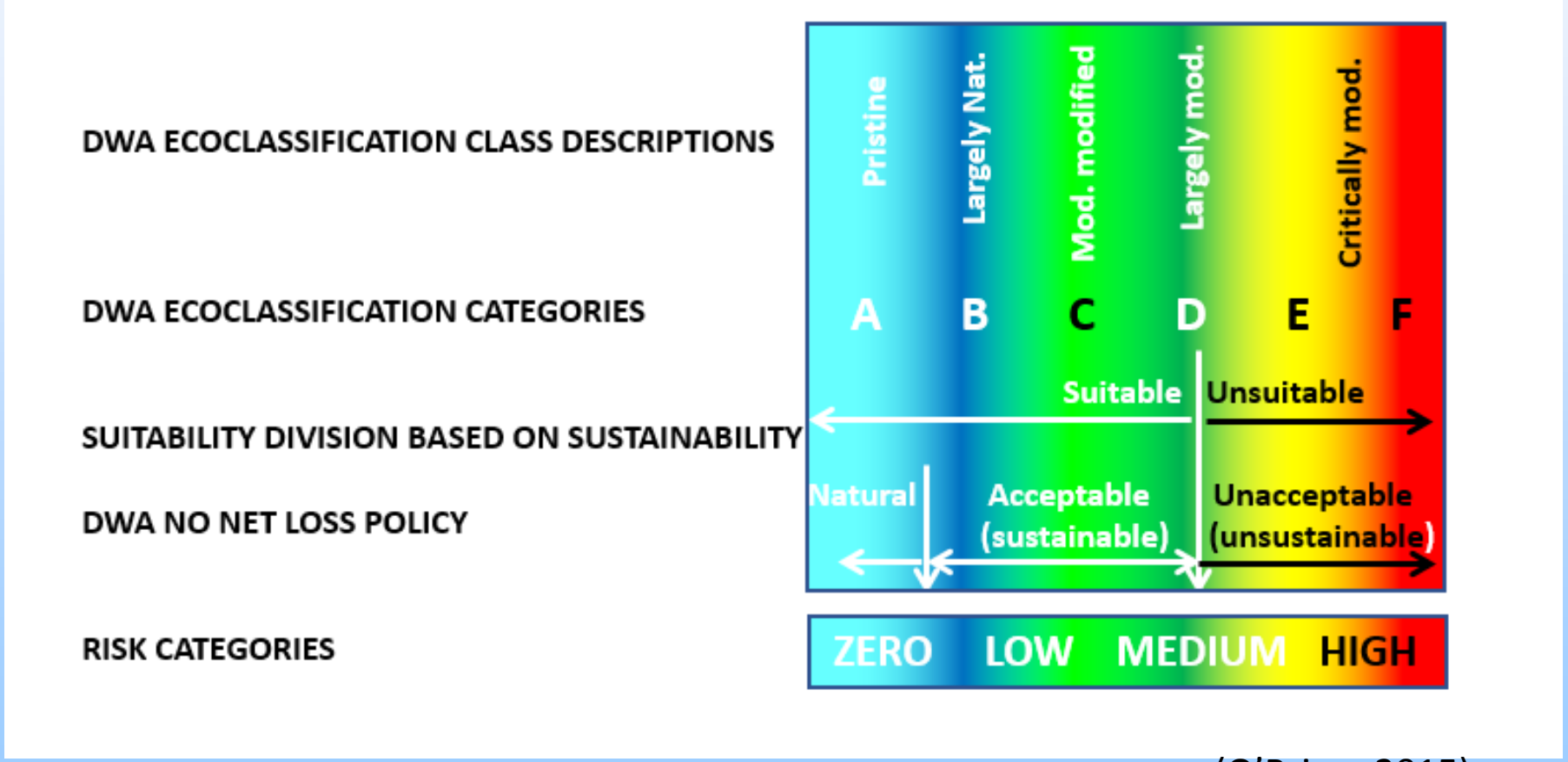
**REC: C/D**

- As the EIS was LOW no improvement was required. The C/D EcoStatus PES mainly due to non-flow related impacts and not representative of flow related problems in the reach. It was decided to exclude alien fish species from the assessment resulting in a PES of a C EC for fish and an instream PES of a C EC for which flow requirements were set.

| Component | PES & REC |
|---|---|
| IHI Hydrology | B |
| Physico chemical | B |
| Fish | D (C) |
| Invertebrates | C |
| Instream | C/D (C) |
| Riparian vegetation | C/D |
| **EcoStatus** | C/D |
| Instream IHI | C |
| Riparian IHI | C |
| **EIS** | LOW |

Department of Water & Sanitation, 2015

# Ecological Classification of water resources in South Africa




(O'Brien, 2015)

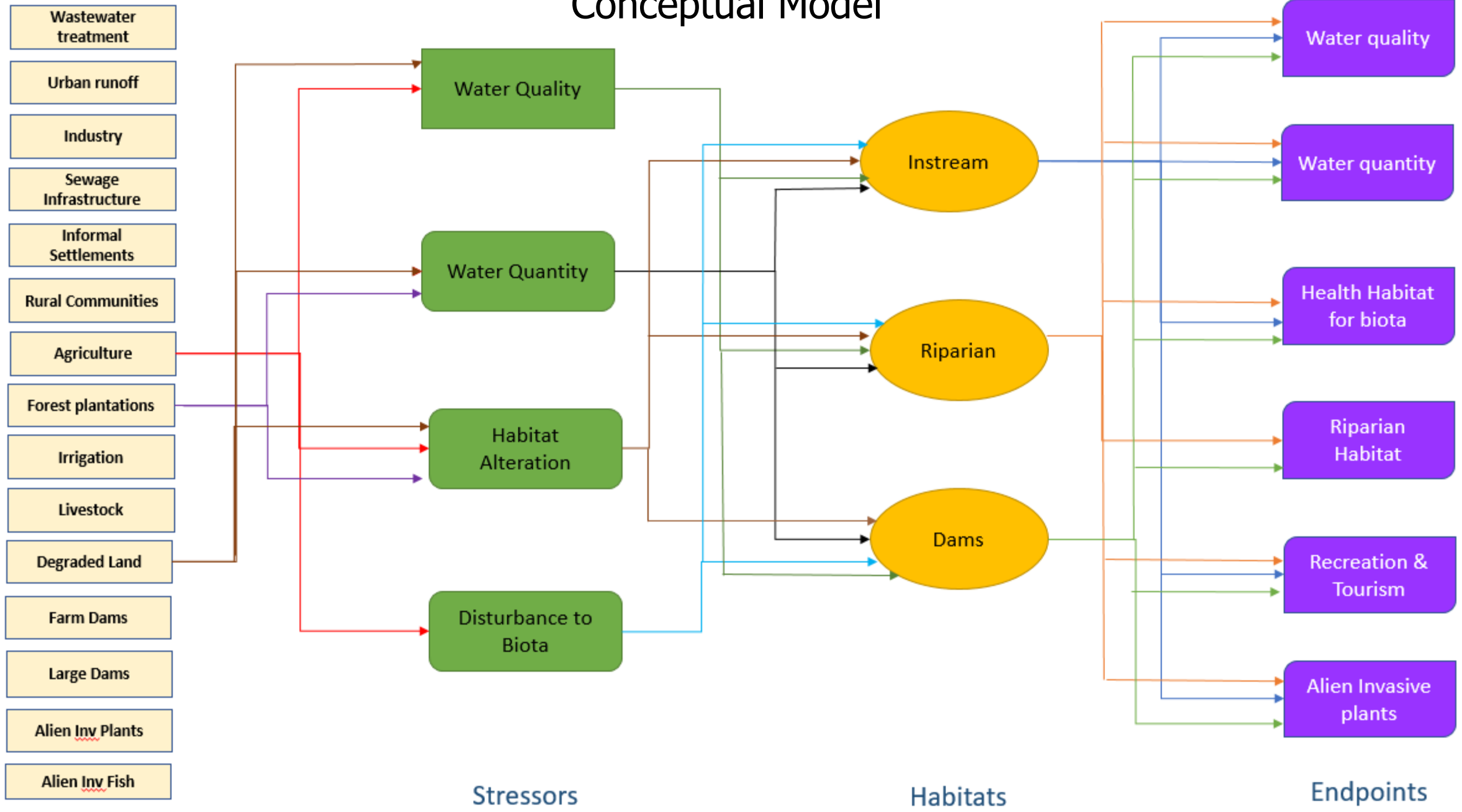
# Aims of the project

- Assess ecological risk using the Resource Quality Objectives (RQOs) under different water management scenarios (for example)
  - Changes in dam operations -> water flows
  - Growth in agricultural development
  - Control of alien vegetation
- Use the Relative Risk Model to demonstrate the implementation of the proposed RQOs for the study area
- Use the BN-RRM to determine the trade-offs between use and protection scenarios to effectively manage water resources holistically

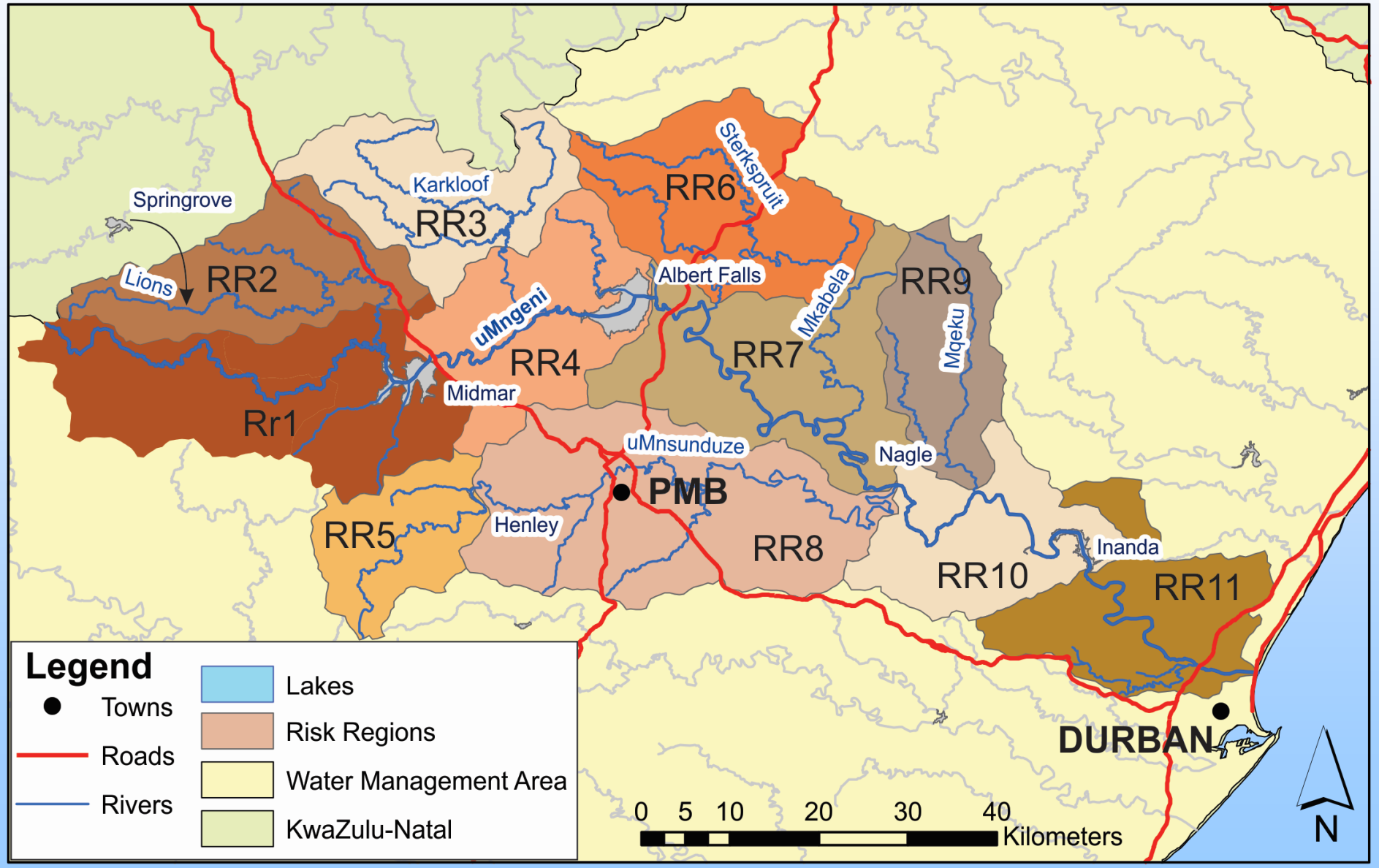
# Relative Risk Model

- Suitable for catchment scale
- Regional and examines risk spatially
- Considers catchment complexity – multiple sources, multiple stressors, multiple habitats, multiple endpoints
- Prioritise different regions of the catchment based on risk score

# Conceptual Model



# Risk Regions in the Study Area



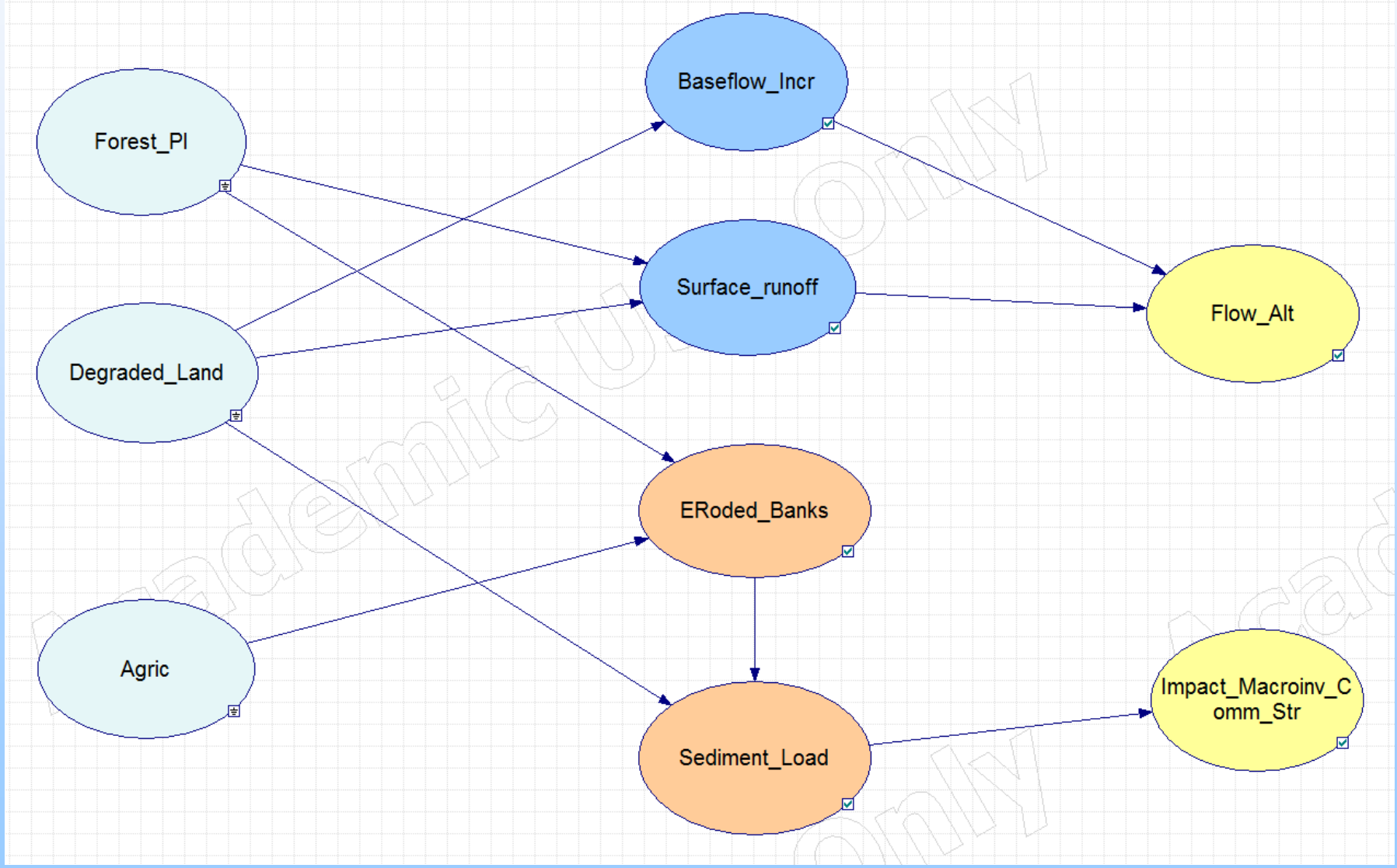
# Calculate the relative risks

Risk $score_{RR}$ = $\sum_{endpoints}$ Stressor $score_{RR}$ * $Exposure_{RR}$ * Habitat $score_{RR}$ * $Effect_{endpoint}$

- Risk per risk region - Can compare risk regions, can aggregate over regions
- $RS_{endpoint} = \sum_i \sum_j \sum_k S_{ij} \cdot Exposure_{ijk} \cdot H_{ik} \cdot Effect_{jk,endpoint}$
- $\boldsymbol{RS} = \sum_{endpoint} RS_{endpoint}$

i - risk regions, j - source, k - habitat

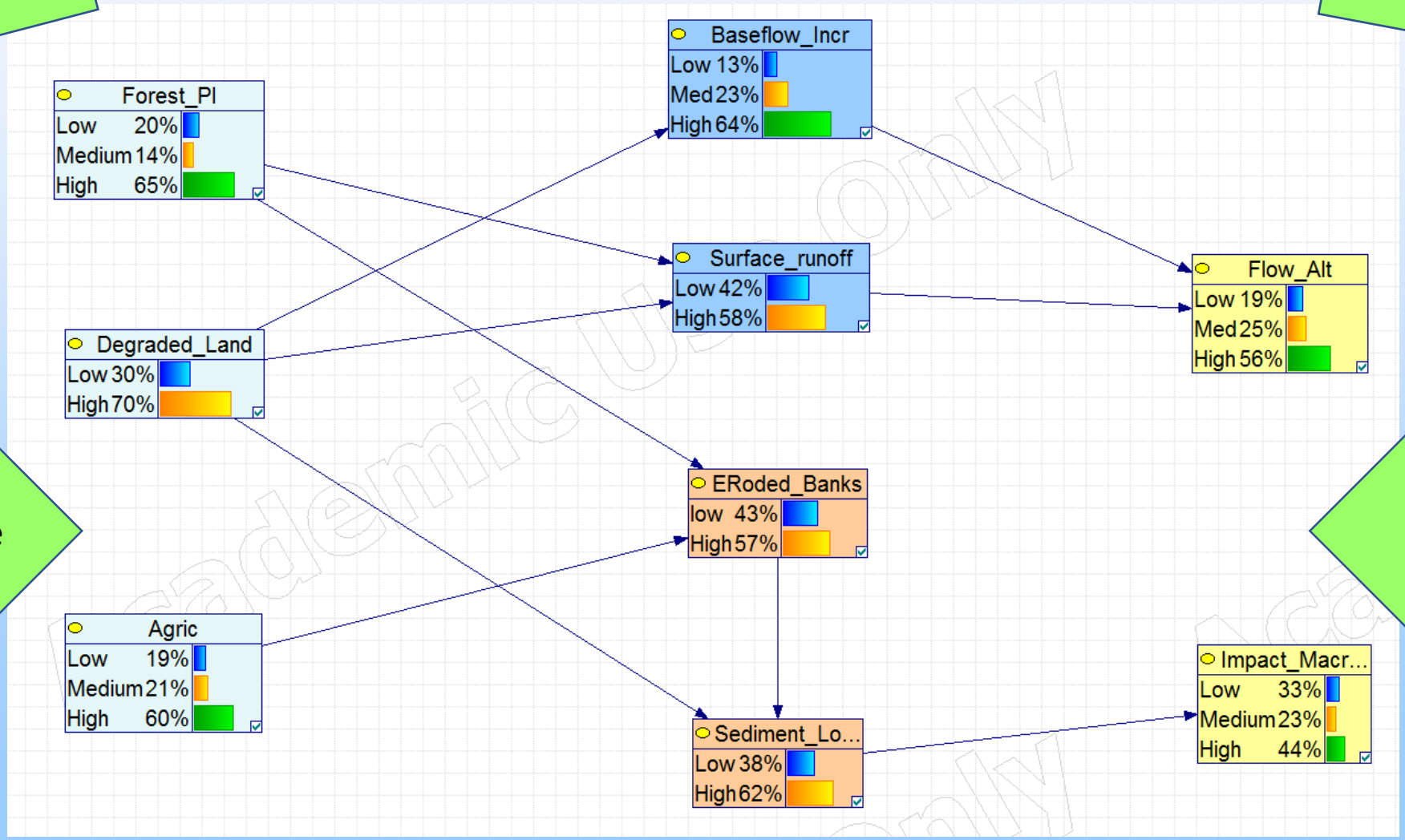
# Bayesian Network – Conceptual Model



# Bayesian Network

Data

Expert knowledge



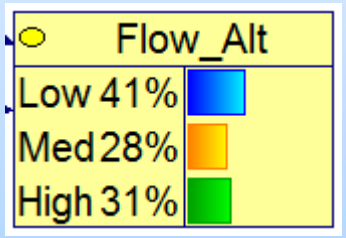

Expert knowledge

Data

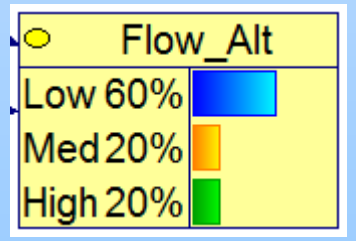
# RRM……BNs……RQOs…..ECs???

- Endpoints are expressions of specific RQO components
- BNs will determine the probability of risk to the different endpoints, relating to EC (A→F) – determine whether there will be improvement or deterioration as we work with different management scenarios.

Scenario 1 (reduced baseflow)

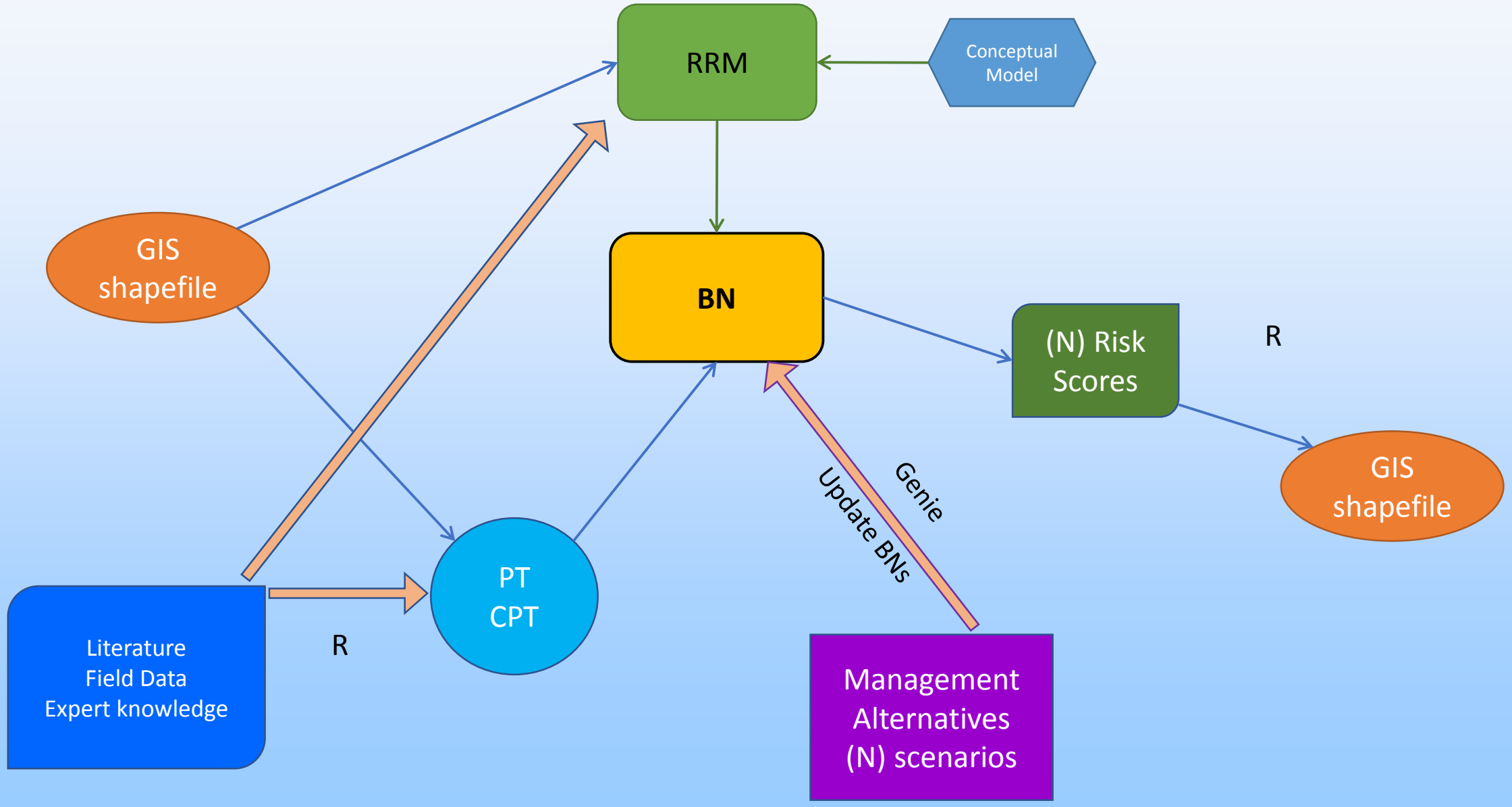



Scenario 2 (increased Forest plantations and low runoff)

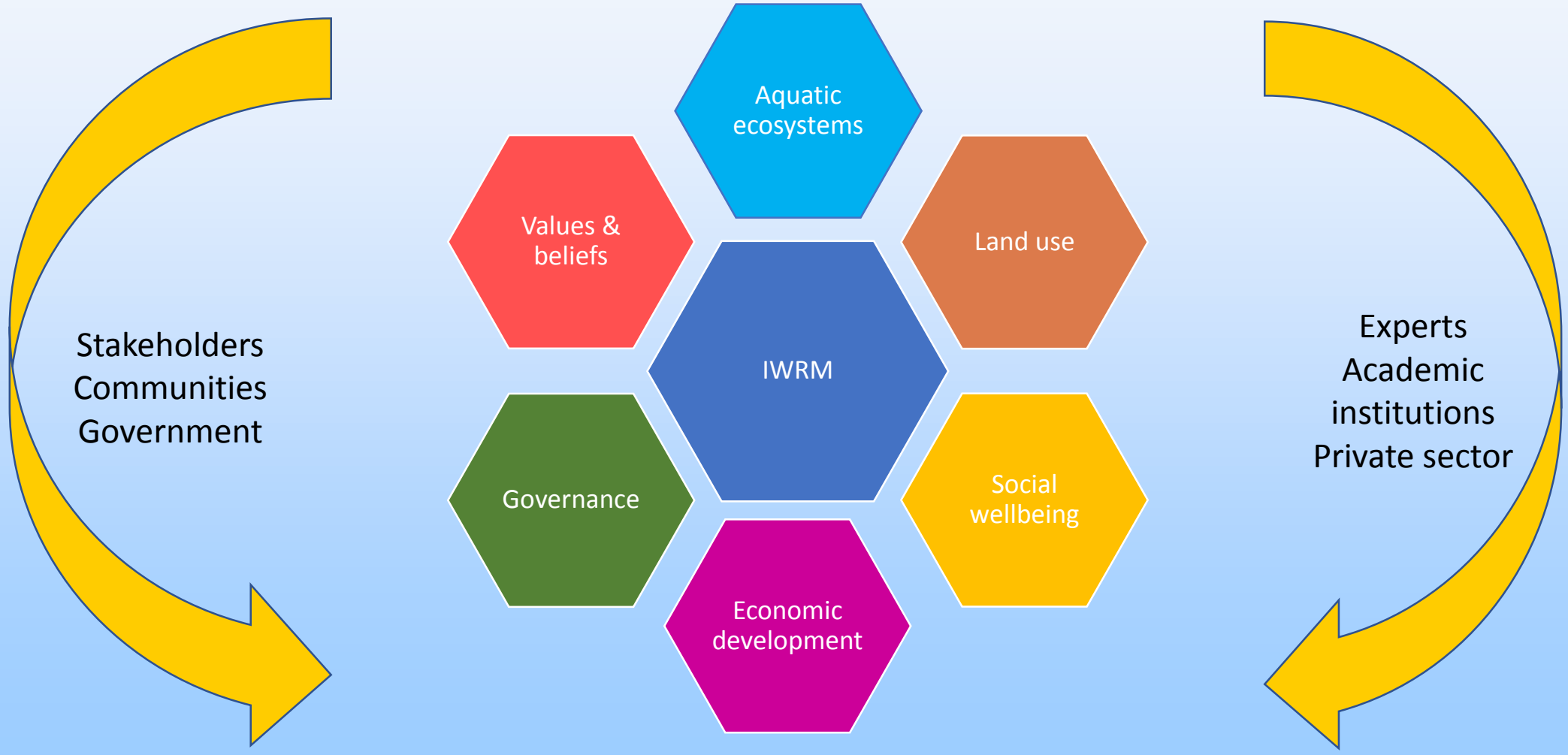



How do these different scenarios affect ECs?

# How does it all come together?



# BNs in Integrated water resource management



# Concluding remarks

- Current and recent research in the uMngeni catchment – sources of information and data to update BNs
- BNs in adaptive management – to explore different management scenarios in an attempt to achieve balance between use and protection
- Final presentation of the model will make it easier for stakeholders to interpret various scenarios
- BNs easily presented to stakeholders due to its ability to communicate visually – graphic in nature
- Make uncertainties explicit
- Contribute to the development of a database and online data management system with direct link to decision makers
- Guide implementation of RQOs and maintain acceptable ECs of water resources

(DWAF, 2002)

# *Thanks for your attention!*