Design and prototype development of an integrated catchment/river model for adaptive learning and ecosystem management on the Crocodile River system

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Presentation -- Overview

- Complex Environmental Challenges
  - Introduction to the Crocodile River Catchment
  - Proposed Problem Statement/Objectives
- Model Development/Decision Integration
  - Management-focused models (QnD)
  - Integration with an agro-hydrological model (Acru2000/NP) to create QnD:CrocRiver v0.0
- Discussion: The Way Forward…

Problem Complexity: An Introduction to "Wicked Problems"

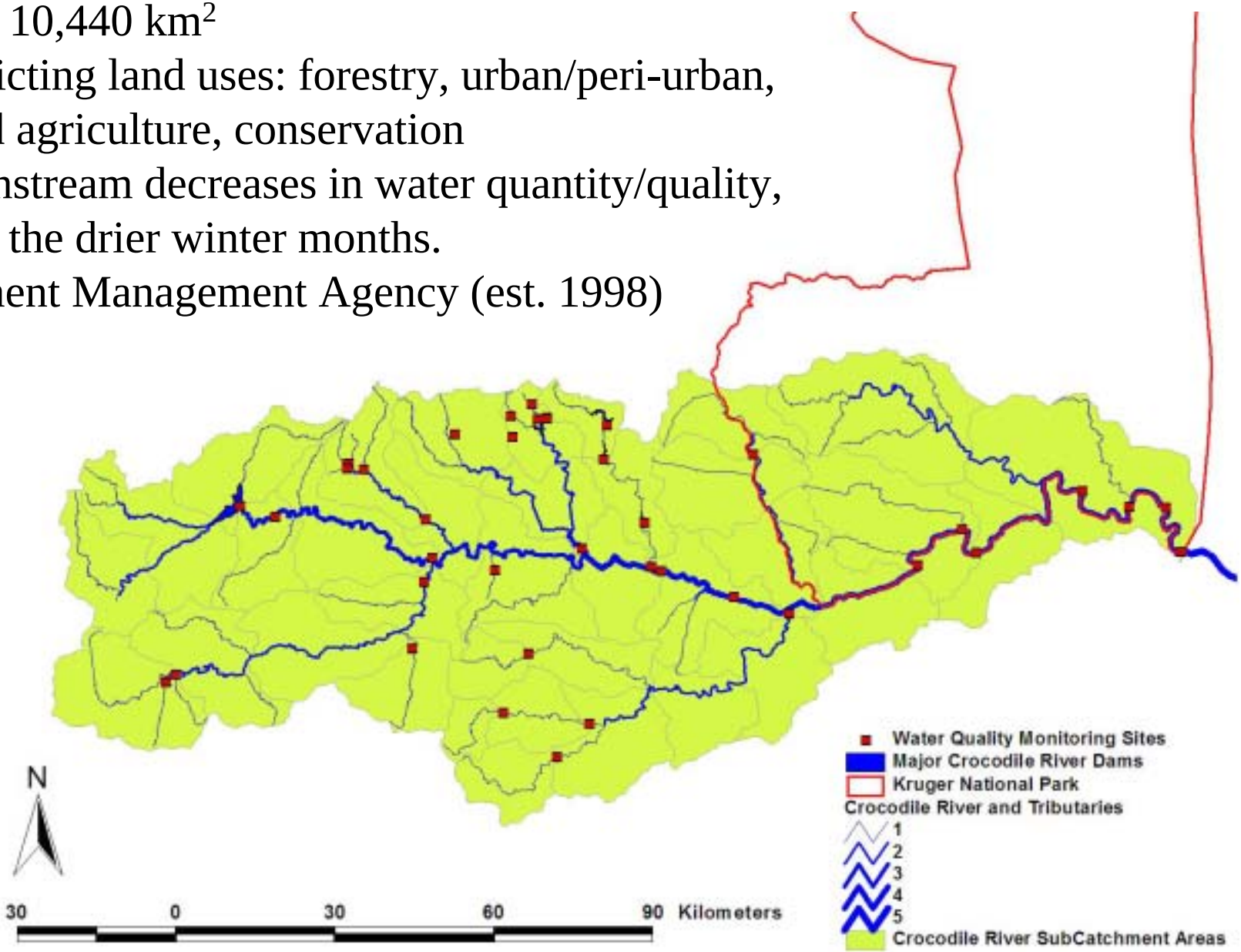
- Definition: Problems that cannot be solved with traditional analytical approaches (Rittel and Webber, 1973).
- Characteristics
  - Occur within a *social context*
  - Interlocking/overlapping issues
  - Shifting goal posts … never finished…
  - No perfect solutions: "better or worse" more than "good/bad"
- Examples
  - Most large-scale environmental projects
  - Any non-trivial, software development
- Solution: Can wicked problems be "tamed"?
  - Discussion, consensus, accepting change, iterations
  - Top-down and bottom-up organization are both integral

Rittel, H. and M. Webber. 1973. Dilemmas in a General Theory of Planning. Policy Sciences. Vol.4: 155-169.

Crocodile River Catchment

"a microcosm of the water resource problems currently facing South Africa as a whole" (Ashton, 1995)

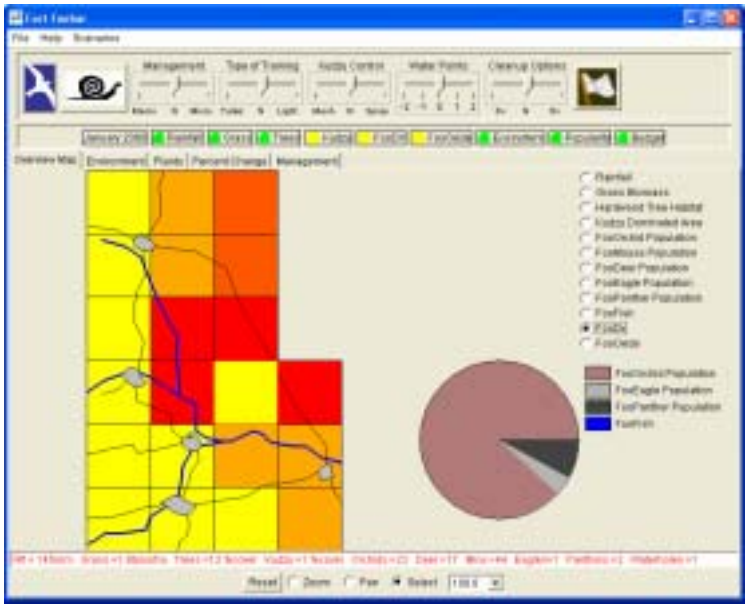
- Catchment Area: 10,440 km^2
- Varied and conflicting land uses: forestry, urban/peri-urban, irrigated/dry land agriculture, conservation
- Progressive downstream decreases in water quantity/quality, especially within the drier winter months.
- Inkomati Catchment Management Agency (est. 1998)

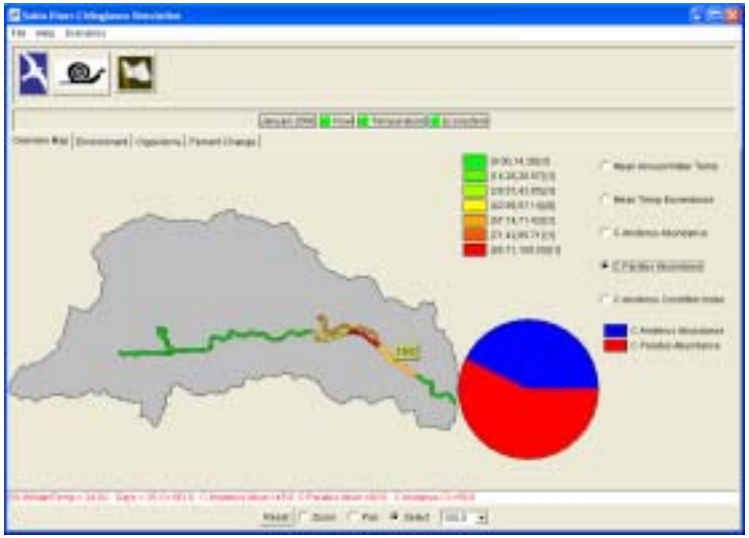


Proposed Problem Statement and Objectives

- *Given the finite amount of scientific and social information that has been gathered to date in the Crocodile River System, a useful approach is a systematic integration of past and on-going studies into iterative and management-focused tools to explore adaptive management options within the watershed.*
- Establish a watershed-level, decision/management-support tool to integrate multi-disciplinary information within an adaptive decision framework,
- Link elementary land use, river health algorithms and thresholds of probable concern to simulate hydrological and water quality conditions under long-term scenarios for the Crocodile River Catchment,
- Explore a range of flow and water quality scenarios for selected TPCs and end users for use in discussions amongst stakeholders and regulatory officials.

QnD Model



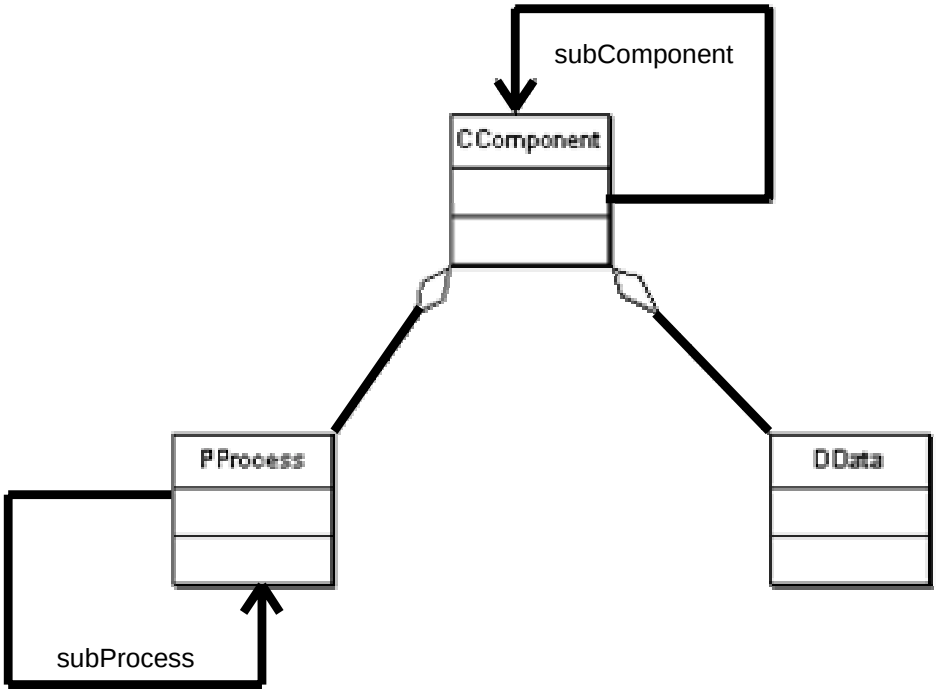


- **QnD™ – *"Questions and Decisions™" or "Quick n Dirty"***
- **A fully integrated, open-source, Graphic User Interface (GUI) with a flexible model engine**
- **One model - Many ecosystems**
  - **Java code / XML inputs**
  - **Dynamically instantiated objects**
- **Java-based deployment in web browsers**
- **"Fast Deployment" (weeks/months)**
- **Spatial simulation with GIS linkage**
- **Multiple maps/graphs/files for output variables**
- **Overview and examples (Kiker *et al.*, 2006; Kiker and Linkov, 2006)**

QnD Model: Main Sections

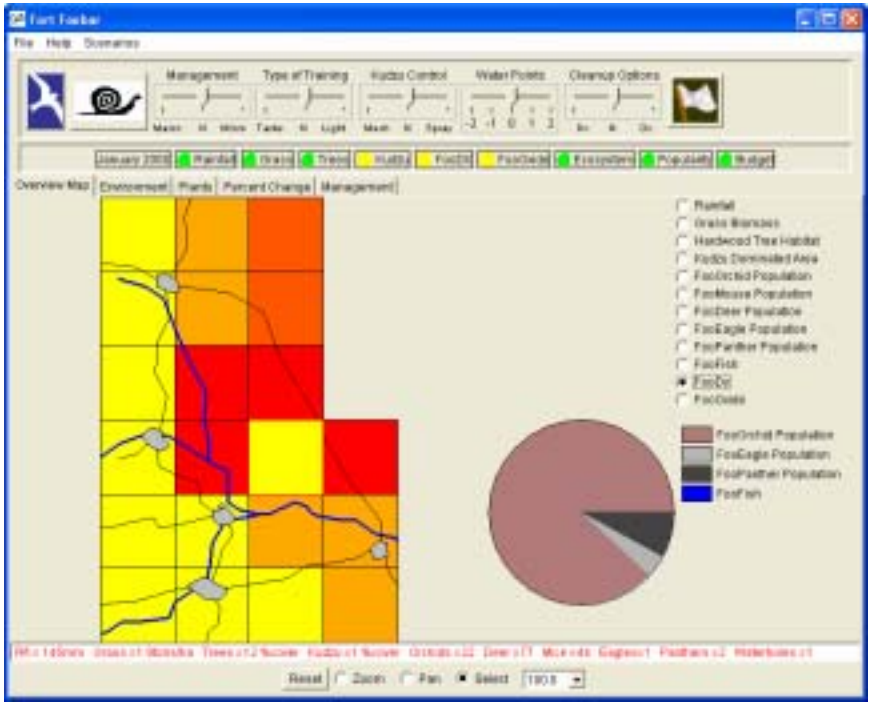
"Simulation Engine"

- Developer's point of contact
- Manages information
- Objects: Components, Processes and Data
- Calculation for selected time step

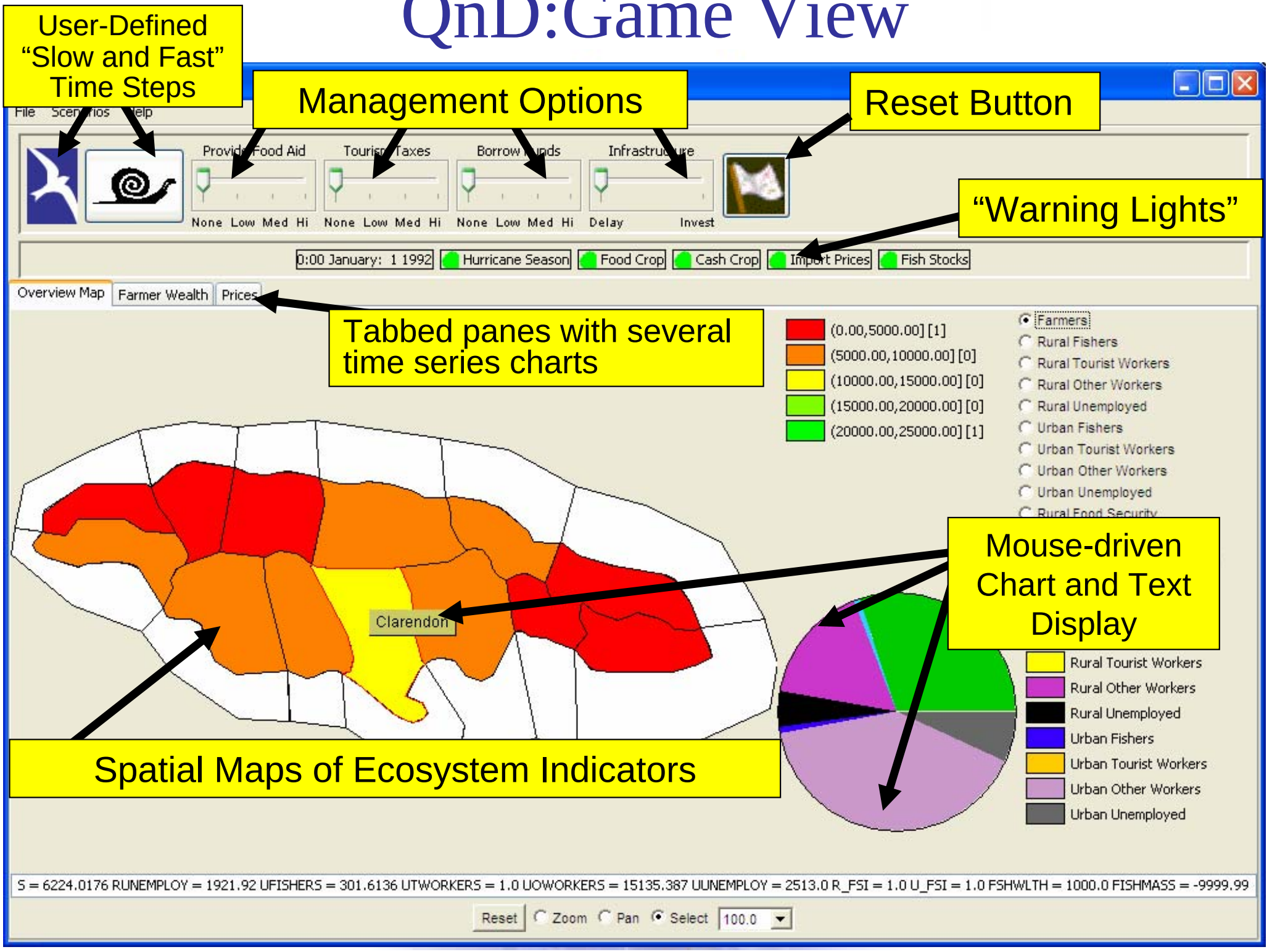


"Game View"

- User/Player's point of contact
- Communicates information
- "Widgets": Maps, Charts, Warning Lights, Text, Sliders, Icons, Buttons
- User choices – management settings, simulate fast or slow time step, reset



QnD:Game View



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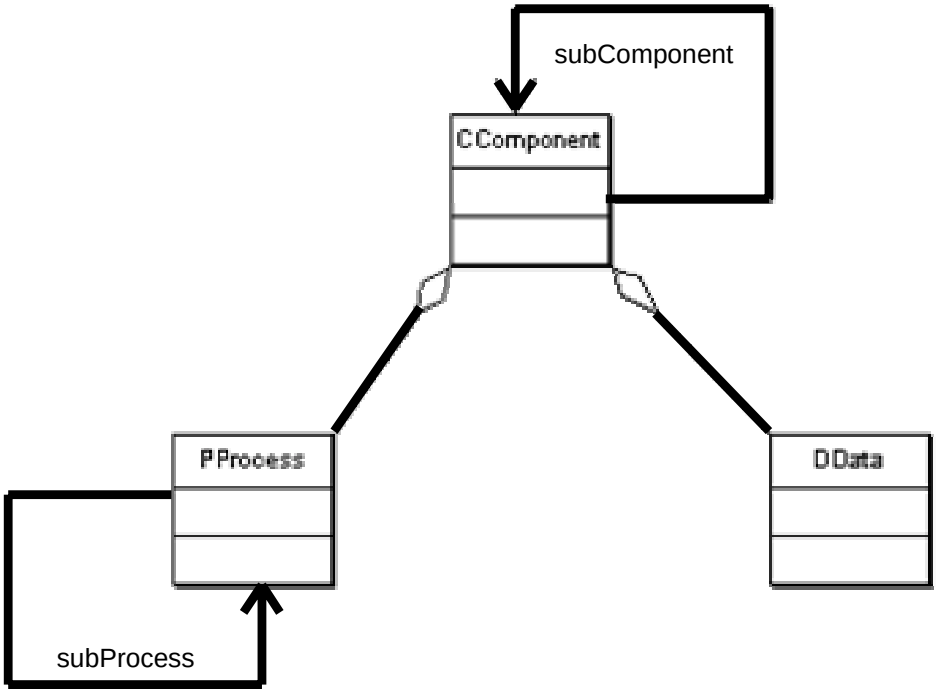

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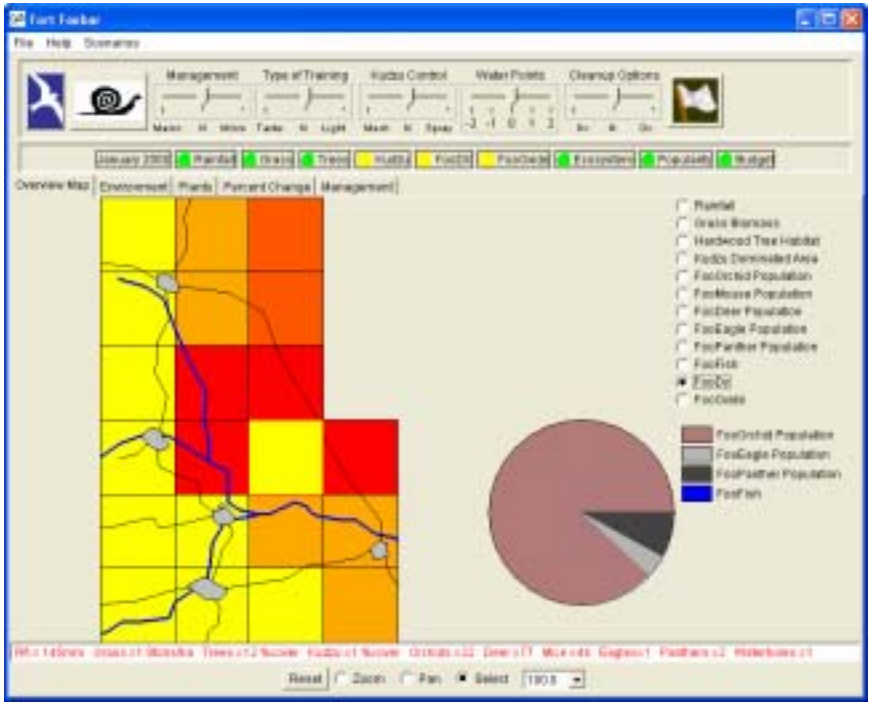
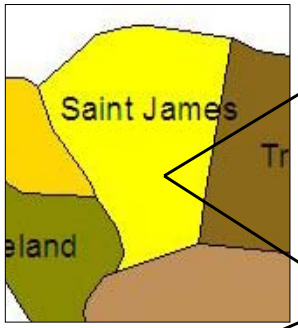


Object Design

Example

Spatial Units



Habitats

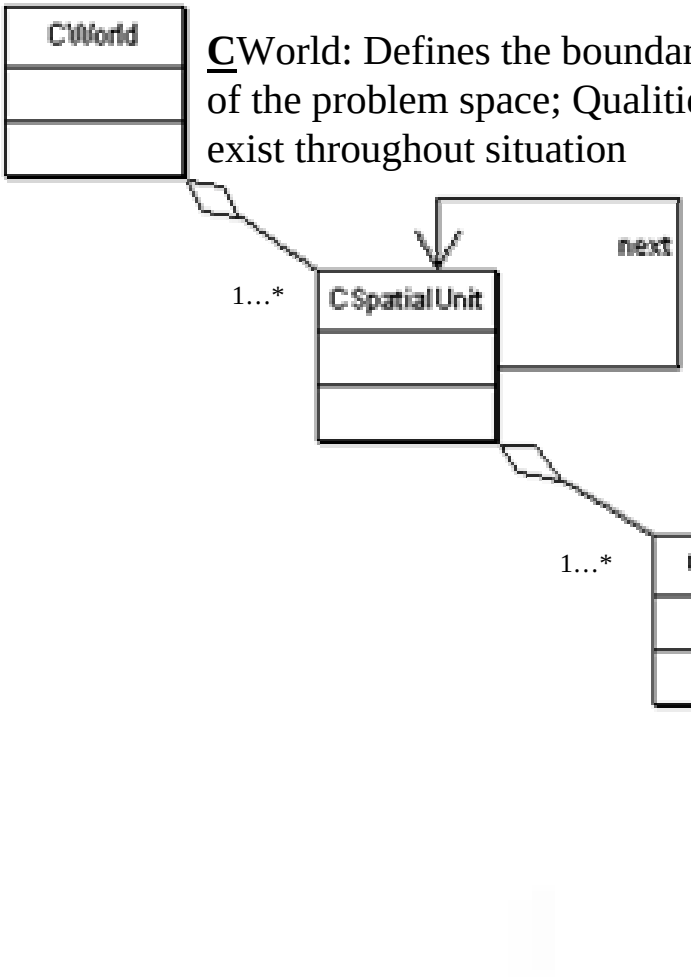
- Urban
- Rural

Landuses with Data Attached

- Food crop (area)
- Export crop (productivity)
- Non-arable land
- Forested land
- Pasture

Employment Units with Data Attached

- Small Farmers (population)
- Tourist workers (population)
- Other wage workers
- Unemployed (population)



CWorld: Defines the boundaries of the problem space; Qualities exist throughout situation

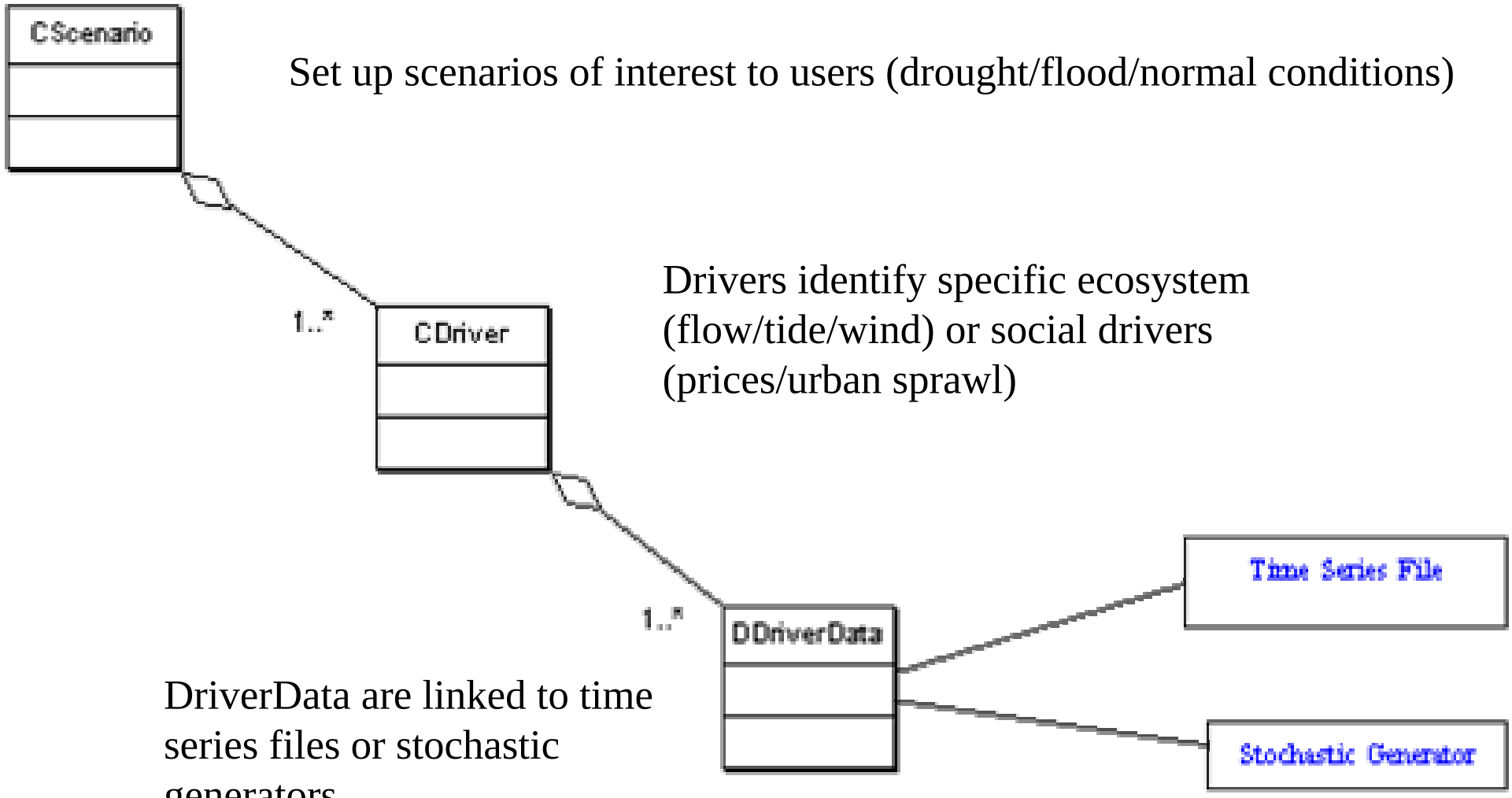
CSpatialUnit: Spatially-explicit areas that can be linked together

CHabitat: Non-spatial areas that contain ecological/environmental elements

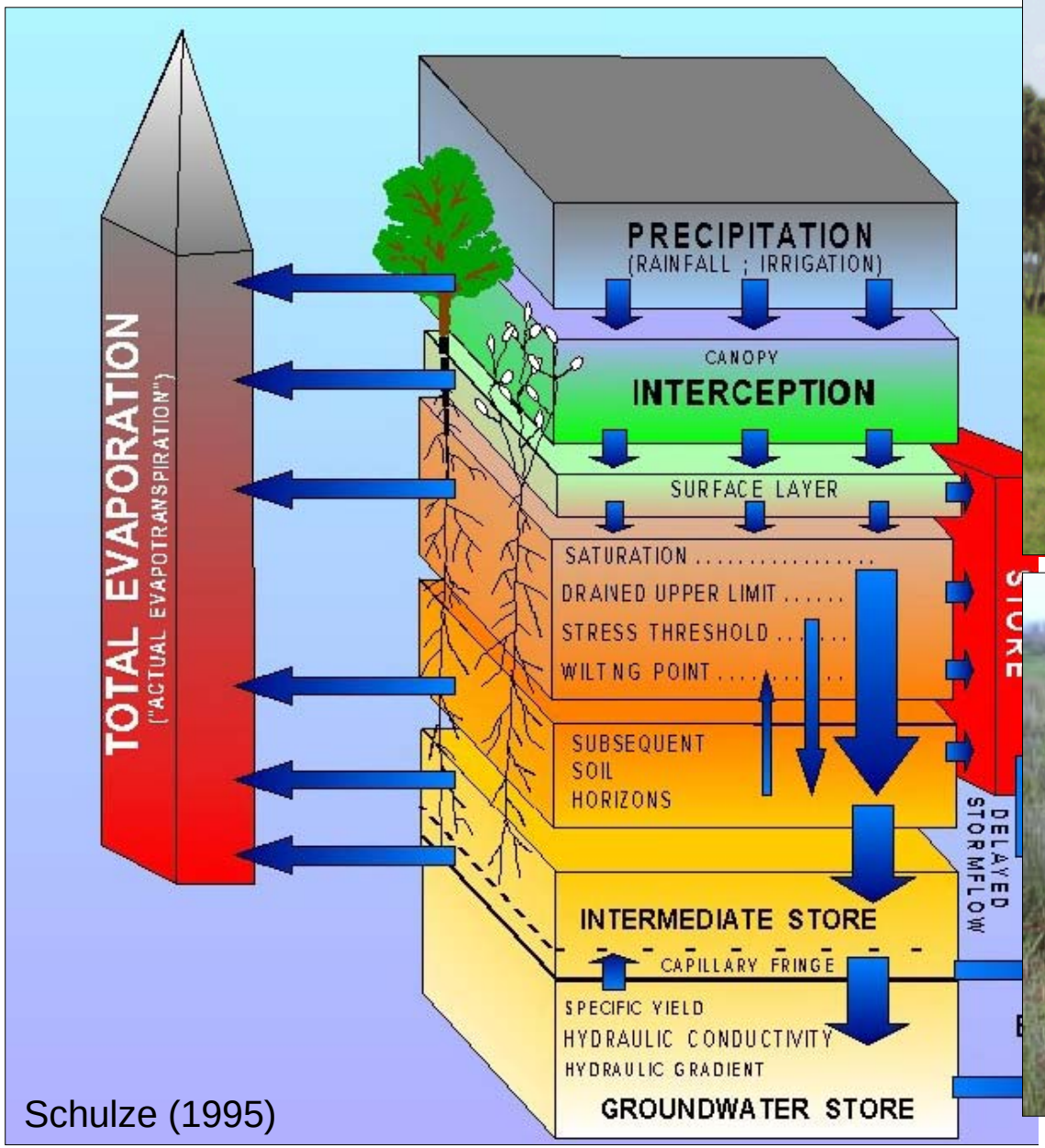
CLocalComponent: Things that exist within CHabitats (human employment units, land uses)

Scenarios, Drivers and Driver Data

Set up scenarios of interest to users (drought/flood/normal conditions)



Integration of Acru2000 + GLEAMS (N/P) (+ CENTURY)



Schulze (1995)

Groundwater

ACRU2000: (Kiker, et al., 2006)
ACRU2k N/P (Campbell et al., 2001)

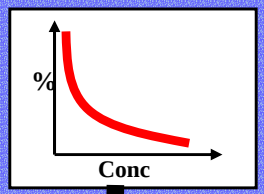
Photo sources: MAERC
http://www.maerc.org

Traditional Discipline-Based Assessment

Scenario Development

Time series
Decision Rules
Stakeholder values
Models or estimates

Acru2k/NP Model:



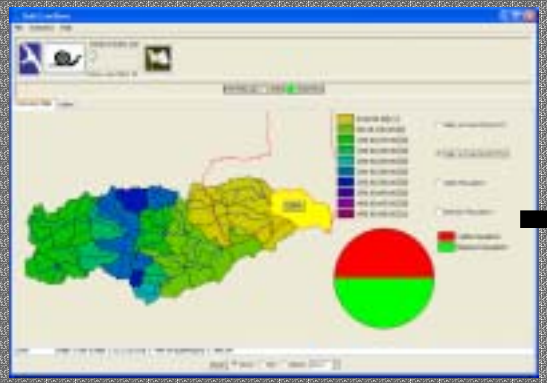
Problem Formulation

Analysis

Solution Formulation

QnD System

Time series
Simulated Effects
Load/ Concentration Relationships



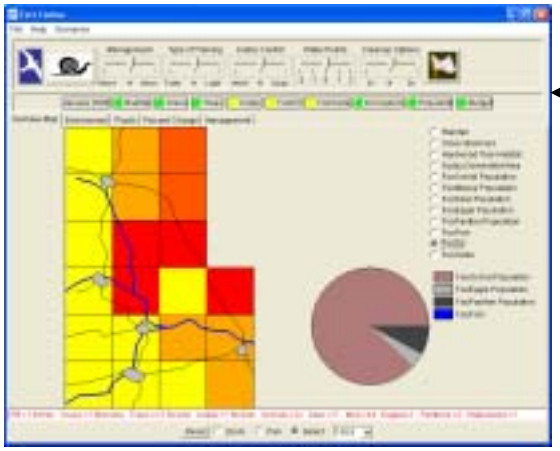
Scenarios → Best/Worst Cases

Adaptive Opportunities

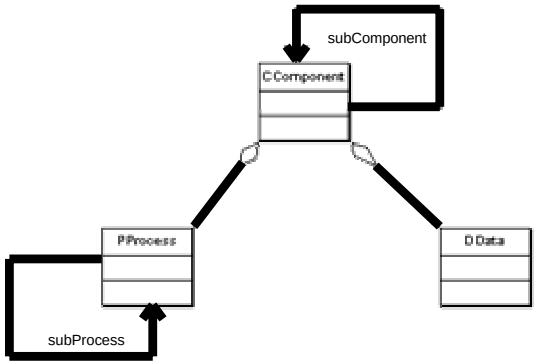
Communications with Resource Managers

Communication with Stakeholders

“Game View”



“Simulation Engine”



QnD Java Source Code

GameDriver.java

ModelCreator.java

PrimaryGameFrame.java

Actors

Players: Interact mostly with the game view.

- Explore management responses, adaptive opportunities, trade-offs for different scenarios.
- Provide reality checks
- Have some interest in the engine structure in their area of interest
- Provide ideas and directions for further iterations

Developers: Interact mostly with the engine.

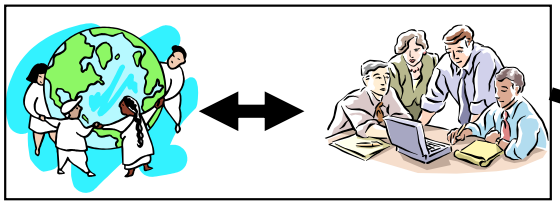
- Design and implement engine/game view through XML files.
- Provide formal calibration/validations
- Implement ideas and directions of Players
- Have some interest in the model code

Coders: Interact mostly with the QnD source code.

- Develop java code to expand engine and game view utility
- Create new programming code for ideas from Players and Developers…

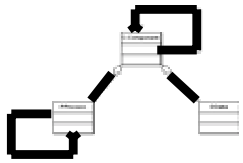
QnD: Development Methodology

Genesis Session



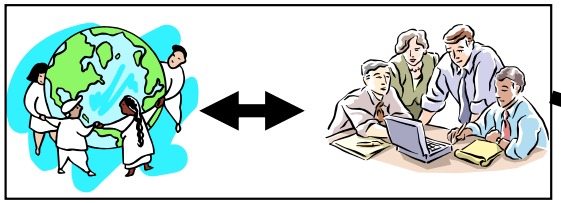
- Talk about the system, goals, desires
- Explore current management options
- Gather initial maps/data
- Brainstorm about desired management options, relevant information and socio-economic realities

Prototype QnD Game View and Simulation Engine



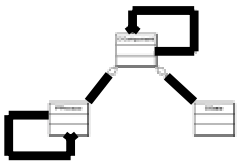
- Rough estimate of components, processes and data
- Simple information
- Deployed in limited circulation for calibration/reality checks

Iterative Sessions 1…n



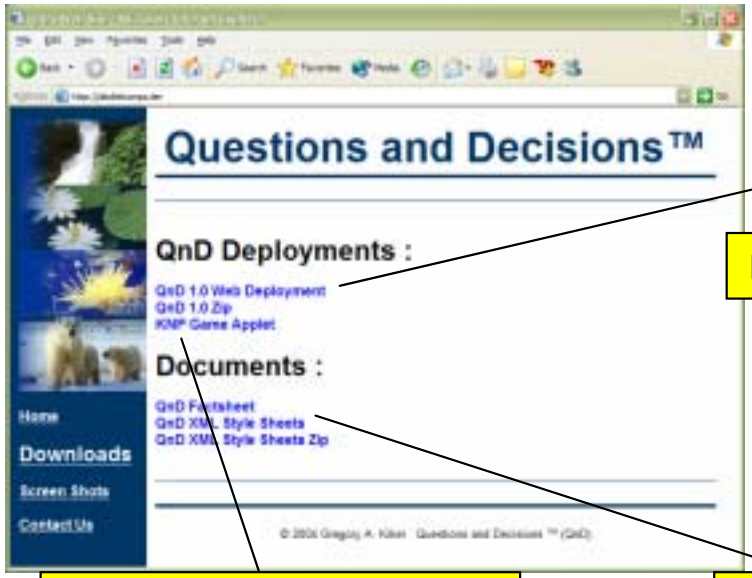
- Refine goals, objectives
- Explore current and possible management options
- Calibrate/Validate engine performance
- Revise Game View for relevant management information
- Make changes concerning management options, relevant information and socio-economic factors

Deployed QnD Model

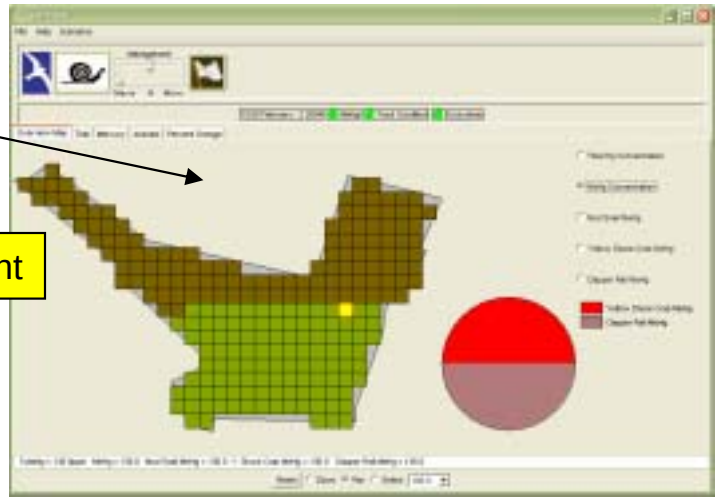


- Player/Developer reviewed components, processes and data
- More relevant information
- Brainstorm about desired management options, relevant information and socio-economic realities

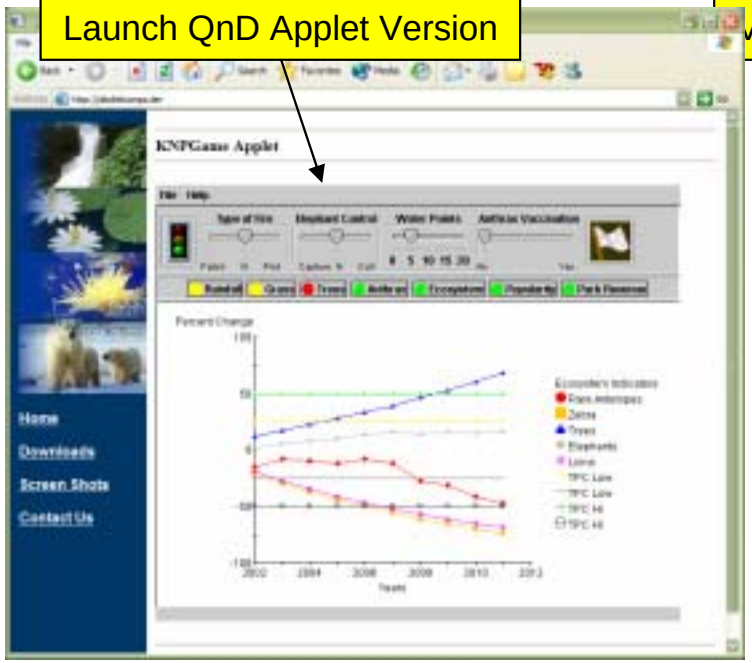
QnD Web Site/Deployment



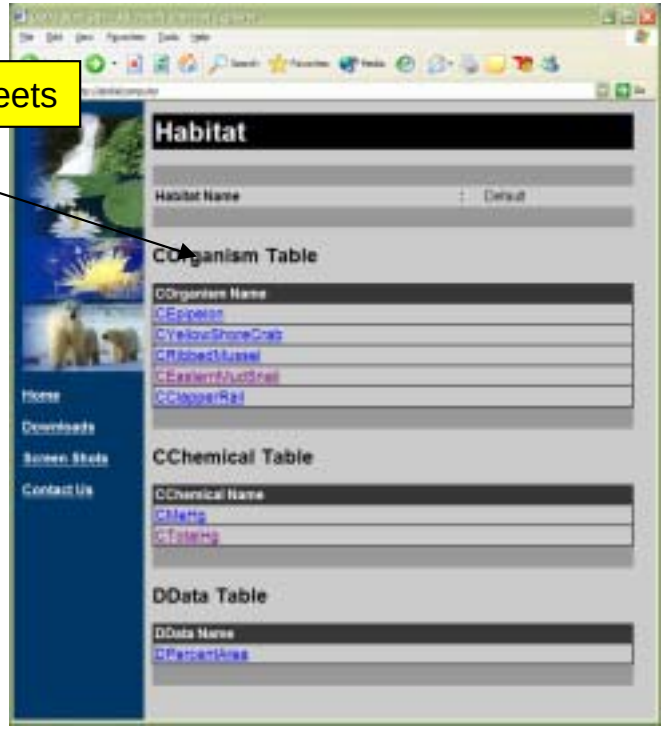
Launch QnD JNLP deployment



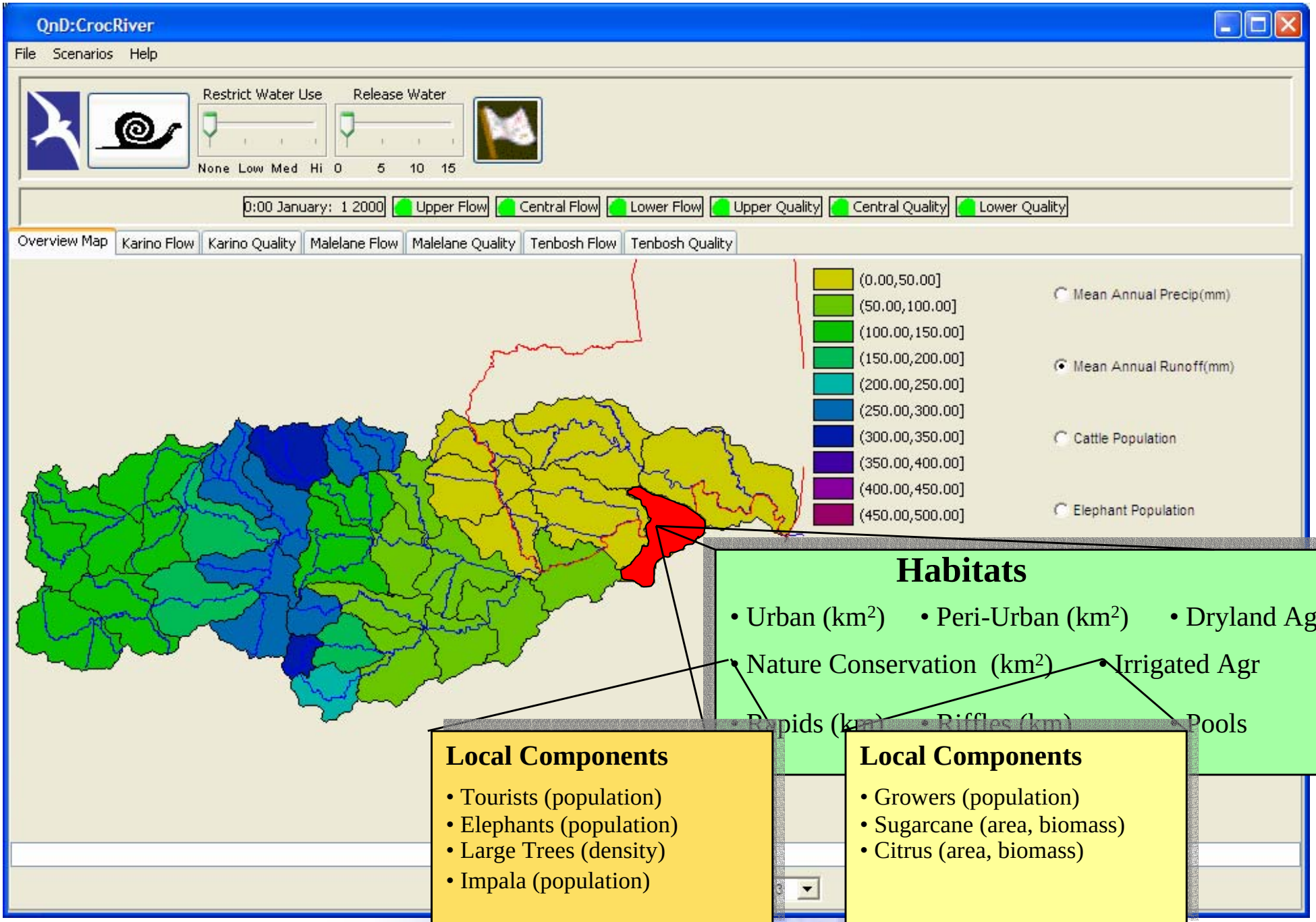
Launch QnD Applet Version



View *QnD XML Files* Style Sheets



QnD:CrocRiver version 0.0 – ever changing



Habitats

- Urban (km^2)
- Peri-Urban (km^2)
- Dryland Agr
- Nature Conservation (km^2)
- Irrigated Agr
- Rapids (km)
- Riffles (km)
- Pools

Local Components

- Tourists (population)
- Elephants (population)
- Large Trees (density)
- Impala (population)

Local Components

- Growers (population)
- Sugarcane (area, biomass)
- Citrus (area, biomass)

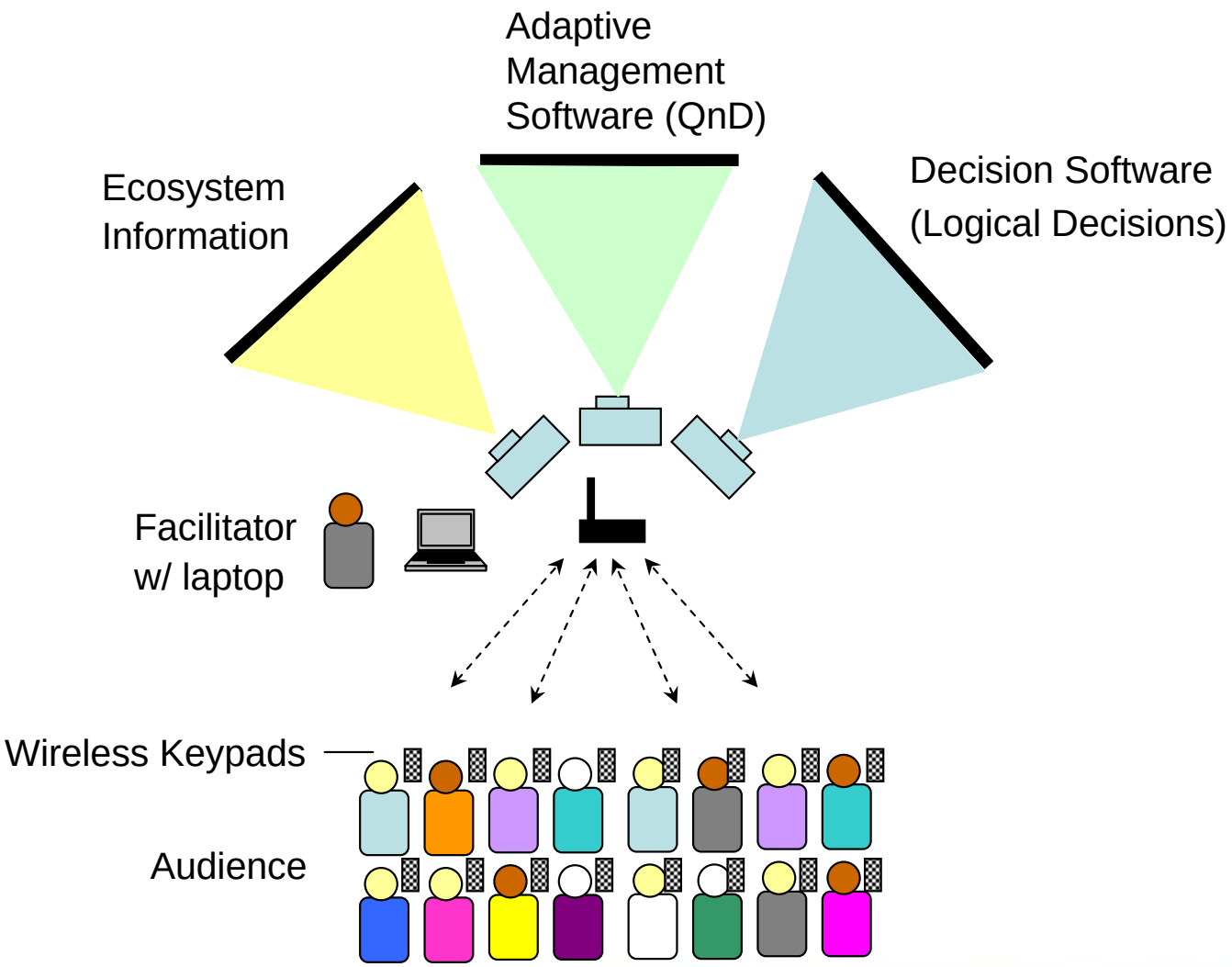
Research Products to Date

- Model Development
  - Early development of QnD:CrocRiver v0.0
  - DWAF flow/WQ data acquisition, Quaternary/"Quintary" Catchments GIS/Time Series Coverages
  - Next Year: Base Simulation/Validation of Acru2k/NP with DWAF Quaternary Catchments
  - Next Year(s): Later construction of socio-ecological components of interest
  - Next Year(s): Global Sensitivity Analysis in conjunction with SIMLAB (Saltelli, 2004)

- Decision Analysis/Integration
  - Literature Review towards WMA/CMA issues and scenarios
  - Early discussions with stakeholders/trustees (KNP, SASA,CSIR, DWAF)
- Continued iterations and changes are expected…

- Enter Mr Nathan Wangusi (UF, PhD candidate, Aug 07)

A possible way forward: Decision Theater Concept



Visualization

- Ecosystem Information
- Spatial Temporal Data Analysis
- Uncertainty and Risk

Calculation:

- Mechanistic Models
- Management-Focused Models

Interaction:

- Brainstorming
- Voting (wireless keypads)
- Scenario Analysis
- Multi-Criteria Decision Analysis

Discussion Points

- **Who will use these Decision Support Tools?**
- **What decisions need to be made?**
  - **Over time?**
  - **Over space?**
  - **Adaptively?**
- **How do you or your constituents currently make decisions?**
- **What new techniques are you willing to explore?**
- **What are your information, support and communication needs?**
  - **Training/Workshops? Reports? Web Tools?**
- **What does transparency in decisions mean to you?**
  - **What does it look like?**
  - **What level of transparency is appropriate?**

And remember…you will almost always change your mind along the way…

Acknowledgements

- SANParks - L. Foxcroft, R. Grant, H. Biggs
- UKZN (PMB) - R Schulze, S Lorentz
- CSIR – P. Ashton
- DWAF – M. Silberbauer
- University of Florida – International Center

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