Integrated ecological modelling for water management in the urbanized area of the Cuenca River basin (Ecuador)

R. Jerves-Cobo, L. Benedetti, Y. Amerlinck, K. Lock, C. De Mulder, J. Van Butsel, F. Cisneros, P. Goethals, I. Nopens

INNOVATION CONFERENCE ON SUSTAINABLE USE OF WATER: CITIES, INDUSTRY AND AGRICULTURE
Guayaquil-Ecuador, 01/10/2019

Urban Catchment Problems

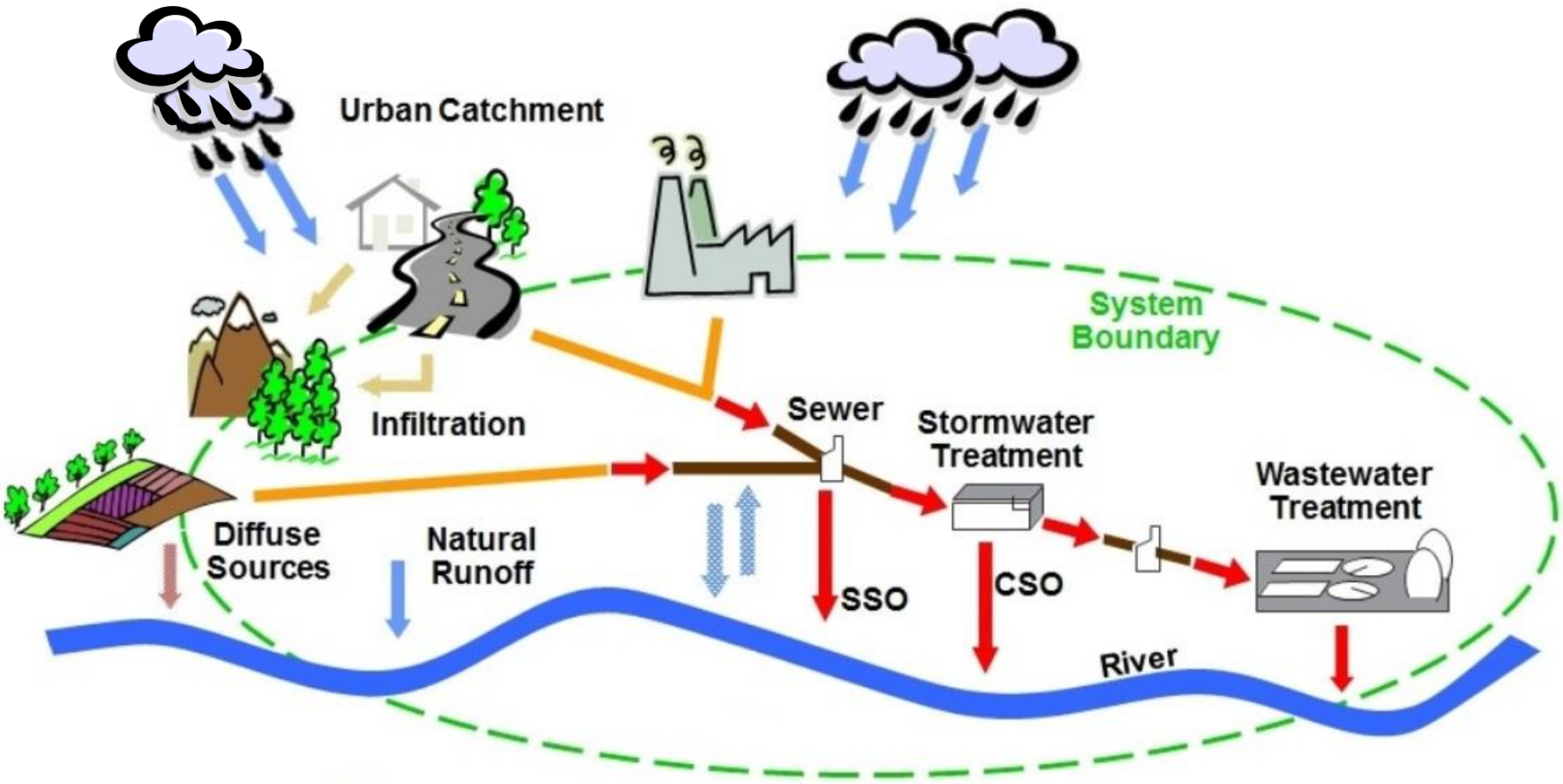
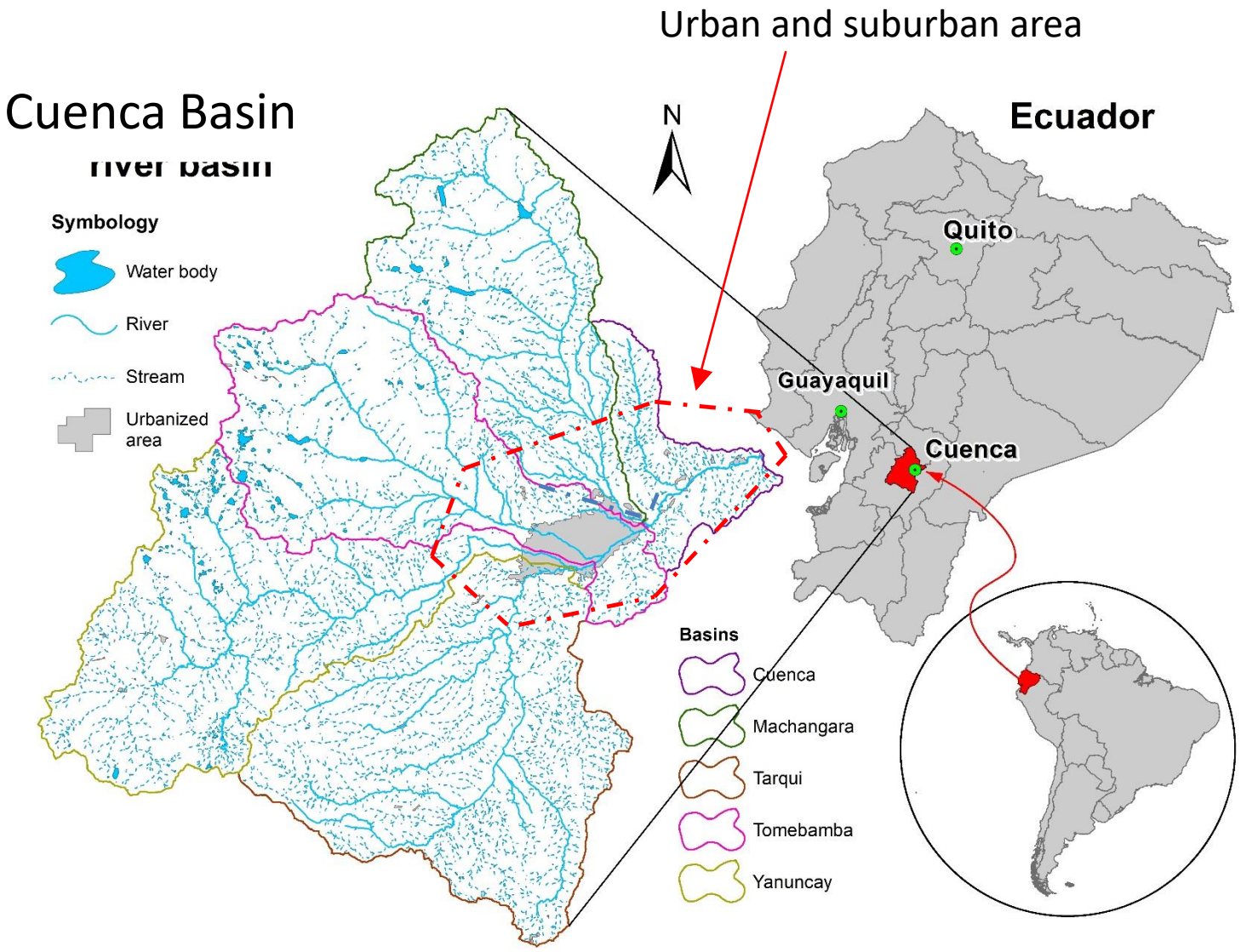


Image: Integrated modelling and design of basin management plans - Nopens - 2016

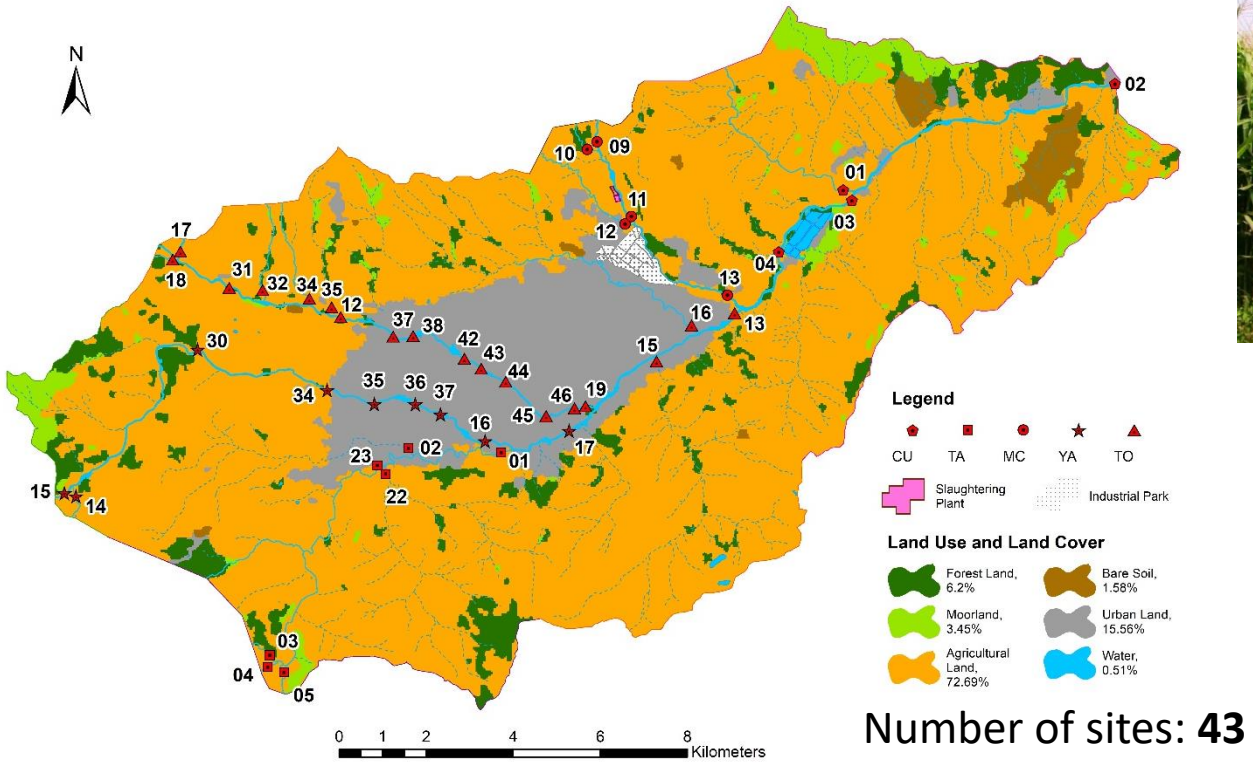
Objectives

Which measures are more effective to improve the current water quality in the Cuenca Basin?

Study area


Urban and suburban area
Cuenca Basin
river basin
Symbology
Water body
River
Stream
Urbanized area
N
Ecuador
Quito
Guayaquil
Cuenca
Basins
Cuenca
Machangara
Tarqui
Tomebamba
Yanuncay

Study area: Urban and suburban area of Cuenca Basin



Number of sites: **43**

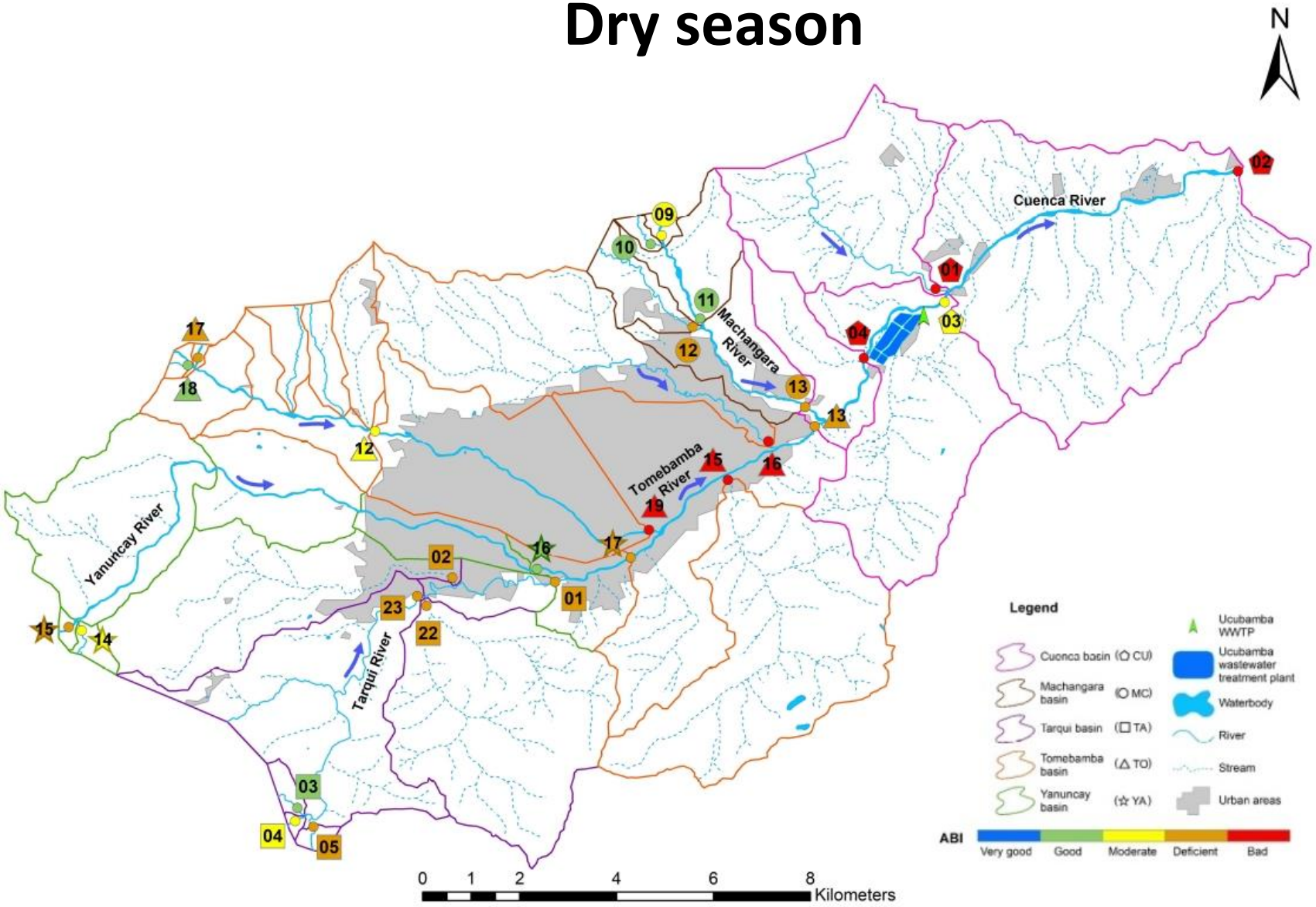
Data collection

In situ measurements

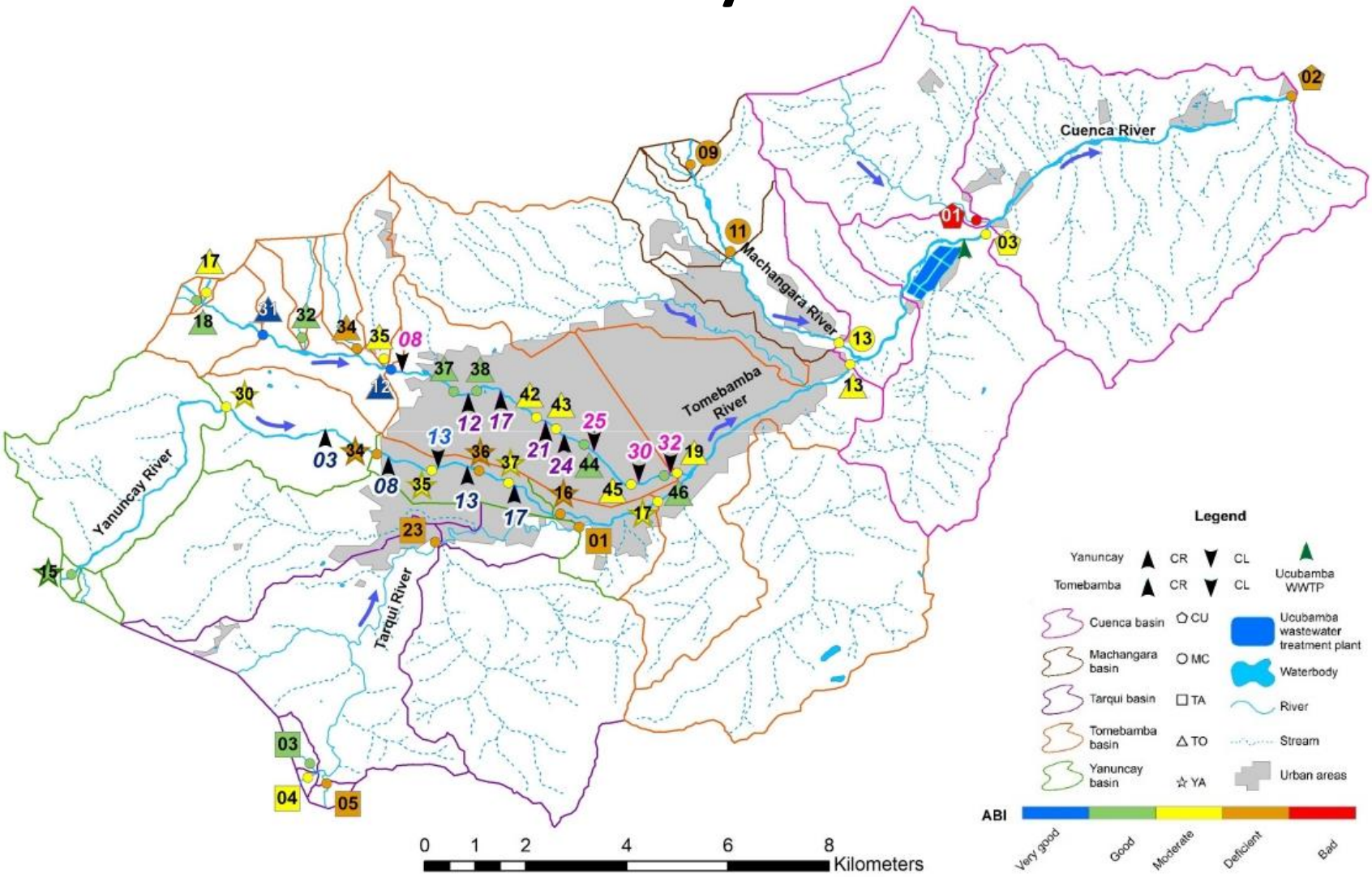
Lab analyses

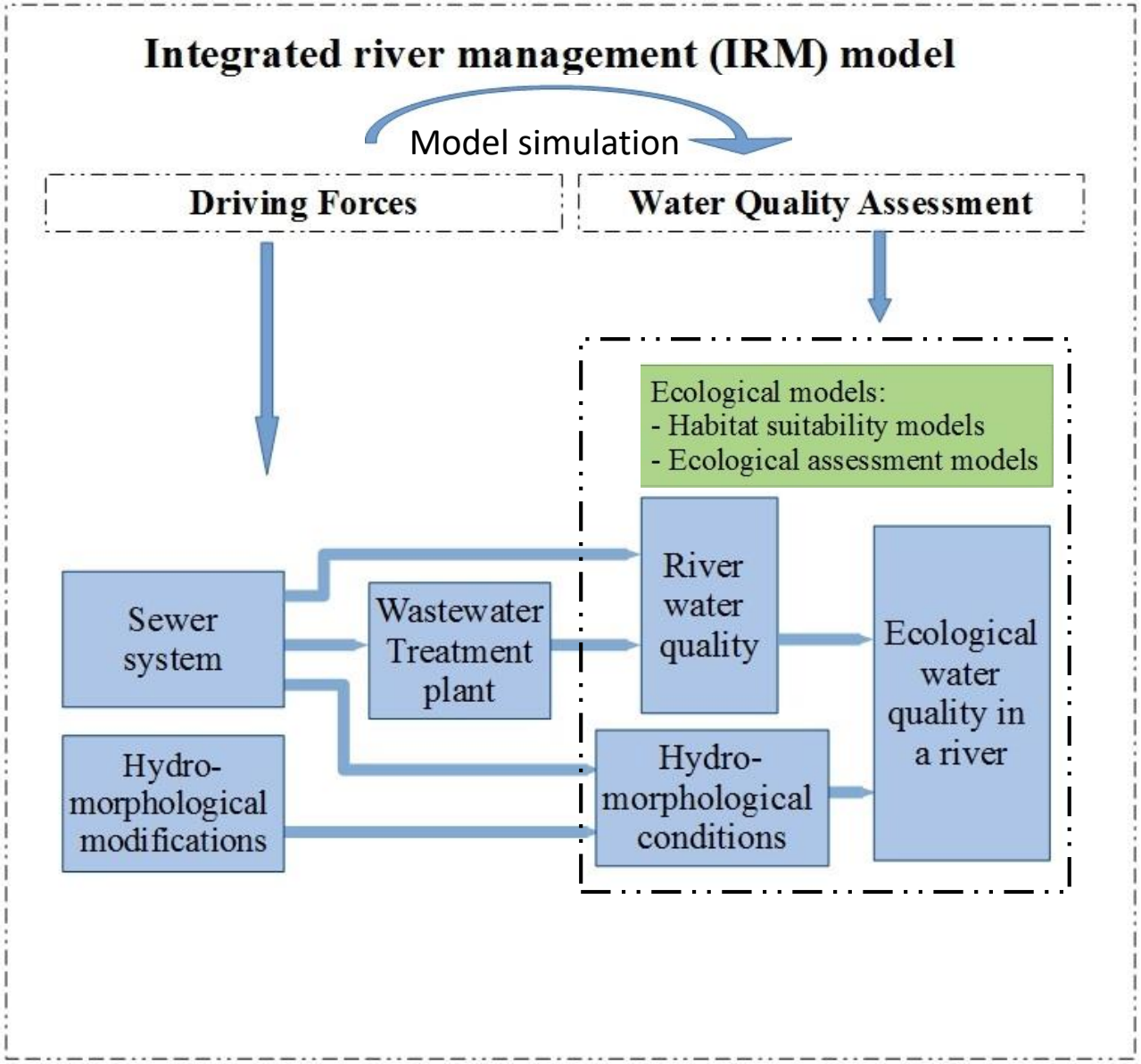
Macroinvertebrates collection

Biological water quality (ABI)
Dry season



Biological water quality (ABI)
Rainy season




Integrated river management (IRM) model
Model simulation
Driving Forces
Water Quality Assessment
Ecological models:
- Habitat suitability models
- Ecological assessment models
Sewer system
Wastewater Treatment plant
Hydro-morphological modifications
River water quality
Hydro-morphological conditions
Ecological water quality in a river

Ecological models development

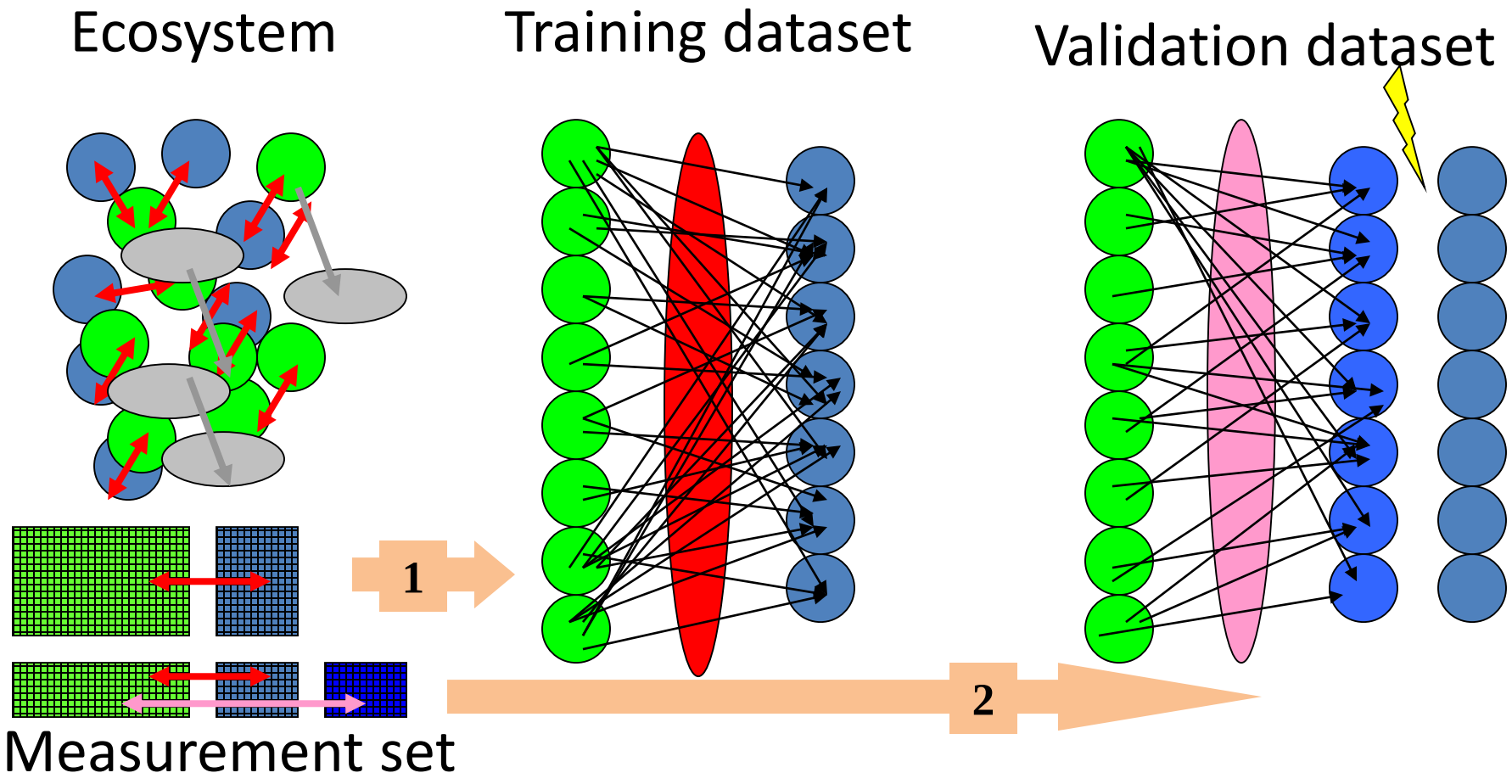


Image: Water Quality Modelling- Goethals - 2015

Generalized Linear Model (GLM) to identify variable that influence the ABI

Gaussian GLM:

$$\mathbf{E}(Y_i) = \mu_i = \eta_i = \alpha + \beta_1 \times X_{1i} + \beta_2 \times X_{2i} + \cdots \ldots + \beta_n \times X_{ni} \quad (1)$$

Gamma GLM:

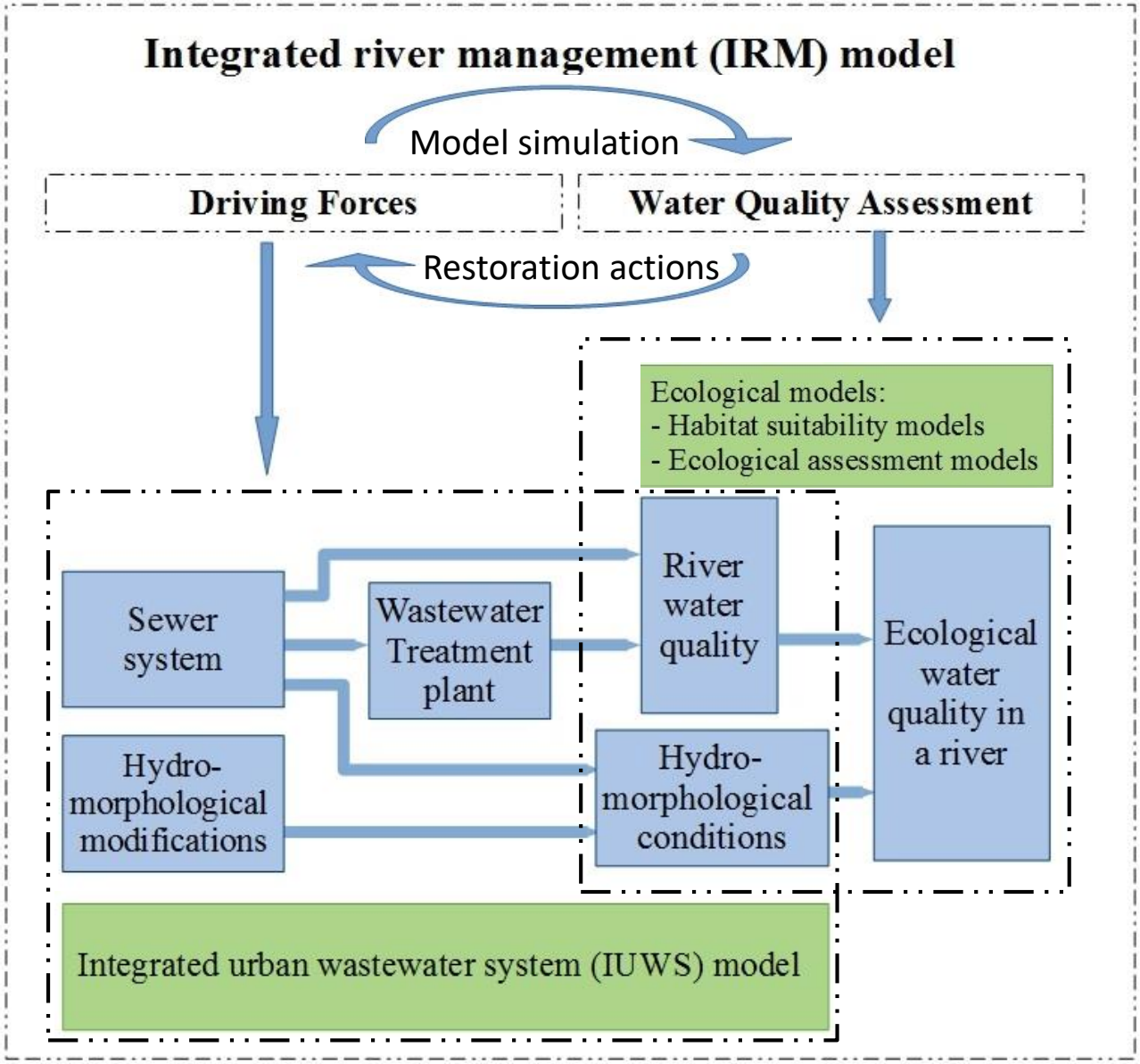
$$\mathbf{E}(Y_i) = \mu_i = \frac{1}{\eta_i} = \frac{1}{\alpha + \beta_1 \times X_{1i} + \beta_2 \times X_{2i} + \cdots \ldots + \beta_n \times X_{ni}} \quad (2)$$

ABI

Inverse Gaussian GLM:

$$\mathbf{E}(Y_i) = \mu_i = \frac{1}{\sqrt{\eta_i}} = \frac{1}{\sqrt{\alpha + \beta_1 \times X_{1i} + \beta_2 \times X_{2i} + \cdots \ldots + \beta_n \times X_{ni}}} \quad (3)$$

Xji = explanatory variables --> physicochemical and hydromorphological variables


Integrated river management (IRM) model
Model simulation
Driving Forces
Water Quality Assessment
Restoration actions
Ecological models:
- Habitat suitability models
- Ecological assessment models
Sewer system
Wastewater Treatment plant
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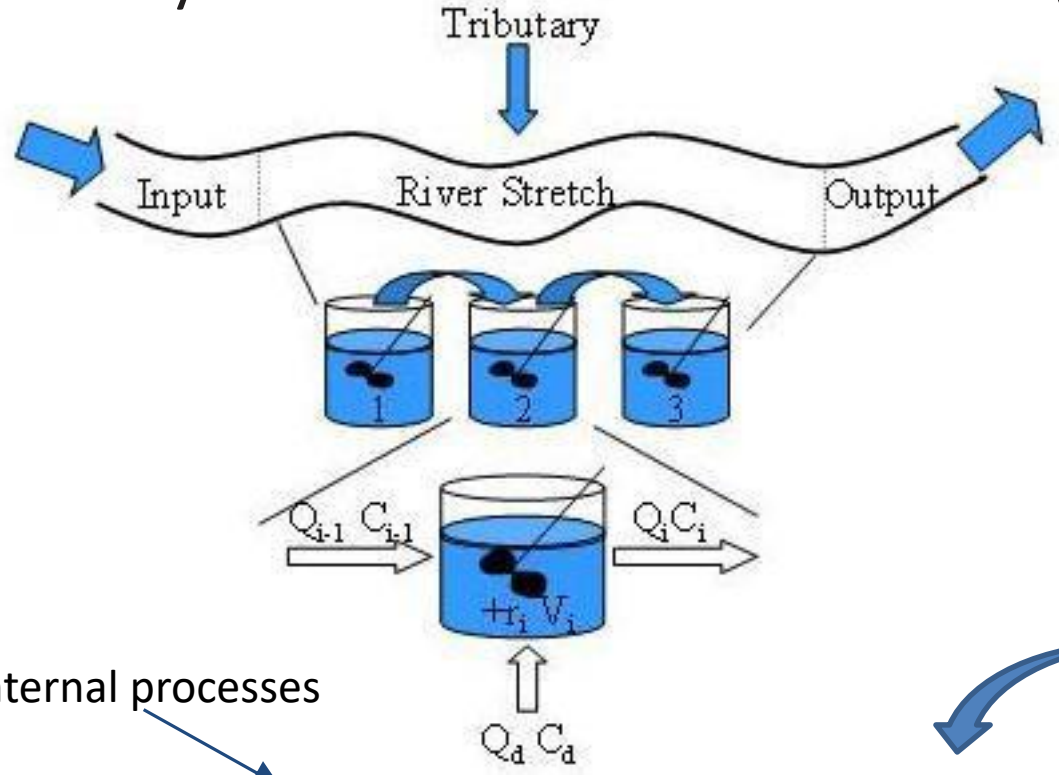
Hydro-morphological conditions
Integrated urban wastewater system (IUWS) model

Integrated urban wastewater system (IUWS) model

Continuously Stirred Tank Reactor in Series (**CSTRS**)



Internal processes

Change in Time = **Advective Transport** + **Mixing (Dispersion - Diffusion)** + **Conversion Processes** + **Sinks & Sources**

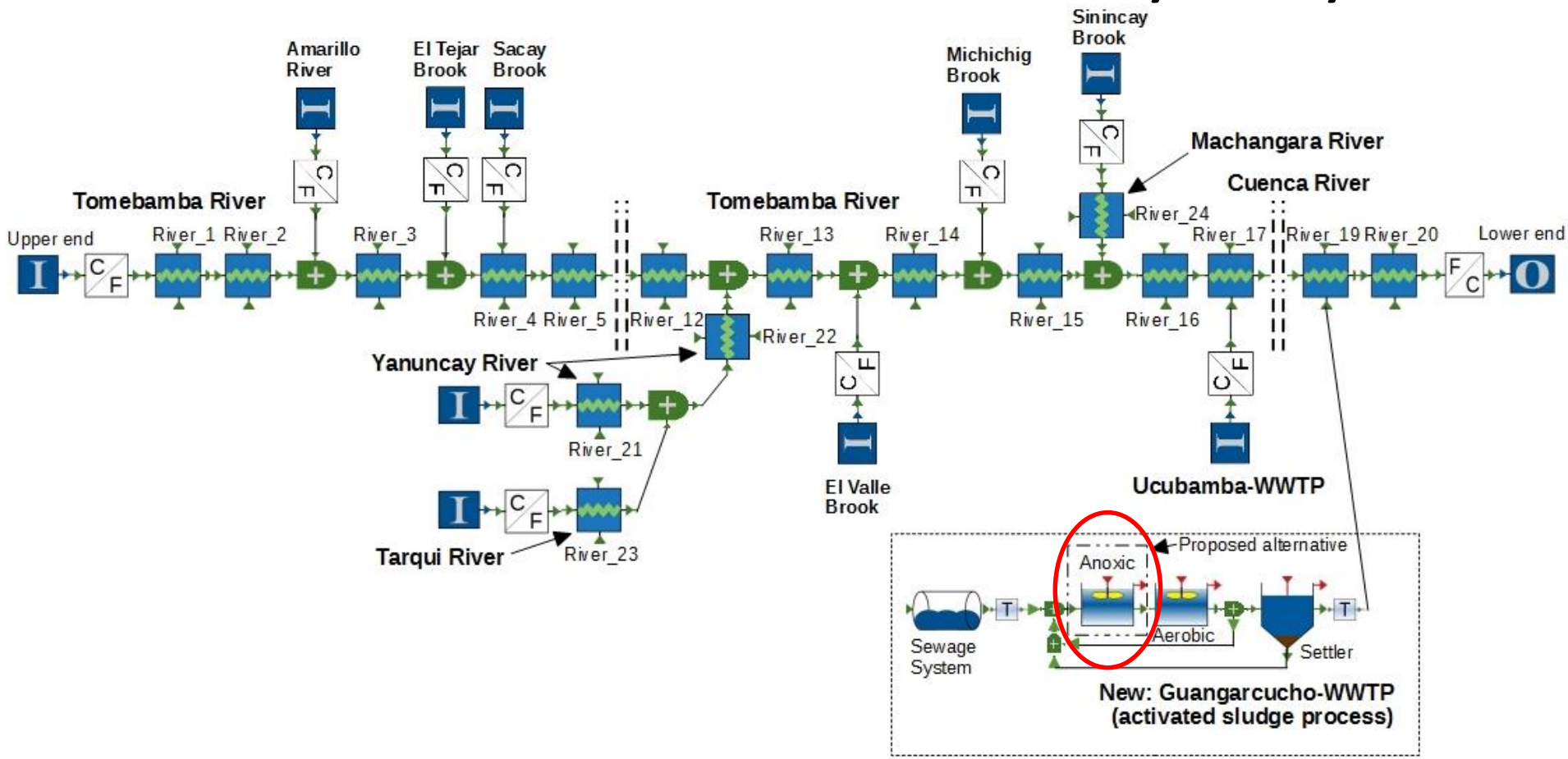
Image: Integrated modelling and design of basin management plans - Nopens - 2016

Scenarios to recover the ecological water quality in the Tomebamba and Cuenca Rivers

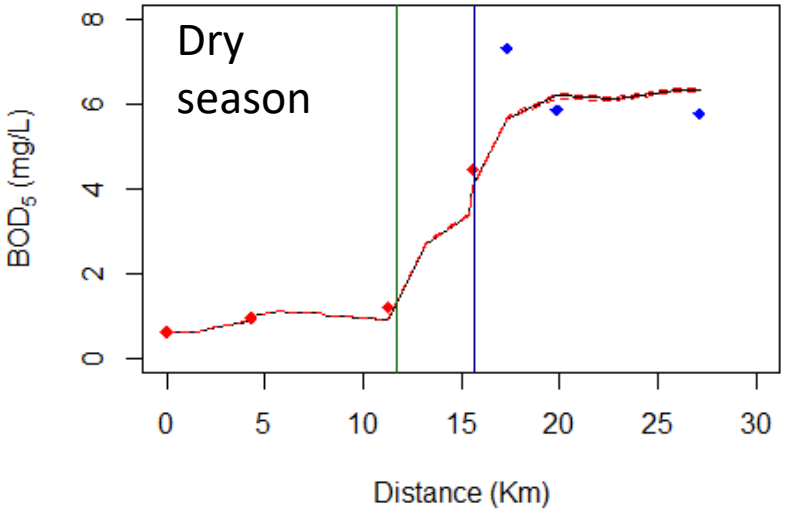
Scenario	Season	Actions
Sc-1	Dry season	Implementation of the new G-WWTP (carbon removal).
Sc-2	Dry season	Implementation of the upgraded G-WWTP (carbon and nutrients removal).
Sc-3	Rainy season	Implementation of the New G-WWTP (carbon removal).
Sc-4	Rainy season	Implementation of the upgraded G-WWTP (carbon and nutrients removal).
Sc-1 to Sc-4	Dry and rainy seasons	Connection of isolated sewage networks to the main network of the city: - Reduction in the concentration of nutrients and organic pollutants in 80% of small streams.
		- Reduction in the concentration of nutrients and organic pollutants in 50% of the main effluents.
Sc-3 & Sc-4	Rainy season	Implementation of four retention tanks before CSO discharges.

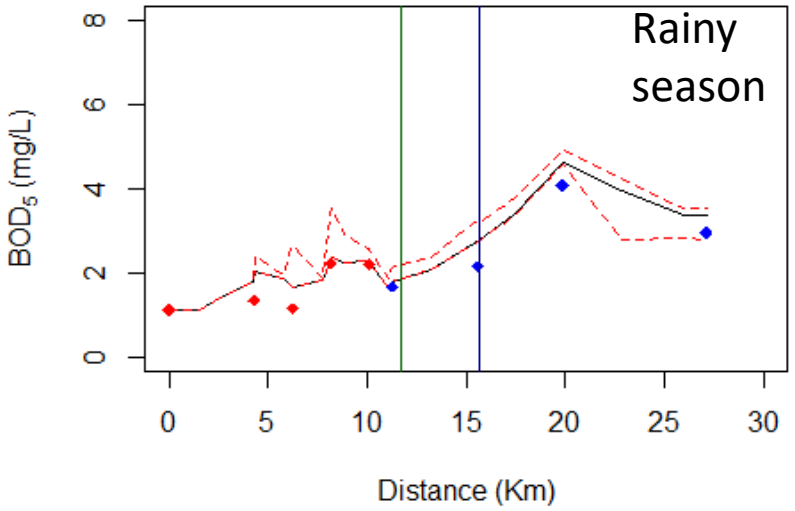
Integrated urban wastewater system (IUWS) model

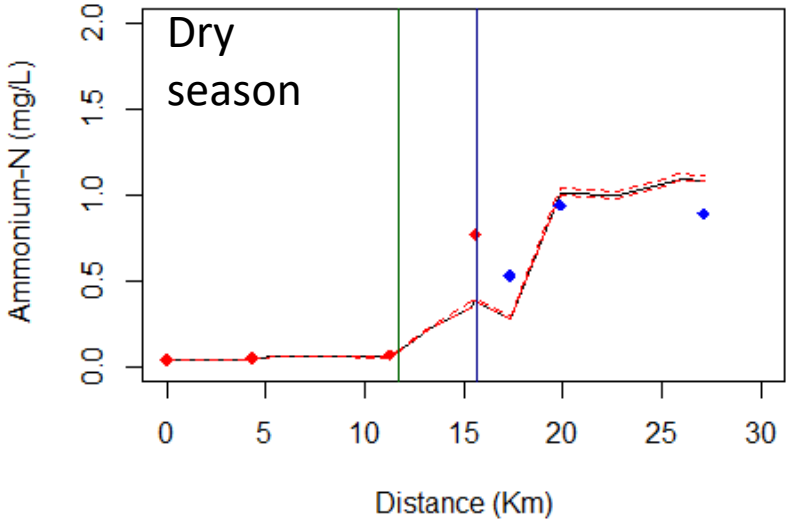
Scenario analysis – dry season

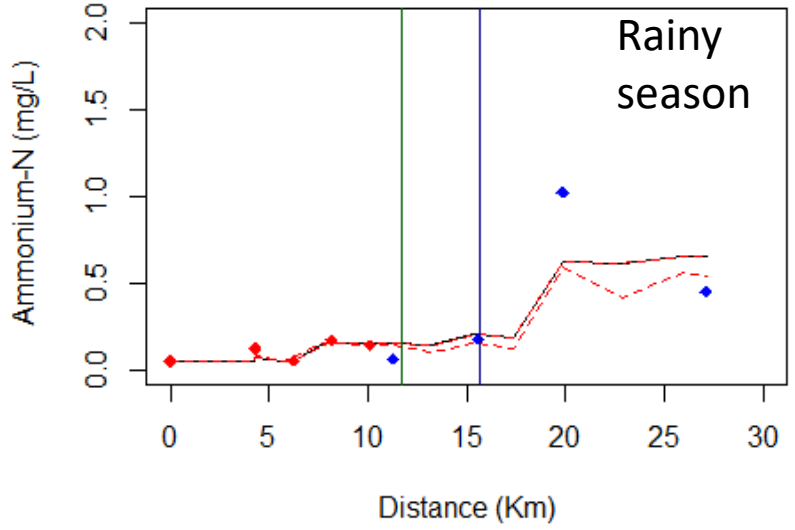


Calibrated and validated river water quality model



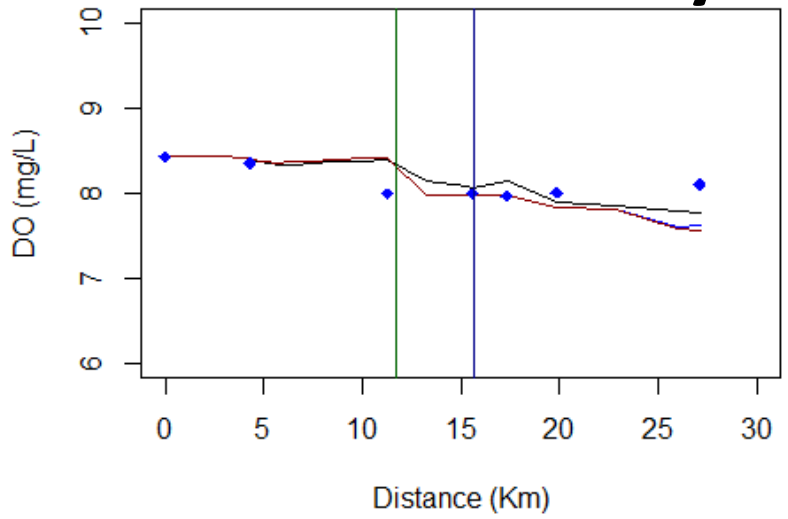


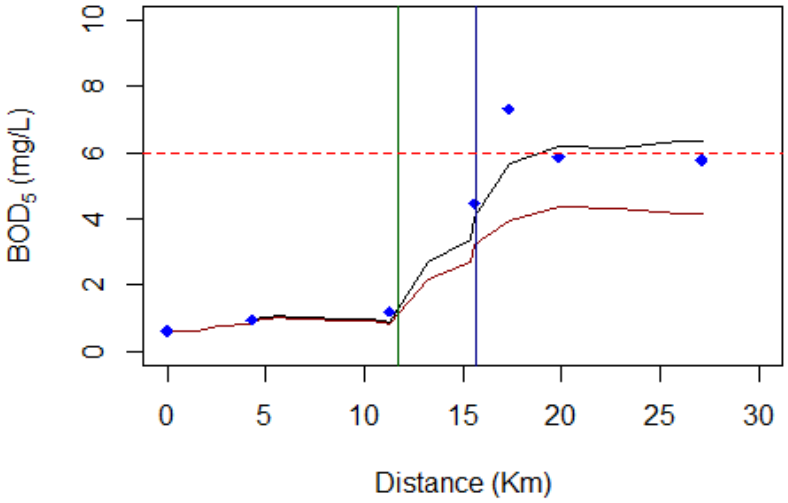


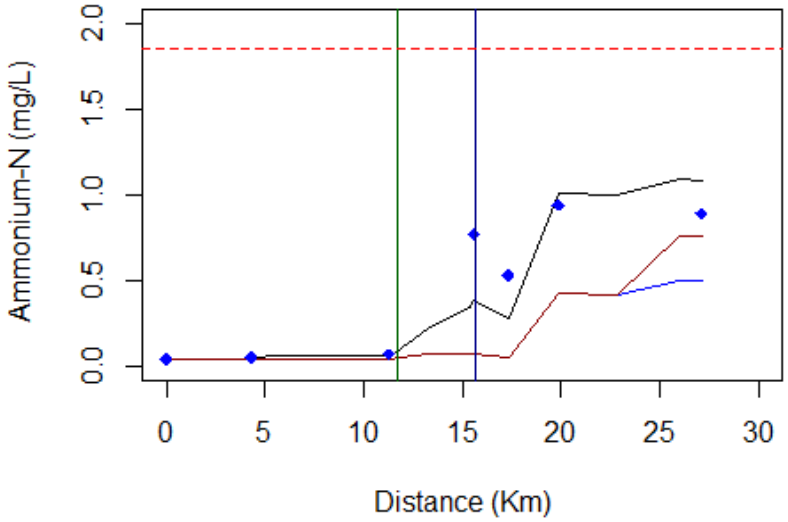


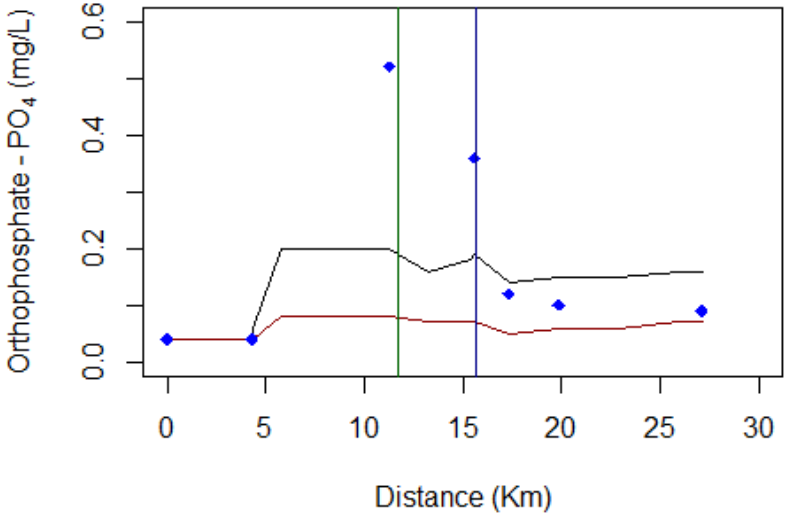
- Dissolved oxygen, nitrites, nitrates, COD and orthophosphates

Scenario analysis: dry season







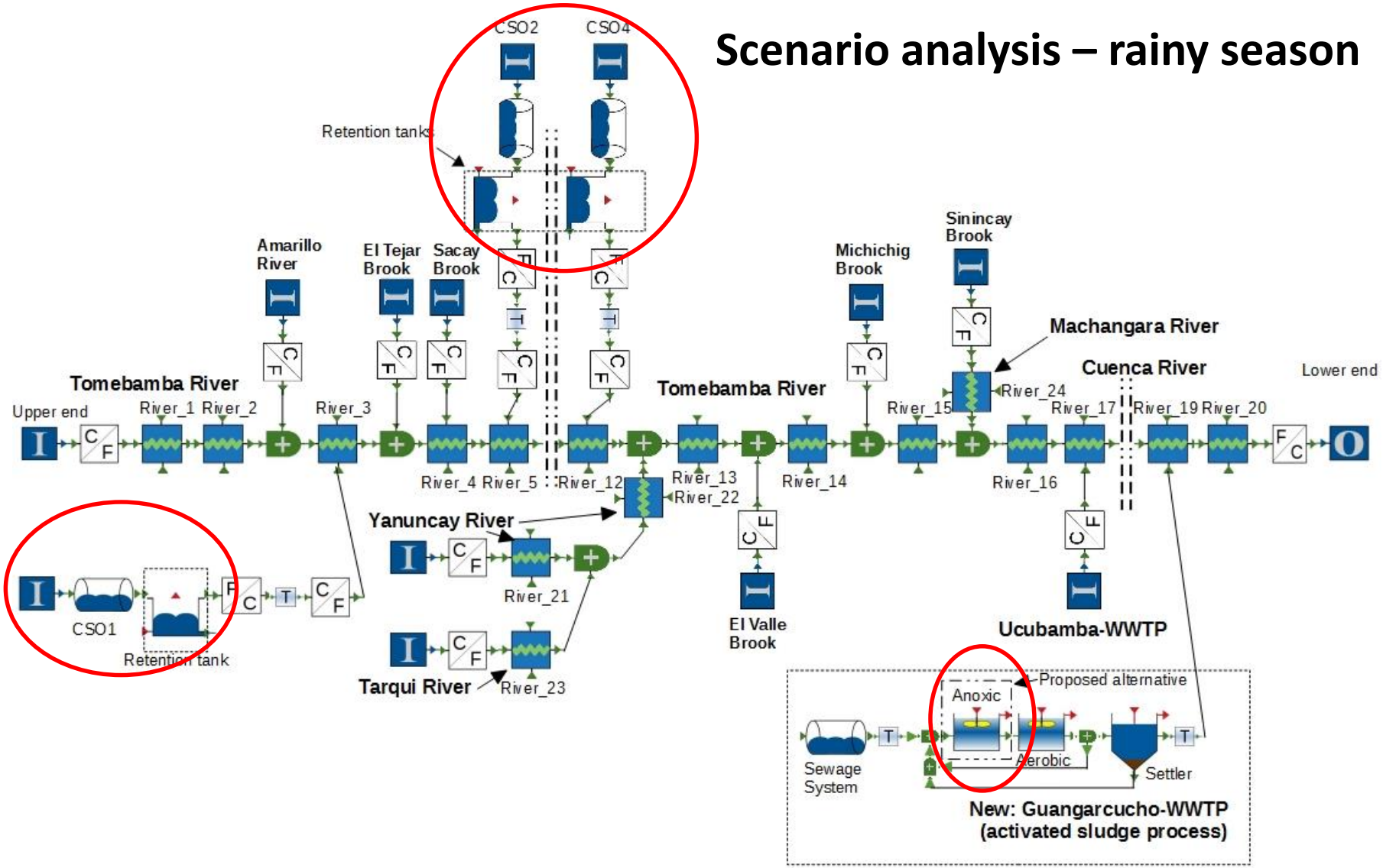


Symbology

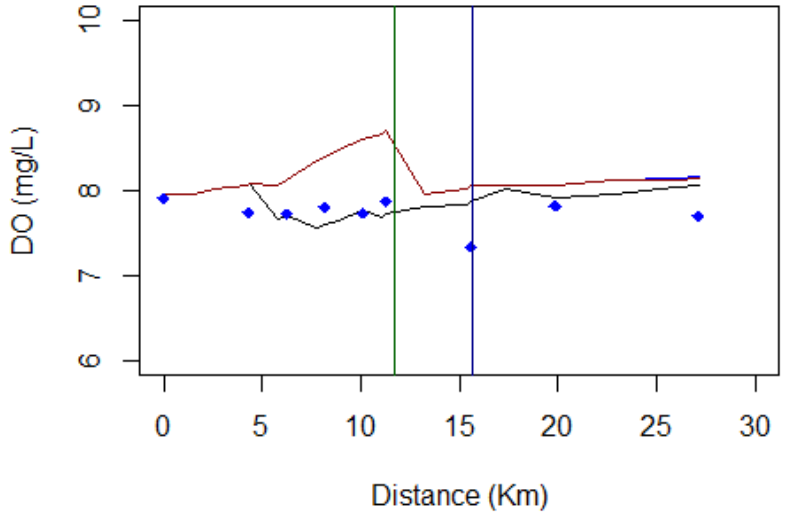
- Current conditions: measured
- Current conditions: simulation
- Scenario 1 & 3: simulation
- Scenario 2 & 4: simulation
- Ecuadorian threshold to preserve the aquatic ecosystem
- Confluence with the Yanuncay River
- Confluence with the Machangara River

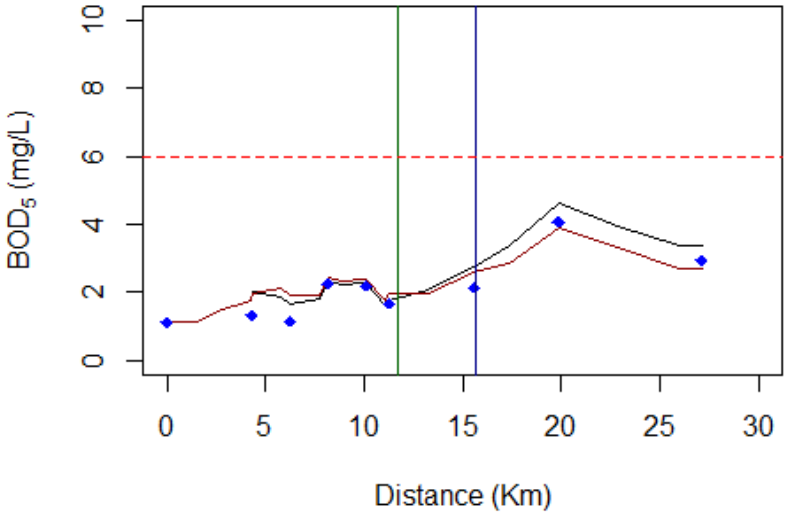
Integrated urban wastewater system (IUWS) model

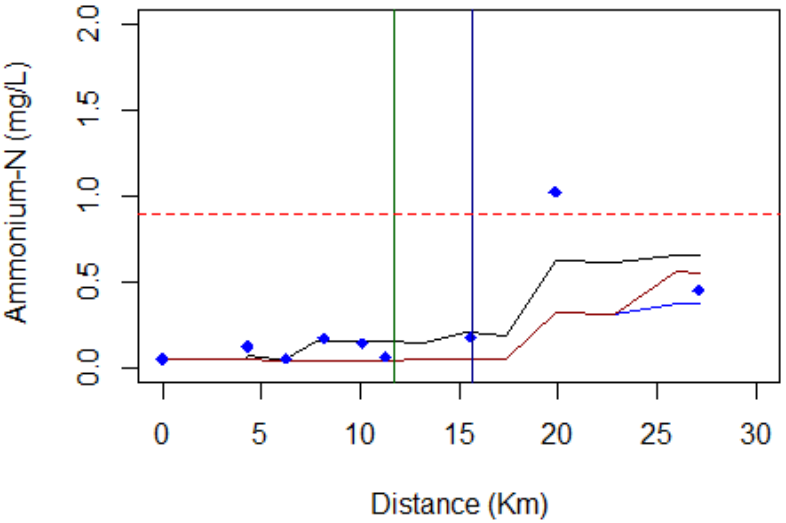
Scenario analysis – rainy season

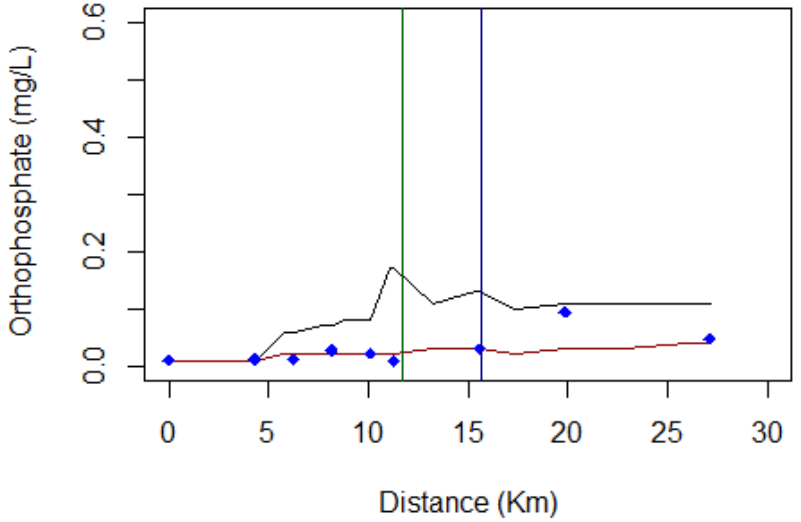


Scenario analysis: rainy season









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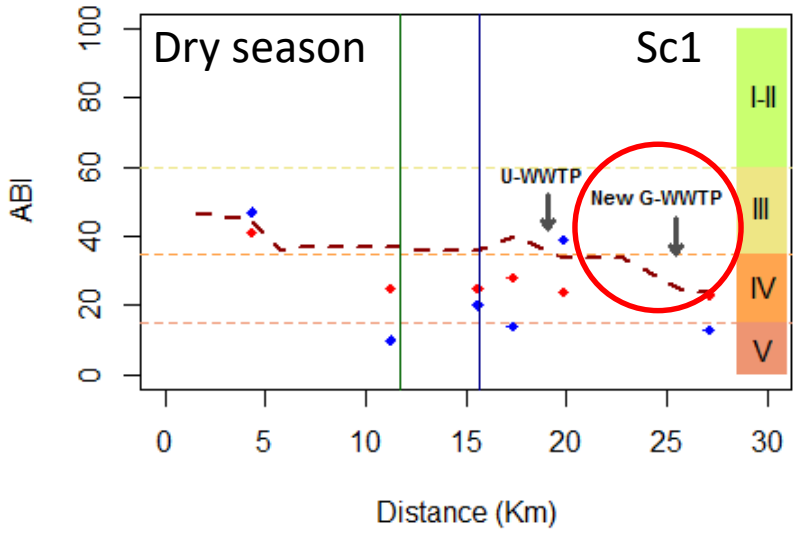
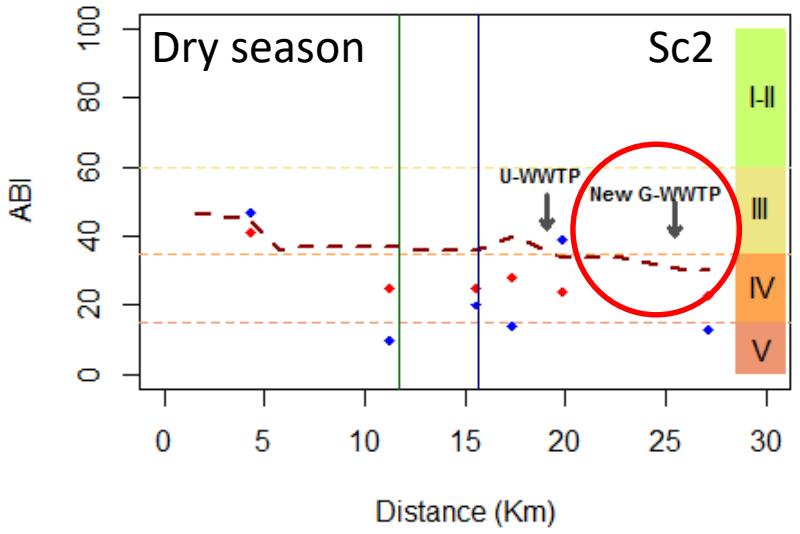
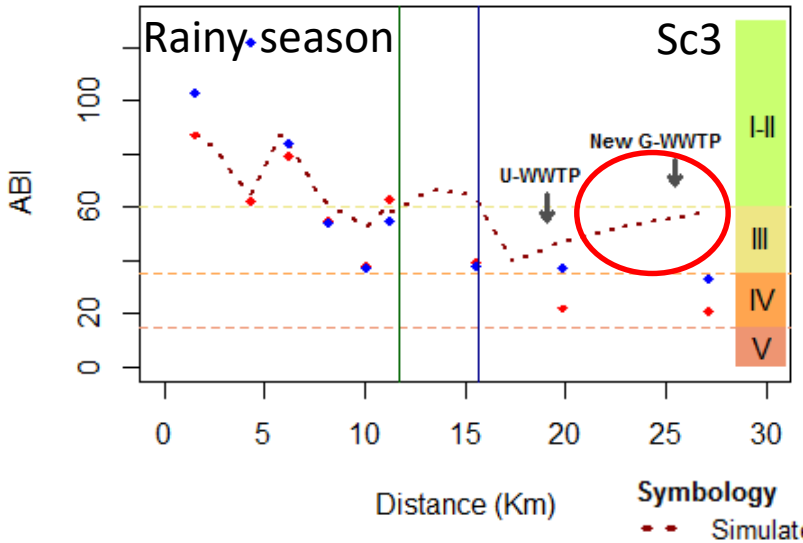
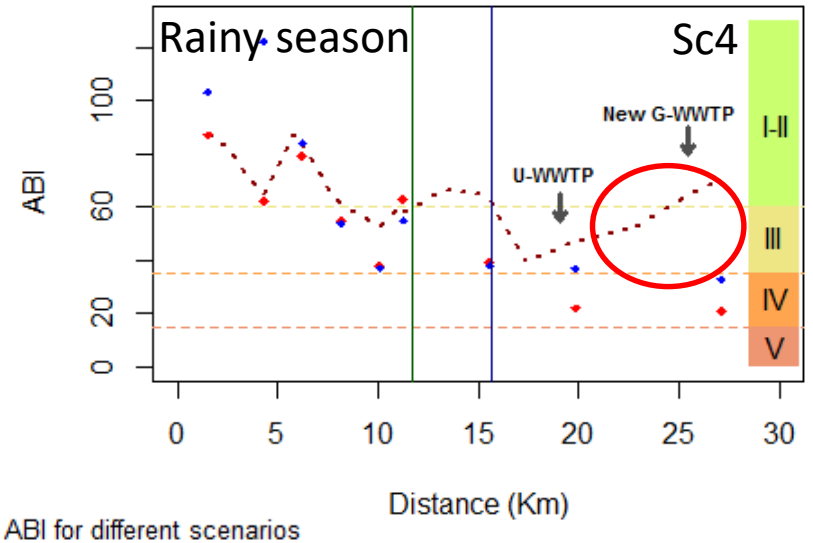
Scenario analysis









Symbology

- Simulated ABI for different scenarios
- Measured ABI: current conditions
- Simulated ABI: current conditions
- Confluence with the Yanuncay River
- Confluence with the Machangara River

Final Conclusions

Which measures are more effective to improve the current water quality in the Cuenca River basin?

- The connection of isolated sewage systems to the urban sewage network.
- The construction of a new wastewater treatment plant with activated sludge technology (carbon and nitrogen removal).
- The inclusion of retention tanks before the discharges of the combined sewer overflows – rainy season.

Acknowledgement

- VLIR-UOS IUC Programme - Universidad de Cuenca
- VLIR Ecuador Biodiversity Network Project
- Water Supply and Wastewater Management Municipal Company ETAPA – EP
- Ecuadorian Environmental Ministry

Thank you

for your attention

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