Stochastic optimization for hydropower schemes design

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1.— Setec & Setec Energy Solutions

1.1 Setec

— One of the biggest French engineering consultants firm

— Provide a global response and associate technical excellence with field experience

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1.2 Setec Energy Solutions

— Subsidiary created in 2011

— Energy production and management

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1.3 Type of work

— Feasibility studies
— Due diligence
— General consultants,
— Project managers

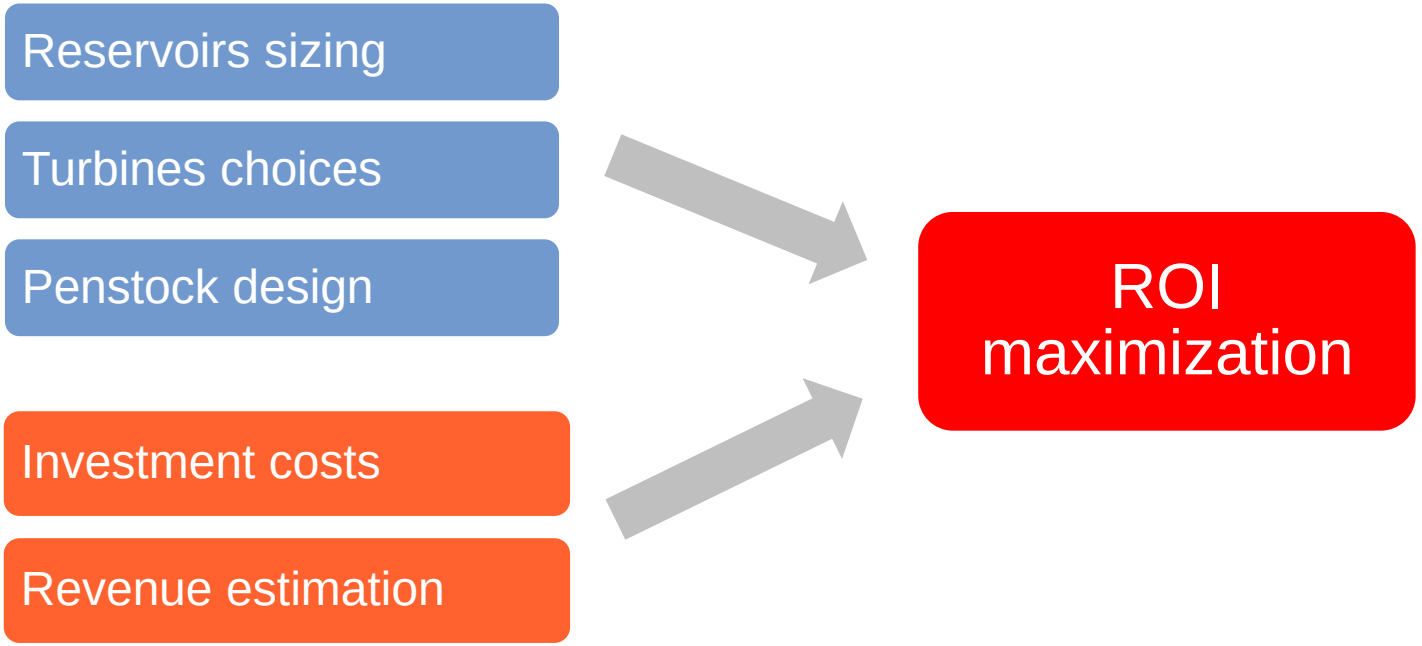
1.4 Field of Competences

— Hydrology & Hydroelectricity
— Civil engineering
— Environment
— Modeling and optimization of hydropower schemes

Hydropower schemes design

2.— Hydropower schemes design

2.1 Elements of design



2.— Hydropower schemes design

2.2 Economic part

GOAL: Estimate the revenue in the coming years

How to manage the plants?

— Decision making tool
— Weather forecast functionality

Will the plant be profitable?

— Uncertainty on the water inflow
— Uncertainty on the prices

Hydroptim

3.— Hydroptim

3.1 Requirements

— Capable to model any chain of dams easily

— Adaptive to time step

— Highly configurable model

— Easy to use

— User interface

3.— Hydroptim

3.2 Components

— Water inflow simulation

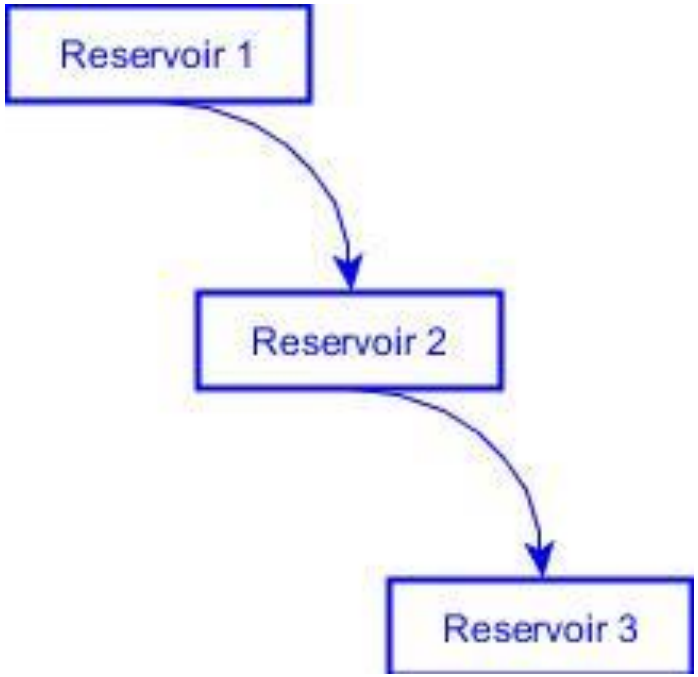
— Barycentric approximation of Bellman values

— Deterministic and Stochastic optimization algorithms

— Decomposition-Coordination methods for large problems

— Algorithm parallelization

— Simulation



3.— Hydroptim

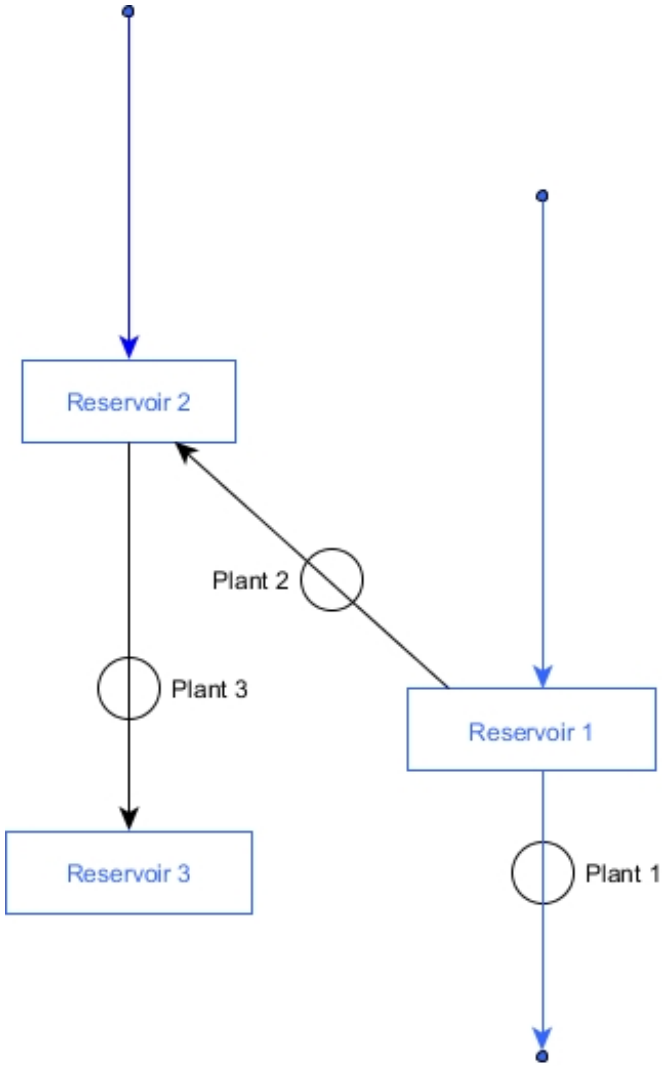
3.3 Classical Dams Problem Modeling

— States: Discretization of the reservoirs

— Control: Water release

Created for conventional dams valleys

$$V_{i,t+1} = V_{i,t} + Inflow_{i,t} - Loss_{i,t} + U_{i-1,t} - U_{i,t}$$



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How to decide where the water from reservoir 1 goes?

— Priorities order

— Predefined sharing between available plants

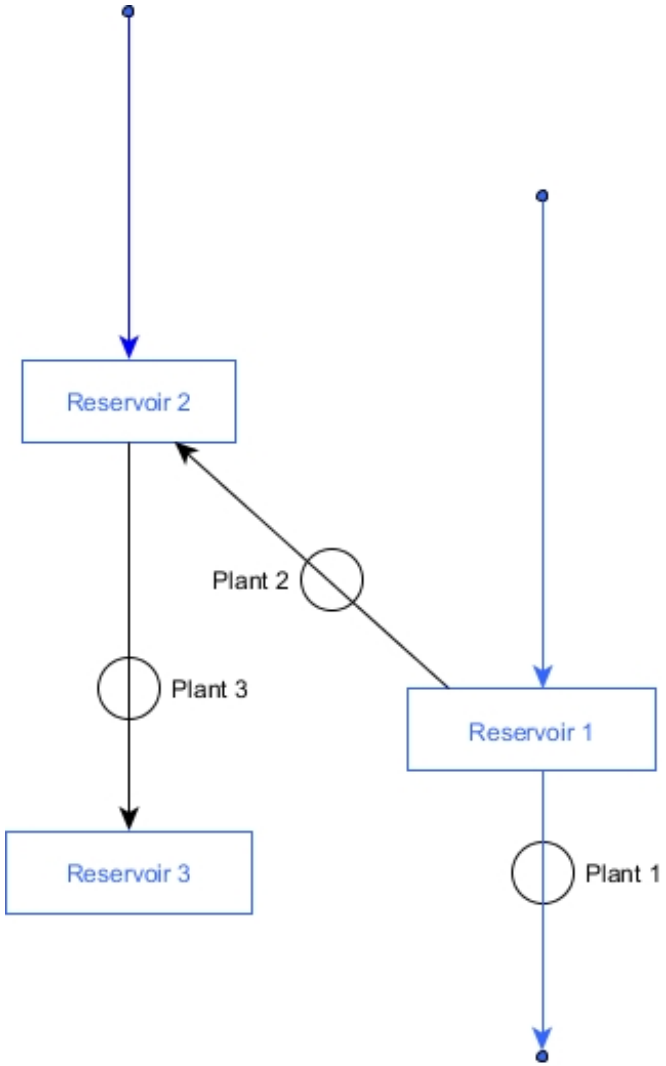
— …

Cons:

— Poor flexibility

— Not scalable

— Approximated optimal control



3.— Hydroptim

3.4 New chain model

— States: Discretization of the reservoirs

— Control: Turbines and pumps

— Structure: entered as a matrix

Pros:

— More flexibility in chains creation

— No assumption on the control

Cons:

— More calculation

— Need to check admissibility

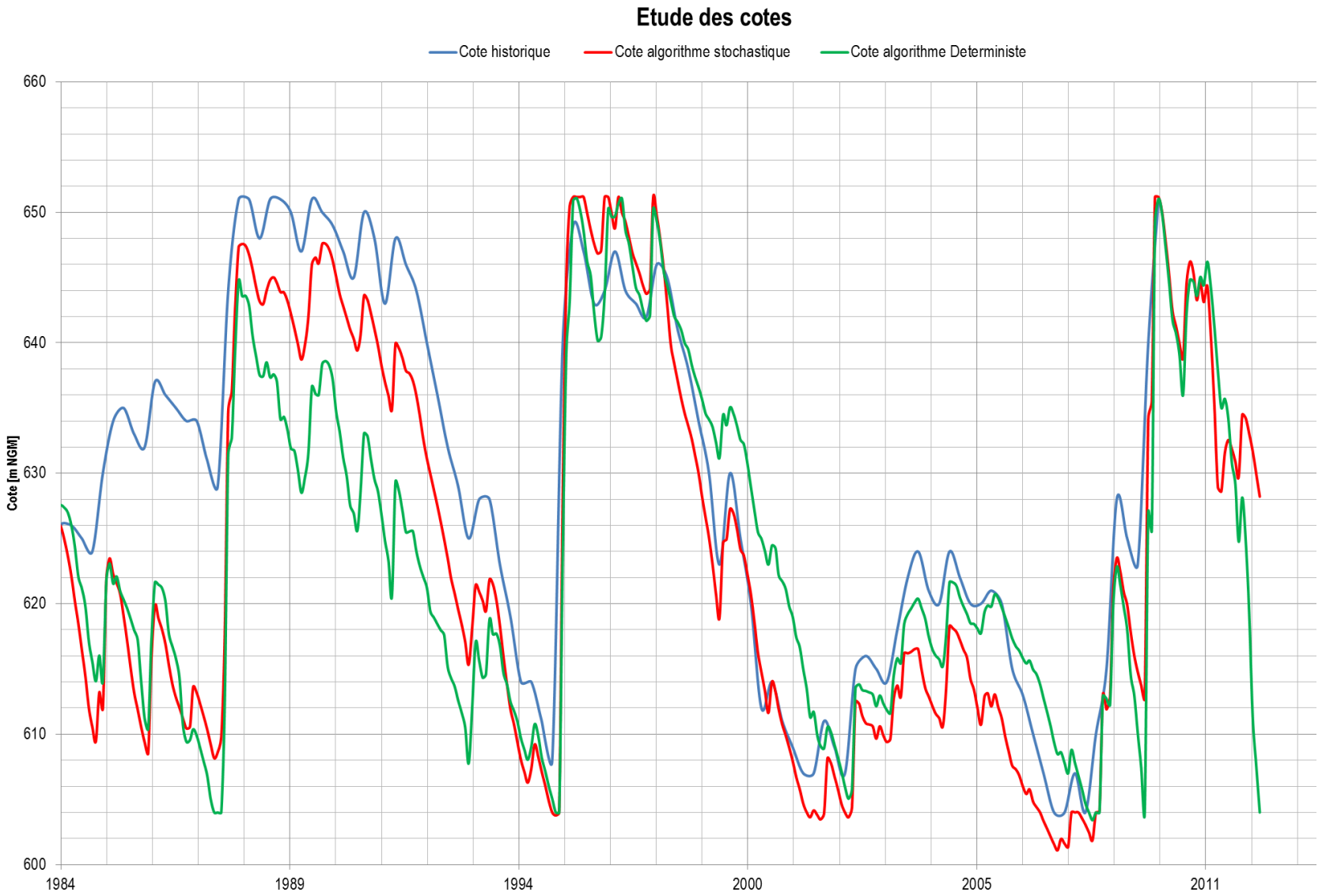
3. Hydroptim

3.5 Algorithm

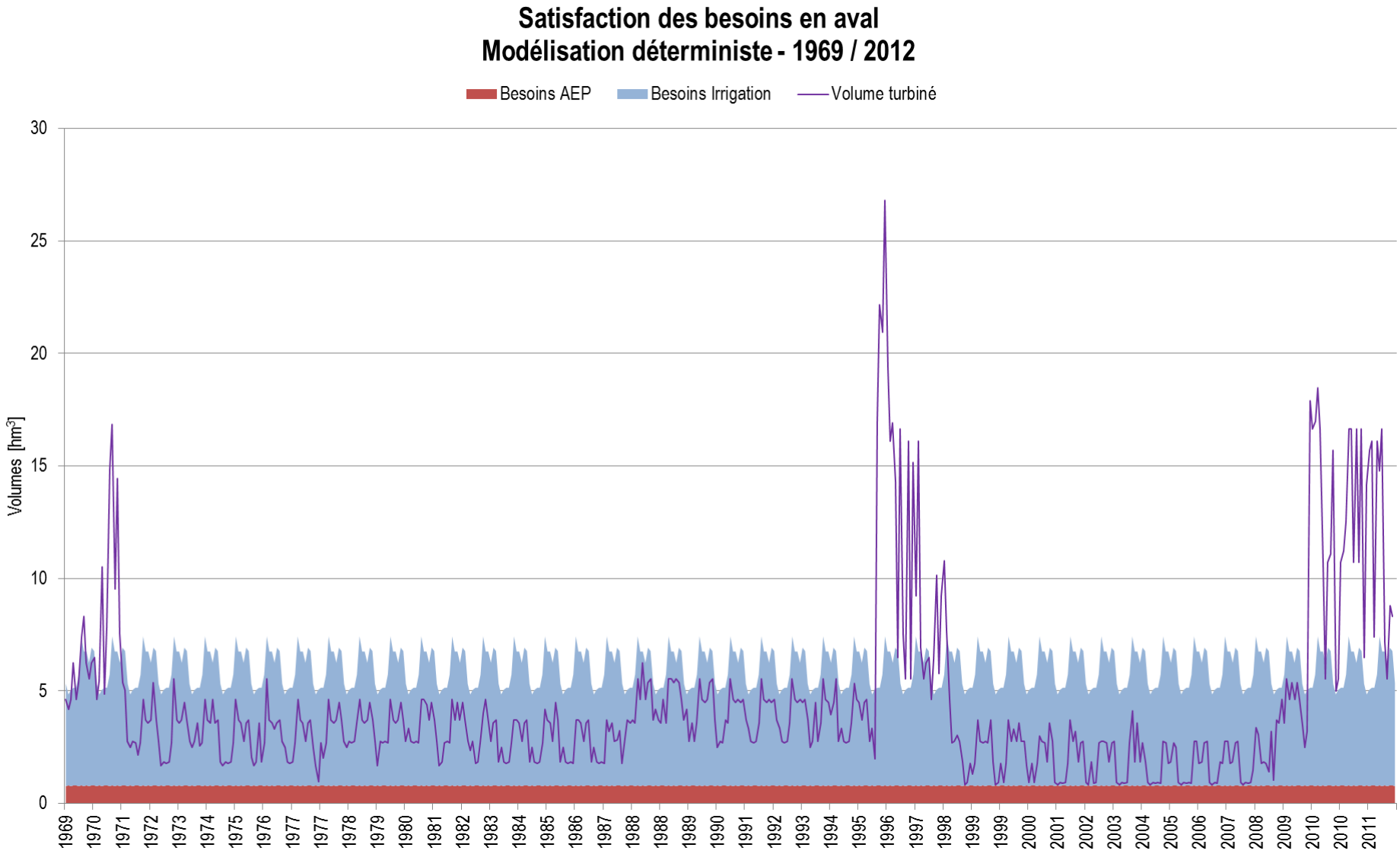
1. Inputs: Reservoirs, Plants, Chains structure
2. Water inflow scenario creation
3. Calculation of Reservoir order calculation
4. For each time t
    1. For each reservoirs states
        1. For each control decisions
            1. Calculation of new reservoirs water level
            2. Profit calculation and admissibility check
        2. Bellman value update

Case study I

Dam in Marocco



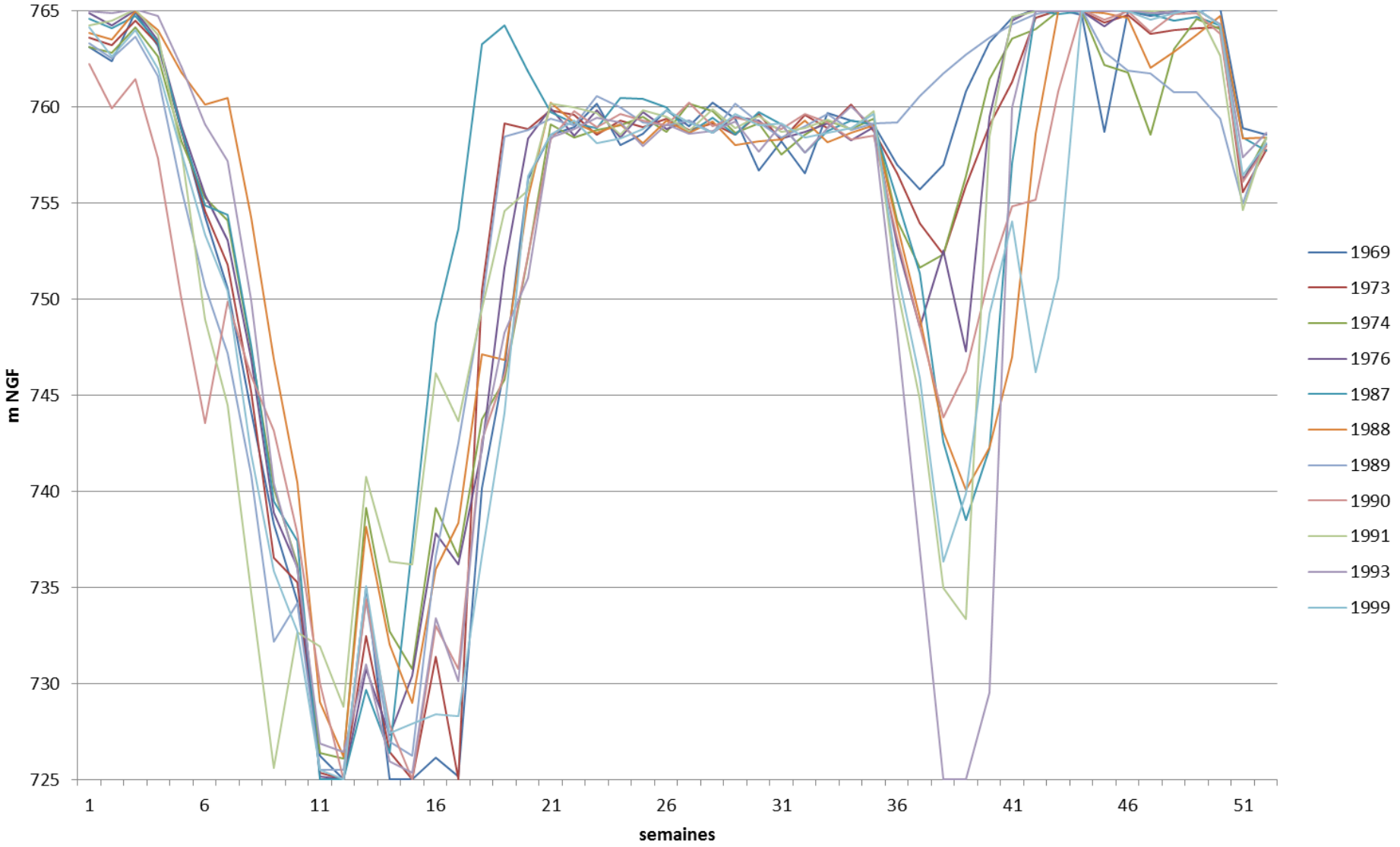
Case study I – Dam in Morocco



Case study I – Dam in Morocco

Case study II

Constraints handling



Case study II – Constraint handling

Perspectives

Next Steps

- Price simulation
- Stochastic optimization with prices uncertainty

- More complex stochastic algorithms for complex chains

Future

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