Food and Agriculture Organization of the United Nations

WATER RESOURCE SYSTEM REPRESENTATION

A GUIDE TO NETWORK REPRESENTATION, WATER BALANCE, AND PROBLEM FORMULATION

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ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

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1) Network representation

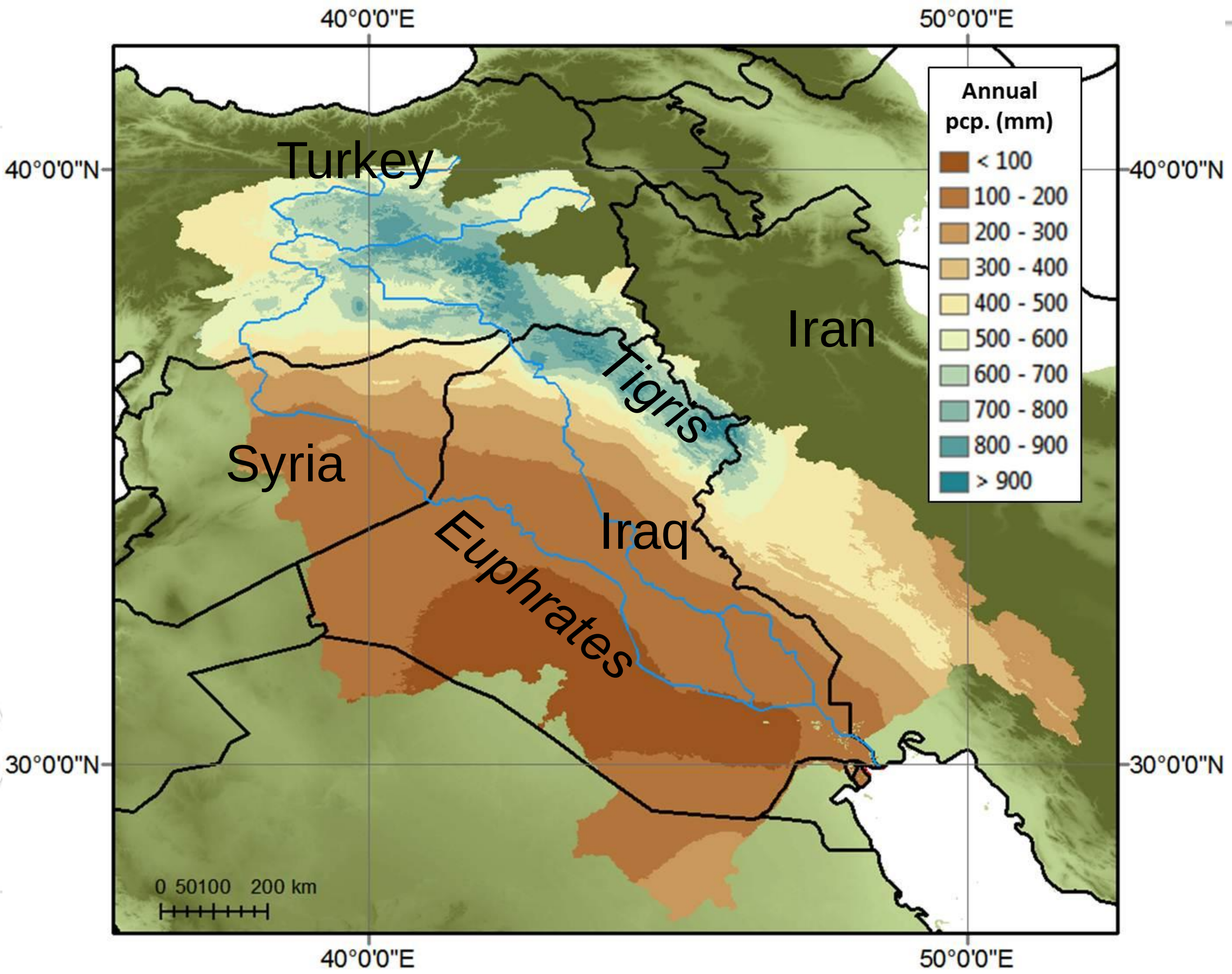
2) Water balance and storage

3) Reservoir operations and optimization

EXAMPLE: MODELING THE TIGRIS-EUPHRATES

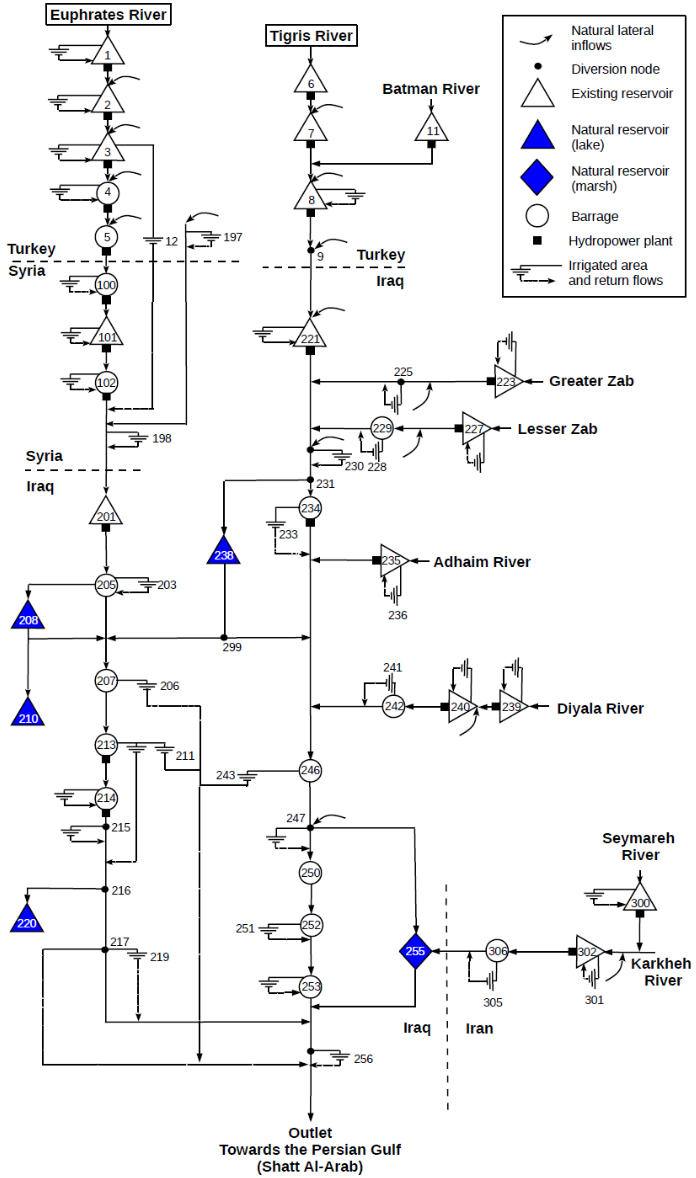
- FAO-funded project “Support cooperation in Lower Mesopotamia”

- Large and complex transboundary basin!
    - *How do we represent water uses?*

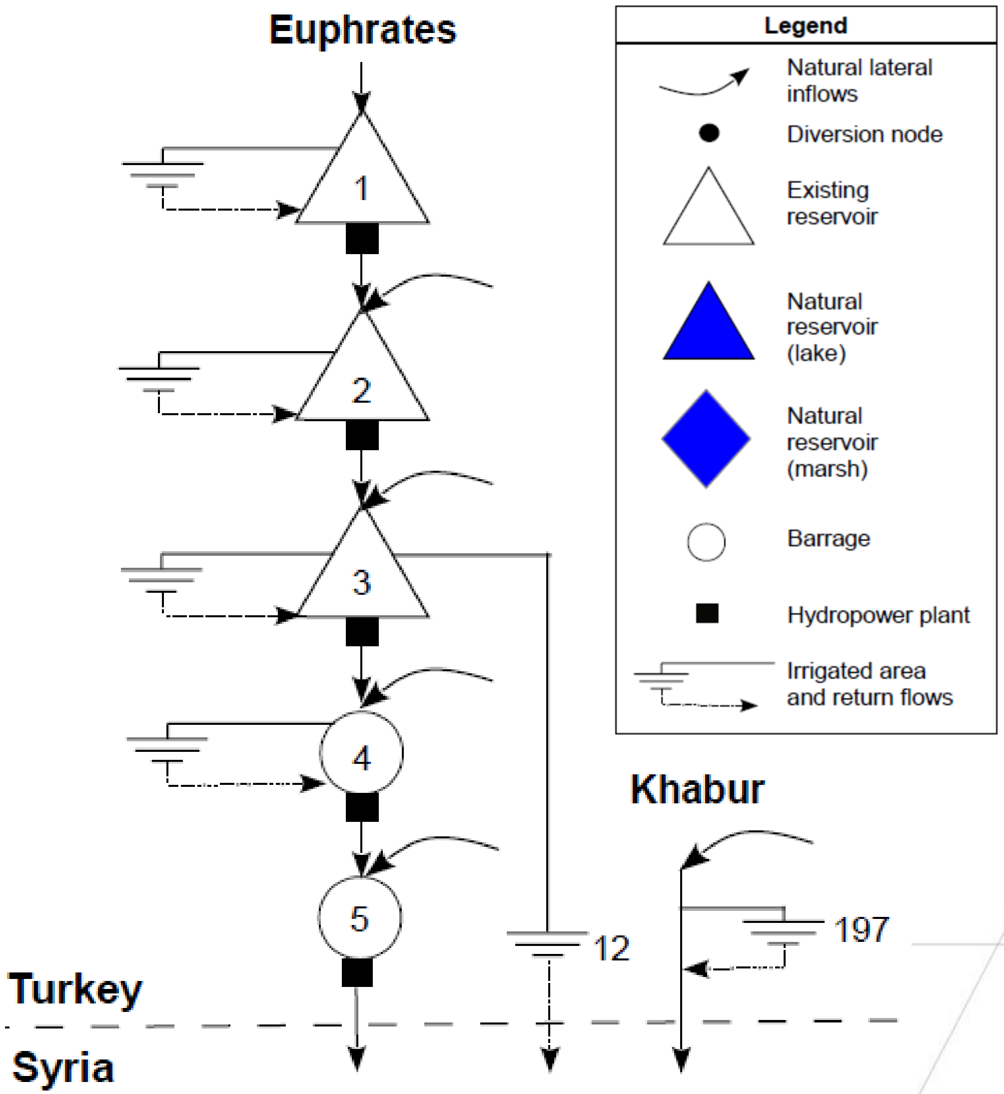


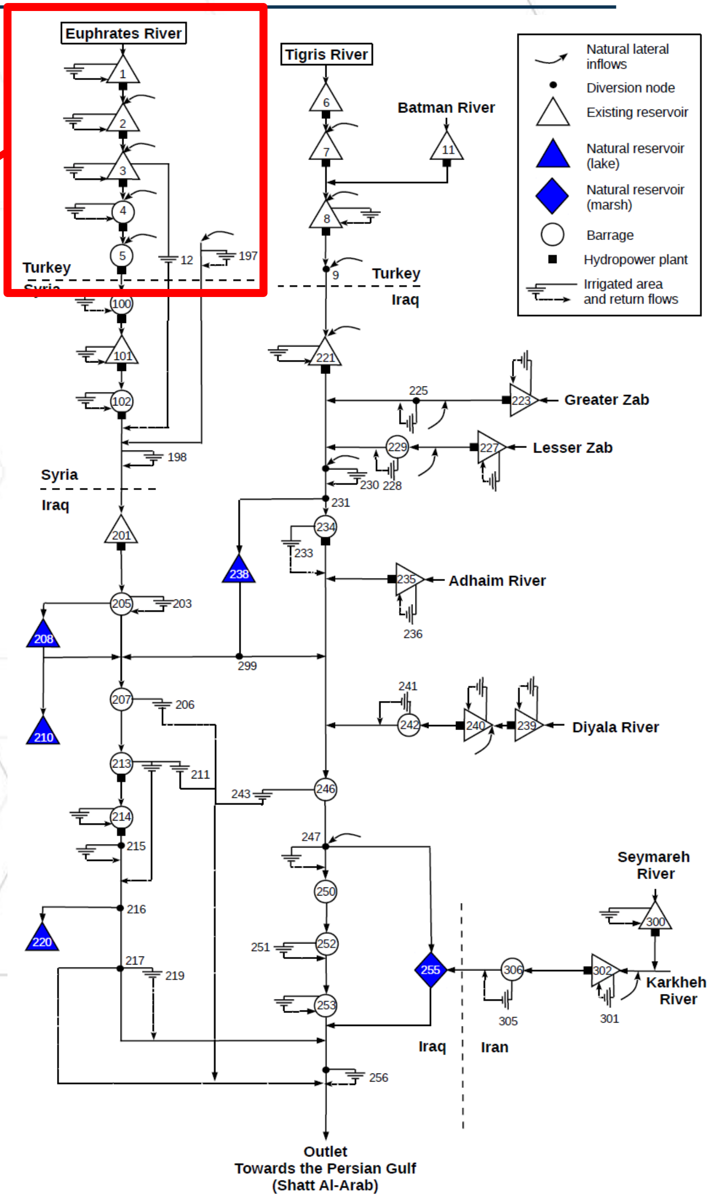
NETWORK REPRESENTATION

- A node-link network:
  - ➢ Links: rivers
  - ➢ Nodes: reservoirs, lakes, power plants, irrigation districts…
- Function of nodes:
  - ➢ Water enter the systems
  - ➢ Water consumed
  - ➢ Water used for economic benefits
  - ➢ Water stored (reservoirs)
- Water in network flows in one direction.



NETWORK ELEMENTS





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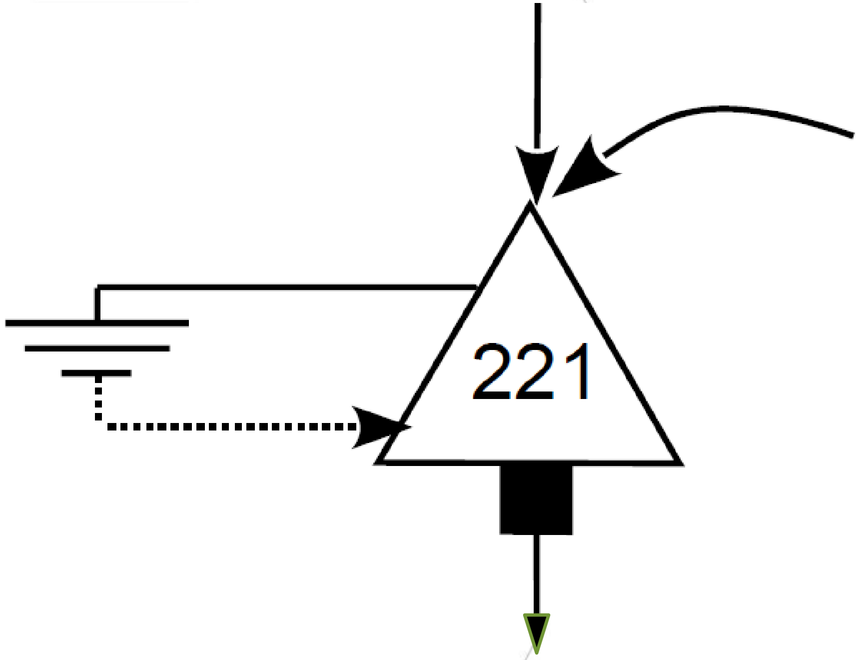
WATER BALANCE AT EACH NODE

- Conservation of water volume over a time step:

$$\Delta S = S_{t+1} - S_t = I_t - O_t$$

(storage variation = inflows – outflows)

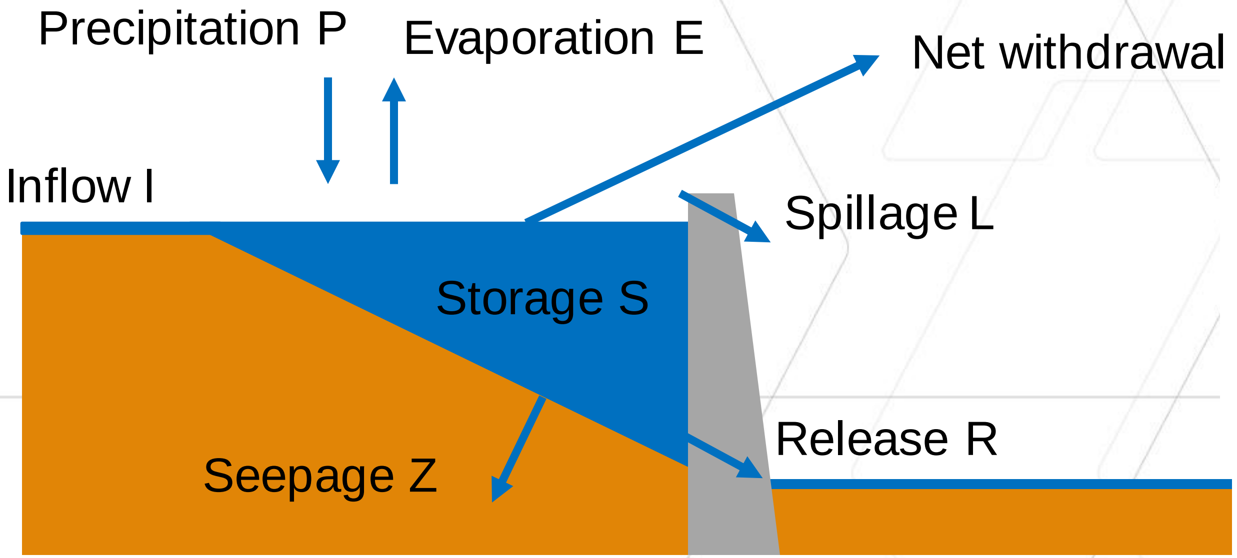
- Trick is accounting for all inflows (local runoff + flows from upstream nodes and links) and outflows (ground losses, evaporation...)

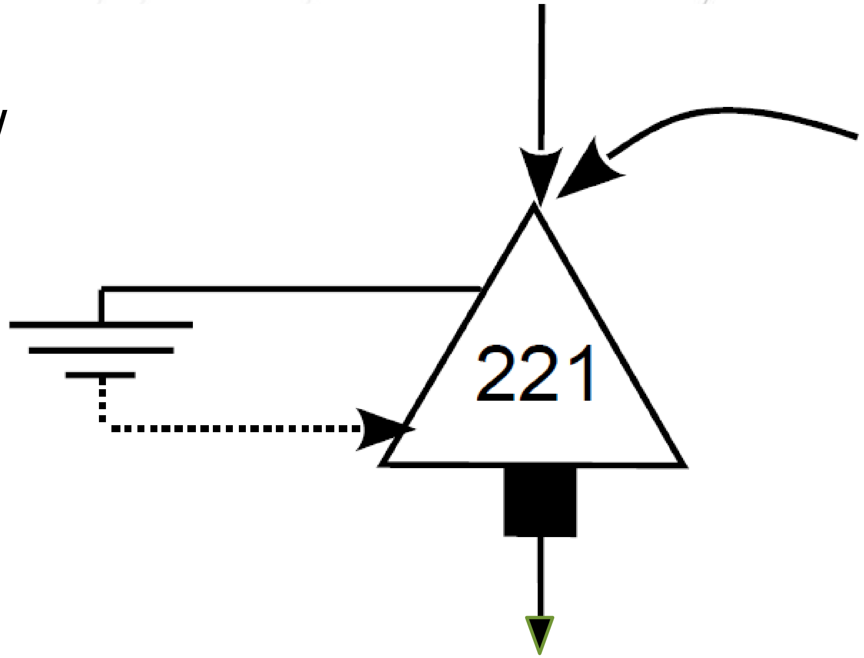


RESERVOIR WATER BALANCE

- Using volumes over a single time step:

$$S_{t+1} - S_t = \underbrace{(I_t + P_t)}_{\text{Inflows}} - \underbrace{(R_t + L_t + E_t + W_t + Z_t)}_{\text{Outflows}}$$





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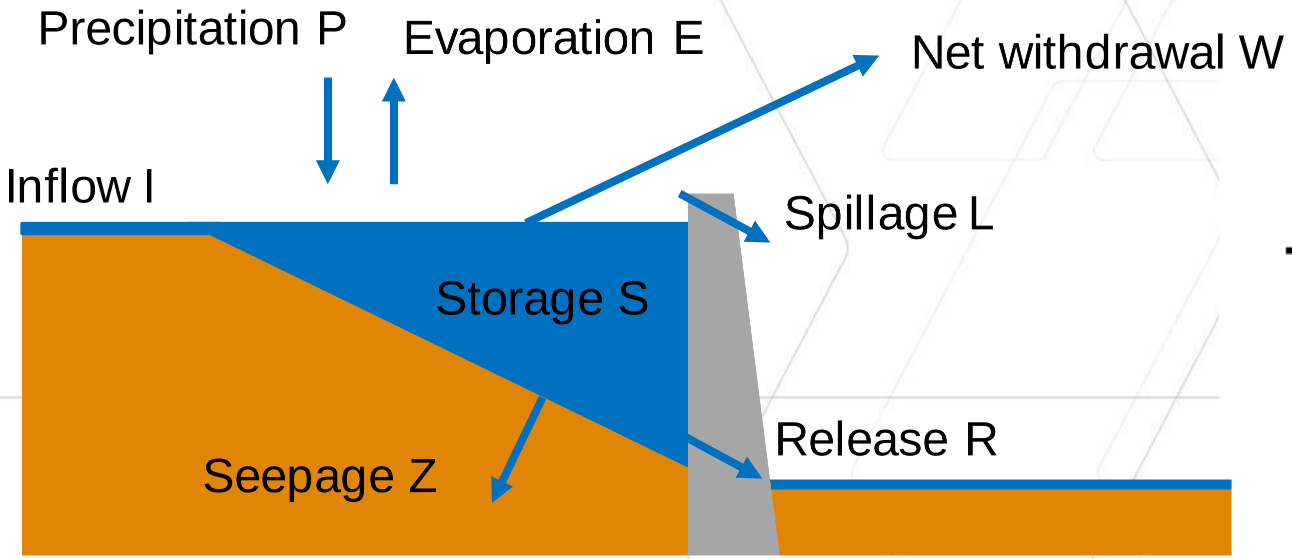
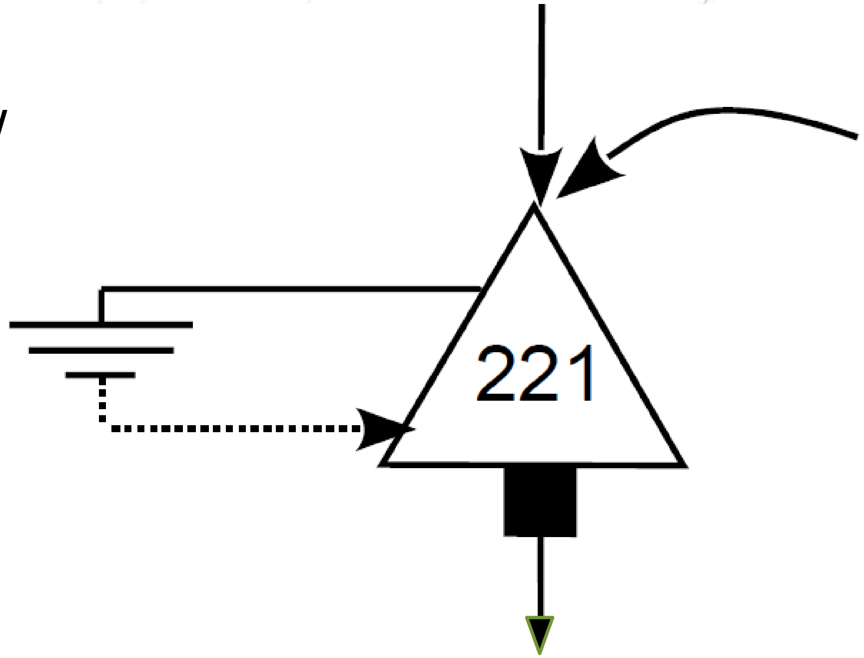
How do we decide on:
1) Release decisions?
2) Allocations (e.g., withdrawals)?





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GOAL OF OPERATIONS

Maximising benefits from water uses:

- Hydropower
- Irrigation
- Domestic or industrial water supply
- Ecosystems

Minimising risks:

- Water scarcity
- Flooding
- Climate change
- Demand growth

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This can be done through modelling but is complex:

1) River network is **interconnected**
2) We have to account for **uncertain** future benefits, risks
3) Competing uses: **trade-offs**

GENERAL PROBLEM FORMULATION

- Finding decisions (releases, withdrawals) that maximise benefits / minimise risks in the river basin and through time.
- Can be expressed as an objective function, objective Z:

$$\underset{\boldsymbol{x}_t}{max}\{Z\} = \underset{\boldsymbol{x}_t}{max}\left\{E\left[\sum_{t=1}^{T}\alpha_t b_t(\boldsymbol{s}_t, \boldsymbol{q}_t, \boldsymbol{x}_t) + \alpha_{T+1}\nu(\boldsymbol{s}_{T+1}, \boldsymbol{q}_T)\right]\right\}$$

$\boldsymbol{x}_t$ are the decisions, b_t the benefits at t,

s_t and q_t are network inflows / storage: the network representation is **key** here!

T is the horizon, where we stop the calculation, function v_t reflects that there will be water use benefits after *T*.

WHAT WE LEARNED

1) Network representation

2) Water balance and storage

3) Reservoir operations and optimization