Conjunctive Management of Surface and Groundwater; Cyclic Storage System approach

IUST

School of civil engineering

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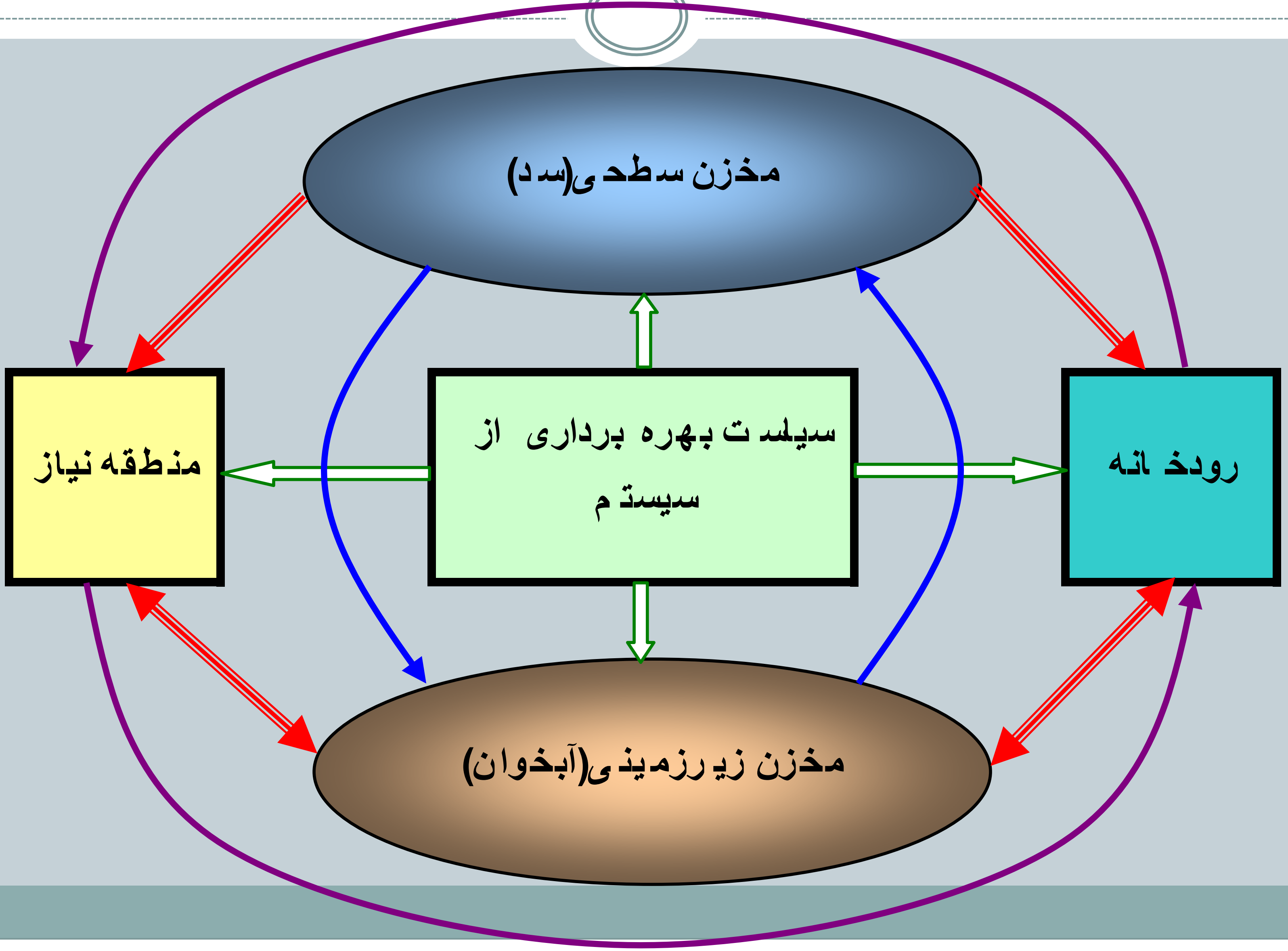
تعاریف



مخزن سطحی(سد)
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Cyclic Storage Definition

physically-integrated

operationally- interconnected surface water and groundwater subsystems

full direct interactions between the subsystems.

cyclic storage system (CS) may be recognized as

A cyclic storage system (CS) may be recognized as an

Integrated- interactive

surface water storage subsystem (reservoir) and a groundwater subsystem

developed to jointly satisfy the predefined demand in a long-term planning horizon

This new definition treats surface and subsurface impoundment subsystems as

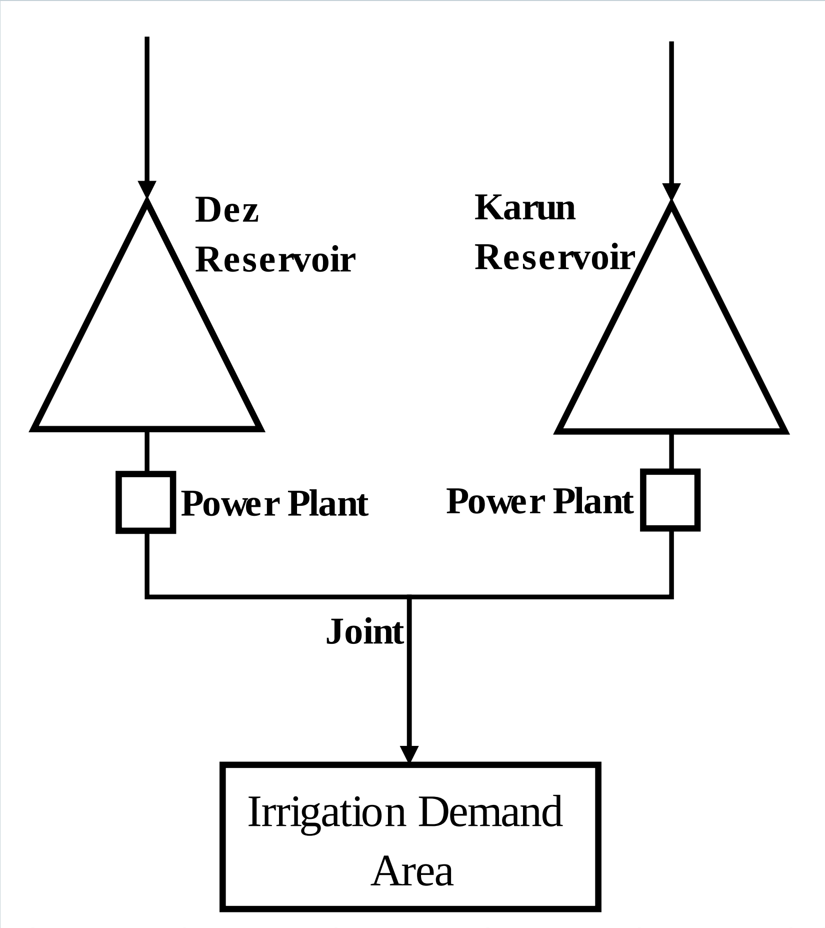
competing and potentially interconnected parallel storage facilities

that will minimize most of the problems associated with large-scale surface impoundments for water supply purposes.

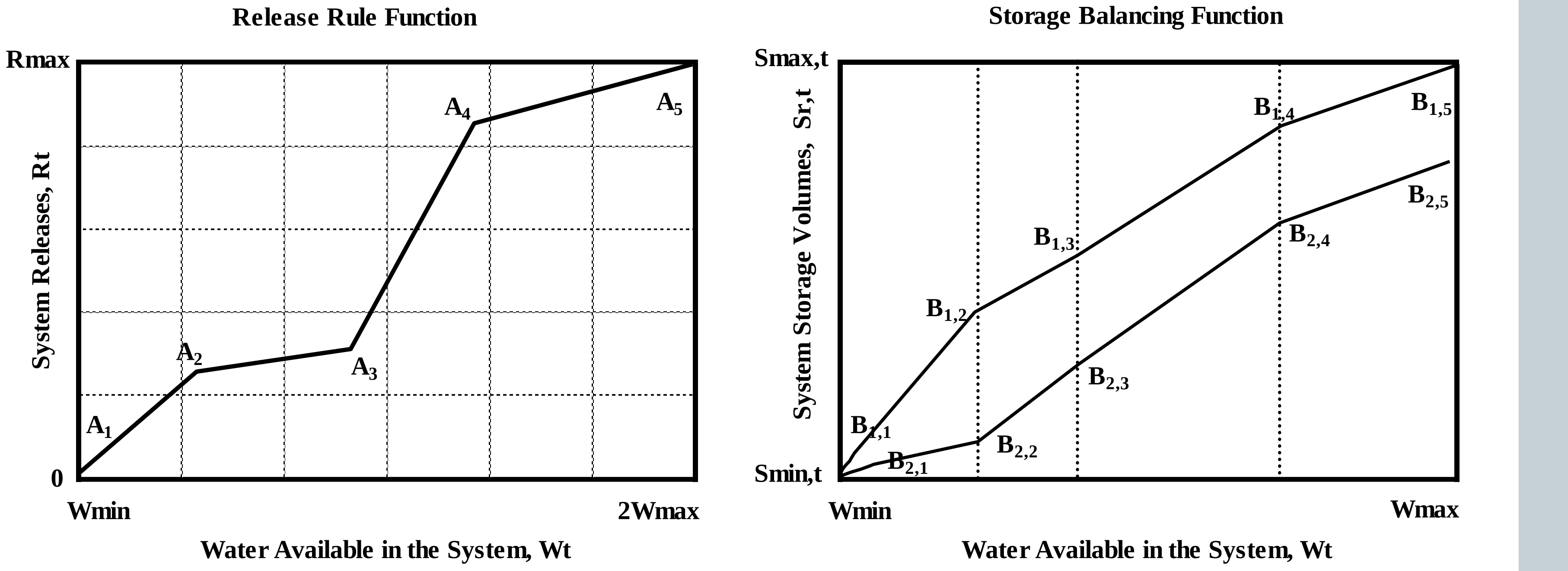
cyclic storage system

- The surface water and groundwater impounding subsystems behave like two parallel reservoirs with the possibility of exchanging stored water while keeping their individual characteristics and operated to satisfy the desired target demand.

Surface Reservoirs



Operation Planninmg



(a)

(b)

System characteristics

Thus, the desired level of development of :

Systems' components,

The amount of water transfer between Elements of the two subsystems, and

Their conjunctive operating rules,

should be determined as CS characteristics.

System characteristics

- Moreover, the amount of water transfer between system components should be considered as decision variables in various periods of the planning horizon

Management Model

A CS system may include:

(1) surface storage subsystem (reservoir),

(2) groundwater storage subsystem (aquifer),

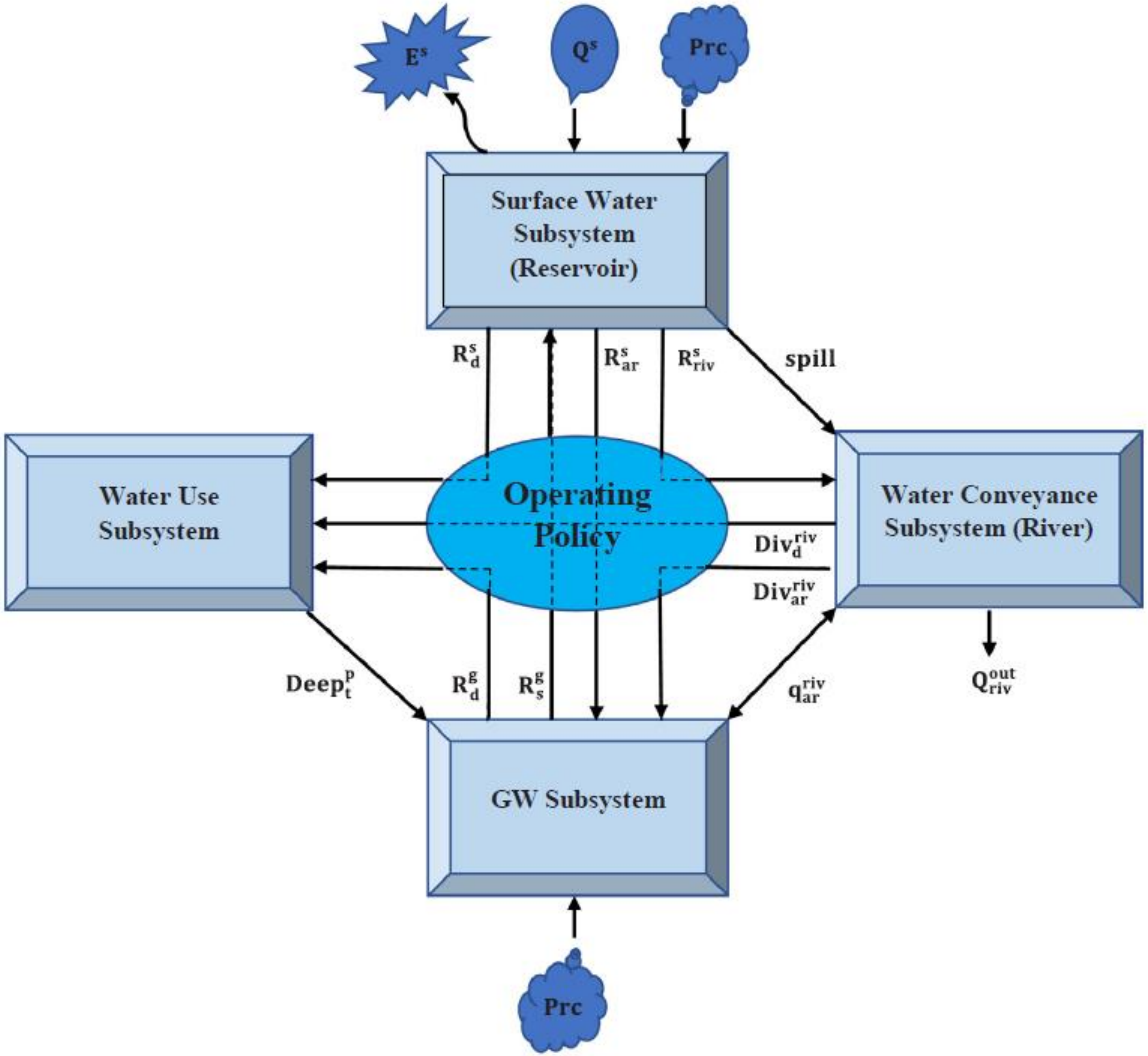
(3) water course subsystem (river),

(4) pumping wells,

(5) recharging wells (or basins),

(6) water transfer and/or diversion systems, and

(7) demand area.



E^s
Q^s
Prc
Surface Water Subsystem (Reservoir)
R^s_d
R^s_ar
R^s_riv
spill
Water Use Subsystem
Operating Policy
Water Conveyance Subsystem (River)
Div^riv_d
Div^riv_ar
Deep^p_t
R^g_d
R^g_s
q^riv_ar
Q^out_riv
GW Subsystem
Prc

Reliability-based design or operation

$$Rel = \frac{No.\ \ of\ \ times D_t = 0}{Total\ \ time\ \ periods}$$

$$D_t = \begin{cases} X_{Target,t} - X_{Supply,t} & if \quad X_{Target,t} > X_{Supply,t} \\ 0 & Otherwise \end{cases}$$

Subject to maximum seasonal deficit of 20 and 30 percent over the entire simulation period, if failure occurs (i.e., β=0.2 and 0.3).

Reliability –Based Multi-Objective Optimization

$$MinimizePVC = Minimize \sum \alpha_{Xi}(CapX_i)^{(bXi)}$$

$$MaximizeRel = \sum_{t=1}^{T} Z_t$$

$$Z_t \begin{cases} 1, & if\ demand\ is\ fully\ satisfied \\ 0, & otherwise \end{cases} ;\ t = 1, 2 \cdots T$$

System's present value of total cost

$$Minimize\ PVC$$

$$PVC = CC + PVC(OC)$$

$$CC = C(D) + C(CD) + C(CAR) + C(Div_d) + C(Div_{ar}) + C(P)$$

$$PVC(OC) = C(W) + C(AR) + C(DEF) + OMR$$

General form of Unit Responses (linear, point, and distributed sinks or sources)

$$S(k,n) = \sum_{t=1}^{n}\sum_{j=1}^{NK} \beta_k(k,j,n-t+1).q(j,t)$$

$$+ \sum_{t=1}^{n}\sum_{j=1}^{NR} \beta_{riv}(k,j,n-t+1).dh_{riv}(j,t)$$

$$+ \sum_{t=1}^{n}\sum_{j=1}^{NA} \beta_a(k,j,n-t+1).P_a(j,t)$$

Constraints

- a) Seasonal mass balance in reservoir and associated bonds:

$$f1_t\,(S_t^s,\; Q_t^s,\; E_t^s,\; R_{d,t,}^s R_{ar,t}^s,\; R_{riv,t}^s,\; C^s,\; C_d^s,\; C_{ar}^s,\; spill_t) = 0,\; \forall\; t$$

- b) Seasonal changes in GW due to pumping and/or recharge

$$f2_t(R_{ar,t}^s,\; Div_{ar,t}^{riv}, q_{j,t}^w,\; q_{aq,t}^{riv},\; q_{l,t}^{ar},\; C_{ar}^{riv},\; Deep_{t,}^i Seep_t^p,\; \delta S_t^g) = 0,\;\; \forall\;\; j,\, l,\, t$$

Constraints

- c)Spatial changes in GW level at discharge and recharge wells:

$$f3_t\,(H^{g}_{k,t},\, q^{ar}_{j,t},\, q^{w}_{j,t},\, s^{k}_{w,t},\, s^{l}_{ar,t},\, q^{riv}_{aq,t}) = 0,\ \ \forall\, j, k, l, t$$

- d) Demand and deficit

$$f4_t\,(R^{s}_{d,t},\, R^{g}_{d,t},\, Div^{riv}_{d,t}, D_t,\, Def_t) = 0,\ \ \forall\, t$$

Constraints

- e) Interaction between the aquifer and river

$$f5_t\,(q_{aq,t}^{riv}, H_t^g, h_t^{riv}, z^{riv}, c^{riv}) = 0, \;\; \forall\, t$$

- f)Spatial and temporal variation in river water level

$$f6_t\,(q_{r,t}^{in}, q_{r,t}^{out}, ql_t^{in}, \delta h_{r,t}^{riv}, \delta s_{r,t}^{riv}) = 0, \;\; \forall\, t$$

Constraints

- g) Bonds on the reliability

$$f4_t\,(R^s_{d,t},\, R^g_{d,t},\, Div^{riv}_{d,t}, D_t,\, \alpha,\, \gamma) = 0,\ \forall\ t$$

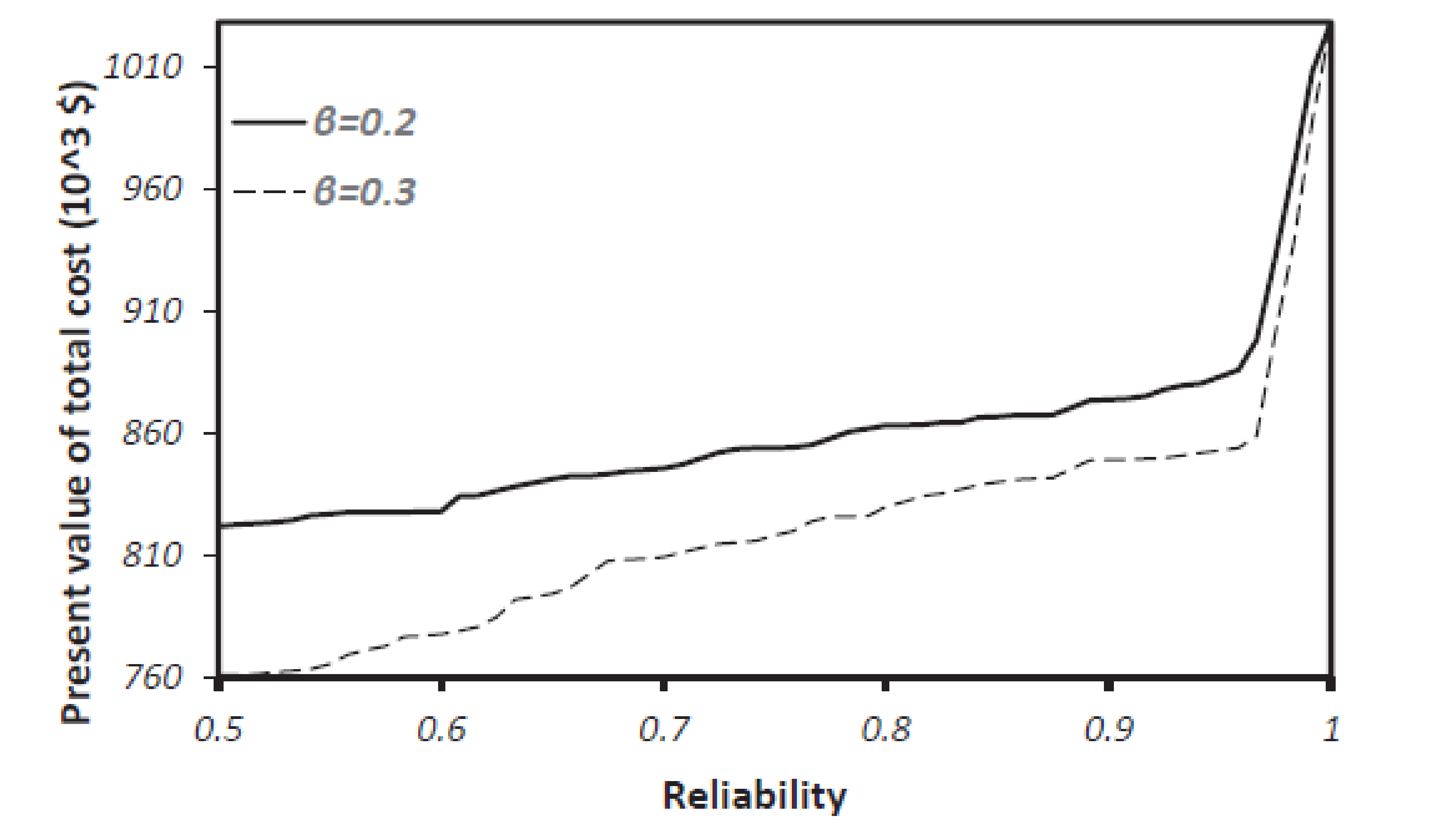
$$Rel = \frac{(\sum_{t=1}^{N} Z_t)}{N} \geq \propto$$

$$Z_t = \begin{cases} 1, & if\ \ demandisfullysatisfied \\ 0, & otherwise \end{cases} \quad \forall\ t$$

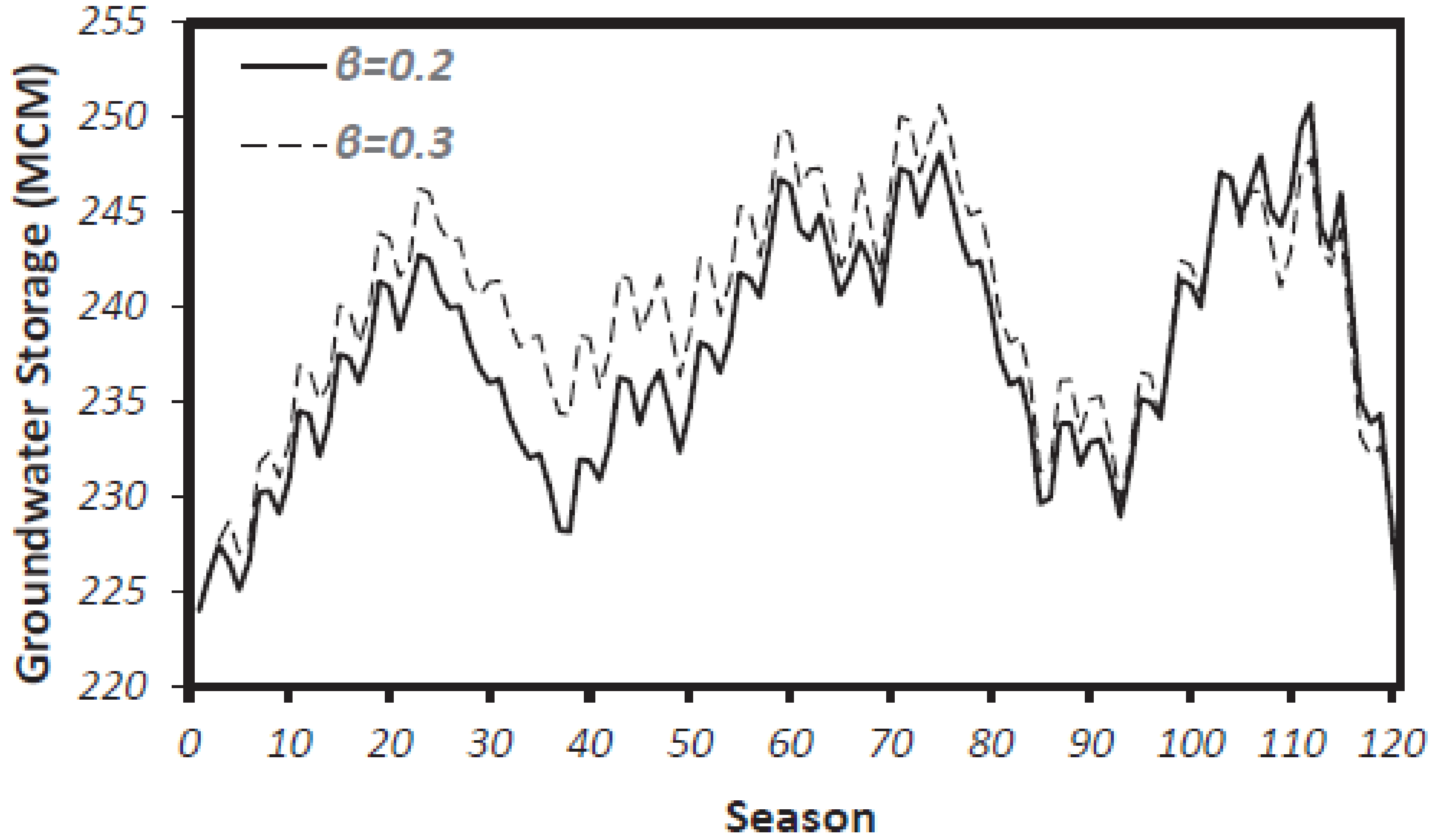
- h)General operation rule (if required)

$$R^x_{y,t} = a^x_{y,\tau}\,[S^s_t,\, Q^s_t] + b^x_{y,\tau}\,\frac{[\sum_{k=1}^{NW} s^k_{w,t-1}]}{NW} + c^x_{y,\tau} D_t,\ \ \forall\ t;\ \ \tau = 1, 2, 3, 4$$

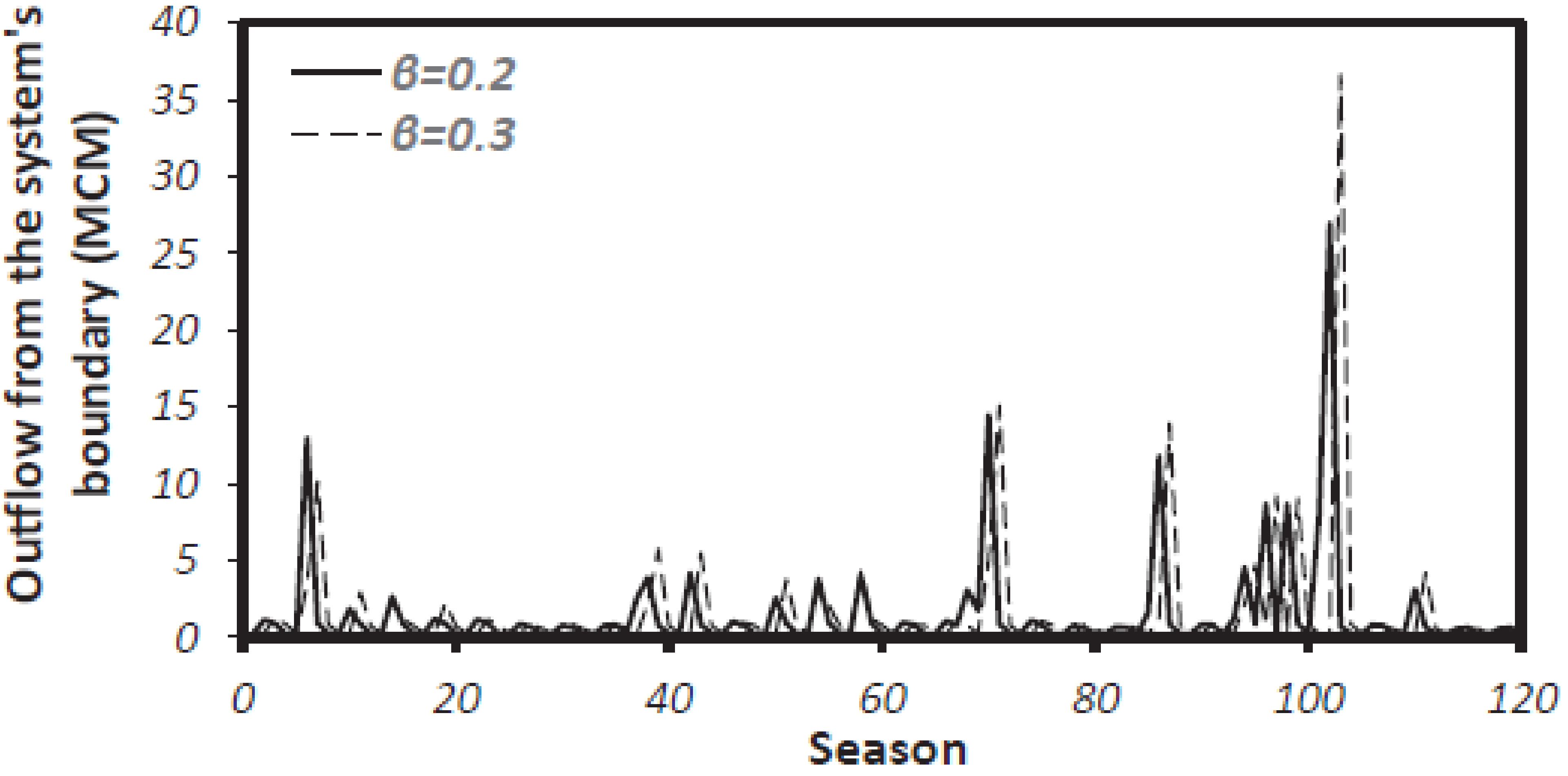
The set of non-dominated optimal solutions for β = 0.2 and 0.3.



Time variation of GW storage for Reliability =0.8



Outflow from system's boundary (Rel.=0.8)



Seasonal Deficit (Rel.=0.8)