Training Institute on Adaptive Water-Energy Management in the Arid Americas

Climate change/variability, water and energy and adaptation

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Multiple Use Reservoir

Considering a system comprised by dam, hydropower plant and a irrigation network. The goal is to design the dam, in terms of elevation, inundated area, and volume of accumulation. At the same time, it must define the discharge to hydropower generation, discharge to irrigation, and area to irrigation, considering the navigation downstream to the dam and the environmental streamflow (minimum streamflow maintained in the river to preserve the biodiversity).

From the topographic survey, it was established the relationship between stage, area of the reservoir and volume storage. The worksheet in annex supplies the curve and series of streamflow of the Castanhão Dam in Ceará State.

The dam must have a freeboard (difference between the maximum water level and the crest of the dam-top of the dam). The expropriated land corresponds to the level including the freeboard (Z_{max}).

The level of the dam (Z_{max}) must be greater than to 80 meters (the minimum level to guarantee the power generation).

The goal is to determine the optimum values of the maximum level of the dam (Z_{max}), the discharge for irrigation and the discharge for power generation. The annual profit must be maximized.

1) Capital investment

Capital investment to be paid in 20 years (to use the formula of capital recovery to calculate the value of a constant annuity). Use interest rate in decimals.

Capital recovery factor

$$R = \frac{i.(1+i)^n}{(1+i)^n - 1}$$

Relation cost of execution of the dam versus maximum level: $C_{ex}=a_3(Z_{max}-Z_1)^{b3}$ (Cost in R$).

The expropriation cost is given by: $C_e = CU_e.A_e$, where CU_e is the unitary cost of expropriated land and A_e is the expropriated area.

Value to consider in the objective-function = R x (C_{ex} + C_e).

2) Benefits of irrigation

Price of selling of the agricultural products, discounting the invested capital: $B=k_1V_{irrig}+k_2.\ln(0{,}01+0{,}3V_{irrig})$ in million R$.
where V_{irrig} is the volume of water withdrawn for irrigation in 10^6 m^3.

3) Benefits of energy

Energy generated using the discharge Q (m3/s) and the water head H (m): E(kwh)=85935,6QHη.

4) Benefits of the navigation

Benefit from the navigation into the downstream dam, in million R$: $C=a_4.Q_{ds}^{b4}$, where Q_{ds} is the remaining discharge in the channel downstream the dam.

DATA

General Data		
Freeboard above the water level (b)	2	m
Maximum level possible	114	m
Minimum level possible	80	m
Coefficient Z_0 (adjust of the functions overflow and yield discharge)	79	
Number of daily hours for irrigation (n)	8	hours
Water consumption for irrigation (q_{irrig})	0.6	L/s/ha
Turbine efficiency (η)	0.95	
Minimum value of water head for power generation (H_{min})	25	m
Minimum discharge for environmental streamflow (Q_{min})	10	m^3/s
Water level in the river downstream the dam (Z_{ds})	55	m
Maximum irrigable area ($A_{max,irrig}$)	40000	ha
Costs		
Unitary cost of expropriated land (CU_e)	1	$R\$/m^2$
Unitary cost of irrigation (CU_{irrig})	5000	R$/ha
Relation cost of execution of the dam versus maximum level		
Coefficient a_3	20000	
Coefficient b_3	2.7	
Coefficient Z_1	50	
Variables for calculation of the capital recovery factor		
Time of amortization (n)	20	years
Annual interest rate (i)	0.12	
Benefits		
Average value of the Kwh (Price Kwh)	0.4	R$/Kwh
Price of selling of the agricultural products		
k_1	0.5	
k_2	20	
Benefits of the navigation		
a_4	100	
b_4	2.5	