

II.4-RES-SNGL-A-SPILLWAY SINGLE RESERVOIR REGULATION OPERATION SCHEME SPILLWAY ROUTING

Description

Scheme SPILLWAY is applicable to uncontrolled spillways, sluices and gated spillways when all gates are fully open.

Routing over an uncontrolled spillway is required when the pool elevation exceeds the spillway crest elevation. For a gated spillway routing is required when inflow exceeds the maximum possible discharge (QPASMX), QPASMX at the elevation (normally about 0.5 feet below the top of closed gates) where inflow is passed. Routing through a sluice is required if the water is above the sluice invert and the sluice is uncontrolled or at the elevation where inflow is passed and the discharge capacity of the sluice is exceeded.

The Modified Puls method is used for routing. The Puls method requires the computation of a (storage + discharge/2) versus spillway discharge relation from relations of elevation versus spillway discharge and elevation versus storage above the spillway crest. For some reservoirs the routing relation becomes unstable when the data time interval is used as the routing time period due to large increases in discharge compared to small increases in storage with elevation. To prevent routing instabilities the length of the routing step is not allowed to be more than twice the lowest ratio of change in storage to change in discharge for consecutive values in the storage versus discharge relation. When the routing step is less than the data time interval, peak values of discharge can occur between data time interval points. These peak values are assigned to the nearest data time interval position but do not replace the computed data time interval discharges until the entire outflow hydrograph has been computed, that is, at the end of the forecast run.

A dam can have facilities for non-spillway discharge in addition to spillway discharge. The non-spillway discharge can be generation (and sluice) discharges for power dams or sluice discharges for non-power dams. The non-spillway discharge can be specified either through a time series or as a constant value. When a time series is used to specify the non-spillway discharge, a default value must be supplied for use when values are missing. The default value will usually be the maximum generation discharge for a power dam.

For many power dams, high tailwater elevations can significantly reduce the maximum possible turbine discharge and may cause the turbine discharge to be completely shut off. In this situation, a total discharge versus maximum generation discharge curve can be used to compute the non-spillway discharge. The total discharge versus maximum generation discharge curve will be derived within the operation using relations of pool elevation versus spillway discharge, tailwater elevation versus discharge and head versus maximum generation discharge. These three curves are input by the user.

The elevation above spillway crest versus spillway discharge relation and tailwater elevation versus discharge relation can usually be found in the reservoir manuals. The head versus maximum generation discharge relation is rarely available but can be computed with reasonable accuracy by assuming that the maximum generation discharge is proportional to the square root of the head. The reservoir manual for a power dam will usually include either a maximum generation discharge for a specified head or a discharge for a specified minimum head. Other discharges can be computed from the specified discharge and head by varying the discharge with the square root of the head. The mean or normal generation for a specified head should not be used unless it is the only available value. The mean or normal is a more efficient but lower generation discharge than the maximum.

Three different cases are considered in the simulation:

- 1) The power generation discharge is not effected by the tailwater.
- 2) The power generation discharge is effected by the tailwater.
- 3) The operation data time interval is greater than the ration of change in storage to change in discharge.
 - A) If power generation discharge is not effected by tailwater and the spillway routing step is equal to the operation data time interval:

$$TIMINT \leq 2(V_2 - V_1)/(QO_2 - QO_1)$$

1. Generate spillway discharge (QS) versus storage-discharge ($V + QS * TIMINT/2$) curve, $QS = qs(V + QS * TIMINT/2)$, from elevation versus spillway discharge curve, $H = h(QS)$ and elevation versus storage curve, $H = h(V)$.

2. From the continuity equation:

$$QIM * TIMINT - (QO_1 + QO_2) * TIMINT/2 = V_2 + V_1$$

Reorder the terms then:

$$V_2 + QO_2 * TIMINT/2 = QIM * TIMINT + V_1 - QO_1 * TIMINT/2$$

Since total discharge is equal to the spillway and non-spillway discharge, $QO = QS + QOK$, then:

$$V_2 + QS_2 * TIMINT/2 = QIM * TIMINT + V_1 - QO_1 * TIMINT/2 - QOK_2 * TIMINT/2$$

where the non-spillway discharge, QOK , is the summation of power generation discharge ($QGEN$) and sluiceway discharge ($SLUICE$):

$$QOK = QGEN + SLUICE$$

Since power generation discharge is not effected by tailwater. Values of QGEN and QSLUICE are either constant or directly obtained from a time series. $V_2 + QS_2 * TIMINT/2$ can be computed explicitly.

3. Compute spillway discharge from spillway discharge versus storage-discharge curve:

$$QS_2 = qs(V_2 + QS_2 * TIMINT/2)$$

4. Compute total reservoir discharge from:

$$QO_2 = QS_2 + QOK_2$$

5. Compute mean discharge from:

$$QOM = (QO_1 + QO_2) * TIMINT/2$$

6. Compute reservoir storage from:

$$V_2 = (QIM - QOM) * TIMINT + V_1$$

7. Compute pool elevation from elevation versus storage curve:

$$H_2 = h(V_2)$$

- B) If power generation discharge is effected by tailwater and the spillway routine step is equal to the operation data time interval,

$$TIMINT < 2 (V_2 - V_1)/(QO - QO_1)$$

1. Generate total discharge versus maximum generation discharge curve:

QG = qgg(QO) from pool elevation versus spillway discharge curve

QS = qs(H), tailwater elevation versus total discharge curve

TH = th(QO) and head (headwater - tailwater) versus maximum generation discharge curve, QG = qgh(DH)

a) Select a pool elevation H_i .

b) Estimate a maximum generation discharge, QG'_i , by assuming no tailwater effect.

c) Compute total discharge from:

$$QO_i = QS_i + QG'_i + SLUICE = qs(H_i) + QG'_i + SLUICE$$

d) Compute tailwater elevation from tailwater elevation versus total discharge curve, TH =

$th(QO), TH_i = th(QO_i).$

- e) Compute differential head between headwater and tailwater:

$$DH_i = H_i - TH_i$$

- f) Compute new maximum generation discharge from head versus maximum generation discharge curve:

$$QG_i = qgh(DH_i)$$

- g) Compare the new maximum generation discharge, QG_i , with estimated value in step b, QG'_i . Set $QG'_i = QG'_i + 0.5 * (QG_i - QG'_i)$ and repeat steps ©) through (f) until the two values are reasonably close.
- h) Repeat steps (a) through (g) for all desired pool elevations.
- I) Figure 1, Figure 2, Figure 3 and Figure 4 are plots of total discharges against computed maximum generation discharges. To complete the graph, a straight line is drawn from the zero-zero coordinate to the maximum generation discharge computed at the spillway crest elevation. For some dams, the draft tubes are closed when the head drops below a specified value and the generation discharge drops to zero. The total discharge versus maximum generation discharge relation must include this decrease to zero for the maximum generation discharge.

2. Generate spillway discharge versus storage-discharge curve, $QS = qs(V + QS * TIMINT/2)$, as in A1.

3. Due to the tailwater effect, power generation discharge, $QGEN$, is dependent on the total discharge, QO . Spillway discharge and non-spillway discharge need to be solved simultaneously by an iterative method.

- a) Estimate a total discharge, $ESTQO_2 = (QO_1 + QIM) * 0.5$.

- b) Compute maximum generation discharge, $QGENO = qgq(ESTQO_2)$

- c) Compute new discharge, QO_2 , using procedures described in A2 - A4.

- d) Compute new maximum generation discharge, $QGEN = qgq(QO_2)$.

- e) Compare $QGENO$ and $QGEN$ and set $ESTQO_2 = QO_2$ and repeat steps (a) through (d) if necessary. In

general, $Q_{GEN} \ll Q_{O_2}$, therefore, only one more interaction is performed.

4. Repeat steps A4 through A7 for Q_{O_2} , Q_{OM} , V_2 and H_2 .

- C) If $TIMINT \geq 2(V_2 - V_1)/(Q_{O_2} - Q_{O_1})$, then a smaller routing step is required. The operation data time interval is subdivided into n equal routing steps, $TIMINT_r$ such that $TIMINT_r \leq 2(V_2 - V_1)/(Q_{O_2} - Q_{O_1})$. Repeat n times, the simulation procedures given in (A) if there are no tailwater effects and (B) if there are tailwater effects.

Figure 1. Curve derived by varying discharge with the square root of the head - the maximum discharge was 27000 CFS at a head of 20 FT

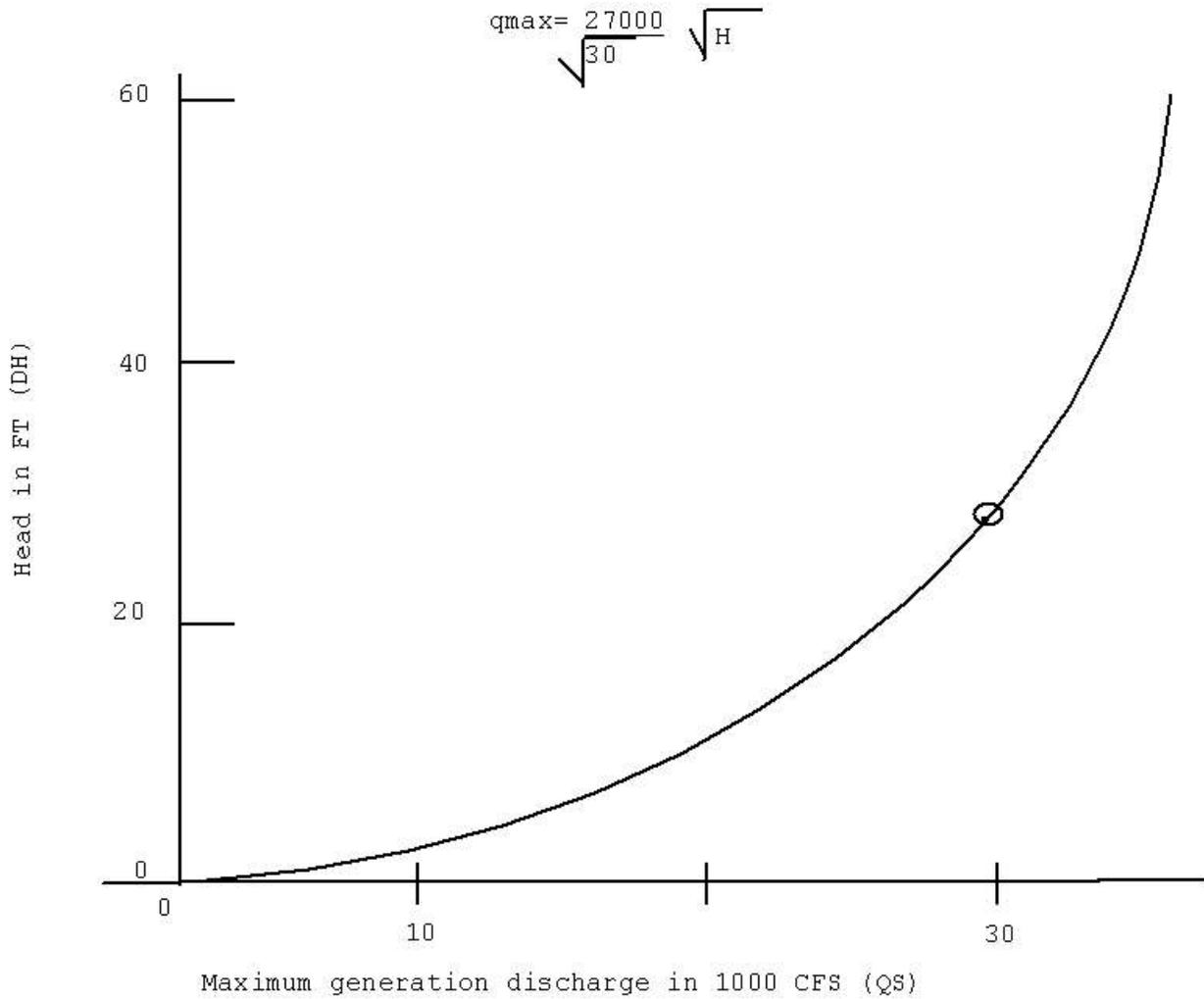


Figure 2. If the draft tube gates are closed at a specified low head then the maximum discharge would be reduced to zero at the total discharge that would produce the specified low head

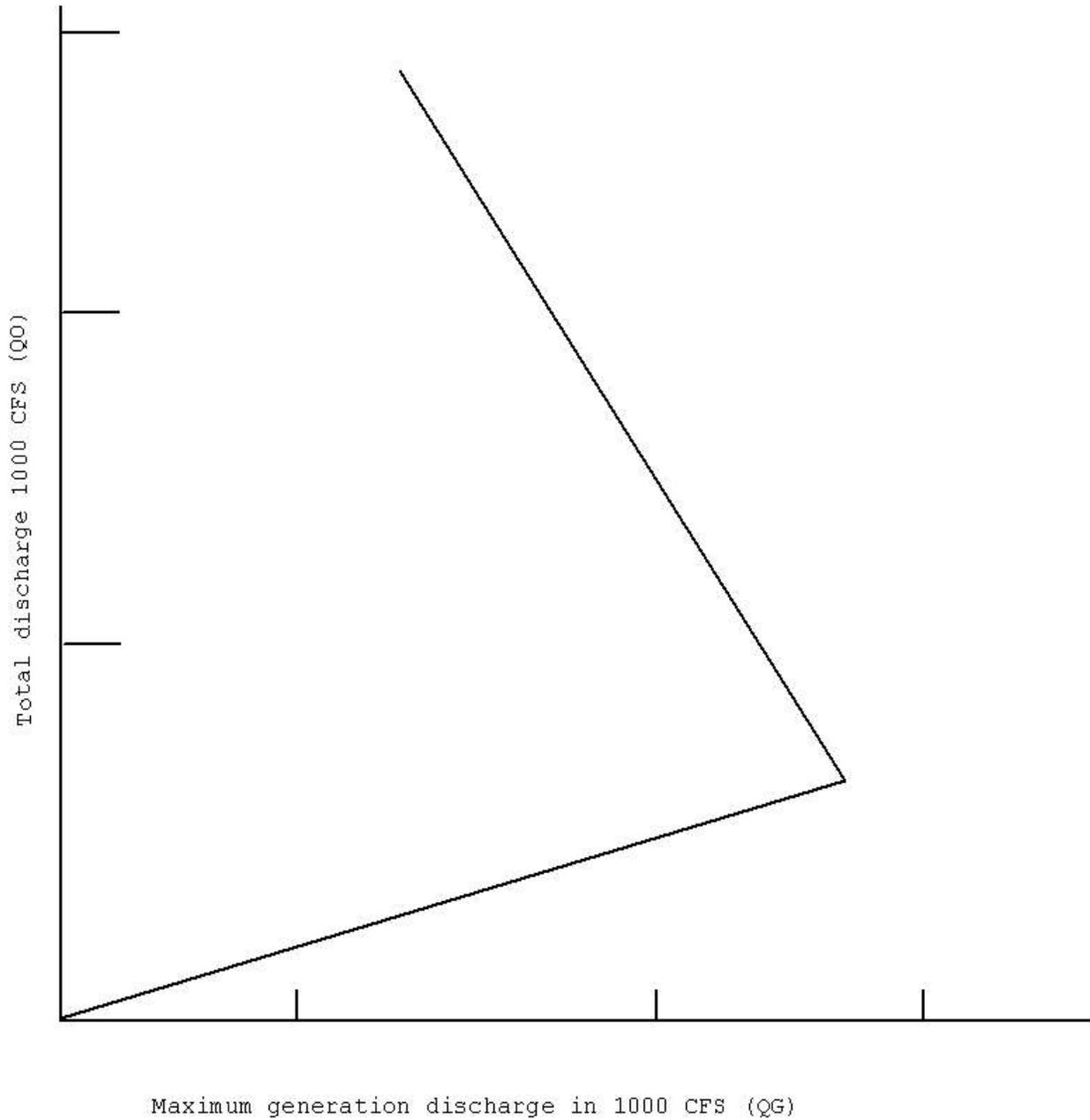


Figure 3. Spillway discharge versus pool elevation

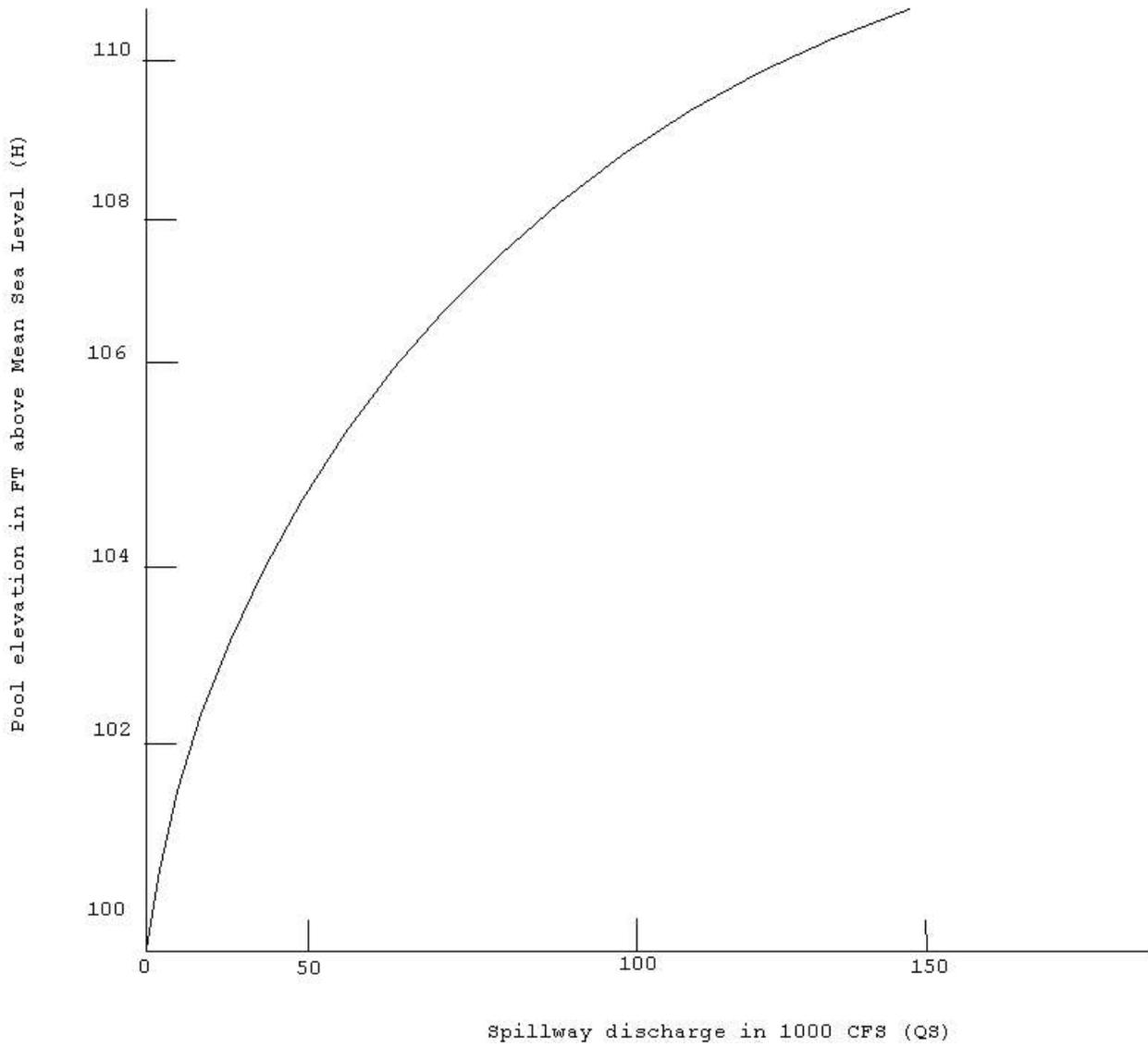


Figure 4. Total discharge versus tailwater elevation

