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Indicators of reservoir performance

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40.232 Water Resources Management
Term 7, 2015

Homework 2
Due date: March 4, 2015, at 11.55 pm

Download the file *Des_Moines_River_flow.xls*, which contains a complete record of mean daily flows (m^3/sec) for the period 1^{st} April 1920 – 16^{th} November 2014 for the Des Moines River, a tributary of the Mississippi in upper Midwestern United States. Suppose this flow sequence feeds a single reservoir, which is used to sustain a downstream demand of 2,500,000 m^3/day. The reservoir has a maximum capacity of 750,000,000 m^3.

Note the following constraints:

- If the sum of the storage s_t [m^3] available at time t and the inflow a_{t+1} [m^3/day] in the time interval $[t,t+1)$ is lower than the downstream demand, the volume discharged in one day from the reservoir is equal to $s_t + a_{t+1}$ (i.e., the reservoir cannot supply more water than what is available in the storage and the available incoming flow in any given time period). Otherwise, the demand is met in full.
- If the storage exceeds the reservoir capacity, the excess water is discharged from the spillways. The volume discharged from the spillways can be considered lost.

Part 1 – Basic indicators of reservoir performance *[65 marks]*

(a) Simulate the dynamics of the reservoir storage[1] over the period 1^{st} April 1920 – 16^{th} November 2014 and produce a reservoir behaviour diagram (storage through time) over the given period. You may assume that the reservoir is full on 1^{st} April 1920 (i.e., s_0 = 750,000,000 m^3).

The **critical period** of a reservoir may be defined as the longest period (on record) from full reservoir condition to empty and then full again. The **critical drawdown period** is the longest period from full reservoir condition to empty.

(b) Report both the critical period and the critical drawdown period for this system. Comment on why these indicators might be useful to the water authority and identify limitations for using the indicators in this way.

The **largest downstream water delivery target** is defined as the maximum constant downstream supply that can be sustained without depleting the reservoir under historical inflow conditions (i.e., storage equal to 0 m^3). This measure is often compared to the required downstream supply to indicate the performance of the system in terms of surplus or deficit.

[1] Assume that the evaporation is negligible.

(c) Using the simulation code developed at point (a), simulate the dynamics[2] of the reservoir storage under different scenarios of downstream water demand to determine the largest downstream water delivery target of the reservoir system to the nearest 10,000 m^3/day. You may assume that the reservoir is full on 1st April 1920. Comment on the difference between the largest downstream water delivery target and the initial demand (i.e., 2,500,000 m^3/day).

(d) The largest downstream water delivery target is often used in reservoir design (i.e., design a reservoir such that the largest downstream water delivery target equals required demand). Comment on what you think are the limitations of using the largest downstream water delivery target in this way and suggest some possible simple improvements.

Part 2 – Risk-based indicators of reservoir performance *[35 marks]*

Suppose that the water authority wishes to understand the risk of the system in its current state and that the historical record of inflows is deemed adequate for understanding water shortages. (Note: assume that the downstream demand is 2,500,000 m^3/day for questions (a) – (c)).

(a) Produce a graph that shows the downstream water supply through the length of the historical sequence.

(b) Produce a graph that shows the discharge from spillways through the length of the historical sequence.

(c) Develop a system performance indicator based on the frequency of failure in meeting the downstream water demand and determine its value under the historical inflow conditions.

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[2] Similarly to point (a), assume that the evaporation is negligible and that the water discharged from the spillways does not contribute to the downstream water supply.