Optimization of New York City's Reservoir System

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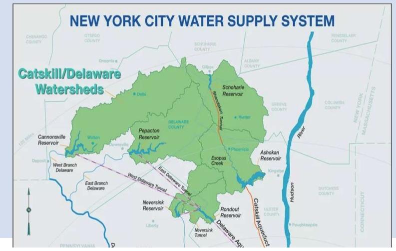


ABSTRACT

Through the Flexible Flow Management Program (FFMP), the reservoirs Pepacton, Cannonsville, and Neversink supply water to New Jersey, New York, Pennsylvania, and Delaware. Consequently, the FFMP enforces policies that determine the amount of water that is released to these areas on a regular basis. To do so, the FFMP uses data on the performance of the reservoirs' water system to verify that such policies are effective. It also uses rule curves to determine the amount of water that is allocated to each party based on the level of water in the reservoirs.

Traditionally, three statistical indicators are used to measure a water system's performance: reliability (probability of success); resilience (probability of recovery in failure); vulnerability (total water shortage in the worst drought phase); these help measure sustainability of the water system.

INTRODUCTION

- The Delaware River flows through the states of NY, NJ, DE, and PA; it supplies roughly 15 million people with drinking water.
- Neversink, Cannonsville, and Pepacton Reservoirs are the main reservoirs in the NYC water system; in conjunction they can hold over 240 BG of water.
- In 1954, the US Supreme Court decreed that all parties involved are given fair access to the reservoirs; today, their releases are managed by the Flexible Flow Management Program (FFMP).

METHODS

- Used observed data for inflows, outflows, and storage levels (Jan. 1982 - Mar. 2010) from NYCDEP to generate our model, which simulated reservoir levels
- Compared the simulated figures to corresponding observed storage levels → validated the model's accuracy; proved that it is possible to simulate storage with predicted inflows and outflows

$$\Delta S/_{\Delta t} = INF_t - OUT_t$$

- Calculated statistical indicators of the reservoirs' water system performance to determine sustainability of the current and past reservoir releases by the FFMP
  - Reliability (probability of water below certain level);

$$\alpha = P(x \in S)$$

1-(# of instances when storage water is below a set level, failure)/(time period, N)

  - Resilience (probability of recovery after given failure);

$$r = P(x_{t+1} \in S \mid x \in F)$$

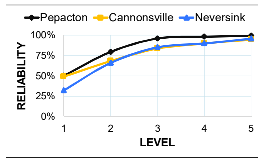
(length of system recovery)/(# of failures)

  - Vulnerability (maximum duration of failure)

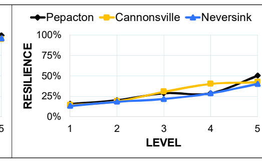
$$v = \max(\text{failures})$$

RESULTS

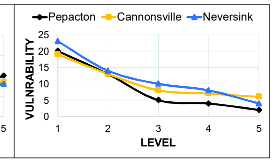
With Observed Storage (1982-2010)



Graph 1

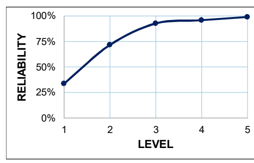


Graph 2

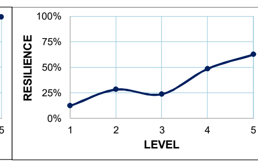


Graph 3

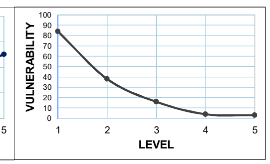
With Simulated Storage (Combined, 1928-2000)



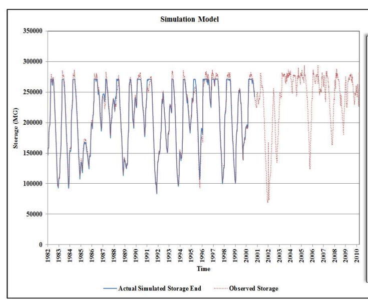
Graph 4



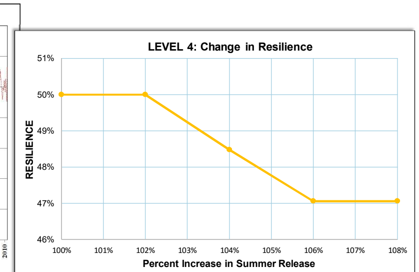
Graph 5



Graph 6



Graph 7



Graph 8

ACKNOWLEDGEMENTS

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DISCUSSION

- G1: Neversink Reservoir's reliability at Level 1 is extremely low (32%);
- G2: Pepacton Reservoir's resilience does not change between Level 3 and 4 (29%), contrary to the change observed for the other reservoirs between levels;
- G3: All reservoirs' vulnerability decrease greatly between levels, as the drought phase for each becomes less lengthy due to increased success

- G4: Simulated reliability appears to be precise as the range and y-values (%) match those of G1 (an estimated average);
- G5: Resilience behaves irregularly at Level 3, in which it is less than that of Level 2, though it resumes regular change (increase) at Level 4 and 5. This is likely due to the 29% constant of Pepacton at Level 3 and 4 (see G2), as a factor of representation for all 3 reservoirs;
- G6: Vulnerability appears to follow the pattern of its corresponding level for observed storage, though at a different range. This can be explained by the variability of N, the time period; for observed storage we used data from 1982-2010 while we simulated storage for 1928-2000, which included the 1960s drought (hence, the simulated vulnerability at Level 1 is 84 months)

- G7: The range of the storage (in MG) of observed and simulated appears to have low variability. Along with the previous graphs, this shows that the simulation model is a good predictor of storage water;
- G8:102% increase in summer release is plausible, as resilience remains the same (50%). This increased water release (271, 000 MG → 276, 420 MG) would be to the parties' benefit as the water would be more useful in the river such that the inhabiting fishes are healthier with more water; and so, sustainability is satisfied, as well as economical concerns.

CONCLUSIONS

The simulation model is a potential tool to generate storage water of the reservoir system of New York City (Pepacton, Cannonsville, Neversink). This is supported by the shared distribution of observed and simulated storage, as well as the levels' corresponding values of the statistical indicators of the water system' performance; that is, reliability, resilience, and vulnerability.

Using this model, we generated new resilience measures at 1% interval increases in the water releases for summer months. We found that at 102% increase, resilience remains the same as its initial value (50%). Thus, it would be a plausible action to increase summer releases by 2% such that environmental sustainability is taken in as a factor for FFMP's policies on water release. Benefits would include economical success for fisheries, as well as proper conservation of water.

However, this is only one of the many possibilities of the usage of this simulation model, but this would be an advantageous choice to make for the parties involved with the reservoirs, such as New York City.