2022 MCM
Problem B: Water and Hydroelectric Power Sharing

Background

For centuries, people have constructed dams across rivers and streams to hold back water to create reservoirs as a means of managing water supplies. These reservoirs store water for a variety of uses (e.g., agriculture, industry, residential), provide an area for leisure and recreation (e.g., fishing, boating), assist in preventing downstream flooding, and feed water to turbines that generate electricity. **Hydroelectric power** (**hydropower**) is electricity produced by these turbines as they convert the potential energy of falling or fast-flowing water into mechanical energy.

With climate change, the volume of water from sources feeding dams and reservoirs is decreasing in many areas. Consequently, dams may not be able to meet the demands for water in these areas. Additionally, low water flow decreases the amount of electricity generated from hydroelectric plants resulting in disruptions of the power supply in these areas. If the water level in the reservoir behind the dam is low enough, hydroelectric power generation stops.

Natural resource officials in the U.S. states of Arizona (AZ), California (CA), Wyoming (WY), New Mexico (NM), and Colorado (CO) are currently negotiating to determine the best way to manage water usage and electricity production at the Glen Canyon and Hoover dams to address these competing interests. Hundreds of years of previous agreements continue to impact current water management regulations, policies, and practices today. The agreements allocate more water from the Colorado River system than is present in the system. It is likely that the system continues to work because some users do not take their full allocations. If drought conditions continue in the Colorado River basin, the water volume at some point will be insufficient to meet the basic water and generated electricity needs of stakeholders. Consequently, a rational, defensible water allocation plan for current and future water supply conditions is critically important.

Additional Guidance

State natural resources negotiators have asked your team to develop a water allocation plan in their five states (AZ, CA, WY, NM, and CO). These officials assume that recent rainfall shortages and hotter temperatures will persist, causing problems with both supply (water availability) and demand (electricity requirements). They provided the following guidance:

- The operations of the Glen Canyon dam (Lake Powell) and the Hoover dam (Lake Mead) should be closely coordinated because water outflows from the Glen Canyon dam supply part of the water input to the Hoover dam.

- The challenge presented by this series configuration of two dams is to determine a suitable allocation of water and electricity to agriculture, industry, and residences in the five states.

- Your solution should address what water flows should be taken from the Glen Canyon and Hoover dams when the demands of the communities of interest are at stated levels and the water in the two reservoirs is at stated height (respecting the relationship between water height in the reservoirs and the volume of water in the reservoirs). Recommend how often the model should be re-run to take into account changes in the supply and demand profiles.

- Mexico has claims on the residual water left after the five states have consumed their shares. Your plan should address Mexico's rights.

- After water allocations from your plan are implemented, discuss how much water (if any) should be allowed to flow into the Gulf of California from the Colorado River?

Requirements
In developing your water allocation plan according to the negotiators' guidance, you should:

- Develop and analyze a mathematical model that will assist negotiators to respond to a fixed set of water supply and demand conditions. Use the model to inform dam operations: When the water level in Lake Mead is M and the water level in Lake Powell is P, how much water should be drawn from each lake to meet stated demands? If no additional water is supplied (from rainfall, etc.), and considering the demands as fixed, how long will it take before the demands are not met? How much additional water must be supplied over time to ensure that these fixed demands are met?

- Use your model to recommend the best means to resolve the competing interests of water availability for general (agricultural, industrial, residential) usage and electricity production. Explicitly state the criteria you are using to resolve competing interests.

- Use your model to address what should be done if there is not enough water to meet all water and electricity demands.

- What does your model indicate under the following conditions?
    - The demands for water and electricity in the communities of interest change over time. What happens when there is population, agricultural, and industrial growth or shrinkage in the affected areas?
    - The proportion of renewable energy technologies increases over the initial value used in your analysis.
    - Additional water and electricity conservation measures are implemented.

Your solution should not utilize or rely on any existing historical agreements or current political powers of organizations or persons in these states but represent your team's best mathematical solution for the allocation of water in this region.

As part of your solution submission, prepare a one- to two-page article of your findings suitable for publication in *Drought and Thirst* magazine, a monthly publication for water infrastructure managers in the American Southwest.

Your PDF solution of no more than 25 total pages should include:

- One-page Summary Sheet.
- Table of Contents.
- Your complete solution.
- One- to two-page Article for *Drought and Thirst* magazine.
- Reference List.

Note: The MCM has a 25-page limit. All aspects of your submission count toward the 25-page limit (Summary Sheet, Table of Contents, Reference List, and any Appendices). You must cite the sources for your ideas, images, and any other materials used in your report.

Glossary

Hydroelectric power (**hydropower**): electricity produced by turbines that convert the potential energy of falling or fast-flowing water into mechanical energy.