Water Dynamics Notes

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1 Reca, et al.: Optimal pumping scheduling model considering reservoir evaporation

1.1 Previous Work

- Evaporation losses
- Cover reservoirs to prevent evaporation; costly for large ones
- Optimizing energy costs of pumping schedules, not considering evaporation

1.2 Methodology

Linear function for surface area A to volume S: $A = c_1 \times S + c_2$

Pan evaporation E_o tends to be proportionally higher reservoir evaporation .E_d

- $E_d = K_{r,d} \times E_{o,d}, K_{r,d} > 1$ for day d
- This requires "daily evaporation estimations into an hourly basis," which is highly variable as it depends more on wind speed than radiation.

1.3 LP Optimization

1.3.1 Objective Function

Optimize total cost C_e, given energy price p and consumption W at time period i

- $C_e = \sum p_i \times W_i$
- $W_i = w_i \times V_i$ for unitary consumption w and volume pumped V at time period i
- Also can include unitary water cost p_w

1.3.2 Constraints

- Max pumping capacity: $V_i \leq Q \times N_i, \forall i$ for system discharge rate Q and duration N at period i
- Max/min storage capacity
- $S_i \in [S_m, S_M], \forall i$ where $S_i = S_{i-1} + V_i + R_i - D_i - RE_i$ for demand D, rainfall R, and evaporation RE at period i
- Non-negativity

1.4 Case Study

Instead of pumping water out from reservoirs, this is pumping water from wells into reservoirs, where evaporation will be more of an issue.

- Given: area-volume measurements, pumping discharge etc., demand, electricity rates
- Measured: evaporation data (via A-class pan and weather station)
- Approximated hourly evaporation patterns with nearby data

1.5 Results

- Two models: control (without considering evaporation), above methodology
- For control, model anticipated pumping hours by maximizing low cost pumping periods
- For methodology, model delayed pumping to minimize stored water pumped into reservoirs

2 Linacre: Estimating U.S. Class A Pan Evaporation from Few Climate Data

2.1 Previous Work

- Comparing variable pan measurements with Penman's equation
- Formula requires temperature, humidity, wind, and irradiance measurements
- Lots of pan data, few lake-evaporation measurements to verify Penman's

Purpose is to modify Penman's equation for a pan to verify its results

2.2 Methodology

2.2.1 Pan

- Wire mesh screen reduces wind and radiation, lowering evaporation
- Higher elevations has thinner air, reducing radiation intensity for higher pans
- Heat transfer through pan walls, depending on solar irradiance of the ground and sun elevation
- Dryer ground increases evaporation

2.2.2 Modified Equation

Similar to that for a leaf because water loss resistance ¿ heat transfer resistance (?)

2.2.3 Conclusions

- $E_o = 0.77$
- E_p depends on solar irradiance (pan geometry, solar positioning, atmosphere)
- Modified equation is more reliable than Penman's, involving "extraterrestrial radiation and rainfall measurements"

3 Ngancha et al.: Optimal Pump Scheduling . . . Incorporating Evaporation and Seepage Effect

3.1 Previous Work

Studies at different levels: water storage, pumping, and cost optimization

3.2 Case Study

- Water treatment system: river water to dams to reservoirs for treatment
- Goal: minimize electricity and water costs while satisfying demand and considering evaporation

4 Sivapragasam, et al.: Modeling Evaporation-Seepage Losses . . .

4.1 Previous Work

- Most research model non-evaporation losses, esp. seepage, as a pre-defined relationship or as negligible
- Penman most commonly used for evaporation modeling, with possible some under-estimation

4.2 Methodology

- GP algorithm
  - Evaporation: meteorological parameters + surface area (volume / depth)
    - $E_t = f(h_{t-1}, SA_{t-1}, T_{t_2 4}, RH_{t-24}, N_{t-24}, V_{t-24})$
    - Evaporation(-seepage?) loss E, temperature T, wind velocity V, sunshine hours N, relative humidity RH, surface area SA, and depth h at time t
    - $t-1$ indicates one fortnight before and $t-24$ indicates the same fortnight one year before
    - inflow not explicitly considered because assume depth accounts for that (h also indirectly accounts for SA as they have a linear relationship)
- Seepage: depth (lack of other info, e.g. saturation) - Assumption: average climate in a given year is not significantly different from the year before - Develop GP equations for both reservoirs in case study, compare to Penman's

4.3 Conclusions

- GP and Penman's corr coe. is 0.85 vs. 0.64, GP model better for March through July, indicating some losses in those months that are beyond evaporation. i.e. models predict evaporation very similarly, but GP performs better by including non-evaporation modeling
- Unsatisfactory predictions from both models because of data frequency and station distance (?)

5 Other Sources

- Small reservoirs depth-area-volume relationships ...
- Establishing Water Surface Area-Storage Capacity Relationship ...