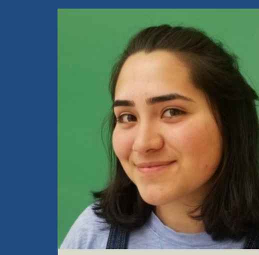
Analyzing losses across California's water distribution system (RRS11)

Decision support systems for utility planning

Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt)



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Background

California's current water conveyance system accumulates a large amount of losses as water is transported and distributed across the state. For example, losses occur in reservoirs where water is stored through seepage into the ground below and through evaporation into the surrounding air. They also occur in the distribution process as leakage from pipes. Additionally, these losses can be associated with a high energy cost for water that has already been pumped long distances or treated, so reducing our water losses could also reduce energy waste and other costs.

As droughts become more frequent and severe in California, we need to make the most use of the state's limited water resources. In order to reduce these losses, we must first characterize the types, locations, and amounts of losses occurring in California.

Project Goals:

- Calculate total losses due to evaporation in California reservoirs that were associated with urban water systems.**
- Identify factors affecting the evaporation rate in said reservoirs

** Private reservoirs and reservoirs from the Bureau of Reclamation were not included in this analysis

Approach

Many techniques were considered to determine the losses due to evaporation across the state. I decided to use the following evaporation equation[1] because it would provide the fullest results given the data that were available to me.

$$E_V = ET_O \times A$$

Where:

E_V = Dam reservoir evaporation in volume (acre-feet/year)

ET_O = Reference evapotranspiration in depth (based on regional ET_O zones) (inches)

A = Reservoir surface area (specific to each dam) (acre-feet)

The ET_O values for the yearly total, the lowest month, highest month, and median month were used alongside reservoir information to calculate the evaporation in each reservoir for the corresponding times. The dam information was sourced from a state database[4]. Each reservoir was grouped into the county it served and the hydrologic region it belongs to in order to ease the future use of this data. The corresponding maps are shown in the Results section.

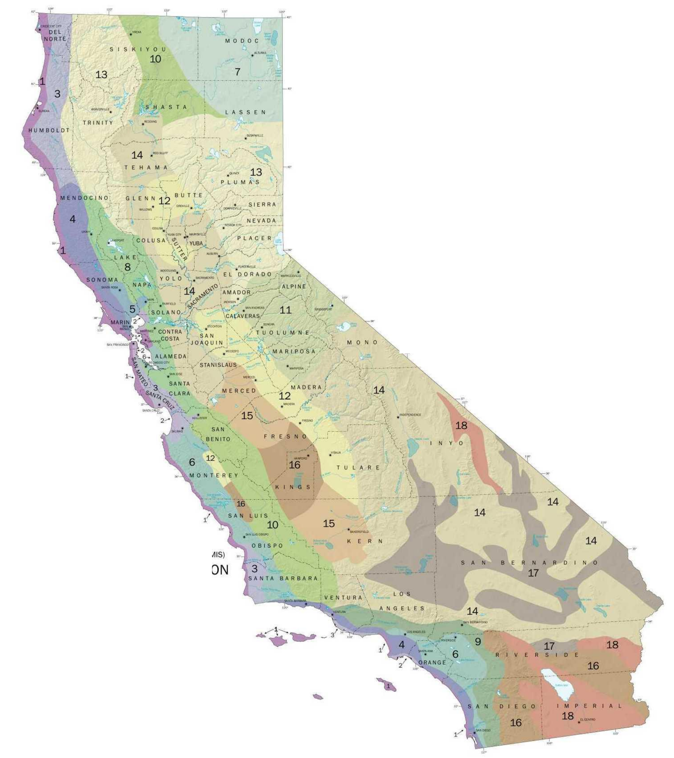
Monthly Average Reference Evotranspiration by Eto Zone (inches/month)

Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Min	Max	Median
1	0.93	1.4	2.48	3.3	4.03	4.5	4.65	4.03	3.3	2.48	1.2	0.62	33	0.62	4.65	2.89
2	1.24	1.68	3.1	3.9	4.65	5.1	4.96	4.65	3.9	2.79	1.8	1.24	39	1.24	5.1	3.5
3	1.86	2.24	3.72	4.8	5.27	5.7	5.58	5.27	4.2	3.41	2.4	1.86	46.3	1.86	5.7	3.96
4	1.86	2.24	3.41	4.5	5.27	5.7	5.89	5.58	4.5	3.41	2.4	1.86	46.6	1.86	5.89	3.955
5	0.93	1.68	2.79	4.2	5.58	6.3	6.51	5.89	4.5	3.1	1.5	0.93	43.9	0.93	6.51	3.65
6	1.86	2.24	3.41	4.8	5.58	6.3	6.51	6.2	4.8	3.72	2.4	1.86	49.7	1.86	6.51	4.26
7	0.62	1.4	2.48	3.9	5.27	6.3	7.44	6.51	4.8	2.79	1.2	0.62	43.4	0.62	7.44	3.345
8	1.24	1.68	3.41	4.8	6.2	6.9	7.44	6.51	5.1	3.41	1.8	0.93	49.4	0.93	7.44	4.105
9	2.17	2.8	4.03	5.1	5.89	6.6	7.44	6.82	5.7	4.03	2.7	1.86	55.1	1.86	7.44	4.565
10	0.93	1.68	3.1	4.5	5.89	7.2	8.06	7.13	5.1	3.1	1.5	0.93	49.1	0.93	8.06	3.8
11	1.55	2.24	3.1	4.5	5.89	7.2	8.06	7.44	5.7	3.72	2.1	1.55	53	1.55	8.06	4.11
12	1.24	1.96	3.41	5.1	6.82	7.8	8.06	7.13	5.4	3.72	1.8	0.93	53.3	0.93	8.06	4.41
13	1.24	1.96	3.1	4.8	6.51	7.8	8.99	7.75	5.7	3.72	1.8	0.93	54.3	0.93	8.99	4.26
14	1.55	2.24	3.72	5.1	6.82	7.8	8.68	7.75	5.7	4.03	2.1	1.55	57	1.55	8.68	4.565
15	1.24	2.24	3.72	5.7	7.44	8.1	8.68	7.75	5.7	4.03	2.1	1.24	57.9	1.24	8.68	4.865
16	1.55	2.52	4.03	5.7	7.75	8.7	9.3	8.37	6.3	4.34	2.4	1.55	62.5	1.55	9.3	5.02
17	1.86	2.8	4.65	6	8.06	9	9.92	8.68	6.6	4.34	2.7	1.86	66.5	1.86	9.92	5.325
18	2.48	3.36	5.27	6.9	8.68	9.6	9.61	8.68	6.9	4.96	3	2.17	71.6	2.17	9.61	6.085

Monthly Evapotranspiration (ET_O) values for each zone in California[2]

Results

California ET_O Zones[2]



California Hydrologic Regions and Counties[3]

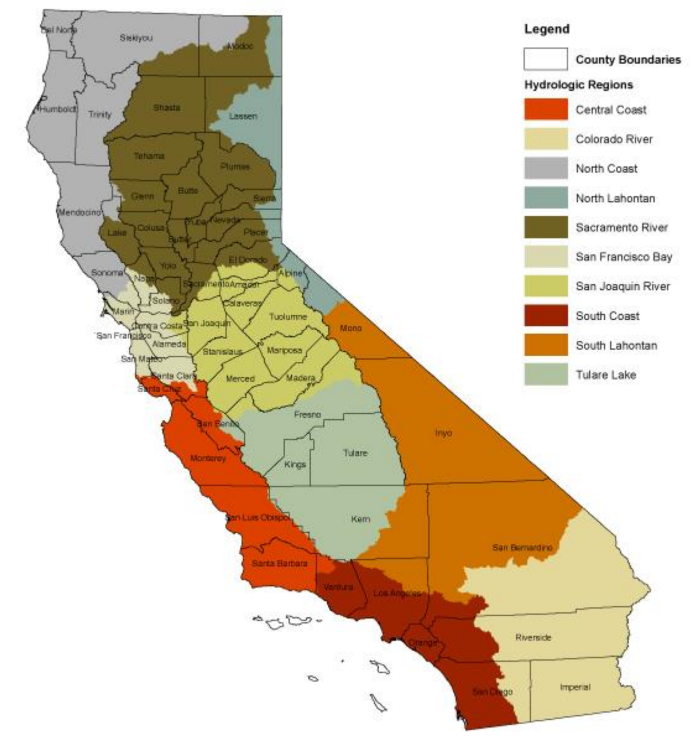


Table 1. Losses due to Evaporation in Volume (ac-ft)

Hydrologic Region	Total Yearly (ac-ft)	Max Month (ac-ft)	Min Month (ac-ft)	Med Month (ac-ft)
Central Coast	22038.27	3585.87	433.96	1712.01
Colorado River	67.66	9.08	2.05	5.75
North Coast	5393.05	836.48	106.90	438.00
North Lahontan	887.50	140.04	21.40	69.16
Sacramento River	244596.66	37134.02	4561.17	20123.10
San Francisco Bay	39099.28	5352.32	1205.95	3307.54
San Joaquin River	93487.25	14213.18	2678.31	7275.86
South Coast	117685.11	17129.99	3418.49	9524.66
South Lahontan	330.89	50.39	9.00	26.50
Tulare Lake	2117.36	322.43	57.58	169.57

Table 2. Losses due to Evaporation as a Percentage of Reservoir Capacity (%)

Hydrologic Region	Total Yearly (%)	Max Month (%)	Min Month (%)	Med Month (%)
Central Coast	5.00	0.81	0.10	0.39
Colorado River	36.57	4.91	1.11	3.11
North Coast	3.59	0.56	0.07	0.29
North Lahontan	1.01	0.16	0.02	0.08
Sacramento River	2.97	0.45	0.06	0.24
San Francisco Bay	4.13	0.57	0.13	0.35
San Joaquin River	1.90	0.29	0.05	0.15
South Coast	3.63	0.53	0.11	0.29
South Lahontan	0.09	0.01	0.00	0.01
Tulare Lake	0.46	0.07	0.01	0.04

Table 3. Losses due to Evaporation in Volume (ac-ft)

Hydrologic Region	Surface Area-to-Volume Ratio (ft^2/ft^3)
Central Coast	1.02E-03
Colorado River	5.11E-03
North Coast	7.50E-04
North Lahontan	1.89E-04
Sacramento River	5.52E-04
San Francisco Bay	8.68E-04
San Joaquin River	3.59E-04
South Coast	6.02E-04
South Lahontan	1.60E-05
Tulare Lake	8.12E-05

Table 1 shows the total volumetric loss of water due to evaporation in each hydrologic region. There is great variability in the amount of water that is stored in each region, however. Therefore, values should be converted into a percentage to compare evaporation rates between regions, as they have been in Table 2. This was done by dividing the total losses in each region for each period by the total capacity of all reservoirs in the region. Finally, a complete analysis must take into account the surface area relative to the volume of each reservoir. The overall ratios are listed in Table 3.

Conclusions

The maximum evaporation occurred in the months of June and July. These values were much larger than those for the minimum evaporation which occurred in the months of December and January. The largest total volume losses occur in the Sacramento River, South Coast, and San Joaquin hydrologic regions. These regions also store the most water, so it makes sense that they have the highest overall losses. After converting the losses in each region to a percentage of the total capacity, we see very different results. I expected to see a clear pattern of evaporation rates increasing from northern to southern. Instead, the data in Table 2 shows no clear pattern. After calculating the ratio of the total surface area to the total volume for each region, it becomes clear that this ratio has a strong effect on the evaporation rate a reservoir will experience. A reservoir with a large surface area-to-volume ratio will likely experience a higher rate of evaporation than a reservoir with a lower ratio that is further south. We can estimate that about 10% of water in urban distribution systems is lost, amounting to about 1 million acre-ft per year. This is significantly higher than the 0.55 million acre-ft lost through evaporation in the reservoirs I analyzed.

Next Steps

The next steps would be to combine this data with data about water losses in utility pipes to assess the comprehensive losses associated with each utility. Further research is necessary to determine the cumulative losses associated with the water distributed to particular areas of California. For example, more losses would be associated with water that has traveled from Northern California to Southern California than there would be for water from the same source that is being consumed in Northern California.

The results from this phase would be combined with the data from my project and used towards an analysis of California's water-energy nexus, tying in with my mentor's previous research.

Acknowledgements

I would like to thank my mentor, Jennifer Stokes-Draut, for guiding me throughout this project, answering my many questions, and giving me the opportunity to explore my interests through research.

Citations

1 – Kohli, Amit, and Karen Frenken. *Evaporation from Artificial Lakes and Reservoirs*. Rep. *Evaporation from Artificial Lakes and Reservoirs*. FAO AQUASTAT Reports.

2 – Jones, David W, 1999. *California Irrigation Management Information System (CIMIS) Reference Evapotranspiration*. Department of Land, Air, and Water Resources

3 – *California Hydrologic Regions and Counties*. California Department of Water Resources. Public Policy Institute of California.

4 – *Dams Within the Jurisdiction of the State of California*. http://www.water.ca.gov/dam_safety/docs/Juris(A-G)1.pdf

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