CE EN 431
Engineering Hydrology
Winter 1994
Section 1

Lab 3: Methods of Determining Mean Precipitation Over an Area

Submitted to:
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by
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Contents

Introduction

The purpose of this report is to show the correlation between the three different methods of finding the amount of precipitation over an area. These methods are:

1. The Thiessen Polygon Method
2. The Iso-hyetal Method
3. The Arithmetic Average Method

For this report, I used information from the 1933 Utah ***Climatological Data***. In this book, I used data from the following towns around Utah Lake to find the 1933 precipitation volume on the lake:

- Elberta
- Payson
- Provo
- Lower American Fork (substituted for Pleasant Grove)
- Utah Lake (Lehi)
- Spanish Fork

Objectives/Procedure

For the objectives and procedure, I have included the lab handout. You can find the lab handout in the appendix.

Results

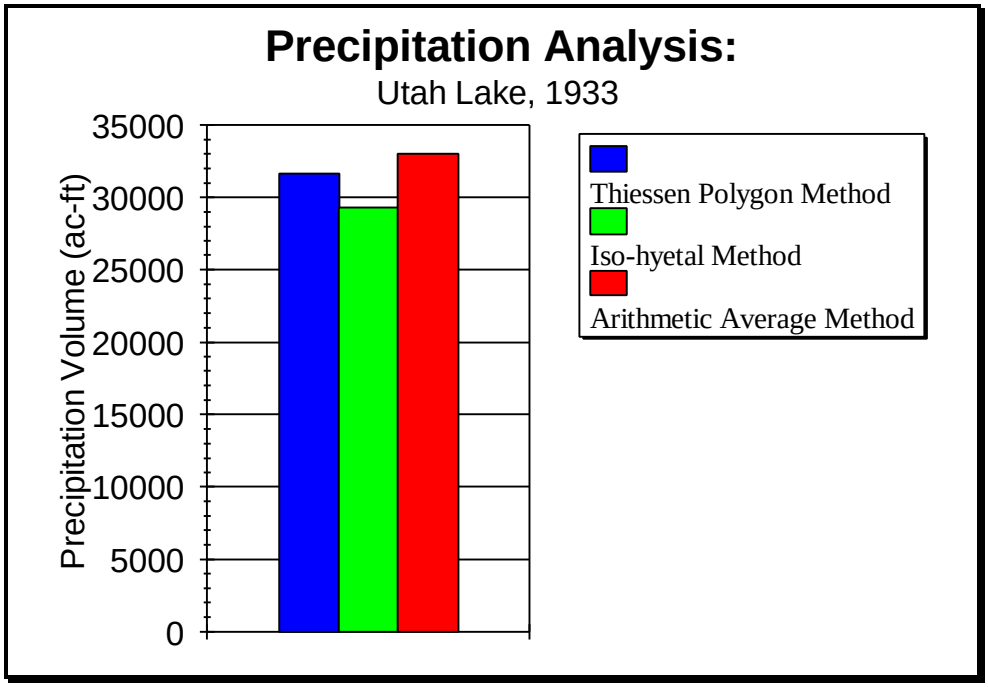

Figure 1: Graphical results from my precipitation analysis for Utah Lake. Standard Deviation = 1539.5 ac-ft.

Table 1: Numerical results from my precipitation analysis for Utah Lake.

Type of Method	**Precipitation Volume (acre-feet)**
Thiessen Polygon	31625.6
Iso-hyetal	29280
Arithmetic Mean	33010
Mean:	31305
Standard Deviation:	1540

Discussion

As you can see, the results are located in figure one and table one above. My results seem reasonable.

Method 1: The thiessen polygon method. In figure one and table two, you can see that the thiessen polygon method gave a precipitation value closest to the average precipitation.

The thiessen method adjusts for the nonuniform location of gaging stations by determining the area of influence. In the thiessen method, the perpendicular bisector of a line between two gaging stations determines the gaging station's area of influence. You can see how I did the thiessen polygon analysis of Utah Lake in Appendix C: Calculations.

Method 2: The iso-hyetal method. The iso-hyetal method gave a smaller value of precipitation volume than the other methods. The iso-hyetal method may have given a lower value of precipitation than expected because the Northern and Western areas around Utah Lake received low precipitation volumes; but Spanish Fork, Payson, and even Provo received high precipitation volumes.

The thiessen polygon method accounted for the high southwestern precipitation volumes. But the iso-hyetal method did not completely account for the high precipitation volumes in Spanish Fork and Payson.

In the iso-hyetal method, I first found the area between each isohyet above Utah Lake. Then, I calculated the average precipitation over the lake. You can see how I did the iso-hyetal analysis of Utah Lake in Appendix C: Calculations.

Method 3: The arithmetic average method. The arithmetic average method was the simplest method of calculating the precipitation volume above Utah Lake. This method gave the highest, and possibly least accurate, value for the precipitation volume above Utah Lake.

In the arithmetic average method, you simply take the average of the precipitation gage values around Utah Lake. This average is then used to calculate the volume of precipitation (in acre-feet) above Utah Lake.

It is hard to positively say which method was most accurate for determining the precipitation over Utah Lake. The arithmetic mean method may be the best method when:

1. Plenty of rain gages are available.
2. A highly accurate solution is not required.

Where there is a lack of precipitation gages in an area and an accurate solution is required, the thiessen or iso-hyetal method would be best.

Answers to questions. The following are answers to the questions on page two of the precipitation lab:

1. ***If you were required to determine average precipitation over the entire area tributary to the lake as accurately as you could with only the "valley" precipitation data available, would the thiessen method be reasonable? Why?*** No, the thiessen method would ***not*** give a reasonable answer. The precipitation in the mountains surrounding Utah Lake is much higher than the valley precipitation. The thiessen polygon method would not account for the large variation in precipitation in the mountains.
2. ***Discuss modification of the Iso-hyetal method in an area of known precipitation differences caused by an increase in elevation, as would be the case with the extensive mountainous area east of the Utah Valley "floor" with which you are working in this problem.*** As you can see on the map I made of Utah Valley (appendix C), as you approach the mountains, the precipitation contours are closer together and more precipitation occurs. If a hydrologist has knowledge of the temperature differences caused by increases in elevation, he could adjust the iso-hyetal

lines to reflect these precipitation differences with elevation. The precipitation contours would look similar to the actual elevation contours, but there would be smaller differences between the precipitation contours. Also, a hydrologist would have to adjust for less precipitation on the eastern side of the mountain.

3. ***Discuss the value of snow surveys to evaluate the precipitation on such an area.*** Using the data from snow surveys such as the density of the snow and the depth of snowpack, a hydrologist could determine the average precipitation in several different parts of the mountains. Using these precipitation values, the hydrologist could draw iso-hyetal lines for these parts of the mountains, adding on the average summer precipitation values.

Calculations

Calculation using the thiessen polygon method:

- I obtained the gage precipitation values for the areas surrounding Utah Lake.
- I divided Utah Lake into 1/4-inch squares. With a scale of 1 inch = 4 miles, each 1/4 X 1/4 inch square represented 1 square mile.
- I divided the map of Utah Lake into sections, using the perpendicular bisector of the line between gages as the sides of each gage polygon.
- I found the area of each gage polygon by counting squares.
- I calculated the weighted area for each gage station. The weighted area is given by:

$$W_i = \frac{A_p}{A}$$

Where:
W_i = The weighted area of a thiessen polygon,
A_p = The area of one thiessen polygon, and
A = The total area of the lake (or topographic basin).

- I calculated the average precipitation over Utah Lake by using the following equation:

$$\overline{P} = \sum_{i=1}^{n} W_i P_i$$

Where:
$\overline{P}$ = The average precipitation over Utah Lake,
P_i = The gage precipitation for polygon i, and
n = The total number of thiessen polygons.

- Finally, I calculated the volume of precipitation over Utah Lake by multiplying $\overline{P}$ (in feet) by the area of the lake (in acres).

Calculation using the iso-hyetal method:

- I obtained the gage precipitation values for the areas surrounding Utah Lake.
- I divided Utah Lake into 1/4-inch squares. With a scale of 1 inch = 4 miles, each 1/4 X 1/4 inch square represented 1 square mile.
- I drew a line between each of the gages, making a network of triangles.

- I drew the precipitation contours at 1-inch intervals on the paper, using linear interpolation between the gage stations. Over Utah Lake, I drew the 6.5-inch precipitation contour to obtain a more accurate result.
- I found the area between each iso-hyetal line by counting squares.
- I calculated the weighted area for each iso-hyetal precipitation value. The weighted area is given by:

$$W_i = \frac{A_i}{A}$$

Where:
W_i = The weighted area between iso-hyets,
A_i = The area between two iso-hyets, and
A = The total area of the lake (or topographic basin).

- I calculated the average precipitation over Utah Lake by using the following equation:

$$\overline{P} = \sum_{i=1}^{n} W_i P_i$$

Where:
$\overline{P}$ = The average precipitation over Utah Lake,
P_i = The iso-hyetal cell average precipitation, and
n = The total number of iso-hyetal cells.

- Finally, I calculated the volume of precipitation over Utah Lake by multiplying $\overline{P}$ (in feet) by the area of the lake (in acres).
- The iso-hyetal method is essentially the same as the thiessen polygon method, except I used iso-hyetal cells instead of thiessen polygons.

Calculation using the arithmetic mean method:

- I obtained the gage precipitation values for the areas surrounding Utah Lake.
- I calculated the average precipitation over Utah Lake by using the following equation:

$$\overline{P} = \sum_{i=1}^{n} \frac{P_i}{n}$$

Where:
$\overline{P}$ = The average precipitation over Utah Lake,
P_i = The precipitation depth at gage i, and
n = The total number of precipitation gages.

- Finally, I calculated the volume of precipitation over Utah Lake by multiplying $\overline{P}$ (in feet) by the area of the lake (in acres).

Conclusions/Applications

In conclusion, the iso-hyetal and thiessen polygon methods give different, but accurate results. When you do not need accuracy, you can use the arithmetic average method to compute the average precipitation over an area.

The calculation of precipitation volume has many applications. Among the applications are the following:

- You would need to know the average and maximum precipitation in an area when designing a housing development. You can keep the houses from flooding by determining where the high water would rise to, then building above that level.
- When you study the water quality of a lake (such as Utah Lake), you need to know all the sources of water to the lake. One of the main sources of water for Utah Lake is precipitation.
- When designing highway culverts, you would need to know what the maximum flow would be through that culvert. If you determine the area of the watershed that leads to that culvert, and the average precipitation in that watershed, you can determine flow through the culvert.

Appendix

Appendix A: References

- Wanielista, Martin. **Hydrology and Water Quantity Control**. John Wiley and Sons, Inc. 1990.
- National Oceanic and Atmospheric Administration (NOAA). **Climatological Data: Utah, 1933**. Printed by the climactic center at Asheville, NC.

The lab handout and my calculations are located on the following pages.

Appendix B: Lab Handout

Appendix C: Calculations