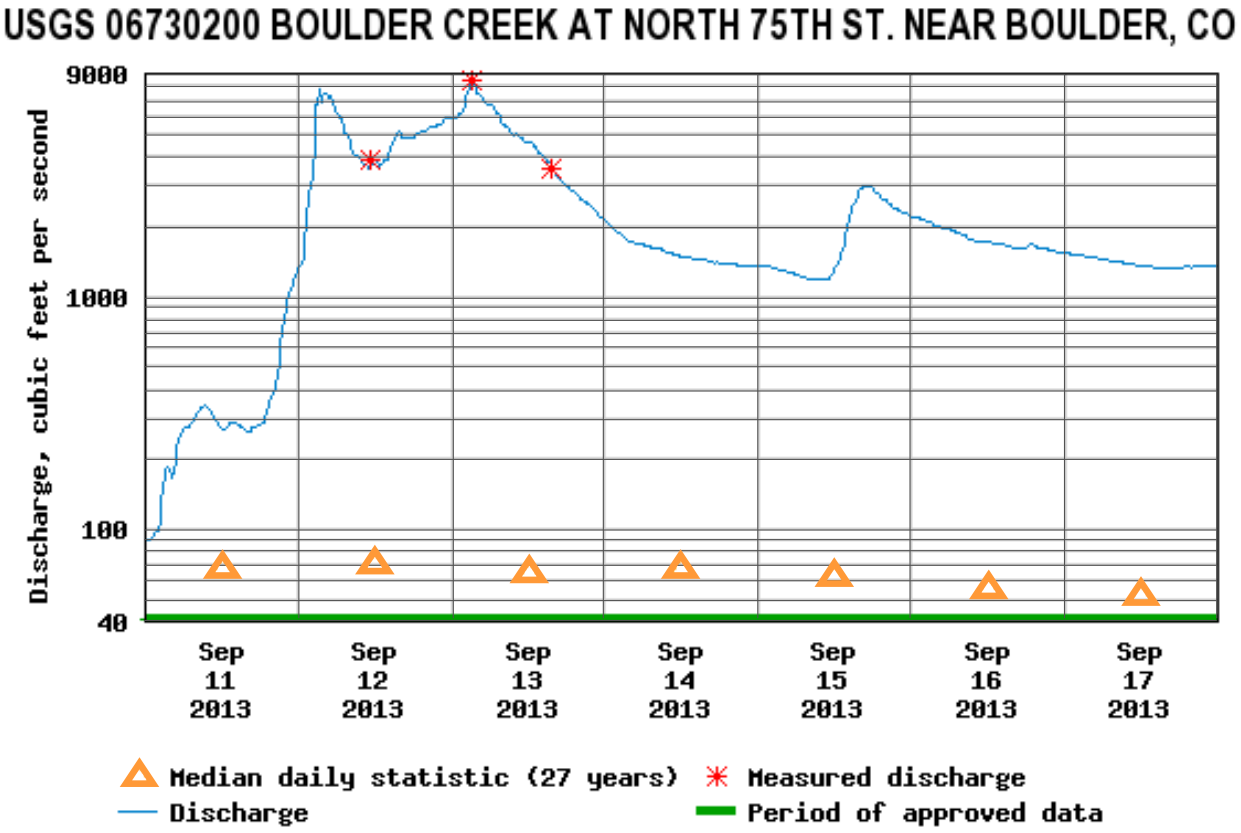
The graph below depicts Boulder Creek flow during the September 2013 Colorado flood, as measured by the U.S. Geological Survey (USGS). The graph uses a logarithmic scale; that is, the horizontal lines above 100 represent 200, 300, 400, 500, 600, 700, 800, 900, 1000, then 2000, 3000, etc. (The term "discharge" on the vertical axis is synonymous with "flow rate.")



(The small asterisks represent certain redundant measurements that were used for calibration. You needn't worry about these.)

(a) What was the approximate flow rate at noon on Thursday, September 12, 2013?

About 4,000 cubic feet per second.

(b) Using *only* your answer to part (a), approximate the quantity of water (in cubic feet) that flowed through Boulder Creek at this station during the day (24-hour period) of Thursday, September 12, 2013. Be careful: the units on the vertical axis are cubic feet per *second*.

Using the above number – 4,000 cubic feet per second – as an estimate of the average flow rate over the course of that day, we estimate the total quantity of water flowing through the creek, at this station, on this day, to be

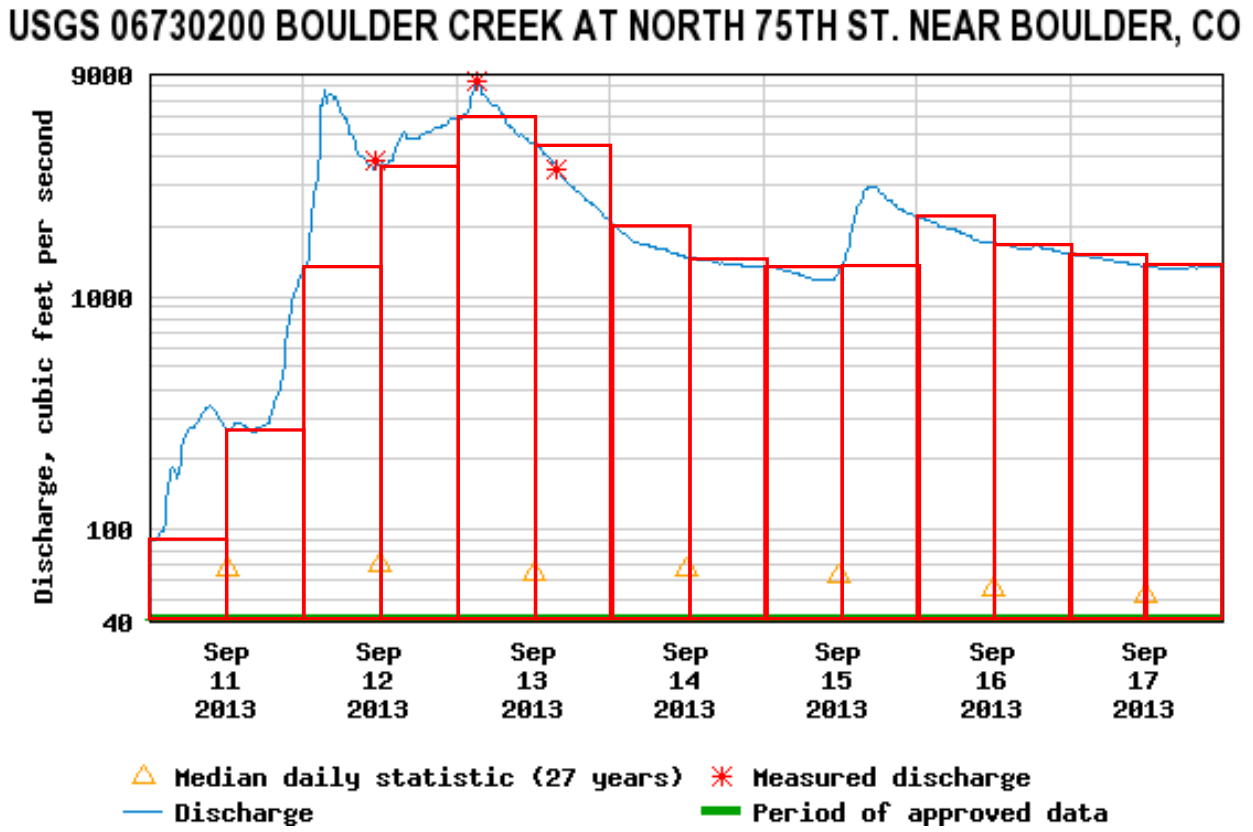
$$\begin{aligned} & 4{,}000\,\frac{\text{ft}^3}{\text{sec}} \times 24\,\text{hr} \\ =& 4{,}000\,\frac{\text{ft}^3}{\text{sec}} \times 60\,\frac{\text{sec}}{\text{min}} \times 60\,\frac{\text{min}}{\text{hr}} \times 24\,\text{hr} \\ =& 4{,}000 \times 60 \times 60 \times 24\,\text{ft}^3 \\ =& 345{,}600{,}000\,\text{ft}^3. \end{aligned}$$

(All units cancel except for ft^3.)

(c) What is the 27-year median flow rate (the "median daily statistic") for September 12? (The median is a kind of average, so the median daily statistic is a kind of measure of the average flow rate for the day in question, averaged over a certain set of 27 years.) Approximate the median, for these 27 years, of the *total amount* of water that flowed through Boulder Creek at this station on the 12th of September.

From the graph, we see that the 27-year median flow rate is about 70 ft^3/sec. So the median quantity of water through the creek, at this station, on this date is about

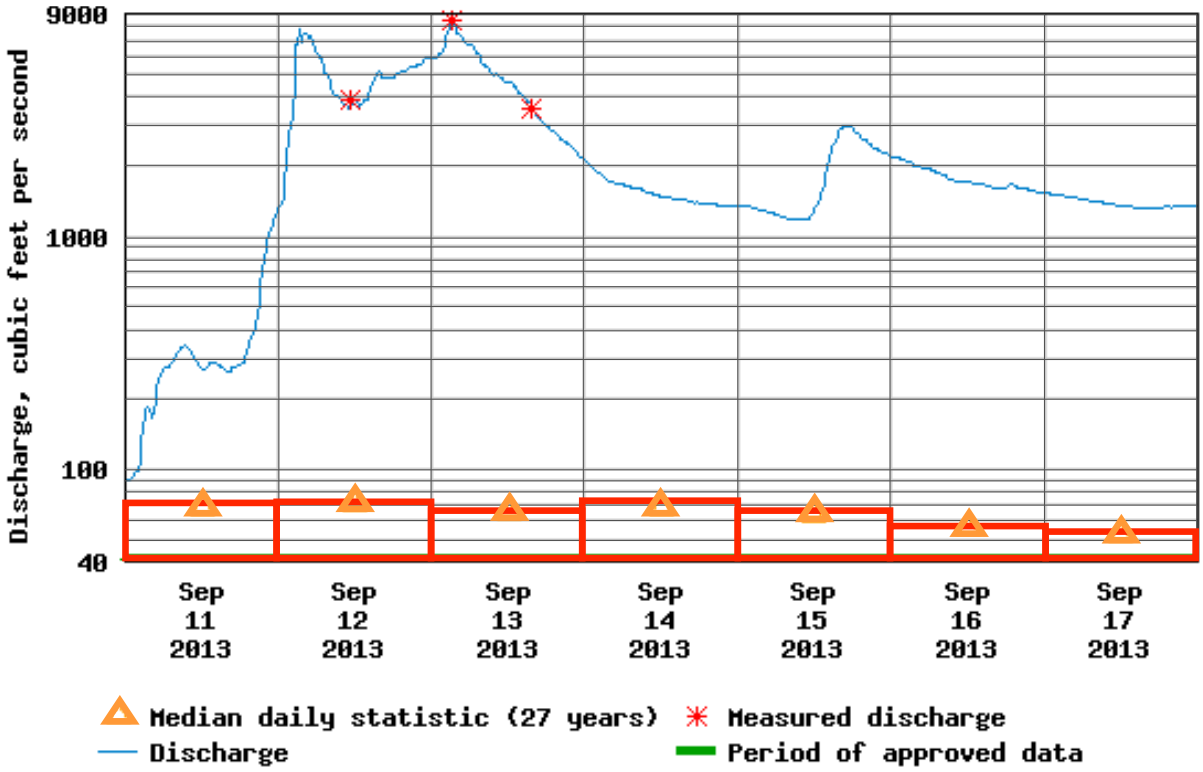
$$\begin{aligned} & 70\,\frac{\text{ft}^3}{\text{sec}} \times 24\,\text{hr} \\ =& 70\,\frac{\text{ft}^3}{\text{sec}} \times 60\,\frac{\text{sec}}{\text{min}} \times 60\,\frac{\text{min}}{\text{hr}} \times 24\,\text{hr} \\ =& 70 \times 60 \times 60 \times 24\,\text{ft}^3 \\ =& 6{,}048{,}000\,\text{ft}^3. \end{aligned}$$



(d) Take $\Delta t = 12$ hours, and use a left-endpoint Riemann sum to approximate the total quantity of water that flowed through Boulder Creek at this station from the beginning of Wednesday, September 11 through the end of Tuesday, September 17. *Draw your boxes directly on top of the graph above* (and write your calculations below). Don't worry about interpolating the logarithmic scale (which can be tricky); just round the height of each rectangle to the nearest horizontal grid line.

We estimate (quite roughly) that the total flow over the week in question is

$$\begin{aligned}
&\text{the sum of areas of the rectangles, in cubic feet} \\
=&(\text{baselength, in sec}) \times \left(\text{sum of heights, in } \frac{\text{ft}^3}{\text{sec}}\right) \\
=&60\,\frac{\text{sec}}{\text{min}} \times 60\,\frac{\text{min}}{\text{hr}} \times 12\,\text{hr} \\
&\times(90 + 300 + 1000 + 4000 + 6000 + 4000 + 2000 + 2000 \\
&+1000 + 1000 + 2000 + 2000 + 2000 + 1000)\,\frac{\text{ft}^3}{\text{sec}} \\
=&43{,}200\,\text{sec} \times 28{,}390\,\frac{\text{ft}^3}{\text{sec}} = 1{,}226{,}448{,}000\,\text{ft}^3.
\end{aligned}$$



(e) Use the median daily statistic data, and a Riemann sum with $\Delta t = 24$ hours, to approximate the median quantity of water that flowed through the creek over the course of these same dates, for the 27-year period considered. *Draw your boxes directly on top of the graph above* (and write your calculations below).

Arguing as in part (d) above, we find the median flow to be about

$$\begin{aligned} &60\,\tfrac{\text{sec}}{\text{min}} \times 60\,\tfrac{\text{min}}{\text{hr}} \times 24\,\text{hr} \\ &\times (70+70+70+70+70+60+50)\,\tfrac{\text{ft}^3}{\text{sec}} \\ =&86{,}400\,\text{sec} \times 460\,\tfrac{\text{ft}^3}{\text{sec}} = 39{,}744{,}000\,\text{ft}^3. \end{aligned}$$

For more flow data, see `http://waterdata.usgs.gov/nwis/uv?06730200` and `http://www.dwr.state.co.us/SurfaceWater/data/district.aspx?div=1&dist=6`