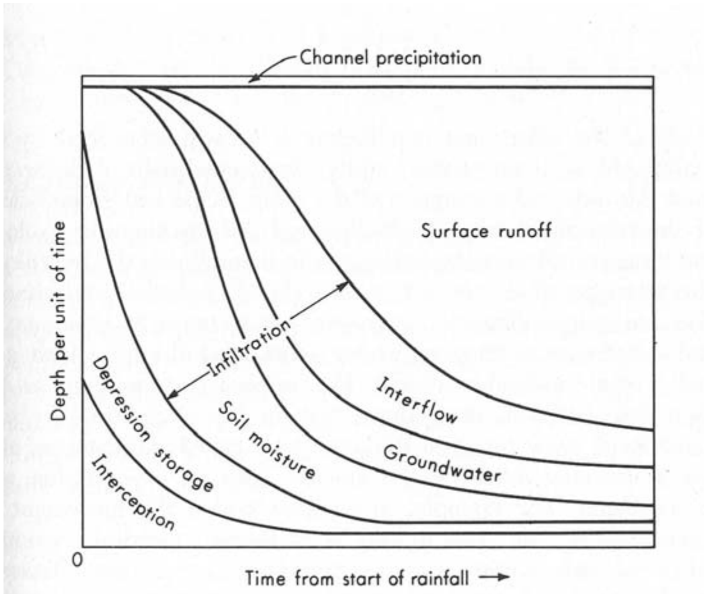
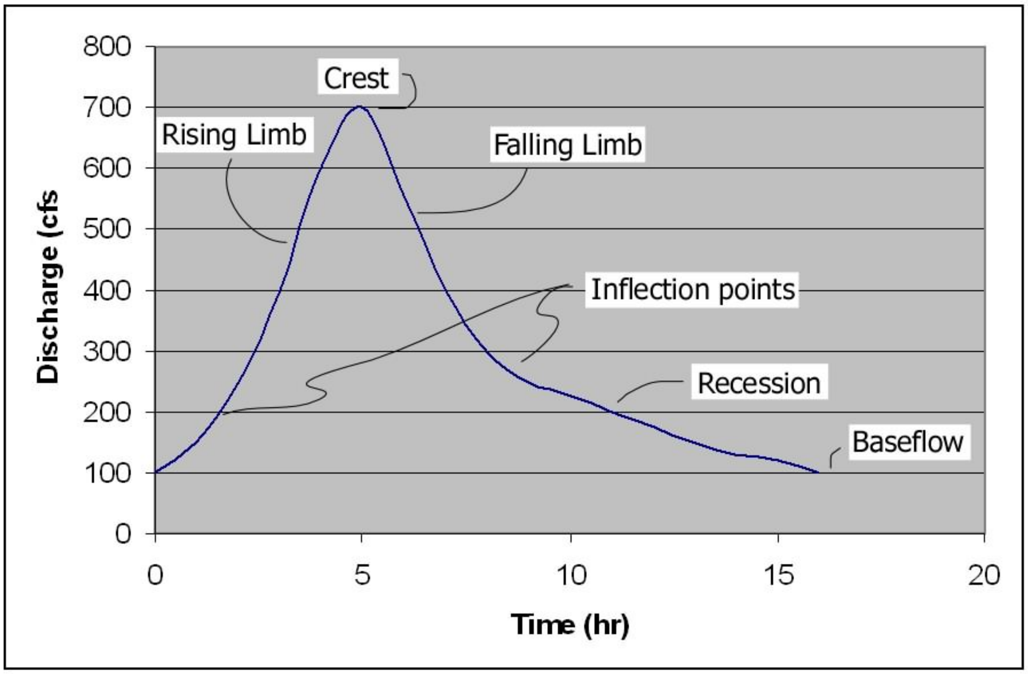
Lecture 19—Hydrographs

I gave you a figure a long time ago that talked about where water goes during a rainstorm.



Remember it? It shows early rain being intercepted by trees and the like, and a lot of rain filling up depressions in the watershed. Also, it shows that Hortonian curve—water infiltrating quite a bit at first, and then tailing off. Eventually, then, most of the rainfall becomes runoff, which in turn affects our hydrograph. I'd like to spend today talking about hydrographs and what affects them.

First, we need a little vocabulary. Any hydrograph consists of three parts—a rising limb, a falling limb, and a recession. The rising limb and falling limb are separated by the hydrograph crest, and the limbs are separated from the recession by inflection points. The rising limb is typically steeper than the falling limb, and the recession marks the end of runoff contribution to the hydrograph.



So what's happening in all this? Assume some base flow, like we saw last Tuesday. The only real contribution to the water in a channel is coming from groundwater, which gradually decreases to some minimum value. When rainfall starts, some of that water gets caught in depressions where it will wait to be evaporated again, but some enters the ground where it will contribute to the channel flow at some later time. The remainder, however, begins to make its way down to the channel, causing that sharply defined rising limb. This tails off gradually with time, and eventually, all direct runoff stops. At this point groundwater takes over again—because groundwater flow is much slower than surface water, the rate of decrease abruptly slows. This marks an inflection point in the flow.

While we're here—consider what happens when:

- There's a short, high-intensity rain
- The basin is rocky
- The watershed becomes urbanized

Ok, so we could, then, separate a hydrograph into two parts—one caused by direct runoff, and one caused by groundwater. We need to do this, by the way, in order to talk about problems like flood routing—consider what happens if a river has low groundwater contribution vs. high groundwater contribution. The direct runoff part is called, naturally, “direct runoff” or DRO. The groundwater contribution is called the base flow (BF). Now for the tricky part—how does one decide where the line between DRO and BF should be?

One quick way is to assume that the recession curve acts as an exponential decay:

$$q_t = q_0 e^{-kt}$$

Where q_0 is the initial discharge and k is the recession constant. Looks familiar, huh? On semi-log paper, though (which is what hydrographs are plotted on), this curve becomes a straight line with a slope of $-k$. So, one way is to plot this line from the base point on the rising limb over to wherever it hits on the recession curve. Another solution is to extend the previous recession under the hydrograph by curve fitting, then connect it to the inflection point between the falling limb and the recession. Last option is to use the empirical formula:

$$N = A^{0.2}$$

Where A is the watershed area in square miles and N is the number of days from crest to end of DRO.

None of these should seem terribly satisfying to you. In fact, they’re all sort of arbitrary. The simple truth is that this is more an art form than a science, and people invent all sort of ideas for it. The good news is that in urban settings, the point is somewhat moot because there’s so little groundwater contribution to flow that effectively all the hydrograph can be considered DRO. Suffice it to say, we fall back on the usual lame adage—“just be consistent.”

One thing we should expect is that the amount of DRO and the *net* rainfall should be the same. Net rainfall would be total rain minus infiltration and depression storage. If we knew how much of each of those there was, we could at least know the area of DRO. We’ll talk about one way of handling this later this week. Once that’s determined, the central problem becomes how to get from rainfall excess to some sort of discharge—this is usually done by combining contributions from overland flow and channel flow.

One way of doing this is to divide up a watershed into zones that are an equal time away from the mouth of the watershed. These zones are called *isochrones*, and you could figure out from them that all the water in subarea A1 drains first, followed by A2, A3, and A4. In fact, if you had an excess rainfall hyetograph, you could use a formula:

$$Q_n = R_i A_1 + R_{i-1} A_2 + \ldots + R_1 A_j$$

Where Q_n is the discharge at time *n*, R_i the ordinate of the rainfall excess at time *n*, and A_j the area of the *j*th segment. With this, you can actually make a hydrograph. Take a look:

A watershed is divided into sections as shown. Rain falls at 0.5 in/hr for 5 hours. Determine the resulting hydrograph.