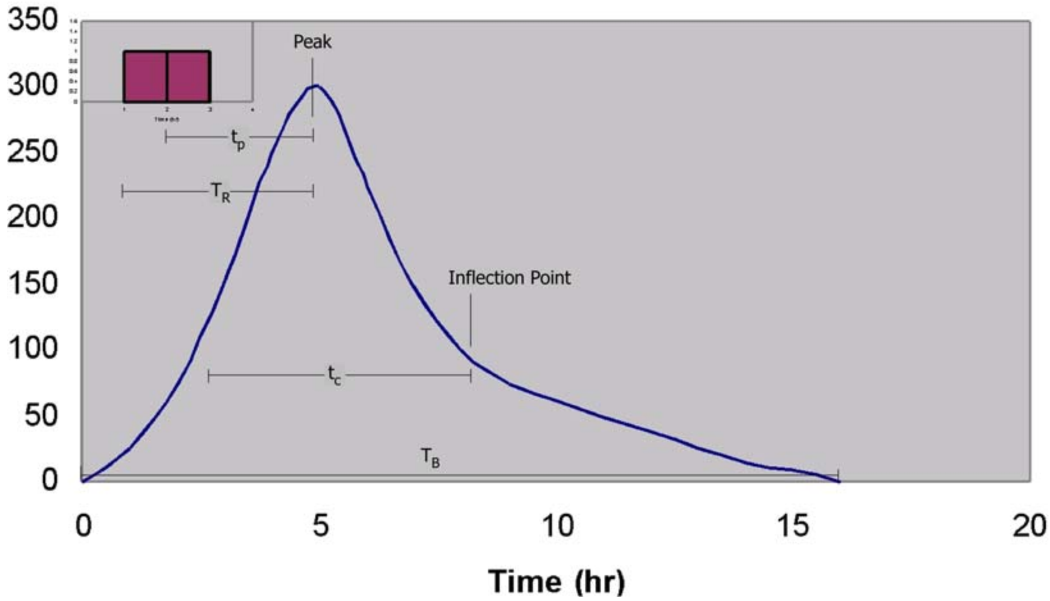
Lecture 20—Unit Hydrographs

Last time we talked about hydrographs—a stream's response to rainfall in its catchment. We described one and talked about how a stream responds to rainfall, but *ideally* we'd like to have some predictive value. We'd like to be able to say "if this much rain falls, we're going to get a flood this big," or "changing the catchment will change flooding in this way." In order to do this, and in order to *compare* two catchments, we need some uniform system.

The system is this. Consider what would happen if 1 inch of direct runoff were generated uniformly over an entire drainage basin during some specified period. This would be called a *unit hydrograph* and it allows researchers to compare the response of two different watersheds to the same runoff, or allows for investigating changes in one watershed. Eventually, we'll talk about producing unit hydrographs for storms that have not happened. What a unit hydrograph amounts to is: taking the DRO portion and manipulating it so that the time axis and the volume are the same. That way we're only talking about changes in shape.

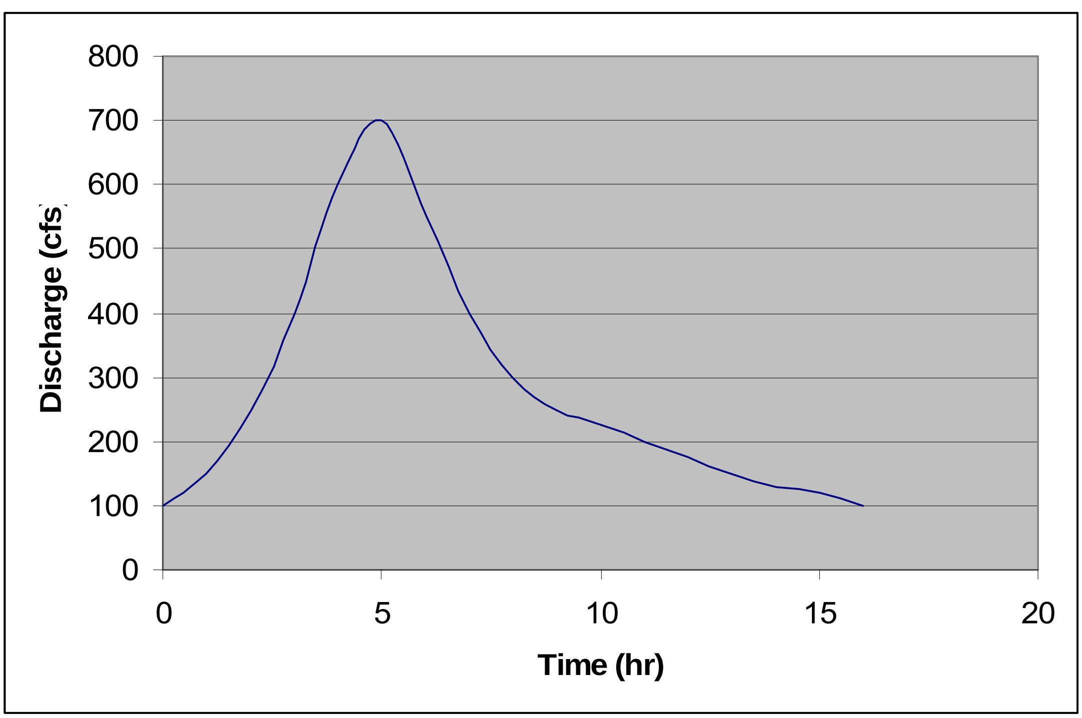
There are some weird assumptions that go into unit hydrographs. It's worth knowing about them. Most important—unit hydrographs assume that watershed response is linear and time-invariant. This means that if it rains twice as much on a watershed, you get exactly the same hydrograph, but it's twice as tall. Conversely, if rain takes twice as long, you get the same hydrograph, but with the x-axis stretched out by twice as much. Let's see…..what else. Ah, yes. Unit hydrograph theory ignores anything that might have been happening before the storm of interest. Like if a hurricane had passed through three days before, versus it's been dry summer and this is the first rain in over a month. Last, *distribution* of rainfall is assumed to be the same for every storm. Despite these assumptions, unit hydrographs remain a way for people to have some basis for comparing two hydrographs.

In order to talk about unit hydrographs, we need some more vocabulary. First, the amount of time between the *center of mass* of rainfall excess (the point at which half the rain that's running off has fallen) and the peak of the hydrograph is called the *lag time* (t_p). The time from the *start* of rainfall excess to the peak of the hydrograph is called the *time of rise* (T_R). The time it takes for water to propagate from the most distant point in the watershed to the outlet is called the *time of concentration* (t_c). This effectively marks the end of direct runoff, so one way to estimate it is to take the difference from the inflection point and the end of rainfall excess. Last, the total duration of the DRO part of the hydrograph is called the *time base* (T_b).



Notice that we're starting to include hyetographs on the hydrograph. This is important, because the *volume* of direct runoff rainfall and the volume of the hydrograph have to be the same. They also aid in finding things like lag time.

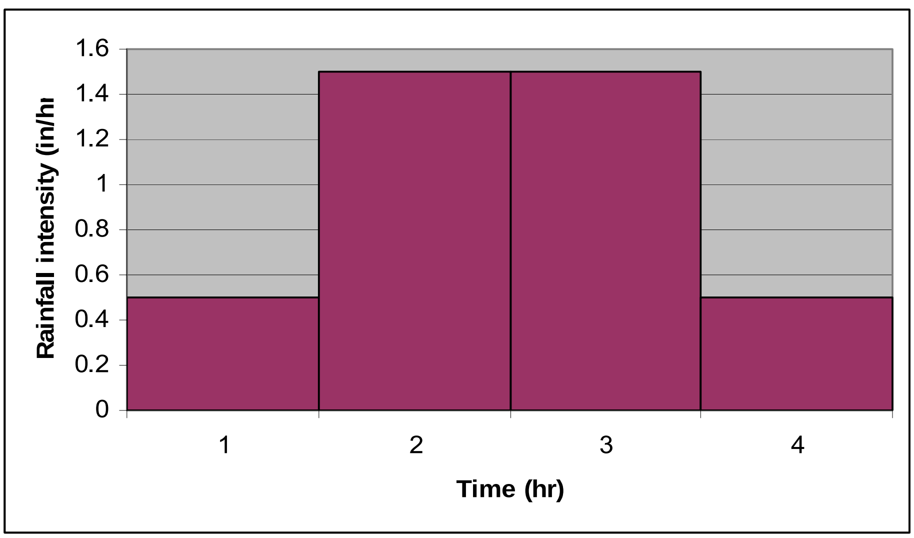
So let's try an example, worked through slowly. Suppose we want to convert this hydrograph:



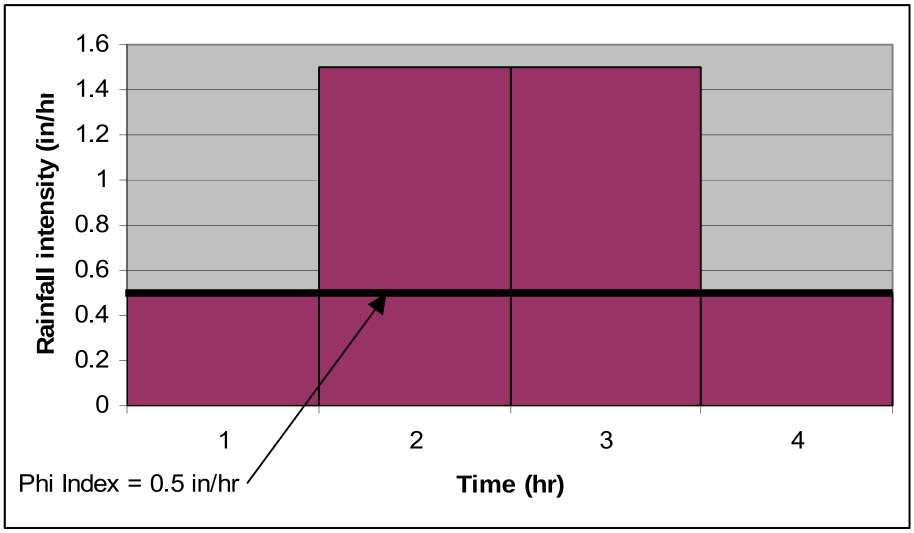
to a *2-hour unit hydrograph*. First of all, what does this mean? It means that the 1 inch of direct runoff rain fell over the course of two hours. We could as easily construct a *1-hour* unit hydrograph, and the assumption there would be that the 1 inch of direct runoff fell over the course of an hour. Note that in our world this rain fell uniformly over the watershed, and also uniformly in time—we'll see later how to handle more natural rainfall patterns.

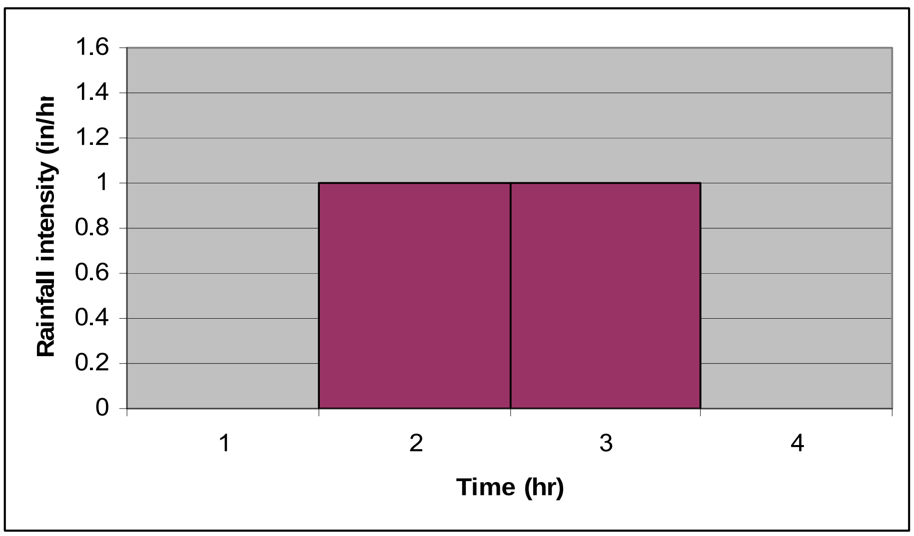
What other goodies does the problem give us? It claims that baseflow is 100 cfs and is constant during the storm (the problem does this so we won't have to worry about DRO separation). Better yet, the Φ index for this storm is given as 0.5 in/hr (the problem does *this* so we can easily separate the direct runoff rain from the infiltrated rain). Ok, so how to do this?

First, take the hyetograph for this storm:



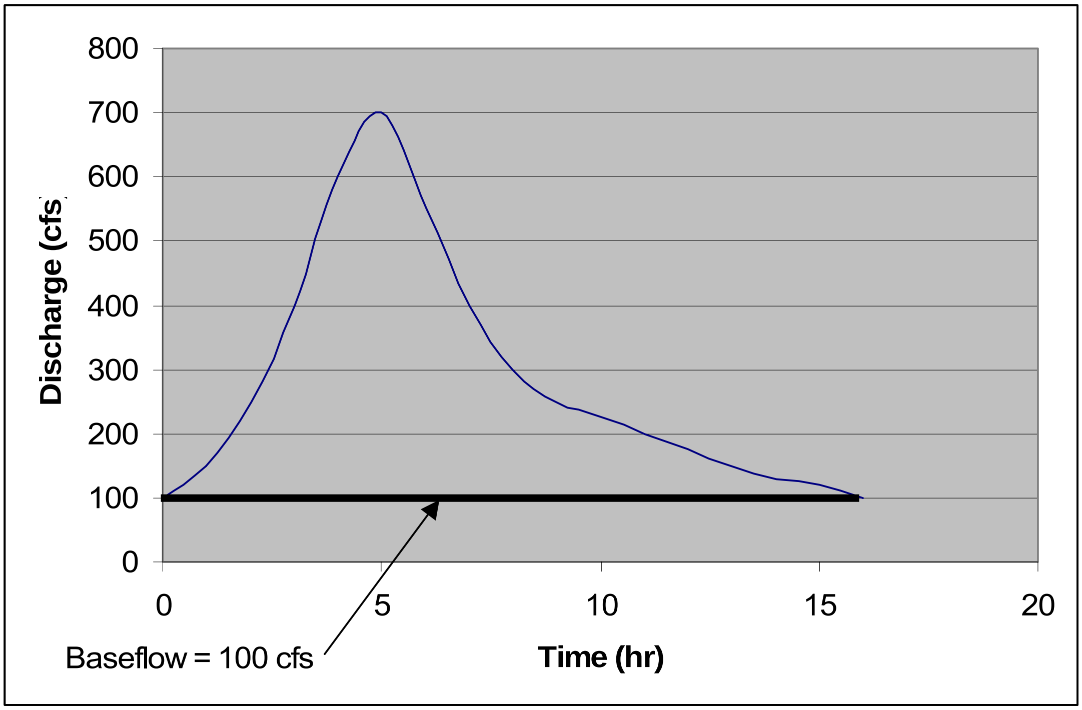
We need to separate out the amount of rain that infiltrated vs. that which ran off. We *could* go through the whole mess with the Horton equation, but….mercifully the Φ index for this storm is known, and it's 0.5 in/hr. With that subtracted, the rain involved in runoff is:

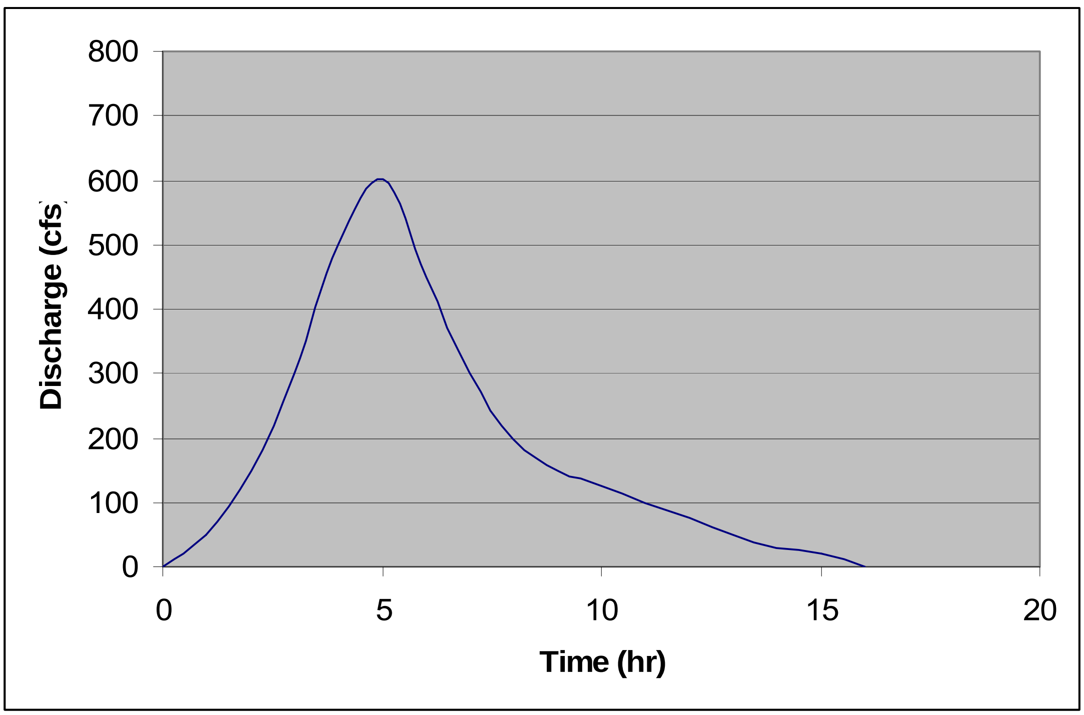




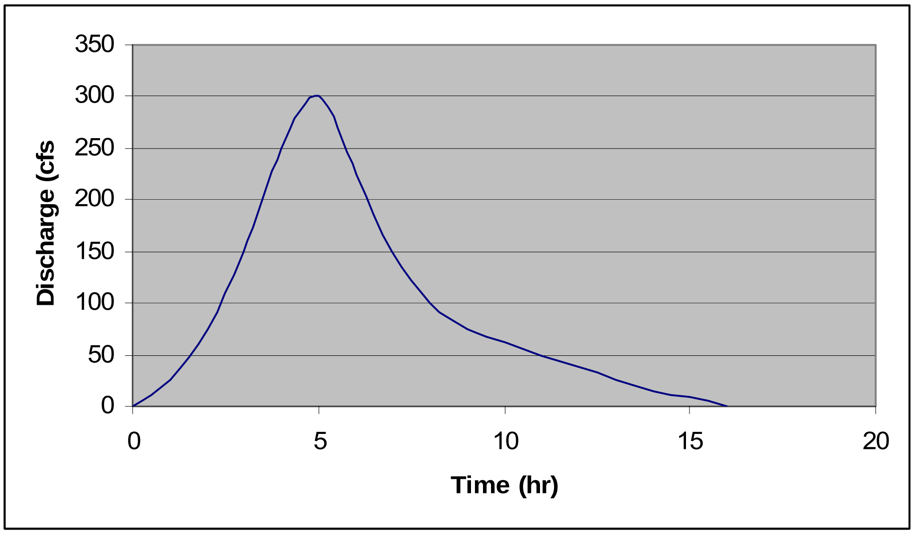
Ah, how nice and simple they made this. Two inches of excess rain in two hours, and it fell at a constant rate (note that what's important to us is that the *excess* rain fell at a constant rate).

Next, we have to remove baseflow from the hydrograph. Because we've been *told* that baseflow is a constant 100 cfs, this is trivial. Just subtract 100 cfs from every measurement, and you have the DRO hydrograph.

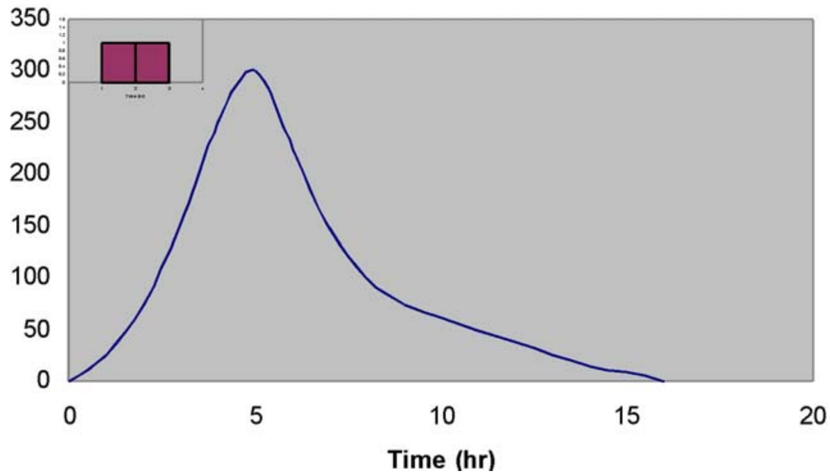




Now for the only bit of trickiness in the whole thing. At the moment we have a hydrograph representing two inches of excess rain in two hours. We *wanted* ONE inch of rain in two hours. Well, unit hydrograph theory makes this easy for us—just divide all our numbers in half, and we'll end up with what results when one inch falls in two hours instead of two.



All that's left is to attach the hyetograph to the upper corner so that we can visualize both together:



That's how to make a unit hydrograph. Next time we'll talk about adding some complexity, including how to make unit hydrographs of any duration, and how to handle rainfall that's not uniform.