2.4 Hydrology and Flood History

Introduction

Hydrology is the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks (groundwater), and in the atmosphere. The *hydrologic cycle* includes all of the ways in which water cycles from the landscape (both underground and in streams and water bodies) to the atmosphere (as water vapor and clouds) and back (as snow, rain and other forms of precipitation) (Figure 2.4.1). Understanding the hydrology of the East Kill will assist us with making land use decisions in the basin that work within the constraints of the hydrologic cycle and won't exacerbate flooding or cause water quality impairment.

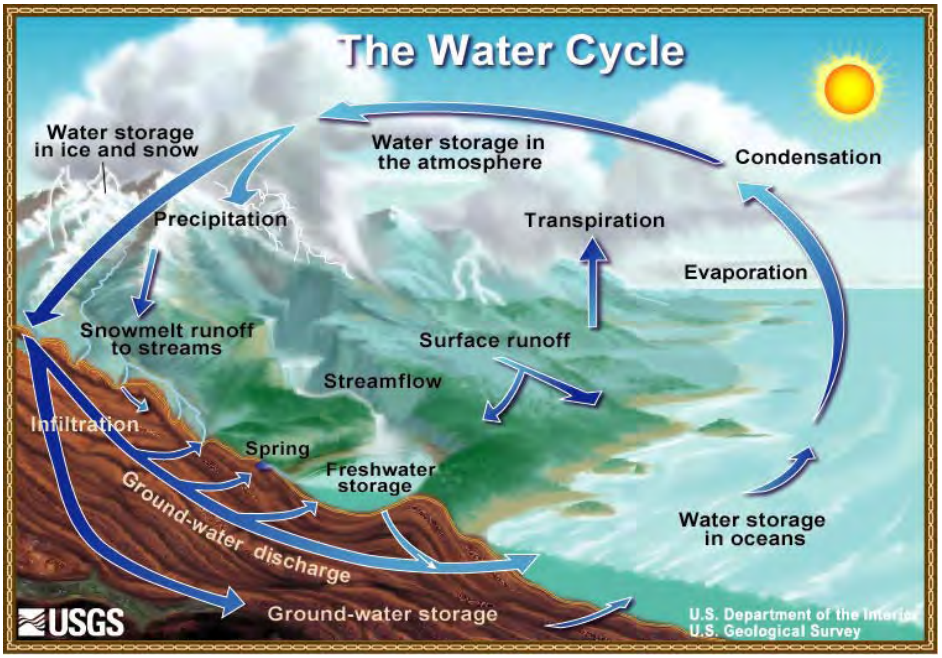

Figure 2.4.1. The Hydrologic (water) Cycle (http://ga.water.usgs.gov/edu/watercyclesummary.html).

Water flowing through the East Kill reflects the integrated effects of all watershed characteristics that influence the hydrologic cycle. Characteristics include climate of the drainage basin (type and distribution patterns of precipitation and temperature regime), geology and land use/cover (permeable or impermeable surfaces and materials affecting timing and amount of infiltration and runoff, and human-built drainage systems), and vegetation (uptake of water by plants, protection against erosion, and influence on infiltration rates). These factors affect timing and amount of stream flow, referred to as the stream's *hydrologic regime*. For example, a stream with an urbanized watershed where water will run off the hardened surfaces directly into the stream will have higher peak discharges following storms than a watershed, such as the East Kill, which is predominantly forested and will infiltrate a higher percentage of rain water before it reaches the stream and release it more slowly over time. Understanding the hydrology of a drainage basin is important to the stream manager because stream flow patterns affect aquatic habitat, flood behavior, recreational use, and water supply and quality.

East Kill Basics

Encompassing approximately 37 square miles of watershed area almost exclusively in the Town of Jewett, the East Kill watershed is typical of main headwaters tributaries to the Schoharie Creek in that it is a long, narrow watershed running east to west. This drainage pattern is controlled by the steep topography, formed in large part during the last period of glacial activity. Streams in the East Kill valley are primarily perennial streams, that is, they flow year-round except in smaller headwater streams or in extreme drought conditions.

The East Kill watershed averages approximately 44 inches of precipitation per year that often comes in dramatic summer downbursts, remnants of autumn hurricanes, or late winter rain-on-snow events. Average slope of the watershed is 17.3% (watershed elevation drops 17.3' feet for every 100 feet horizontal distance). *Drainage density*, or how much stream length is available to carry water off the landscape is slightly higher than average for the Catskills, at 0.0016m/m . Given the average drainage density, combined with steep mountainous slopes, and high precipitation, the East Kill stream system is relatively *flashy*, that is, stream levels rise and fall quickly in response to storm events. This flashiness is somewhat mitigated by heavy forest cover throughout much of the watershed. Therefore, efforts to protect upland, as well as riparian, forest are important to reduce flooding.

Stream flow Primer

There are two general categories of streamflow: storm flow (also called flood flow) and base flow, between which streams fluctuate over time. Storm flow fills the stream channel in direct response to precipitation (rain or snow) or snowmelt, whereas base flow is primarily groundwater fed and sustains streamflow between storms and during subfreezing or drought periods. A large portion of storm flow is made up of *overland flow*, runoff that occurs over and just below the soil surface during a rain or snowmelt event. This surface runoff appears in the stream relatively quickly and recedes soon after the event. The role of overland flow in East Kill watershed is variable, depending upon time of year and severity of storms or snowmelt events. In general, higher streamflows are more common during spring due to rain, snowmelt and combination events, and during hurricane season in the fall. During summer months, actively growing vegetation on the landscape draws vast amounts of water from the soil through *evapotranspiration*. This demand for groundwater by vegetation can significantly delay and reduce the amount of runoff reaching streams during a rain storm. During winter months, precipitation is held in the landscape as snow and ice, so precipitation events do not generally result in significant runoff to streams. However, frozen ground may increase the amount of overland flow resulting from a rain storm if the air temperature is above freezing, particularly in spring on north facing slopes.

Subsurface storm flow, or *interflow*, comes from rain or snow melt that infiltrates the soil and runs down slope through the ground. Infiltrated water can flow rapidly through highly permeable portions of the soil or displace existing water into a channel by “pushing” it from behind. In the East Kill valley, subsurface flow can occur fairly rapidly along layers of essentially impermeable glacial lake silt/clay deposits. Subsurface storm flow shows up in the stream following overland flow, as stream flow declines back to base flow conditions.

Base flow consists of water that infiltrates into the ground during and after a rain storm, sustaining streamflow during dry periods and between storm flows. The source of base flow is groundwater that flows through unsaturated and saturated soils and cracks or layers in bedrock adjacent to the stream. In this way streams can sustain flow for weeks or months between precipitation events and through the winter when the ground surface and all precipitation is otherwise frozen. Stable-temperature groundwater inputs is what enables fish and other aquatic life to survive in streams year-round.

Hydrologists use a hydrograph of a stream to illustrate specific hydrologic measurements, such as water level, discharge or velocity, over a period of time. A *stream gage* is necessary to monitor stream discharge and develop a hydrograph. The United States

Geological Survey (USGS) maintains a continuously recording stream gage on the East Kill near Jewett Center (established 1996, drainage area 35.6 mi^2, USGS ID# 01349700). Prior to 1996, a crest stage gage was maintained starting in 1929. All gage information is available online at the USGS website: http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01349700. This gage measures the *stage*, or height, of the water surface at a specific location, typically updating the measurement every 15 minutes. By knowing the stage, we can calculate the magnitude of the *discharge*, or volume of water flowing by that point using a relationship developed by USGS called a *rating curve*. Using this rating curve, the magnitude of flow in East Kill at the gage location can be determined at any time just by knowing current stage, or flow can be predicted for any other stage of interest. Additionally, we can use the historic record of constantly changing stage values to construct a picture of stream response to rain storms, snow melt or extended periods of drought, to analyze seasonal patterns or flood characteristics.

The East Kill gage has a long enough period of record to prepare a hydrograph for the stream (Figure 2.4.2). Each spike on the graph represents a peak in stream flow (and stage) in response to rain storms. Stream level rises (called the “rising limb” of the hydrograph) and falls as the flood recedes (called the “falling (or receding) limb” of the hydrograph). We can analyze long time periods to see seasonal trends or long-term averages for the entire length (period) of gage record. We can see the record for the gage shows higher flows in fall (hurricane season) compared to winter (water held in ice and snow), and higher flows in spring (snow and ice melt, with rain-on-snow events) compared to summer (drought conditions with vegetation using a lot of water). The highest flows of the year are generally associated with the hurricane season in the fall, followed by winter and spring snowmelt or rain-on-snow events. Overland flow accounts for most of water that causes the sharp peaks in the hydrograph.

Streamflow always rises and peaks following the height of a precipitation event because it takes time for water to hit the ground and run off to the stream (this is known as lag time). Knowing storm timing, we could also calculate lag time for East Kill at the gage location for particular storms or types of storms, and determine how the stream responds to storms both in timing and flood recession.

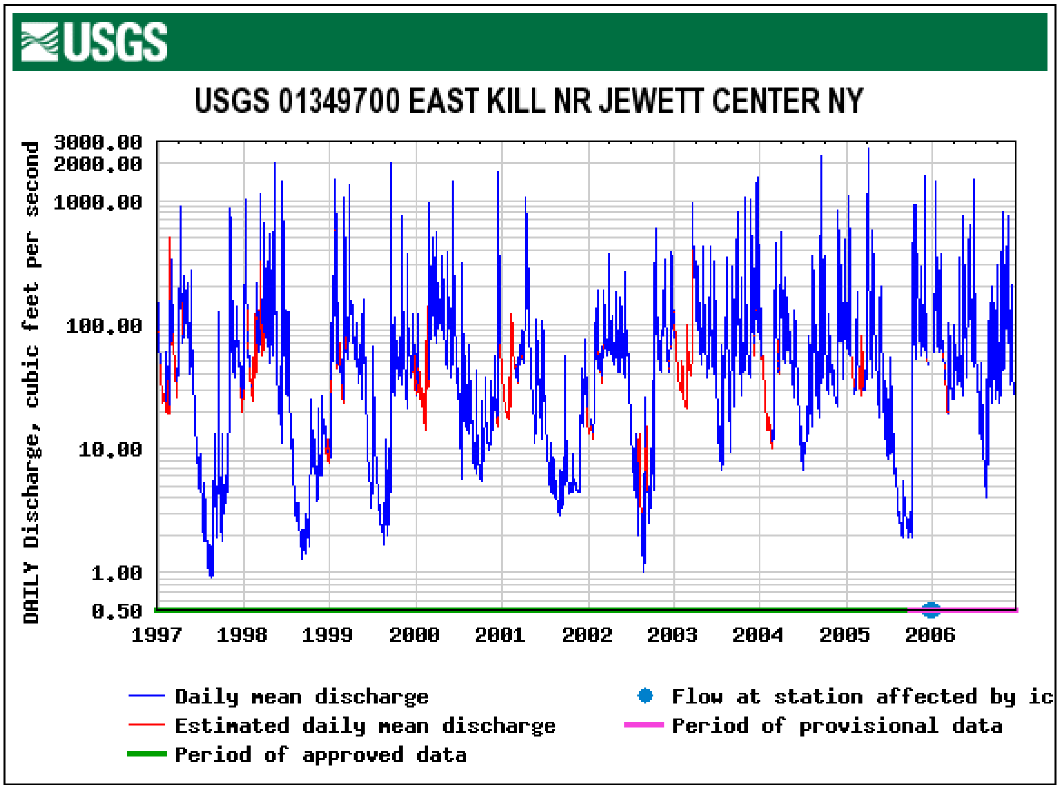

Figure 2.4.2. This hydrograph represents the daily average flow from 12/96 through 12/06.

The hydrograph of April, 2005 illustrates the effects of a spring storm on top of snow (Figure 2.4.3). The East Kill rose quickly from the precipitation from a daily average of 411 CFS to 2,290 CFS in 24-hours. The recession took longer than a large summer storm due to the vegetation still being dormant, or just emerging, and the snow pack.

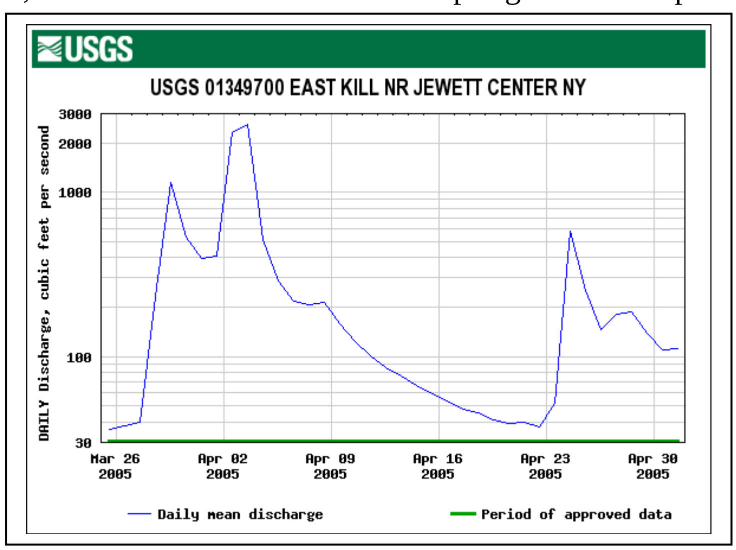

Figure 2.4.3. This hydrograph represents the daily average flow for April, 2005, including a large rain on snow precipitation event.

East Kill Flood History

As a mountain stream the East Kill rises quickly as precipitation falls. Between 1951 and 2006, the East Kill at Jewett Center has gone over 10,000 CFS five times (Figure 2.4.4). For the period of record, the annual average peak flow was 5,816 CFS. The peak flow in any given year is not necessarily a significant/damaging storm event, but could be a dramatic increase in flow following drought. To put this in perspective, the flood of record in1996 pushed the East Kill to its highest stage at 17' (max flow of 13,500 CFS daily average) reaching its 100 year flood stage (as it did the Schoharie). After this flood $15.2 million of federal and state funding was distributed amongst 377 municipalities to help repair damage. Of this, the town of Jewett received $52,135. FEMA estimated that approximately $102 million worth of damage had occurred state wide during the flood (New York State, 1996). The flooding in 2000 was much less than 1996 (stage height 10.5'/4,140 CFS), but still brought comparable damage, with $12.7 million being released to 206 municipalities across NY. Greene County received $176,596.23. Only three towns within Greene County received additional funding following this flood event. The three received $44,320.79 in total and Jewett was one of them, receiving $11,041.23 of the total (New York State, 2000).

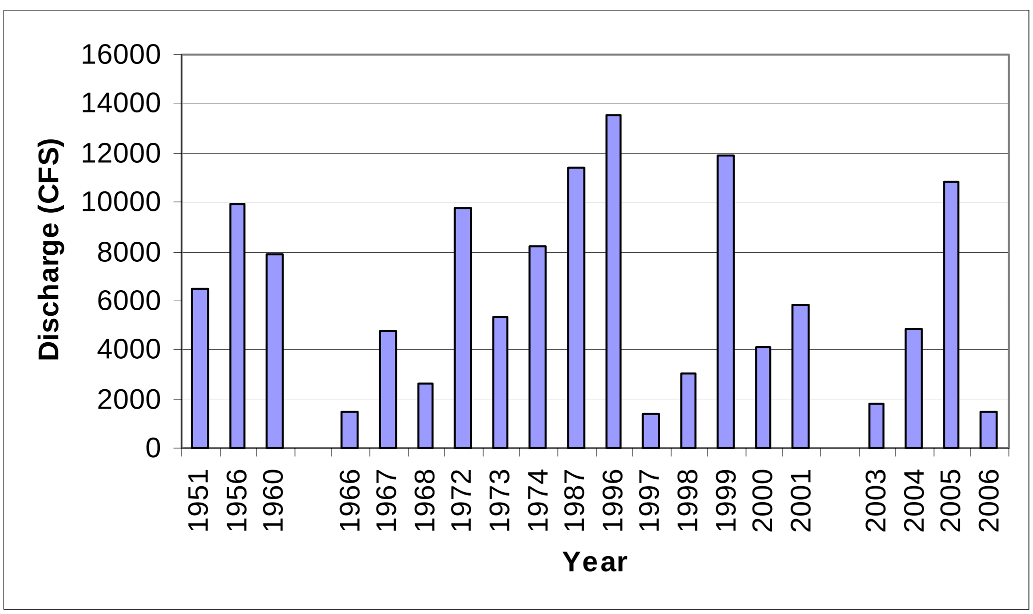

Figure 2.4.4. Annual peak flows for the period 1951 through 2006.

Flood events have not been as well documented for the East Kill Valley as other areas due to its relatively small population. However, considering its location and relationship with the Schoharie Creek, it is safe to assume that flooding has historically been a problem in the East Kill, as it has been throughout the Schoharie Valley. North facing slopes of the East Kill valley receive little sun exposure compared to south facing slopes. As a result, half of the valley retains a snow pack well into the spring when rain on snow events can cause dramatic spring flooding. Tropical storms and hurricanes in the late summer and early fall also trigger flooding in the valley. Through analysis of the long-term flood records provided by the USGS, the town, its residents and resource managers can begin to better understand the cause/effect of various precipitation amounts on flooding.

Flood frequency distributions show flood magnitude for various degrees of probability (or percent likelihood). This value is most often converted to a number of years, called the "recurrence interval" (RI) or "return period". For example, the flood with 20% chance of occurring or being exceeded in any single year corresponds to what is commonly referred to as a "5-year flood" (each of these values is the inverse of the other - just divide 1 by % probability to get RI in years, or divide 1 by RI in years to get % probability). This simply means that on average, for the period of record (the very long term), this magnitude flood will occur about once every 5 years. This probability is purely statistical; probability remains the same year to year over time for a particular size flood to occur, though the actual distribution of flood events in time is not regular; many years may go by without a certain magnitude flood, or it may occur several times in a single year. As another interesting characteristic of flood frequency distributions, the 5-year flood may not occur the "right" number of times in a certain period of record. For example, we might expect to see about 2 "5-year floods" for every 10 years of record, but any particular 10 year period may contain greater or fewer of this size flood.

Because the flood frequency curve is not linear, that is, the shape of the curve doesn't progress along a steady line, we can't simply divide up the floods in a record in rank them in order. For example, in a 10 year record, the largest flood is not necessarily a 10-year flood, even though that flood only occurred once in that ten year record. The length of gaging records is typically short compared to long-term history, on the order of 10-30 years, whereas 200-300 years might give a better picture of how often the range of floods may occur.

Therefore, we need to fit some other probability to the floods we do see, based on their magnitude in relation to the other floods in the record, and the average shape of distributions for very long-term records – so individual floods can be plotted where they belong in a more accurate risk of occurrence. Floods recorded at the Esopus, Bushnellsville and Prattsville gages that exceed a 5-year recurrence interval provide an example of distribution of medium to large floods over time (Table 2.4.1).

Table 2.4.1. Flood Flows at Nearby Gages that Exceed Five Year Recurrence Intervals (Flood frequency statistics based on recorded peak flows through 1997. Esopus Creek at Allaben, NY: 5 yr RI flood:~6,500 cfs 10 yr RI flood: ~9,500 cfs Bushnellsville Creek at Shandaken, NY 5 yr RI flood:~800 cfs 10 yr RI flood: ~1,000 cfs Schoharie Creek at Prattsville, NY: 5 yr RI flood: ~24,000 cfs 10 yr RI flood: ~33,000 cfs.).	
Esopus Creek at Allaben, NY	
Date	***Flood Discharge (cfs)***
3/30/51	*20,000*
7/28/69	*7,870*
3/21/80	*15,900*
2/20/81	*6,540*
4/5/84	*8,470*
4/4/87	*16,100*
1/19/96	*15,000*
9/18/04	*6,700*
4/02/05	*20,400*
Bushnellsville Creek at Shandaken, NY	
Date	***Flood Discharge (cfs)***
11/25/50	*1,350*
10/15/55	*1,830*
3/21/80	*845*
4/5/84	*896*
4/4/87	*1,000*
1/19/96	*996*
9/18/04	*No data available*
4/02/05	*No data available*
Schoharie Creek at Prattsville, NY	
Date	***Flood Discharge (cfs)***
Sep. 30, 1924	*29,000*
Nov. 16, 1926	*42,300*
Aug. 24, 1933	*39,000*
Mar. 03, 1934	*50,002*
Jul. 08, 1935	*27,400*
Mar. 18, 1936	*38,500*
Feb. 22, 1937	*29,800*
Sep. 21, 1938	*45,000*
Nov. 25, 1950	*49,500*

Dec. 11, 1952	*28,200*
Aug. 13, 1955	*25,100*
Oct. 16, 1955	*51,600*
Dec. 21, 1957	*31,000*
Sep. 12, 1960	*49,900*
Jun. 22, 1972	*27,400*
Dec. 21, 1973	*24,900*
Dec. 08, 1974	*24,800*
Jan. 09, 1978	*30,600*
Mar. 21, 1980	*39,600*
Apr. 05, 1984	*29,500*
Apr. 04, 1987	*47,600*
Jan. 19, 1996	*52,800*
Sep. 16, 1999	*42,800*
Sep. 18, 2004	*26,500*
Apr. 2, 2005	*42,500*

However, recurrence interval can be misleading if a flood of a certain size is expected to occur at regular intervals. For example, during the 1980s four floods exceeding the "5-year event" occurred within a seven-year span on the Esopus, while there were no such events during the entire decade of the 1970s. On the Schoharie Creek in the 1930s, there were significant floods six years in a row, with two greater than the 25-year event – the size flood for which most NYS and county bridges are designed. By contrast, there were no such events during the entire decade of the 1940s.

Flooding occurs in response to excessive runoff associated with spring snowmelt, summer thunderstorms, fall hurricanes, and winter rain-on-snow events. Five of the seven major floods recorded at the Esopus Creek at Allaben station occurred in late winter/early spring and are presumably associated with major snowmelt events from either spring thaw or rain-on-snow events. The largest recorded flood is a spring runoff event. A summer flood in 1969 and the flood of January 1996 are the two other large floods recorded at the gage. Three of the six major floods recorded at the Bushnellsville gage occurred during the spring and are coincident with three of the Esopus events, showing some comparison can be made between nearby streams. Conversely, weather in the Catskills can produce localized historically significant flood events such that a peak event may not be recorded at each gage for the same time period or storm event. Significantly, we can see that 10 of 25 events at Schoharie Creek occurred during hurricane season (late summer to late fall), 13 occurred during winter and spring, and only 2 occurred during summer. The January 1996 flood was approximately a 10-year recurrence interval flood on the Bushnellsville Creek, less than a 40 year event at Esopus Creek, and the "flood of record" at the Schoharie Creek. This shows that between-stream comparisons are not always perfect. This is especially so with summer thunderstorms, where highly localized storm cells can produce 10 or more inches of rain in one watershed, and only a few inches in an adjacent watershed for the same storm. Summer peaks shown in Table 2.4.1 do not overlap between any of the three sites.

From review of available data we can generalize that most bankfull and greater events will occur in late winter/spring as the result of thaws and major rain-on-snow events. This is in large part due to landscape storage of available water as snow and ice, reduced infiltration capacity if the ground is still frozen (or partially so), and minimal evapotranspiration from vegetation, which would otherwise route moisture back into the atmosphere. Other major floods can be expected during hurricane and tropical storm season in the late summer and fall, particularly as vegetation enters the dormant season and demand for water in the landscape drops off.

The 1990s were generally a time of moderate flood events in the vicinity of the East Kill, with the exception of the winter flood of January 19, 1996, which was similar in scale to April 1987. Tropical Storm Floyd flood (September 1999) was typical of tropical storm events and sometimes uneven distribution of precipitation associated with those storms. While flooding in Esopus drainages was typically less than a 5-year event, several drainages in bordering Schoharie system had over a foot of precipitation in 24 hours with flooding that exceeded the 10-year event discharge.

The years 2000 – 2002 were characterized by droughty conditions with intervening wet conditions. High water events were typically limited to bankfull (or smaller) events. 2003 was an unusually wet year, with several larger than bankfull events occurring during the summer. Predicting precisely when the next 5-year (or greater) flood will occur in the East Kill is impossible – the probability for a large flood, or a flood of any particular size, is the same each year – though weather and storm patterns can be used to anticipate conditions for a few months out, and seasonal patterns are generally reliable. The last really large flood was in April, 2005, but the probability is high that, when the next flood occurs, late winter/early spring during snowmelt/rainy season will be prime time.

Implications of East Kill Flooding

The unique hydrology of the East Kill has consequences for how the stream corridor should be managed. Flood history and dynamics play a large role in determining the shape, or morphology, of stream channels and the hazards associated with land uses on the banks and in the floodplain. For example, applications for stream disturbance permits (from NYS DEC) typically increase following floods, as landowners and municipalities attempt to repair damage caused by floods. If we want to minimize their impact on property, infrastructure and other damages or inconvenience, it is critical that we understand and plan for flooding behavior. Historically, this “planning” has emphasized attempts to constrain and control stream channels, rather than working with processes we can measure and, to some extent, predict. The results are often costly, and sometimes catastrophic, such as when berms or levees fail, or bridges wash out. These “control” approaches typically result in ongoing maintenance costs that can draw valuable community resources away from other projects. With a better understanding of stream and floodplain processes, we can reduce these costs. For more information, see Section 3.2, Introduction to Stream Processes.