Appendix 9:

Dutchess Area Environmental Science Advisory Network (ESAN)

Recommendations for Stream & Flood Management in Dutchess County

Compiled by the
Dutchess Area Environmental Science Advisory Network
September 2008

Dutchess Area Environmental Science Advisory Network (ESAN)

September 5, 2008

Dear Local Officials and Interested Parties:

The Dutchess Area Environmental Science Advisory Network (ESAN) is pleased to provide you with a copy of a new ESAN report on *Recommendations for Stream & Flood Management in Dutchess County*. Primary authors of the report are David Burns and Thomas Lynch, with input from several other authors identified in the report. The ESAN is a non-advocacy network of environmental scientists who are available to provide non-biased, scientific input on important issues surrounding the use and management of natural resources and humans' interactions with the environment.

While recognizing that protection of life and property is the highest priority during extreme weather events, the attached recommendations seek such protection while also considering long-term risk abatement, ecological habitat preservation, infrastructure investments which will reduce flooding harm, and storm pre-planning measures. Two important steps are assessing where the risks for floods are the greatest in our municipalities and where there are opportunities for mitigating potential problems. We envision the document being useful to planners, engineers, and municipal leaders seeking general guidance; these general recommendations can be adopted at the local level based on site specific knowledge in particular areas about flood histories, risks, and preparedness.

For more information on this report, or the ESAN, please contact me at 845.677.5343 or findlays@ecostudies.org. The report is available online through the Cornell Cooperative Extension Dutchess County Environment Program website at http://counties.cce.cornell.edu/dutchess/002_environment/003_our_water_resources/. ESAN members are available to present these recommendations for stream & flood management to local boards and in public forums, and welcome suggestions about other critical environmental issues that need similar analysis by the Network in the future.

Sincerely,

Dr. Stuart Findlay
Cary Institute of Ecosystem Studies *and*
Chair of the Dutchess Area ESAN

Foreword

The Dutchess Area Environmental Science Advisory Network (ESAN) is a network of local environmental scientists and professionals who work to promote the improved scientific understanding of critical environmental issues by the public and local municipal officials through the collection, analysis, sharing, and diffusion of reliable and unbiased scientific information. ESAN works to provide a forum to infuse scientific knowledge into environmental decision-making; convey ecological science to the media and the general public; and provide a collaborative network for the environmental science community. To accomplish this mission, and to be able to work with all stakeholders, ESAN is an independent, apolitical and non-advocacy organization, and will draw on all available resources to present the state of our understanding of various environmental issues.[1]

This document was generated through the collaborative efforts of the Dutchess Area ESAN and is not meant as a panacea, but rather a logical approach towards the development of solutions to the complicated and recurring problem of flooding and subsequent calls for in-stream modifications. This document is organized into a series of recommendations encompassing stream management, floodplain planning and management, and needed research, as well as a section dealing with supporting technical background material.

The ESAN would particularly like to thank lead authors David Burns and Thomas Lynch for compiling the document, and Mark Vian and the New York City Department of Environmental Protection for providing assistance. Finally, the ESAN would like to thank the following individuals for their technical review and comments: Roy Budnik, Scott Chase, Allison Chatrchyan, Stuart Findlay, Nat Gillespie, Ed Hoxsie, Carolyn Klocker, Cathy McGlynn, Kirsten Menking, Rebecca Schneider, Russell Urban-Mead, and several anonymous reviewers.

Introduction

In response to the recent flooding events and damage in Dutchess County, there has been increased concern by the general public and several courses of action proposed by various local officials. The Dutchess Area Environmental Science Advisory Network (ESAN) felt it would be beneficial to develop a set of recommendations based on existing knowledge, and sound geomorphic and ecological science, to assist communities as they consider various options and potential stream management. The

[1] For information on the ESAN, contact Dr. Stuart Findlay, Cary Institute of Ecosystem Studies, at 845 677-7600 Ext. 138, or findlays@ecostudies.org.

following recommendations and background material are intended to protect human life and critical infrastructure, while preserving the ecological functions and value of streams and floodplains.

Recommendations

These recommendations are intended to be used in conjunction with one another to form a successful flood management strategy:

Stream Management

1) **The County and/or its various municipalities should identify specific infrastructure threatened by flooding or erosion through the stream feature inventory (see page 8) and interviews with local highway superintendents**. Undersized culverts and bridges should be replaced as opportunities arise (routine replacement, FEMA funding); undersized bridges should be replaced with single span bridges where practical. For road and bridge sites identified by the highway superintendents as repeatedly damaged, proper channel dimensions based on hydraulic geometry regional curves should be utilized when making both emergency and permanent repairs. Emerging geomorphic science allows for the determination of a stream channel's cross-sectional dimension for a given drainage area. A reasonable stream slope and geometric pattern can also be determined. This approach closely replicates how a stream naturally behaves and allows it to return to a healthier and more stable condition while improving water quality and aquatic habitat. Higher peak flows due to an anticipated increase in the amount of impervious surfaces and more intense precipitation events associated with global climate change should be considered when calculating the proper size of infrastructure.

2) **Municipalities should facilitate the development of a GIS-based flood damage reporting system and database to track types of flooding, their location, and the costs associated with flood damage.** An inventory of areas likely to flood at various flows should be developed. The flood tracking database should be maintained in a uniform format by the County.

3) **Stormwater run-off and the need for infrastructure should be minimized where possible.** Where appropriate, retrofits and new construction should seek to maximize onsite infiltration and slow run-off. Wherever possible, runoff generated from impervious surfaces of rooftops, parking

lots, and walkways should be retained on-site and not routed to the roadside ditches via pipes, ditches, etc.; roadside ditches should not be scraped and left with exposed substrates. Ideally, ditches should be reconfigured to allow for regular mowing instead of scraping as the primary form of management and where scraping is necessary, a small patch of vegetated ditch should be left intact at the downstream end of the ditch to capture any eroding sediments and the ditch should be hydroseeded immediately after scraping. Finally, ditches should be disconnected from the stream channel system. Instead, infiltration basins, detention ponds or constructed wetlands should be used as ditch collection points in order to allow the water to re-infiltrate and recharge the groundwater. There are many additional proven techniques for treating, infiltrating, and storing stormwater. The Hudson River Estuary Program is a good starting point for information: http://www.dec.ny.gov/lands/5098.html.

4) **Deepening and straightening of stream channels should be avoided as these practices typically result in increased erosion and stream instability.** The slope of the stream bed is one of the factors affecting current velocity. By shortening the distance between two points while maintaining the same vertical drop, the slope and, in turn, the current velocity is increased, resulting in higher energy and more erosion downstream. Deepening the channel will cause undercutting of the steeper banks, ultimately resulting in bank failure and greater deposition of sediments at downstream locations.

5) **Removal of woody debris from the stream channel should generally be avoided.** In many Dutchess County streams, the woody debris provides prime habitat for stream fishes and aquatic invertebrates that are an important part of the food chain. Woody debris also plays a critical role in stream stability by providing roughness and capturing bedload (see page 13). Removal of woody material should only occur after consideration of the viewpoints of multiple stakeholders. Wood removal at sites posing an ***imminent threat*** to critical infrastructure, such as bridge footings and culverts, could be considered on a case-by-case basis. Such actions in regulated streams require consultation with the New York State Department of Environmental Conservation, Region 3 Permitting Office at Tel: 845-256-3054. For more information on the importance of maintaining wood in streams visit: http://anrcatalog.ucdavis.edu/Items/8157.aspx and download the report "*Maintaining Wood in Streams: A Vital Action for Fish Conservation.*"

6) **Because gravel is highly mobile and provides valuable ecological habitat, its removal should generally be discouraged.** All rivers and streams, including those in Dutchess County, carry massive amounts of water and sediment during flood flows. Gravel bars form when the flood waters begin to drop, but they generally move the next time the water rises, and typically are not the root cause of increased flooding. Furthermore, the existence of a gravel bar is likely due to the stream's hydraulic characteristics, so the deposit is likely to reform if it has been excavated as a short term fix. Thus, removing a gravel bar may temporarily treat a symptom, but it doesn't solve the problem, and may cause additional bank erosion as the stream finds an alternate supply of sediment to replace what was removed. Gravel removal in regulated streams also requires permits from the New York State Department of Environmental Conservation Region 3 Permitting Office at Tel: (845)-256-3054.

Floodplain Planning and Management

1) **Municipalities should conduct a review of current floodplain ordinances and adopt revisions as appropriate**. Revisions should reflect current building trends, new technologies, compliance with regulations, and integration with broader community plans as appropriate. Municipalities should make every effort to not allow any new structures in the 100-year floodplain and should work to remove existing structures over time as opportunities arise.

2) **Communities are encouraged to participate in the development of a county-wide All Hazards Mitigation Plan.** The Disaster Mitigation Act (DMA) of 2000 resulted in significant changes in the mitigation programs offered by FEMA. Under the 2000 DMA, local communities seeking funding under the Hazard Mitigation Grant Program and Flood Mitigation Assistance Program will be required to have an All Hazards Mitigation Plan approved by FEMA to be eligible for these funds. These plans are designed to reduce repeated flood damages within a community and can improve a community's Community Rating within the National Flood Insurance Program. Several communities are currently developing plans. FEMA has Mitigation Planning Guidance Documents available at http://www.fema.gov/plan/mitplanning/index.shtm.

3) **Identify and protect flood storage areas – this includes protecting wetlands, forested riparian buffers, uplands and floodplains**. Floodplains that are connected to the stream should be protected as flood storage areas. This will help to alleviate downstream flooding by providing a

location for the floodwaters to spread out thereby reducing their velocity and destructive energy while also lowering the flood crests. Additionally, identify floodplains suitable for restoration to encourage storage of floodwaters and sediment, including berm removal, excavation of fill previously placed in the floodplain, and creation of floodplain benches. Natural impoundments including beaver ponds should also be identified and effects on storage capacity determined.

4) **Dutchess County open space funds should be utilized for a flood buyout program for repeatedly flooded properties.** To maximize the effectiveness of the funds, they could be leveraged as the local cost-share with FEMA buyout funding following a declared disaster. Once the property is purchased, any buildings should be removed and the property should be reforested and utilized for flood storage if possible.

5) **Re-establish floodplain wetlands and forests where possible.** Wetlands act as water storage locations during heavy precipitation events and release the water slowly over time. Homeowners throughout the watersheds should be encouraged to reduce lawn size by the replanting of trees since lawns provide less erosion protection and generate more runoff than forests. The Dutchess County Soil and Water District [http://dutchessswcd.org/ or 845-677-8011, ext. 3] can help homeowners obtain appropriate seedlings. The Hudson River Estuary Program's *"Trees for Tribs"* Program also provides planting materials and technical assistance to interested organizations and homeowners. Contact information is available at http://www.dec.ny.gov/lands/43668.html.

6) **Encourage landowners through multiple approaches (including tax abatements) to maintain a healthy forested riparian stream buffer.** Healthy, robust riparian zones slow erosion of stream banks, help keep streams cooler by shading, serve as an important source of organic matter for stream ecosystems, and provide habitat for wildlife. See the Cornell University, *"Stand by Your Stream"* Fact Sheet Series for more information, at http://strmhlth.cfe.cornell.edu/index.html.

Education and Outreach

1) **Dutchess County (perhaps in cooperation with Dutchess County Soil and Water Conservation District and/or Cornell Cooperative Extension Dutchess County) should**

collect information regarding flood prevention/protection. Access to current information should be established for the public at multiple repositories in Dutchess County. This would include reference materials, floodplain maps and guidance documents that should be continually updated.

2) **Municipalities should facilitate periodic notification to landowners who have special flood hazard areas (SFHA) located on their property.**

3) **Municipalities and watershed organizations should work with local and state agencies to provide periodic training sessions on flood related issues.** The audience should include municipal leaders, code enforcement staff, planning boards, landowners, realtors, highway crews, lending institutions and others.

4) **Dutchess County and municipalities should identify trained professionals to provide on-site guidance for stream modifications.** In particular, this guidance should be available immediately following floods. The existing approach to flood management of patching flood damage without stream process knowledge wastes limited funding, may leave localities more vulnerable to future floods, often makes a bad situation worse, and may create liability for already devastated communities. Minimal stream disturbance to repair immediate infrastructure problems should be the short-term goal following flooding. A long-term flood response program is needed, one that is based upon current river science and is designed to achieve channel stability while meeting human and infrastructure needs. The stream professionals will provide for rapid and coordinated expert review and guidance on a regional basis during planning, funding, permitting and construction phases of flood remediation.

5) **Dutchess County should develop a training program to include workshops, demonstrations, simulations, site visits and possibly a certification process for contractors and highway departments interested in performing natural channel design work.** The multiple agencies involved (Transportation, Health, etc.) should coordinate more closely in setting goals and laying out desirable approaches to stream management. In addition, a Stream Table can provide a great hands-on tool to illustrate how streams function and the underlying stream

morphology (*The Cornell Cooperative Extension Dutchess County Environment Program owns a stream table that is used for education and outreach*).

Research

1) **A stream feature inventory should be conducted.** The inventory provides a basic familiarity with the stream corridor and surrounding watershed and can reveal trends important to understanding the stream system. The stream feature inventory should provide the following information: a) conditions that affect hydraulic function, particularly sediment transport function such as bedrock sills and banks, cultural and natural grade controls, berms, and rip-rap or other revetment, and inadequate riparian vegetation; b) potential sources of water quality impairment in the corridor, especially eroding banks, road runoff outfalls, dump sites, and exposed septic leach fields or other hazards; c) locations of bank erosion sites that need to be documented and surveyed regularly for study of bank erosion rates; d) infrastructure, including road crossings, bridge abutments, culverts and outfalls, and utility lines or poles; e) other features such as tributary confluences, water intakes, springs, wells, diversions, and invasive species. This effort can be accomplished by trained staff utilizing a Global Positioning System (GPS) and a stream feature inventory data dictionary at a rate of approximately one mile/day.

2) **Historical records for precipitation amount, intensity and resulting stream flow response should be analyzed.** With impending climate change there is a need to document current trends (if any) in precipitation amount, intensity, timing of snowmelt and other forces potentially affecting flood frequency and magnitude. Dutchess County and the nearby Hudson Valley have several long-term weather monitoring sites suitable for analysis.

3) **Aerial photography should be geo-referenced and used to digitize stream channel alignments and overlayed to detect historical stream channel alignments.** These historical alignments can determine the frequency and magnitude of channel migrations, typically over the last 50-60 years. The DCSWCD has historical photos and additional photos can be purchased from: http://www.apfo.usda.gov/.

Background for Further Reading on Stream Functions and Hydrology

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 to the landscape (as snow, rain and other forms of precipitation) (Figure 1). Understanding the hydrology within Dutchess County will; a) assist managers in land use decisions that work within the constraints of the hydrologic cycle and, b) help to avoid exacerbating flooding or further water quality impairment.

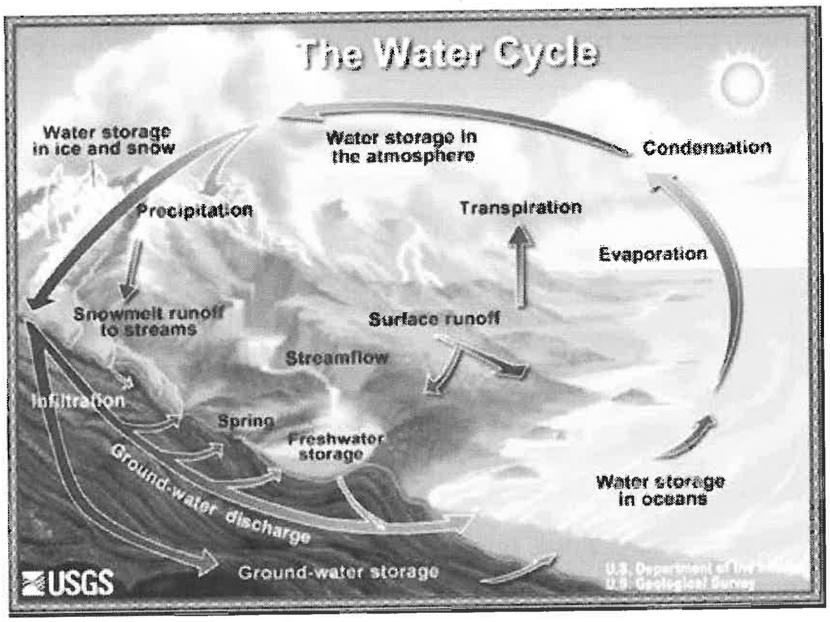

Figure 1. The Hydrologic (water) Cycle. Source: http://ga.water.usgs.gov/edu/watercyclesummary.html.

Water flowing through the streams and rivers in the County 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 runs off hardened surfaces directly into the stream will have higher peak discharges following storms than a watershed of similar size which is predominantly forested and allows a higher percentage of rain water to infiltrate into the ground, releasing the water 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.

There are two general categories of stream flow between which streams fluctuate over time: storm flow (also called flood flow) and base flow. Storm flow fills the stream channel in direct response to precipitation (rain or snow) or snowmelt, whereas base flow originates primarily from groundwater and sustains stream flow 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. In general, higher stream flows 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.

Base flow consists of water that seeps or rises from the ground and sustains stream flow 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 keep stream water warmer than the air in winter and cooler than the air in summer – this enables fish and other aquatic life to survive in streams year-round. For these reasons it is important to protect these groundwater inputs.

Hydrologists use a hydrograph, which is a graph showing the volume of flow (discharge) in a stream over time, to analyze flow patterns and trends such as flood frequency or drought cycles. A stream gage, a device that primarily measures water level, is necessary to monitor stream discharge and develop a hydrograph. The United States Geological Survey (USGS) maintains two continuously recording stream gages on streams that flow through Dutchess County: Wappinger (established in 1928 with some earlier data, drainage area of 181 mi^2, USGS ID# 01372500) and Tenmile (established in 1938, drainage area of 203 mi^2, USGS ID# 01200000). Prior to 1996, a crest stage gage was maintained at Lexington starting in 1929. All gage information is available online at the USGS website:

1) for the Wappinger Creek at (http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01372500&PARAmeter_cd=00065,00060) and
2) for the Tenmile River at Gaylordsville, CT at

(http://waterdata.usgs.gov/ny/nwis/uv/?site_no=01200000&PARAmeter_cd=00065,00060).

3) In addition, the Cary Institute of Ecosystem Studies has operated a gage on the East Branch of the Wappinger Creek near Millbrook, NY; and
4) Faculty of Vassar College have recently installed a gage on the Casperkill Creek in Poughkeepsie, NY.
5) There are also several historic gages with varying levels of information. They can be accessed at: http://waterdata.usgs.gov/ny/nwis/nwis.

These stream gages measure 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 the relationship between stage and discharge called a rating curve. Using this rating curve, the volume of flow in the stream at the gage location can be determined at any time just by knowing the current stage. Discharge can also be calculated 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, and to analyze seasonal patterns or flood characteristics.

The Wappinger gage at Red Oaks Mill has a period of record covering almost 80 years. Data gathered over long time periods can be analyzed to see seasonal trends, changes from year to year, or changes in long-term averages for the entire length (period) of the gage record. The gages provide information that can be analyzed to determine whether or not recent flood damage might be due to increased intensity of storm events, ongoing development in watersheds and its attendant change in hydrology, or a combination of these and other factors. The hydrograph below of the April 2007 illustrates flood flows that caused damage in Dutchess County (Figure 2).

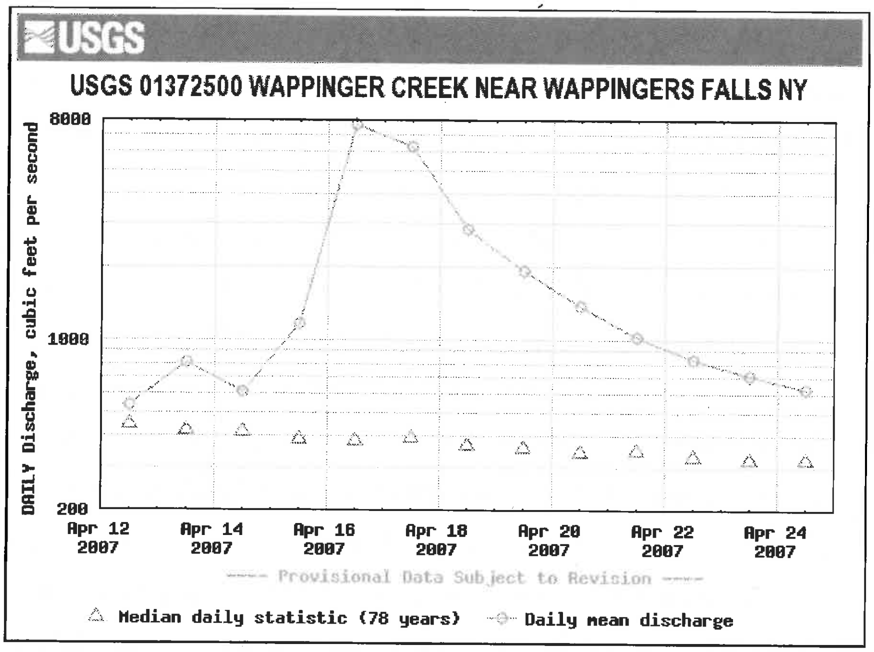

Figure 2. Daily average flow during the flood of April 2007 on Wappinger Creek.

The Wappinger Creek rose from a daily average of 613 cubic feet per second (CFS) to 7,640 CFS in approximately 48 hours. This event was not unique in that this daily average was exceeded by higher flows (and flooding) in 1938, 1949, 1955, 1973 and 1984 (Figure 3). Following 1984 there was a period of relatively lower flows (perhaps due to lower average precipitation) until 2006 and 2007. At the same time that Dutchess County was experiencing lower precipitation and stream flows, there was a dramatic increase in development with its attendant increase in impervious surface. Some of this development unfortunately took place in floodplains.

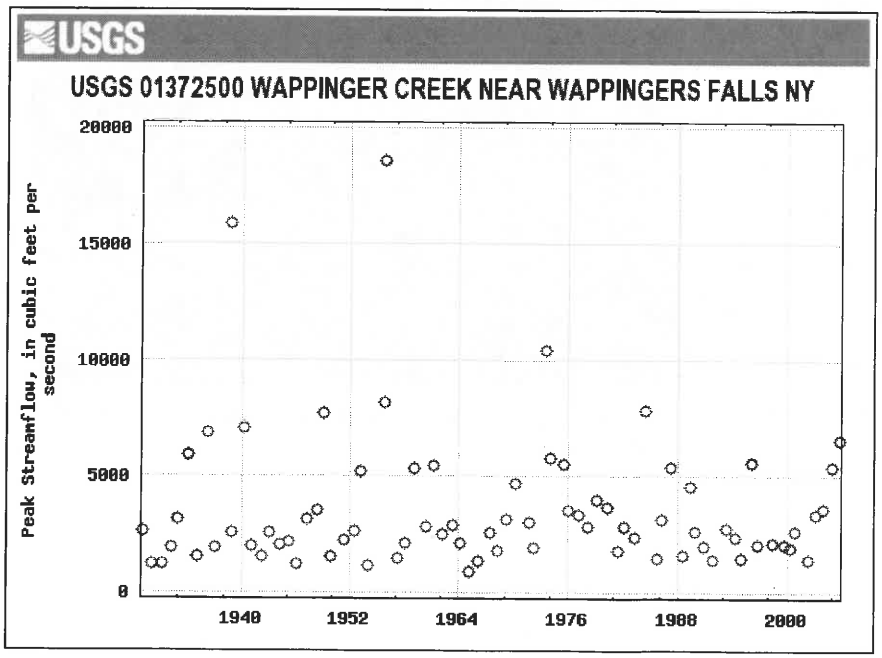

Figure 3. Peak stream flows on Wappinger Creek for the period 1929 to 2006.

Another approach to interpreting flooding magnitudes and patterns uses analysis of flood frequency distributions that indicate the probability of floods of different magnitudes. In other words, how likely is it that a flood of a given size will occur in any one year, or over a period of years? For example, each year it is possible, but not likely, that we will see a large flood (a flood so large it might recur once every 100 years on average) and almost a certainty we will see a small one (1-2 year recurrence). This value is actually calculated as a percent likelihood, but is most often converted to a number of years (e.g. the 100-year flood). This number of years is called the "recurrence interval" (RI) or "return period" of an event of certain size. For example, the flood with a 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, a flood of this magnitude will occur about once every 5 years. This probability remains the same year to year over time for a particular size flood to occur, although the actual distribution of flood events in time is not regular. Many years may go by without a certain magnitude flood or a flood of a particular magnitude may occur several times in a single year. 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 more or fewer floods of this size.

Introduction to Stream Processes

Living near a stream or river involves both benefits and risks; to enjoy the benefits, the risks are accepted. Both the pleasures as well as the dangers of living near streams stem in part from their ever-changing nature. Icy spring flood-flows are exciting and beautiful until they flow over their banks and run across yards into the basement windows or suddenly tear out a stream bank and begin flowing down the only access road to homes. For many reasons, the relatively flat land in the

Figure 4. The Fishkill Creek in Beacon, NY. ***Photo courtesy of Dave Burns.***

floodplain of a stream may be an inviting place to build a home or road –in fact, it may be the only place. However, long-time residents of floodplains know only too well that it is not a matter of *if* they will see floodwaters, but of *when*.

Even though streams are dynamic systems, their changes are predictable based on season or storm event. If we take the time to observe them carefully, we can begin to understand patterns of stream behavior and, more importantly, learn how to make proximity to streams and rivers more beneficial and less risky.

Streams drain water from the landscape, but they also carry bedload - gravel, cobble, and even boulders, that have been eroded from streambeds and banks upstream. During a storm event the water begins to rise in the stream channel. At some point the force of the water begins to move the material on the bottom of the channel. The gravel, cobble and boulders tumble against each other as they are pushed downstream by the force of the floodwaters and the stream banks vibrate with the force of these collisions. As the storm waters recede, the force decreases and the gravel and cobble stop moving.

The shape and size of a stream channel are determined by the amount of water and bedload it carries. Within certain limits, the form (morphology) of a stream is self-adjusting, self-stabilizing and self-sustaining. If stream managers alter the ability of a stream to self-regulate, the stream may remain unstable for a long time as its channel erodes and meanders in an attempt to reach a new state of stability.

Over the period since the last glaciers retreated some 12,000 years ago, Dutchess County streams have been shaped by regional conditions. Climate, topography, geology and vegetation of a region usually change only very slowly over time. Therefore the amount of water moving through a stream from year to year, or streamflow regime, is variable but somewhat predictable within broad limits at any given location.[2] This stream flow regime, in turn, defines when and how much bedload will be moving through the stream channel from year to year. Together, the movement of water and bedload carve the form of the stream channel into the landscape. In the absence of human influence, streamflow regime tends to be fairly consistent year after year which provides for relatively slow changes in stream channels. Over the 120 centuries since glaciers covered the region, the stream channel and the landscape conditions evolved in a dynamic balance.

However, as human activity altered the landscape (e.g. clearing forests for pastures or straightening stream channels to avoid having to build bridges), the balance between streams and their landscapes was changed. Some parts of streams seem to change form very quickly, while others parts remain much the

[2] One exception is when the vegetation changes quickly, such as can happen during forest fires, volcanic eruptions or even rapid commercial or residential development.

same year after year, even after great floods. Why is this? Streams that are in dynamic balance with their landscapes develop forms that can pass the water and bedload associated with both small and large floods, often regaining their previous forms (although specific locations may shift) after the flood passes. This is the definition of stability. In many situations, however, stream reaches become unstable when some human activity on the watershed has upset that balance and altered the stream's ability to move its water and bedload effectively. Due to the increase in impervious surfaces associated with development, increase in ditches and the drainage network, and /or increased erosion from soils in the watershed, the volume of water or sediment that the stream must carry increases. To compensate, the stream must widen or deepen its channel.

The potential force generated by water that moves its bedload is determined by its slope and its depth: the steeper and deeper the stream, the more force it exerts. For example, if changes made to a stable reach of stream reduce its slope and/or depth, the stream may not be able to effectively move the bedload supplied to it from upstream. The likely result will be that the material will be deposited in that section and the streambed will start building up or aggrading. This can often be seen upstream of bridges.

Changes in the length of a stream also affect its ability to move its bedload. When a stream is straightened it becomes shorter; this means that its slope is increased resulting in an increase in its potential force to move its bedload. Road encroachment narrows and deepens many streams which increases potential force to the point of stream bed degradation. In these cases streams become deeply incised within their valleys. Both aggradation and degradation result in a stream reach that has become unstable. Rapid bank erosion, as well as impairment of water quality and stream health, is likely to occur. Unfortunately these local changes can spread upstream and downstream causing great lengths of stream to become unstable.

The stream pattern we now see throughout Dutchess County is the result of millions of years of landscape evolution. Fractured bedrock was chiseled repeatedly by rivers and then glaciers and then rivers again. As glacial ages came and went, the valleys were eroded out of the mountains and their remnants washed out to sea. As the steeper streams coming off the mountainsides flowed into more gently sloped channels running through the main valley, the streams became wider and shallower. The valleys developed floodplains and the streams flowing through them became less steep. Stream pattern and shape progressively adjusted to assume new stable forms in balance with the new landscape. This adjustment often causes the river to meander over its floodplain. As time progresses, the meanders will increase in amplitude as erosion occurs on the outside of bends and deposition takes place on the inside. Streams, particularly in low gradient floodplains, are constantly changing the location of their channels. This is completely natural and should be anticipated. Failure to give the stream "room to roam" will produce ongoing problems that will require large and reoccurring expenditures over time.

As the earth's climate warmed, grasses and trees returned to the floodplains and the conditions that determined the balance between stream shape and the landscape changed once again. Stream banks that had a dense network of tree and shrub roots anchoring the soil were better able to resist the erosive power of flood flows and consequently a new stable stream form emerged; a new balance was struck between resistive and erosive forces. Dense mats of woody roots are essential for maintaining stable stream banks. If streamside trees and shrubs are removed, banks will often begin to erode resulting in water quality impairment or loss of habitat.

Summary

The hydrology of Dutchess County affects 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, the number of applications for stream disturbance permits (from NYS DEC) typically increases following floods as landowners and municipalities attempt to repair damage caused by flooding. If we want to minimize flooding impacts on property and infrastructure, it is critical that we understand that flooding of variable severity is inevitable and we should plan accordingly. Historically, this "planning" has emphasized constraining and controlling stream channels. Results of this type of planning 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.

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NEW YORK STATE OF OPPORTUNITY | Department of Environmental Conservation

Post-Flood Stream Reconstruction

Guidelines and Best Practices

Post-Flood Stream Repair Guidelines

DEC has developed guidelines to assist with stream repairs, or "interventions," after a major storm. This includes priority repairs when public health and safety are immediately threatened, such as removing flood debris from plugged culvert pipes and bridges; opening up clogged stream channels; repairing or replacing critical infrastructure; and reopening roads.

- **DEC Guidelines for Post-Flood Stream Construction (PDF)** (815 KB)
- **DEC Guidelines for Post-Food Stream Construction Large Format (PDF)** (775 KB) *You must set your printer to 11" x 17" paper.

Educational Materials for Landowners

See the Cuyahoga Soil and Water Conservation District's publication *"Life at the Water's Edge - Living in harmony with your backyard streams"* and other informative publications. Use the link to the Cuyahoga SWCD at right and scroll down to "Educational Materials" on their site.

Post-Flood Stream Repair Training

DEC and the Delaware County Soil and Water Conservation District have developed a training program and manual to help municipal officials, contractors and machine operators respond to flood damage. The training is based on sound stream science and processes. Following the guidelines and recommended procedures will eliminate the need for communities to go back and repair mistakes, saving time, money and resources.

DEC in partnership with NYS soil and water conservation districts are offering trainings at selected locations around the state. Trainings offered may include three day trainings, comprised of one day of classroom instruction and two days of field study or shorter 4 (four) hour or 6 (six) hour trainings. See a list of scheduled trainings or contact the DEC at (518) 402-8044 for more information.

The training manual can be viewed using these links:

Post-Flood Emergency Stream Intervention Training Manual (PDF) (4.89 MB)

Appendices to the Stream Intervention Training Manual (PDF) (2.8 MB)

Post-Flood Emergency Stream Intervention Trained Contacts

The link below provides contacts and locations from New York Soil and Water Conservation Districts trained in the Post-Flood Emergency Stream Intervention (ESI) Program. Please feel free to contact these individuals for technical assistance and/or questions related to the ESI program within your county.

Post-Flood Emergency Stream Intervention Trainer Contact List and Watershed Map

If you have additional questions with regard to the ESI program, please feel free to contact Tom Snow, DEC's New York City Watershed Coordinator at 518-402-9395.

Interagency Post-Flood Stream Intervention Training

In response to storm damage to streams following Tropical Storm Irene, DEC working with the Delaware County Soil and Water Conservation District, recently provided a Post-Flood Stream Intervention training. On January 8, 2013, DEC held this training with over 200 participants video-cast to 17 DEC office locations statewide.The Delaware County Soil and Water Conservation District instructed the class.

Participants included staff from DEC, Cornell Cooperative Extension, Soil and Water Conservation Districts, Department of Transportation, Department of Agriculture and Markets, Army Corp of Engineers, Lower Hudson Coalition of Conservation Districts, and Lake George and Ausable River Associations.

This one-day condensed format training complemented a more comprehensive three-day training being developed for municipal officials, contractors, and the machine operators that typically respond to flood damage. The full training has already taken place in Delaware County with over 400 participants. Overviews of the program have been provided in a number of other forums, including an Association of General Contractors meeting. The full three-day training will be offered at selected locations around the state this coming summer. DEC is developing partnerships with staff from the Soil and Water Conservation Districts as well as the various Cornell Cooperative Extension offices, to provide this training.

Post-Flood Emergency Stream Intervention Training

Part 1 (PDF) 3.49 MB (Overview, Stream Mechanics, Stream Types, Floodplains, Stream Instability)

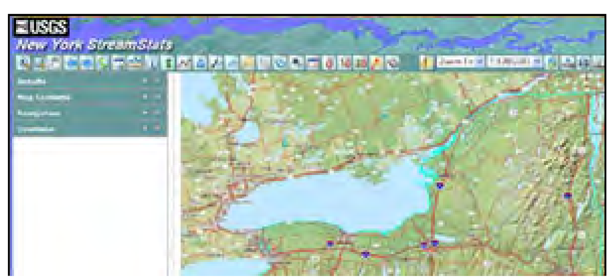
Part 2 (PDF) 4.62 MB (Stream Table, Unstable Channels, Flood Response, Channel Sizing)

Part 3 (PDF) 4.9 MB (Classroom Examples, Work Methods, De-watering)

Part 4 (PDF) 4.6 MB (Project Sites - before and after examples)

Part 5 (PDF) 1.47 MB (Bioengineering techniques, Hydraulic structures)

How to Determine Proper Channel/Bankfull Dimensions



1. Determine the watershed area using the USGS Streamstats web tool
In order to determine proper channel dimensions, you must know the watershed area in square miles. The watershed area can be determined using the USGS Streamstats web tool. (See "Links Leaving DEC's

Website" at right) Instructions on how to use the USGS streamstats tool are in Appendix D of the training manual.

The USGS Streamstat web tool will allow you to quickly determine watershed area.

2. Look up the required channel dimensions for your drainage area
Once you've determined the watershed area, you can use the Bank-full Hydraulic Geometry Tables (PDF) 88 KB, to determine proper stream channel construction dimensions. While this may sound complicated, it is actually fairly easy and straight forward. Examples of how to use the bankfull hydraulic geometry tables are included in the training manual.

More about Post-Flood Stream Reconstruction:

Post-Flood Stream Contacts - A map and list of contacts trained in post-flood emergency stream response across NY state.

Woody Debris Removal from Rivers and Streams - Guidelines on when you should and should not remove woody debris

Post-Flood Emergency Stream Intervention Trainings - A schedule of upcoming post-flood emergency stream intervention trainings for municipal officials, environmental organizations, contracotrs, and county legislators.

Permits Information

For information on the necessary permits to conduct work in and around waterbodies, please contact the NYSDEC regional office for your county and the U.S. Army Corp of Engineers:

Region 1	Nassau and Suffolk **(631) 444-0365**
Region 2	New York, Kings, Queens, Bronx, Richmond **(718) 482-4997**
Region 3	Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster and Westchester **(845) 256-3054**
Region 4	Albany, Columbia, Delaware, Greene, Montgomery, Otsego, Rensselaer, Schenectady, Schoharie **(518) 357-2069**
Region 5	Clinton, Essex, Franklin, Fulton, Hamilton, Saratoga, Warren and Washington **(518) 897-1234**
Region 6	Herkimer, Jefferson, Lewis, Oneida and St. Lawrence **(315) 785-2245**
Region 7	Broome, Cayuga, Chenango, Cortland, Madison, Onondaga, Oswego, Tioga and Tompkins **(315) 426-7438**
Region 8	Chemung, Genesee, Livingston, Monroe, Ontario, Orleans, Schuyler, Seneca, Steuben, Wayne, Yates **(585) 226-2466**
Region 9	Allegany, Chautauqua, Cattaraugus, Erie, Niagara and Wyoming **(716) 851-7165**

U.S. Army Corps of Engineers Contact Information

Covering DEC Regions 1, 2 and 3:
US Army Corps of Engineers NY District
ATTN: Regulatory Branch
26 Federal Plaza, Room 1937
New York, NY 10278-0090
For DEC Regions 1 & 2 and Westchester and Rockland counties in Region 3, call **(917) 790-8511.** For other counties in Region 3, call **(917) 790-8411**.
E-mail: **CENAN.PublicNotice@usace.army.mil**

Covering DEC Regions 4 & 5:
Department of the Army
ATTN: CENAN-OP-R
NY District, Corps of Engineers
1 Buffington Street
Building 10, 3rd Floor
Watervliet, NY 12189-4000
Call **(518) 266-6350** - Permits Team Call **(518) 266-6360** - Compliance Team
E-mail: **cenan.rfo@usace.army.mil**

Covering DEC Regions 6, 7, 8 & 9:
US Army Corps of Engineers
Buffalo District
ATTN: Regulatory Branch
1776 Niagara Street
Buffalo, NY 14207-3199
Call **(716) 879-4330**
E-mail: **LRB.Regulatory@usace.army.mil**

NEW YORK STATE
Department of Environmental Conservation

Guidelines for Post-flood Stream Construction

What to do and not do after a major storm

When communities are hit by major floods, roadways, bridges and culverts suffer severe damage and need to be repaired quickly. These guidelines have been developed to assist in post-flood stream repairs, or "interventions," after a major storm. These include priority repairs when public health and safety are immediately threatened, such as:

- Removing flood debris from plugged culvert pipes and bridges
- Opening up clogged stream channels
- Repairing or replacing critical infrastructure
- Reopening roads

To rescue people and keep them safe after a flood, emergency repairs are often necessary in order to re-establish vital community access routes and services. Sometimes emergency repairs leave stream conditions that, if not subsequently addressed, will cause further problems. These guidelines will help you minimize adverse impacts and the need for subsequent repairs.

NOTE: The activities described in this publication require permits from the New York State Department of Environmental Conservation (NYSDEC) and United States Army Corps of Engineers. See "Permits Information" for contacts. ***These guidelines are not intended to apply to routine or non-emergency stream work, which must follow the normal administrative and regulatory review and approval process.***

Emergency Repairs

General Considerations

Emergency stream repairs should:

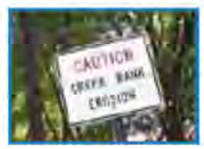
- Be done in a timely manner;
- Consider factors that have a long-term effect on the economic well-being of your community, such as fish habitat protection and
- Avoid contributing to future flooding problems. If done incorrectly, work in a stream can create worse problems for you and your downstream neighbors.

Repair Recommendations

NYSDEC recommends the following steps to properly repair streams.

1. **Clear debris and log jams at bridges and culverts:**
   - Remove only the debris necessary to re-establish original stream-channel dimensions.
   - Do not use cleared debris to build berms on top of stream banks.
2. **Clear gravel deposits clogging the stream:**
   - Remove gravel deposits to pre-flood grade level only.
   - When possible, relocate gravel deposits to areas where gravel was scoured away.
3. **Reconstruct the stream channel**
   - Do not build permanent berms on top of stream banks. If you need to pile material on banks temporarily, be sure to remove it before you are done. Berms block streams from spilling into their natural floodplains and may result in increased flooding, channel scouring, or erosion caused by higher streamflow velocities and flood elevations. Also, berms are generally not engineered to withstand flood forces and will likely blow out during the next flood, increasing damage and erosion in adjacent areas.
   - Do not attempt to deepen or widen the channel. Over-excavating the stream channel will have the same effects as berms, increasing flood risks to the site or downstream areas by increasing streamflow velocities and bank erosion, or sediment deposits in the channel.
   - Only remove the amount of debris necessary to re-establish original stream-channel dimensions. See "Reconstruct the stream channel to pre-flood, bank-full dimensions" in the next section.

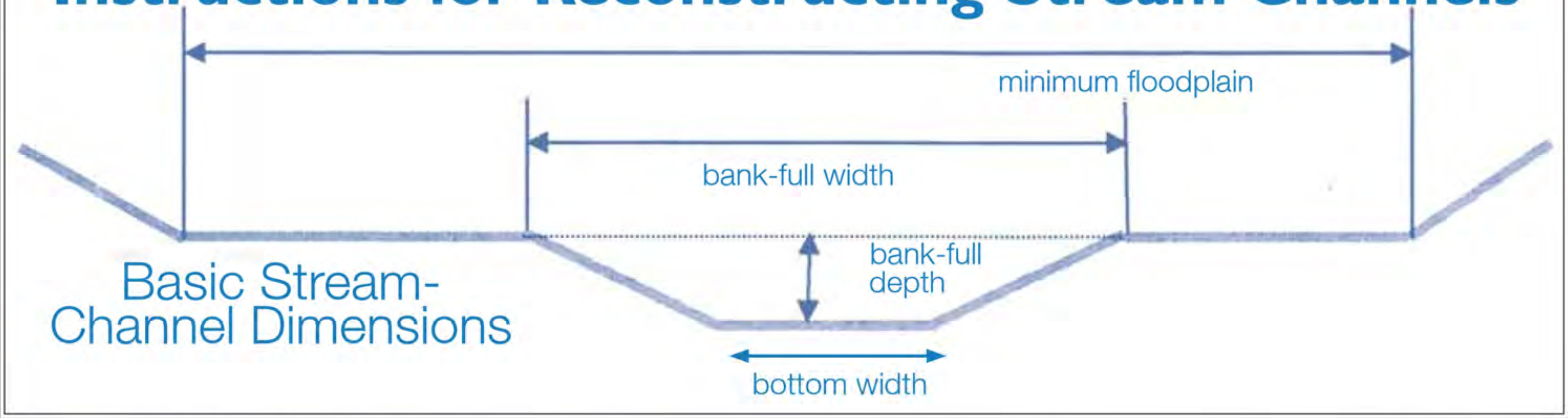
Post-Emergency Repairs

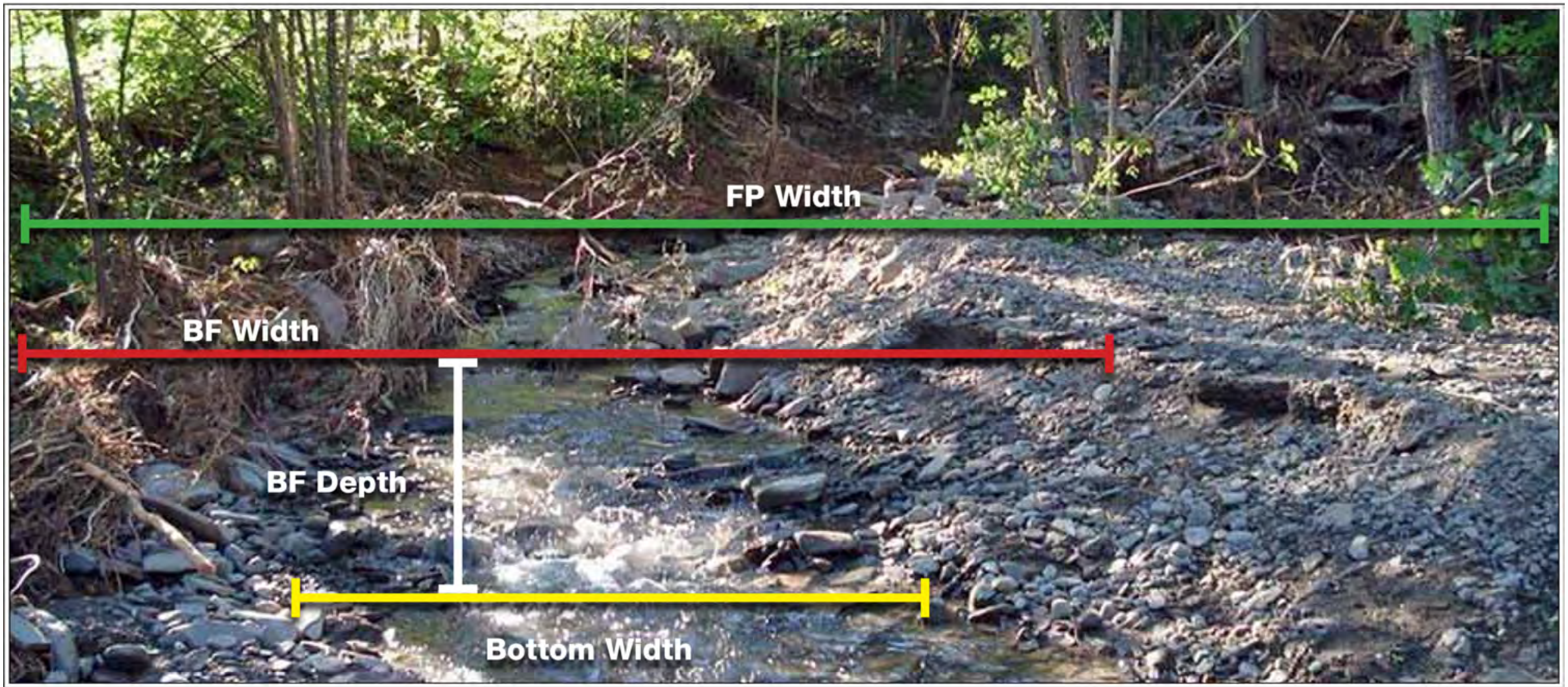


After the emergency response, more measured and deliberate stream repair work should begin in order to return the channel to pre-flood conditions.

The best model for managing high volumes of floodwater in a stream channel is one that slows the flow of floodwaters and increases their retention over an entire watershed, spreading them out instead of concentrating them in one area. Delaware County Soil and Water Conservation District's (DCSWCD) *Post-Flood Emergency Stream Intervention Training Manual,* available on DEC's website at **www.dec.ny.gov/lands/86450.html**, is an excellent source of information on this subject.

Instructions for Reconstructing Stream Channels





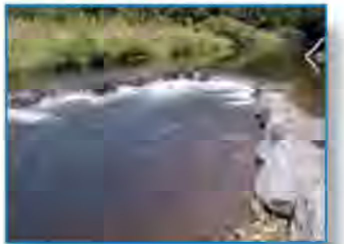
1. Reconstruct the stream channel to pre-flood, bank-full dimensions

- Proper stream-channel dimensions can be obtained by measuring an undamaged or "reference" stream reach immediately upstream or downstream of the planned worksite.

  Reconstruct the damaged channel using the bank-full depth, bank-full width, and floodplain width measurements from a comparable reach. See the Basic Stream- Channel Dimensions diagram for where to measure these dimensions.

- After severe flooding, an undamaged stream reach comparable to a damaged section may be difficult to find. In these circumstances, stream-channel dimensions can be calculated using the Bank-full Hydraulic Geometry Tables for Selected Hydrologic Regions (Regional Tables). Find directions for using Regional Tables on DEC's website at **www.dec.ny.gov/lands/86450.html**

2. Avoid creating a head cut (an abrupt vertical drop)



- Installing rock cross-vanes, or another similar in-stream structure, may be required to prevent head cutting.
- Please seek technical assistance from your county's soil and water conservation district or NYSDEC.

3. Avoid scouring/down-cutting (increasing channel depth)

- Reconstructing the channel to bank-full dimensions, the appropriate grade, and with as much floodplain access or bench as available room allows should minimize channel scouring and bank erosion afterwards.
- Often, flooding causes an alternating damage pattern of scouring/down-cutting and gravel deposits in a stream. Therefore, a source of material for filling scour holes may be located downstream of the scoured/down-cut reach.

4. Repair eroded banks

- If space allows, slope eroding banks to a stable slope, such as 3:1 (units of width to units of elevation) or flatter. Slope protection or erosion-control methods may be required. Slopes of as much as 2:1 may be considered when using rocks or other stable materials.

- To prevent future erosion on a river bend, incorporate rock vanes to deflect current away from the bank.

Important Notes on Water Quality When Working Near Streams

- All actions that cause erosion or affect water quality should be minimized to the greatest extent practicable, including the release of turbid (muddy) water.
- Machinery should be operated from the stream banks, avoiding use in flowing water to the greatest extent practicable.
- To avoid disruption of trout spawning, in-stream work should be avoided to the greatest extent practicable from November 1 - June 15.

NOTE: County soil and water conservation districts can be a great resource for information, training and help when working in and around waterbodies. Find a complete list of county contacts on the New York State Soil and Water Conservation Committee's website: **www.nys-soilandwater.org/contacts/county_offices.html**

Post-Flood Emergency Stream Intervention


Before repairs


After repairs

Training Manual

Originally prepared by:
Delaware County Soil and Water Conservation District
Delaware County Planning Department

In cooperation with:
The New York City Department of Environmental Protection,
Bureau of Water Supply, Stream Management Program

With permission, this document was edited and expanded for state-wide application by:
New York Department of Environmental Conservation

Updated - March 2014

~ Table of Contents ~

~ I. Foreword~

After a flood event, streams may look unraveled with gravel and debris strewn all over the place. Our first reaction is to put everything back to the way it was and maybe do some extra work. Typically this extra work consists of widening and dredging the channel to increase capacity. While the pressure to get into the area and move material to protect the public is understood, it is important to understand how the stream has changed as a result of the flood. Quick assessment can give the contractor or highway superintendent valuable information that will help determine how much work needs to be done and how the problem can be best resolved. Because the damage is widespread, the objective is to do the most good with the least effort. This is accomplished by addressing the most pressing problem areas and phasing the work so more complex work is left to the later stage of flood recovery. The process is akin to First Aid where the first responder must assess the scene, decide who the priority for treatment is and only do what is required to stabilize the situation until additional assistance arrives. This training material will provide information on how to assess the situation, decide where to work and what the right approach to be under and emergency response condition.

The development of this training program was initially funded in part by a grant from the New York State Department of Environmental Conservation's Water Quality Improvement Program and in part through the Delaware County Soil and Water Conservation District Stream Management Program contract with the New York City Department of Environmental Protection's Bureau of Water Supply. Subsequent edits were made to this manual by DEC to facilitate its use state-wide.

~ II. Introduction to Streams ~

Understanding the stream mechanics is important when conducting stream management practices because there can be an impact upstream and downstream of your project site. In the course of transporting water from the tops of mountains to the ocean, streams also transport sediment scoured from their own beds and banks. Streams and rivers are never constant, and it is important to understand how and why streams change. An understanding of how streams work is essential when approaching stream management at any level. This section is intended to serve as an overview of stream science, as well as its relation to management practices past and present.

Watershed

Streams reflect the regional climate, biology and geology. The water flowing through the drainage system reflects the watershed characteristics that influence the hydrologic cycle (**Figure 2.1**). These characteristics include the climate of the drainage basin, geology, topography, land use/land cover, infrastructure and vegetation.

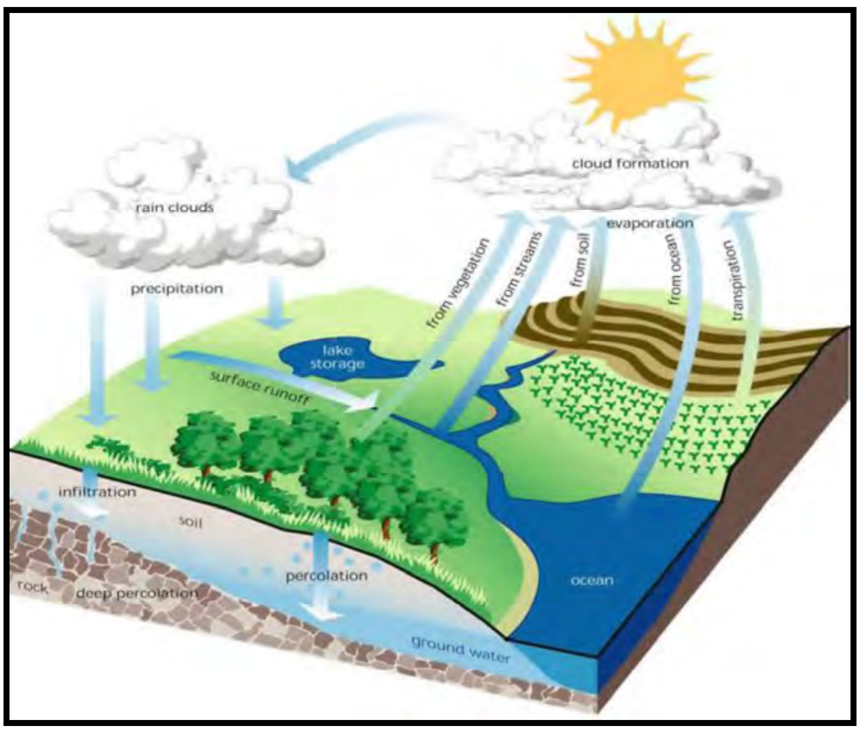


Figure 2.1 The Hydrologic Cycle (USDA-NRCS, 1998)

Drainage area or watershed size is part of the physical characteristics of the watershed. The size of the watershed is defined by the amount of land area that has the potential to drain stormwater runoff into the stream network. The shape of the watershed also plays a key role in the stream network; if two watersheds have the same size but different shapes, they will have different peak discharges and times of concentration resulting from the same storm event. Travel time for runoff to move through the stream network varies with watershed topography. A steep watershed typically exhibits a higher peak discharge than a flatter watershed. Climate, geology, topography, vegetation, etc. affect timing and amount of stream flow, referred to as the stream's hydrologic regime. **Figure 2.2** is a drainage area map for Chambers Hollow in the Town of Hamden, produced using StreamStats; a water resource program developed by the United States Geological Survey (USGS).

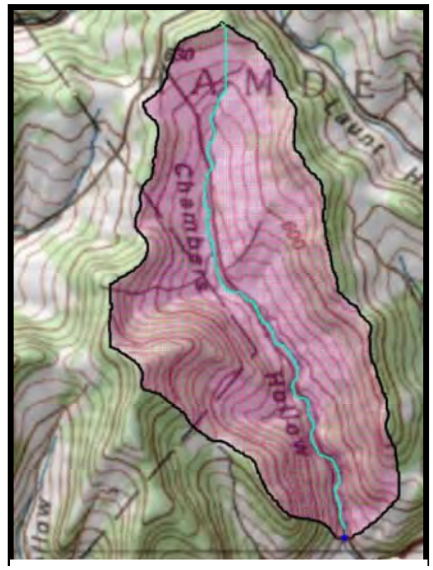


Figure 2.2 Drainage area map from USGS StreamStat

Stream Flow

Streams flow at many different levels over the course of a year, ranging from the small trickle of a dry summer to the raging torrent associated with the rapid thaw of a thick snowpack. There are essentially three basic types of stream flow: base flow, storm flow, and flood flow. Base flow sustains stream flow between storms, during subfreezing, or during drought periods and is largely the water flowing into the stream from groundwater springs and seeps. Storm flow, also known as bank full flow, appears in the channel in direct response to precipitation and/or snowmelt. Flood flow is water that gets outside of the stream banks. **Figure 2.3** illustrates the basic stream flow patterns in a typical stream cross section.

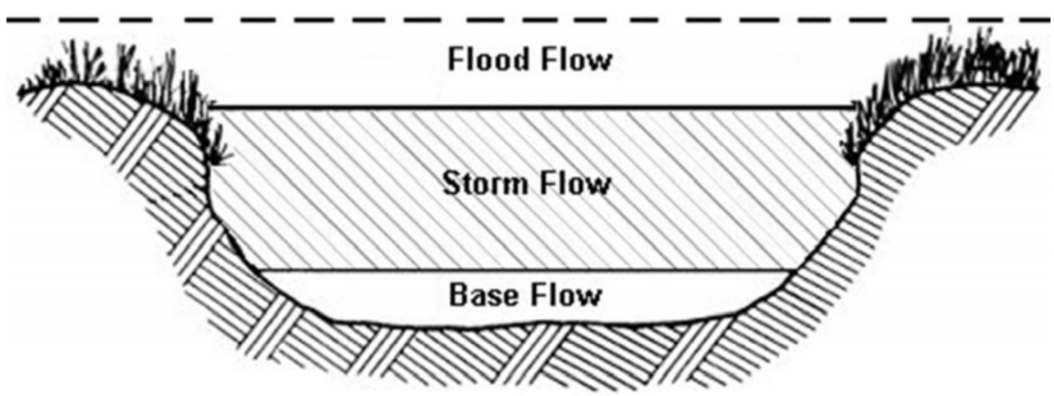


Figure 2.3 Illustration of a typical stream cross section showing stream flows.

A daily mean discharge curve for the stream gage at Margaretville, NY for the period from September 2006 to August 2007 is provided below in **Figure 2.4**. Note that the brown line indicates the average daily mean discharge (stream flow measured in cubic feet per second) for the 69 years of gage records, and the light blue line shows the daily mean discharge for the 2006-2007 period. United States Geological Survey (USGS)[1] graph also shows that most of the runoff for the watershed occurs between mid March and mid May, with a second period of runoff in the fall in November and December. This is a period when the ground is often bare and evapo-transpiration from plants is low. The precipitation that falls during this period quickly runs off and the streams are full.

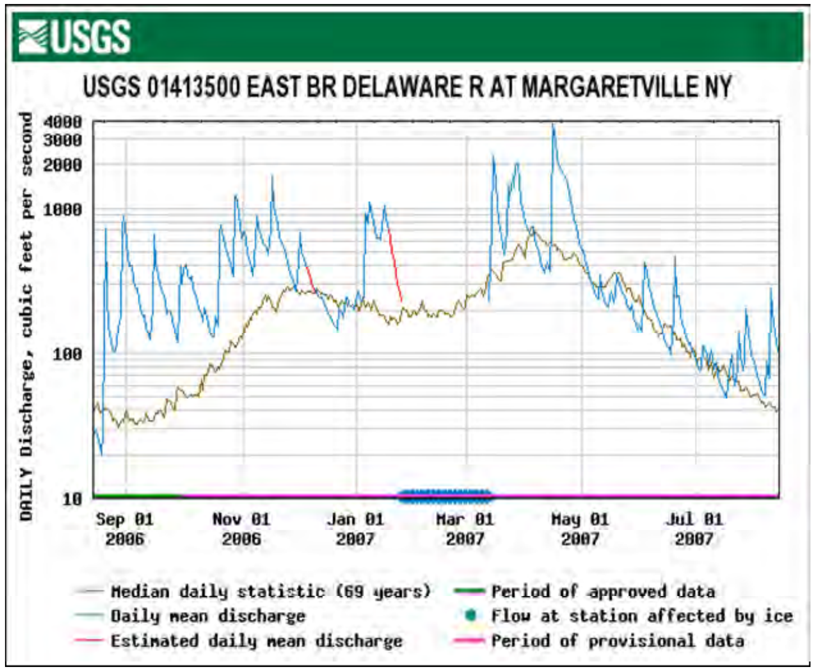


Figure 2.4 Daily Mean Discharge Curve

Stream Stability

The definition of a stable stream is: "The tendency of a stream to maintain its cross-section, plan form and profile geometry over time, effectively transporting its water and sediment supply without aggrading (building up), degrading (down cutting), or adjusting laterally (eroding its banks)." (Rosgen, 1996)

Streams that are in balance with their landscape adapt a form that can pass the water and sediment through both small and large floods, regaining their previous form after the flood passes. In many situations, however, stream reaches become unstable when some management activity has upset that balance, altering the stream's ability to move its water and sediment effectively.

The form of a stream that is considered "stable" varies with topography. When it is in balance with mountainous terrain, a stable stream will look different than one that is in balance with rolling hills or broad floodplains. Stable streams are less likely to experience bank erosion, water quality and habitat problems. A number of factors can change the stability of streams such as changes in flow input, sediment, and land use. Channelization of the stream and placement of berms, culverts and bridges can also have a negative impact on stream stability.

Sediment Balance

Sediment discharge has long been recognized as one of the primary variables that determine the characteristics of a stream. **Figure 2.5** below illustrates the relationship between a set of four primary physical variables (sediment size, sediment load, stream discharge and stream slope) and two opposing processes (stream bed aggradation and degradation) that determine stream

[1] USGS stream gage information can be found on their website http://nwis.waterdata.usgs.gov/ny/nwis/rt

sediment and channel characteristics and balance. The figure suggests that a change in one of four physical variables will trigger a response in the two process variables. This in turn creates changes in stream characteristics. See **Figure 2.5a** and **Figure 2.5b**. Streams are said to be in equilibrium when the volume of water is enough to transport the available sediment without building up in the channel (also known as aggradations) or cutting down the channel bed (known as degradation). Streams will adjust their shape, size, and slope in order to transport the sediment.

LOAD **DISCHARGE**

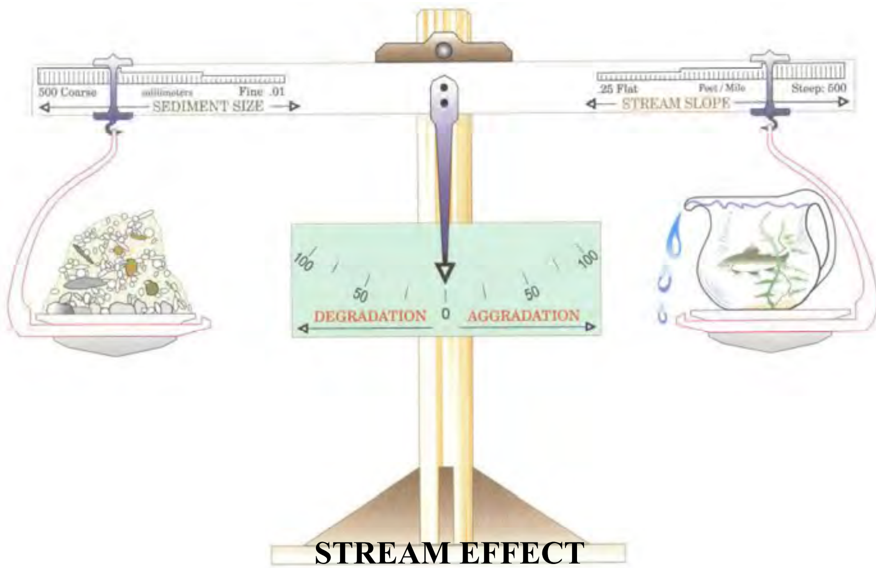


Figure 2.5 Sediment Balance (Sediment LOAD) x (Sediment SIZE) is proportional to (Stream SLOPE) x (Stream DISCHARGE) **(Rosgen, 1996)**

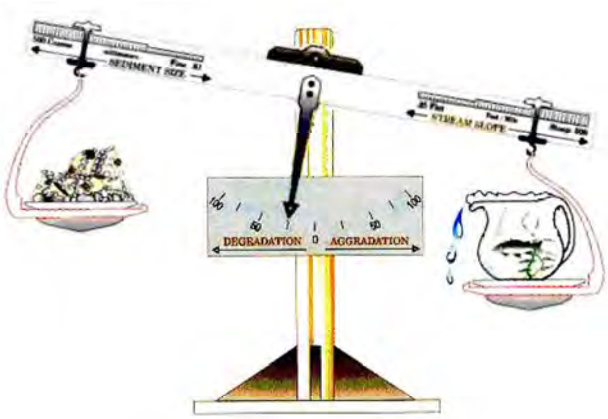


Figure 2.5a If the supply of sediment decreases or the supply of water increases, the stream will begin to erode the stream bed or degrade. (After Rosgen, 1996)

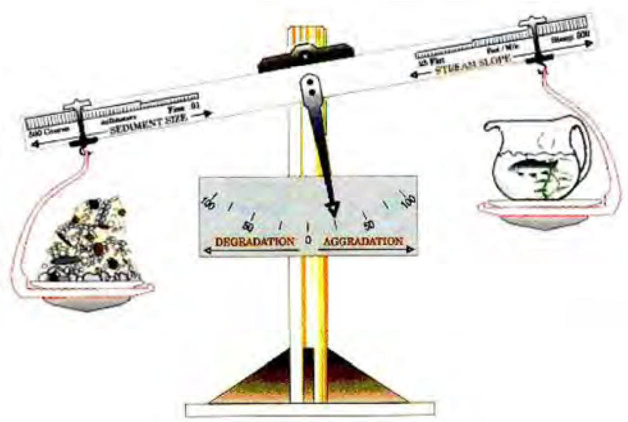


Figure 2.5b If the supply of sediment increases or the supply of water decreases, the stream will begin to fill in with gravel or aggrade. (After Rosgen, 1996)

Stream Features

The features of a stream are described in terms of their planform dimensions, their longitudinal dimensions, and their cross-sectional dimension.

The overhead or "planform" view of the stream focuses on the path that the stream follows within its valley (**Figure 2.6**). Stream managers speak of a stream's sinuosity as they describe the coverage the stream meanders across the valley. Sinuosity is related to slope and energy. A stream that has sinuosity has a longer distance than a stream that is straight. The associated elevations will also differ whereas the greater the sinuosity the lower the average slope. The sinuosity of a stream is generally greater at the lower end of the valley closer to the mouth of the watershed.

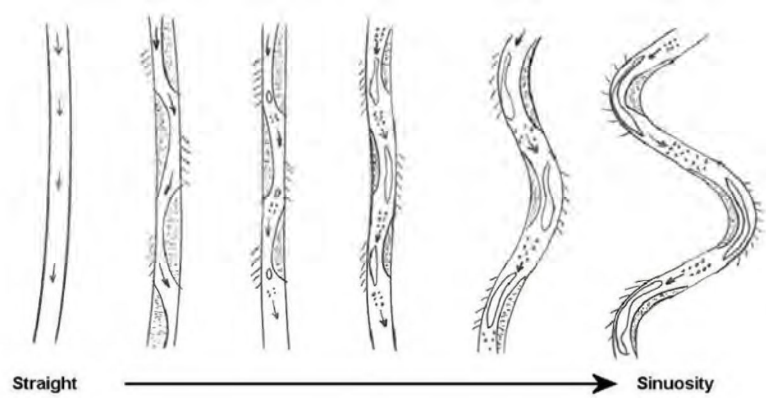


Figure 2.6 Planform of a Stream with Increasing Sinuosity (After Keller, 1972)

Longitudinal dimensions of a stream are used to describe how the stream changes from the top of the watershed to the mouth of the stream. The most important factor is the slope of the stream. Slope is a critical contributor to the energy of the stream. The energy of water flowing down a slope is needed to move sediment. A stream's slope can vary from high gradient (slope greater than 4%) to medium gradient (2%-4%) to low gradient (less than 2%)(see **Figure 2.7**). The slope of the stream typically is greatest at the top of the watershed (high gradient stream) and gradually declines as the stream flows down the valley (medium gradient stream) and makes its way to the bottom of the watershed (low gradient streams).

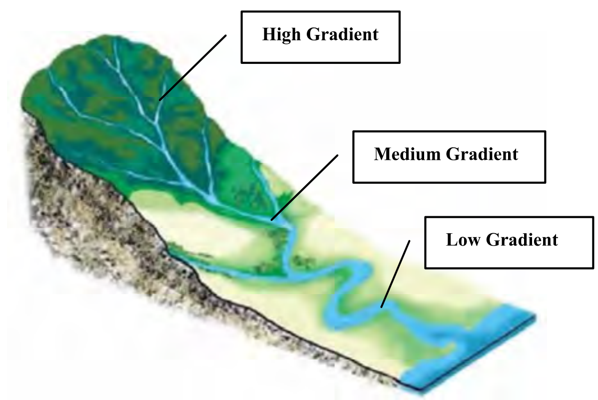


Figure 2.7 Stream's slope from high gradient to low

In terms of its cross-sectional dimension, a stream has a primary channel that conveys most of the flow throughout the year. Secondary conveyance of flow is the floodplain. Floodplains are the flat area of a stream system located above the top of the stream bank that is inundated with slower flowing water during and following flood flow events. Flood flows in some streams sections may not rise over the top of the banks and therefore may lack or are disconnected from their historic floodplain. Such stream channels are commonly called entrenched channels (**Figure 2.8**). Maximum depth is the distance from the top of the water at bank full elevation to the deepest part of the channel. If at twice maximum depth the stream cannot access it's floodplain it is considered to be entrenched.

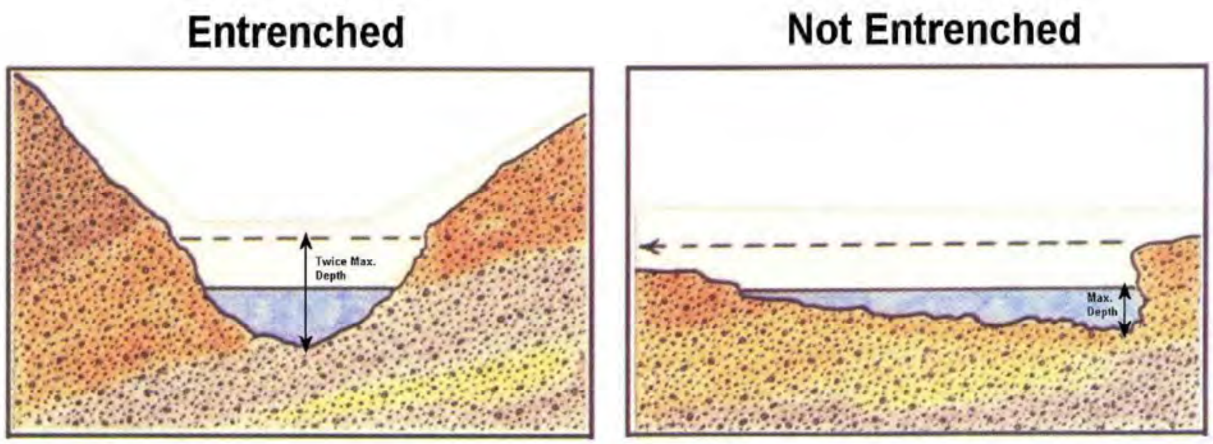


Figure 2.8 Shows entrenched channel (After Rosgen, 1996)

"The floodplain is defined as the flat area bordering a stream, constructed by the river in the present climate and inundated during periods of high flow" (Leopold, 1997). The floodplain is a critical component of stream function. The floodplain serves as an energy dissipater and depository of finer sediments during high flows. **Figure 2.9** shows a typical cross section of a stream system with bank full and floodplain. Notice that a bank full event is not considered a flood event until it over tops the banks. Bank full happens on average, every 1.2 to 2.0 years. This discharge, from relatively frequent storms, is largely responsible for the shape of the stream channel within the floodplain.

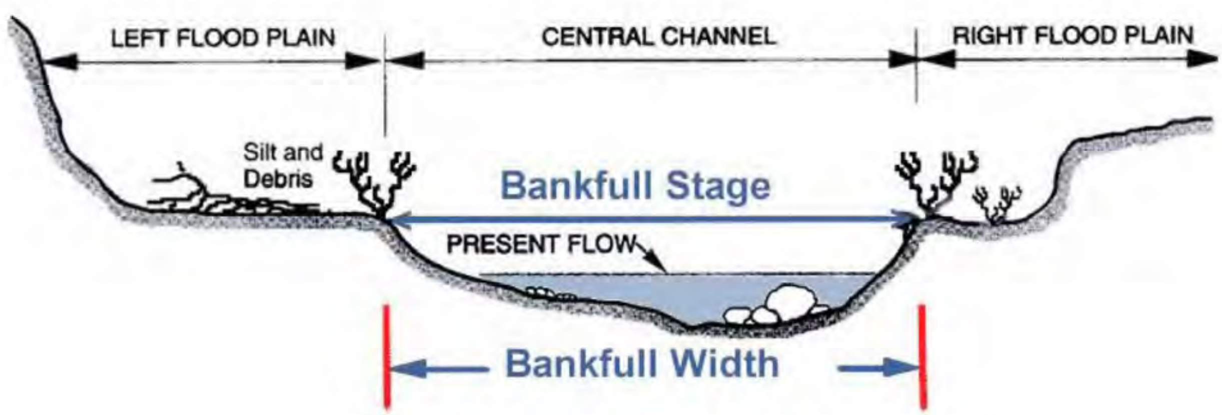


Figure 2.9 Shows a typical cross section of a stream system (After Newbury & Gaboury, 1993))

Stream Type

There are two basic stream types that can be identified in the field. One is the riffle-pool sequence illustrated in **Figure 2.10**. Typically a stable stream reach will maintain a balance in the ratio of the length of riffles to the length of pools. This balance helps regulate the velocity of water when it speeds up in riffles and slows down in the pools. Pools are important features in the stream since their low slope acts to slow the velocity (hence reduce the energy of the stream). Pools are found on the stream bends and the water enters the bend into a vortex pattern dissipating the energy in the deep water. Gravel can be found on the inside of the bend (point bar), which is a characteristic of a stable stream.

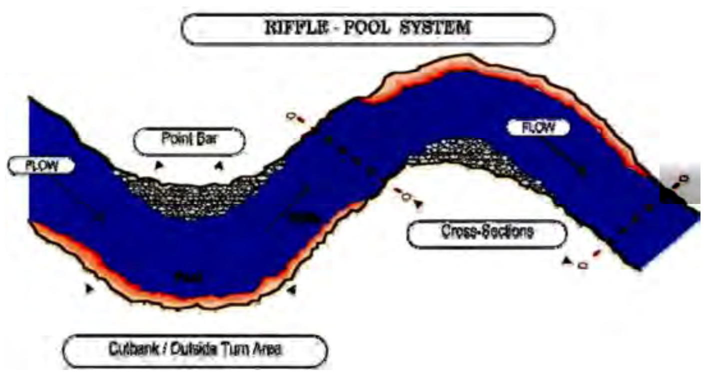
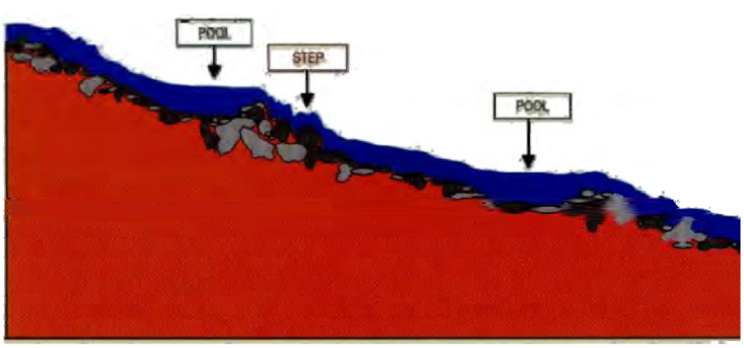


Figure 2.10 Typical Riffle-Pool Sequence (Rosgen, 1996)

The second stream type is called a step-pool sequence which is illustrated in **Figure 2.11**. The energy is dissipated through the stepped pools much like a series of speed bumps would slow down a car. This stream type is typically found in the headwaters or in steep narrow valleys.



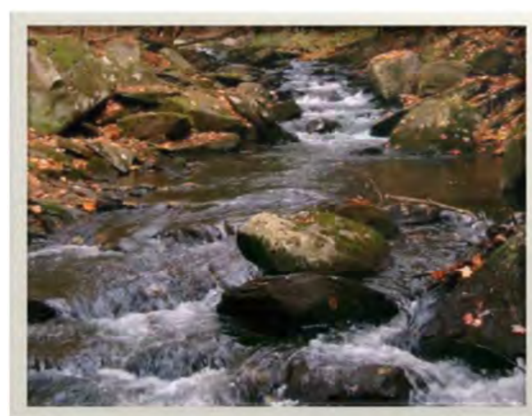


Figure 2.11 Typical Step-Pool Sequence (Rosgen, 1996)

Channel Disturbance – Evolutionary Sequence

Channels that have been disturbed by dredging, incision, or channelization follow a systematic path to recovery. This process has been documented in six classes described by Simon and Hupp (1992) in **Figure 2.12**. This process can happen naturally.

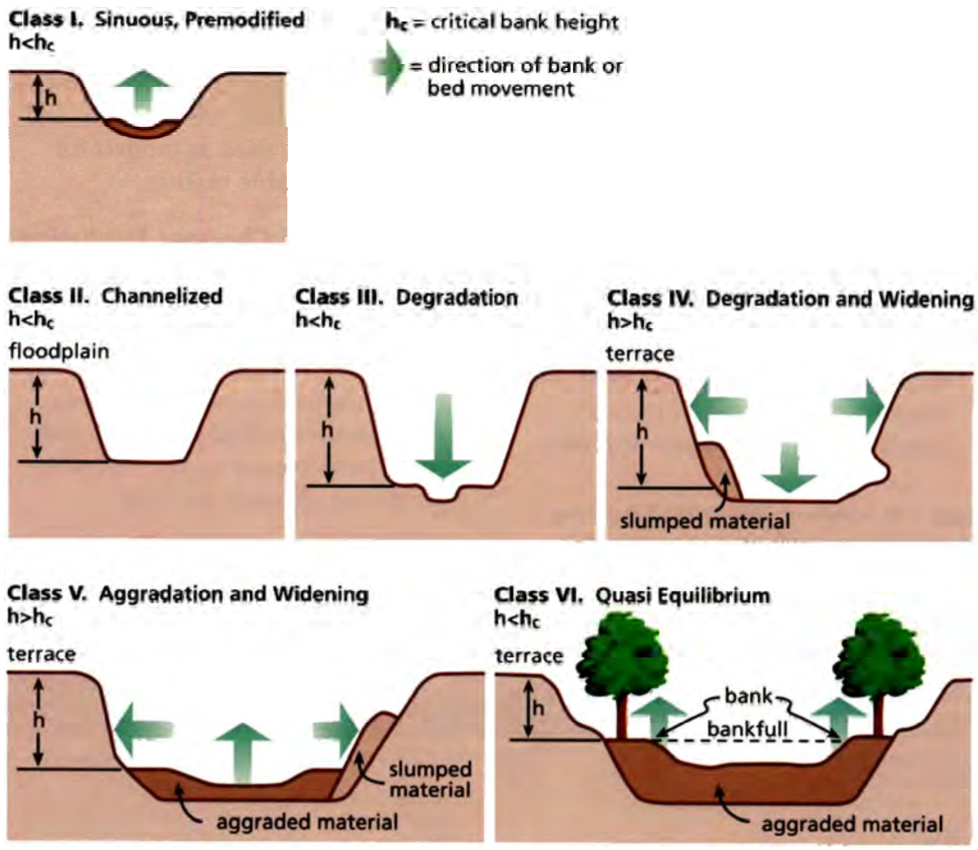


Figure 2.12 Stream Evolutionary Sequence (Simon and Hupp, 1992)

- Class I, is the channel in its natural pre-disturbed state.
- Class II, is the channel immediately after being disturbed (in this case, channelized, presumably straightened and steepened in addition to over-widened).
- Class III, is the channel eroding down (degrading) due to the flood waters being confined because channel is lower and out of contact with the former floodplain.
- Class IV, the channel continues to degrade, the banks become unstable, and the channel erodes laterally.
- Class V, the channel begins to deposit eroded material in the over-wide channel, and the newly developing floodplain continues to widen.
- Class VI, and a new channel is established and becomes relatively stable. A new floodplain is established within the original channel, and the former floodplain becomes a terrace (abandoned or inactive floodplain).

Immediate Effects of Dredging

Dredging is often proposed as a means of increasing channel capacity after a flood. On the previous page we have shown the evolutionary sequence that the stream must go through when channelization occurs. The immediate consequences of dredging are illustrated below:

Figure 2.13 (after R. Hey, 2003) shows a stream in profile view that has just been dredged. This corresponds to Simon and Hupp's Class II in Figure 2.12.

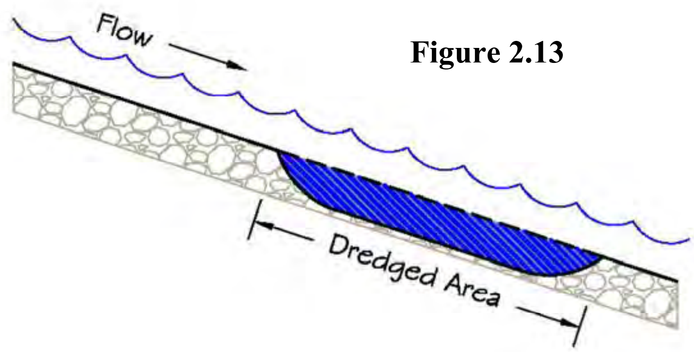
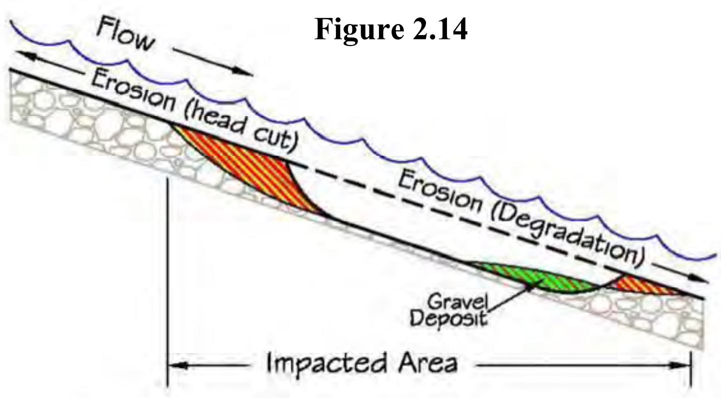


Figure 2.13

Figure 2.14



Within days, certainly no longer than weeks, the disturbances illustrated in **Figure 2.14** (after R. Hey, 2003) will be seen on the dredged stream.

Three things are occurring in the stream when it is dredged:

- A headcut occurs as a steep abrupt change in elevation in the stream bottom which forms upstream of the dredged area. The headcut will continue to move upstream releasing a huge amount of sediment supply from the bed and banks.
- This new sediment will be deposited at the location shown in the sketch labeled gravel deposit.
- Since the headcut is in effect lowering the elevation of the channel, erosion will occur downstream of the gravel deposit and outside of the area dredged. This occurs because the stream is trying to achieve equilibrium with a new bottom elevation and slope. In short, it is trying to match downstream with what is happening upstream.

Figure 2.15 is an illustration of a headcut that shows the instability that progresses upstream and the impacts that happen downstream.

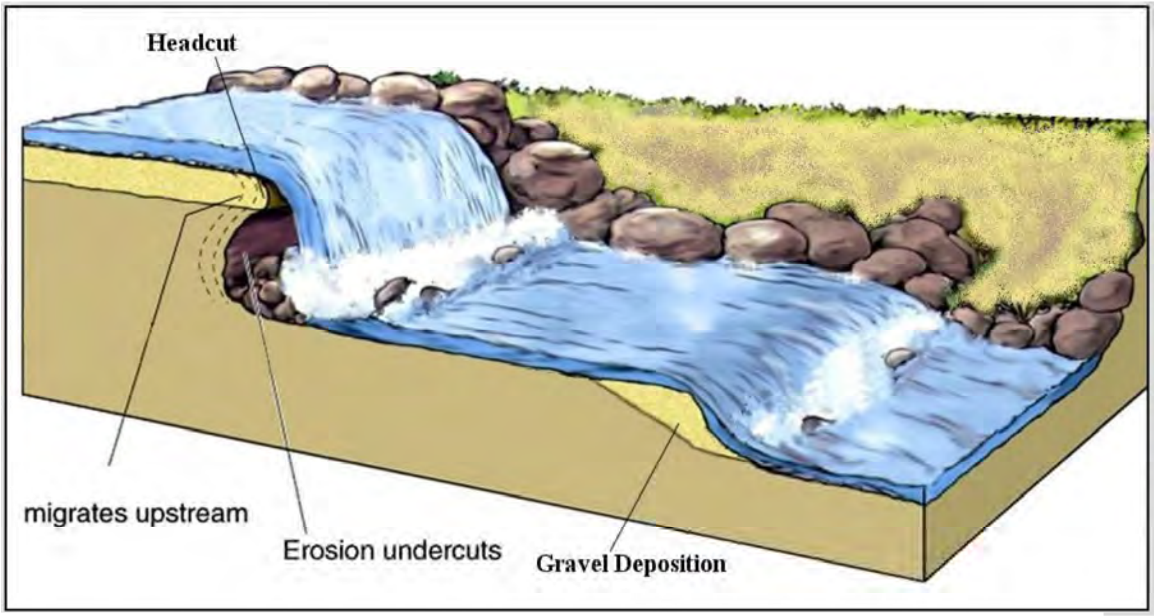


Figure 2.15 Headcut illustration showing instability of the stream channel

All of this leads to serious instabilities in the reach. Unfortunately, that is not all that can happen. The headcut, if left unchecked, will proceed upstream and destabilize more of the stream. The erosion and gravel deposition will proceed downstream and destabilize the downstream reach. If the upstream and downstream reaches are stable then this chain reaction will result in an unstable reach. If the unstable reach was further compromised with improper stream management such as dredging, the impact will further destabilized the reach resulting in steeper bank erosion. This will be greater nuisance to the municipality or landowner which may be a danger to public safety and may cost additional funding to correct the situation. The example shown in **Figure 2.16,** shows a headcut moving upstream on Third Brook in Walton, NY after post-flood work using traditional deeper -wider u-shape (parabolic) stream channel was completed to repair damages from the 2006 storm event. This headcut eroded the streambed down 6 feet which has compromised existing high eroding banks within the reach. The municipality has received funding to repair some areas of the reach and is currently in the process of developing a stream management plan to address several mass slope failures within the reach.

Figure 2.16 Headcut on Third Brook in Walton, NY

Human Activities and Impacts on Stream Health

The distinction between natural and human disturbances is important to understand. Human disturbances often significantly alter natural conditions and can have a longer lasting impact on the capability of the stream to function. These disturbances can include logging practices, livestock overgrazing, cropping practices, construction and maintenance of highway infrastructure, real estate development, gravel mining, dredging, channelization, berming, and introduction of non-native species in the riparian corridor. All of these practices have impacted stream stability on a watershed scale.

Highway/Public Utility Infrastructure Influence

Some of the most easily visible impacts to stream stability result from the construction or maintenance of highway infrastructure. Roads are commonly located close to streams, especially in mountainous regions that typically have narrow and winding valleys. Road encroachment has narrowed and deepened many streams, resulting in increased velocity. This causes the bed of the stream to degrade and, ultimately, to become incised, like a gully in its valley. This means that the stream reach has become unstable, which can lead to rapid streambank erosion as well as impairment of the water quality and stream health. Worse yet, these local changes can spread upstream and downstream, causing great lengths of stream to become unstable.

Roadside ditches collect stormwater runoff, carrying it away from the road and sometimes directly into streams. Roadside ditches have an impact on water quality and quantity. Without stormwater retention and/or filtration, runoff may impact streams by transporting contaminants, excess sediment, and excess nutrients as well as carrying excess water. The re-direction of water away from property, fields or roads without giving the water the chance to absorb into the ground, will increase runoff into the streams which raises water levels during storm events. If ditches are maintained without re-seeding, their discharge to streams can increase sediment (turbidity) in the stream system. This can aggravate gravel deposition problems.

Proper culvert installation and sizing is also important for stream stability (see **Figure 2.17**). Culvert installation that utilizes improper size, slope, and headwall can lead to streambank erosion and/or gravel deposition both upstream and downstream of the culvert.

Figure 2.17 Culvert Conveying on Holliday Brook Colchester, NY

Orientation, size and approaches for bridges have had a considerable impact on stream system stability. Bridges built wider than the stream's natural dimensions will lead to the deposition of sediment under and near the structure during periods of low or base flow. Localized scour may also be present. Sediment that is deposited under the bridge may affect the designed flow capacity of the channel beneath the bridge. In many instances, the sediment must be excavated to maintain the design capacity. Bridges built narrower than the stream's natural dimensions will exhibit a depositional wedge upstream of the structure. This may lead to water to become backed up behind the bridge, resulting in local flooding upstream. Bridge approaches are usually built across floodplains in order to have a gradual transition onto the bridge. These become a floodplain block (see Figure 2.18).

Figure 2.18 Bridge results in elimination of Floodplain

Bridges can force water and debris that would normally be on the floodplain through a narrow opening, concentrating energy that can cause problems downstream of the bridge, such as streambank and stream bed erosion or debris plugging bridge openings. Allowing the water to convey thru floodplain culverts placed in bridge approaches will allow water to access the floodplain and reduce the risk of water backing up behind the bridge debris jams under bridges (**Figure 2.19)**.

Figure 2.19 Floodplain culverts along Delaware County Route 2 Hamden, NY

Residential and Commercial Development Influence

Development of new residential and commercial districts can have a significant impact on the watershed and on the ecology of the riparian (streamside) area. Developments require access roads and utility lines that often are required to cross streams. Stormwater runoff in a natural landscape is compared to runoff in a developed landscape in **Figure 2.20**. Homeowners who enjoy their stream and desire to be close

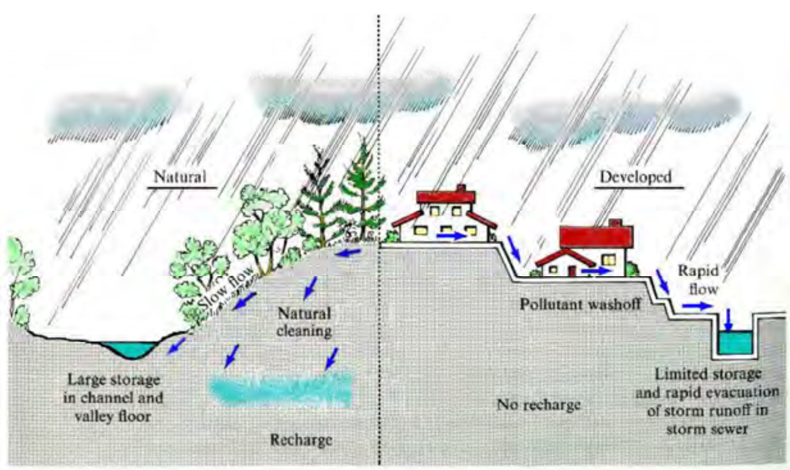


Figure 2.20 Natural vs. Developed Runoff (Dunne & Leopold, 1978)

to it may clear all the trees and shrubs along it to provide views and access. They may replace natural conditions with an un-natural mowed lawn that provides little benefit to stream health or local wildlife. Mowed lawn will increase stormwater runoff that would normally be a slow flow that would be absorbed by the trees, shrubs and ground. This leads to increase water to the stream system that may produce new streambank erosion or increase existing erosion issues. Landowners that live close to a stream and desire access to the water can minimize the destabilization of the streambank. Careful selection of a route to the stream and locating access where the water's force on the bank is lower, a landowner can minimize disturbance to riparian vegetation and the streambank. Minimizing the disturbance in the flood prone area and promoting a dense natural buffer provide property protection, aesthetic value and wildlife habitat. Landowners should be aware of planting appropriate riparian species along the stream to maximize streambank stability.

Impervious surfaces such as houses, buildings, paved parking lots or driveways will not allow for water to be absorbed into the ground. This water will become surface water runoff that is directed into ditches or swales to be removed from the property and directed towards the stream. The increase stormwater runoff to the streams will raise water levels and will reduce groundwater recharge.

Agricultural Influence

The abundance of water and cold-hardy grasses have supported agricultural industries for centuries. As fields were created to obtain the most profitable land for growing crops or grazing cattle, the streams were moved to maximize property. Streams were pushed to the sides of valleys which are no longer the lowest point of elevation. These streams are traditionally maintained and reinforced to stay in place by berms, riprap or other stabilization methods. **Figure 2.21** illustrates the stream reaction to the displacement where the channel bed is filled with gravel and erosion on the streambank occurs. When water flows over the streambanks during storm events the water will flow to the lowest elevation of the valley.

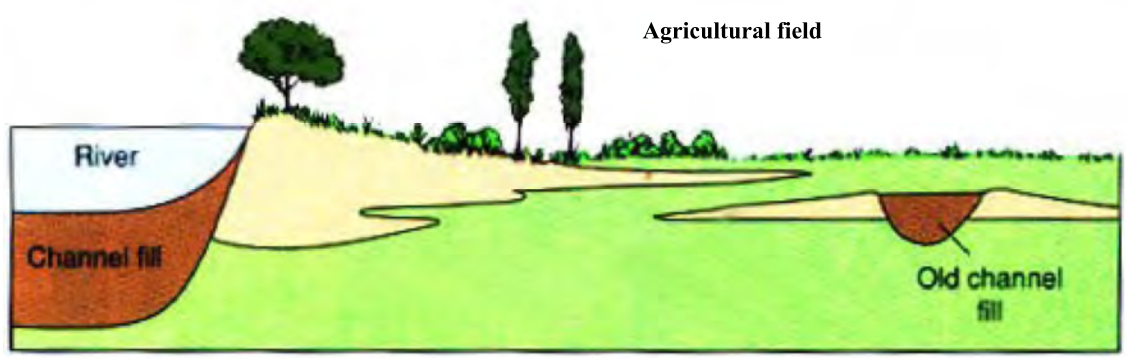


Figure 2.21 Stream that has been moved to higher elevation in a valley.

~ III. Flood Response~

After a flood event, streams may look unraveled with all the gravel and debris all over the place. A first reaction is to put everything back to the way it was and maybe do some extra work. Some of these attempts at fixing the streams have been "band-aid" solutions for spot problems and have often created additional problems. Understanding the stream conditions and using stream friendly techniques can help contractors and municipalities prioritize post-flood unstable reaches for treatment. Identifying areas that are in most need of help is essential. Often looking upstream and downstream can help a contractor determine the best fit channel shape. Allowing the stream to be re-connected to the floodplain will help maintain the new constructed channel. Remember that what you do at a given site should not significantly affect areas upstream and downstream. A variety of management strategies can be provided to address post-flood issues problems on both short and long-term bases.

Protocol

There is a need to develop a protocol for flood response to ensure the best results with minimal adverse impacts. Developing an emergency plan can help with organization of resources and determine where work is needed. Assessing and correcting stream channel conditions on a short-term basis can be completed with minimum adverse effect on the streams and can save time and money in the long run.

Immediate Priority

During and after a flood certain things need to be completed and they must be done immediately. Immediate priority items include, but are not limited to:

- Opening clogged bridges
- Opening closed roads
- Keeping important installations functioning, such as:
  - Power plants
  - Fire stations
  - Rescue centers
  - Water wells and systems
  - Sewage treatment plants and systems
  - Hospitals

Immediate priority items are those facilities and infrastructure which need to be repaired and/or kept open in order that further recovery may be allowed to continue, or to prevent immediate loss of human life.

High Priority

High priority items are those items of work that are necessary for the first part of the cleanup process. Generally, one of the first high priority items is to get the stream channels back into some sort of a functioning condition. The reason this needs to be accomplished is to:

- Open up clogged channels so they can convey their normal flow.
- Put channels back in place to prevent continued flooding.
- Open up clogged bridges to prevent additional flooding should there be another storm.
- Stabilize streambanks to prevent erosion. If left unchecked this can lead to deposition, which in turn can lead to more localized flooding.
- Attempt to stabilize landslides, at least on a temporary basis, so they do not slide into the channel and trigger an avulsion and/or localized flooding.
- Get the channel into a condition such that the natural processes of streams can begin to return the stream to its pre-flood condition.

Other work may also qualify as high priority. This training guide is intended to describe an efficient method that may be used for the emergency repair of impaired stream channels after a flood. The material which follows concentrates primarily, although perhaps not exclusively, on post-flood emergency channel repair.

Assess the Stream Reach

Knowing where to work and where not to work in a stream will help save time and money. Not all streams will need to have work done to them after a flood, even if at first glance, they appear to be in bad condition. In many cases the stream will have created a new, stable condition. Therefore, the first thing to do is assess the condition of the stream.

Appendix A is the "Problem Itemization Sheet". It is a check list of problems commonly found after a flood. It is highly recommended to take copies of this sheet out in the field, to be used in the assessment of streams. The sheet can be used to:

- Identify the number of problem sites
- Itemize the number and type of problems on a given reach
- Identify the most severely impacted reaches
- Prioritize reaches with more severe problems
- Determine manpower and equipment needs
- Serve as documentation for state or federal reimbursement
- Help document work done under an emergency permit
- Serve as documentation for additional permits

When a damaged reach is assessed, the upstream and downstream reaches should be assessed as well. For example, the upstream reach is not damaged, it is possible to measure certain physical features and then "duplicate" that reach at the damaged reach.

Perform the Work

When the assessment is complete and priorities have been established, work can begin to restore the damaged steam reaches.

Assess and Document Further Needs

Documentation is important for any project. This information can be used for flood aid reimbursement and/or future long term mitigation planning. A stream manager/contractor should provide the following:

- Project sketch or drawing
- Before and after photos
- Written description of work
  - Date
  - Time
  - Equipment
  - Material
  - Labor force

Note any future work that needs to be done. Even though the channel may be reformed to the approximate correct size, long term mitigation may be required. Such as:

- Vegetation that may need to be planted
- Structures that may be required to permanently stabilize the stream

A post construction assessment should be made. Staff from your local SWCD and DEC offices can be asked to provide technical assistance and to help with a monitoring plan.

Improper Sizing of Channels

Over-sizing or under-sizing a stream may create future problems for the area and should be avoided. Dredging the entire stream from top to bottom creates more problems. If the stream is disconnected from its floodplain, the stream will begin to down-cut, causing the streambanks to be taller, steeper, and more unstable. This can create a whole new set of problems that will end up costing more money in the end.

An example of improper stream sizing is the classic parabolic shape, or u-shape, channels. This technique is highly discouraged due to the fact that the parabolic shape concentrates the water flow with no energy dissipation and the smooth surface increases the water velocity. The series of figures below show the sequence of stream evolution after the Third Brook stream located in Walton, NY was fixed after the 2006 flood event using the parabolic design.

Figure 3.1 shows an area of stream directly after a flood event. This area appears to be in bad condition, but it is in relatively stable form. The sediment after a flood flow settles out into an overlapping or shingle-like effect wedging sediment material together. This interlocked material is less likely to move in a smaller storm event.

Figure 3.1 Section of stream that has been flooded.

Figure 3.2 is in the same location as in Figure 3.1 after some stream construction was conducted. Notice the classic parabolic shape stream channel. Re-arranging the stream bed and banks loosened the sediment material which allows this material to be more transportable. The smooth bank and rounded streambed allows for the water to speed up.

Figure 3.2 The classic parabolic stream channel shape.

Figure 3.3 shows the stream channel two months later. Notice that the stream has begun to erode its streambanks and become wider. The loose sediment is easily transported downstream.

Figure 3.3 Two months of stream channel evolution.

Figure 3.4 shows the stream channel three months after construction. The stream has continued to adjust, further eroding its streambanks and creating a floodplain. The original floodplain is so high that it is now a terrace.

Figure 3.4 Three months of stream channel evolution.

Proper Sizing of Channels

To avoid situations such as described on the previous pages, it is necessary to work with the stream and to have an understanding of how streams work. The simplest solution is to do nothing and allow natural processes to do the work. But in most situations this cannot happen due to existing infrastructure such as homes, bridges, or roads that are threatened.

Various solutions are provided in the next few pages as an alternative to just going into a stream and "winging it". There is no one answer that fits all streams, and in some cases technical assistance may be needed. In these cases, contact your SWCD or regional DEC staff for any assistance.

There are two ways to properly size channels:

- The Stable Riffle Reach Concept
- Using Regional Bank Full Hydraulic Geometry Tables

The Stable Riffle Reach Concept:

This is the preferred method. In some cases only a section of stream is damaged, typically associated with riffles. The simplest solution in this case is to look upstream and/or downstream of the area to find a relatively undisturbed "stable" riffle section. Measure the width, depth, and slope of this area and duplicate these measurements at the impacted area. A suggested method of surveying the cross section is shown in **Figure 3.5**. These measurements should be checked using the Regional Bank Full Hydraulic Geometry Tables as the example table is shown in **Figure 3.9**. This "duplicating" method will allow for natural processes to adjust the stream and have minimal adverse impact to the stream health. It will also give you information about the presence and size of important features of the stream, such as the floodplain benches, pool depths, or the stream's meander geometry.

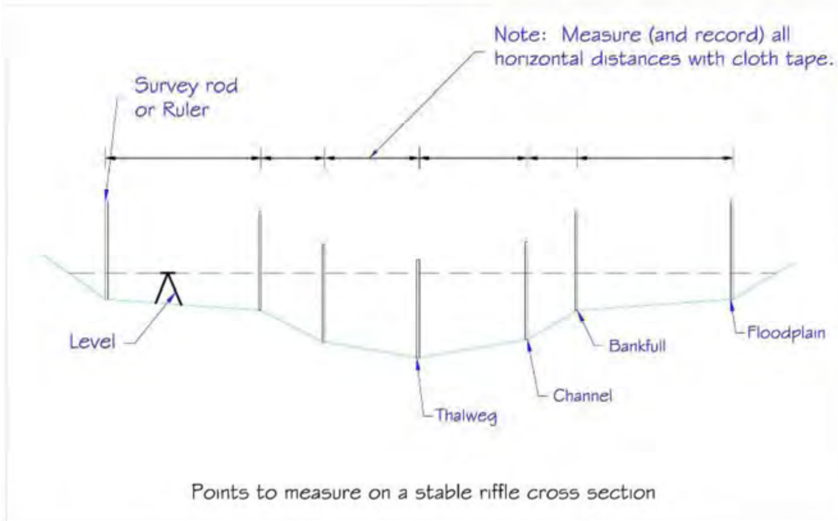


Figure 3.5 Surveying A Stable Riffle Cross Section

When you have finished your survey your sketch of the riffle cross section should approximate something like **Figure 3.6**.

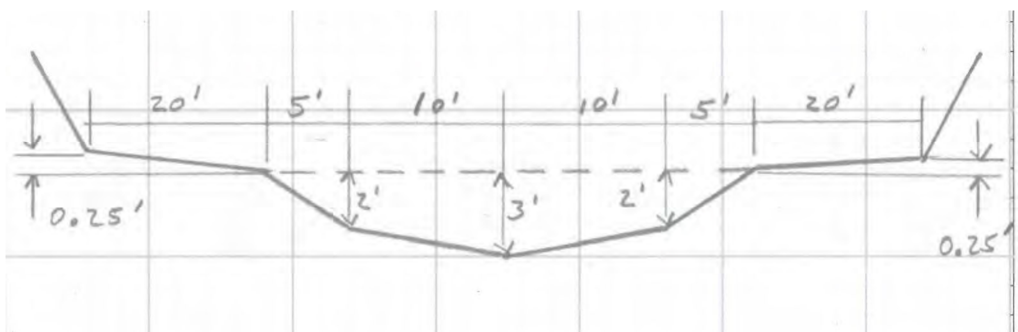


Figure 3.6 Sketch of Stable Riffle Cross Section

Using Regional Bank Full Hydraulic Geometry Tables:

In cases where the stream was completely devastated by a flood event a determination of the bank full hydraulic geometry can be used to determine stream channel dimensions. Regional bank full discharge and channel-characteristic models have been developed by the USGS using linear regression equations to relate bank full discharge and bank full channel dimensions (width, depth, and cross-sectional area) to drainage-area size. Regional Bank Full Hydraulic Geometry Tables for use throughout New York State were developed by DEC using information gathered from USGS stream gaging stations. New York's highly variable physiographic features and climate necessitated that the state be divided into hydrologic regions on the basis of the physiographic and geologic characteristics that affect streamflow. The resulting tables are therefore specific to eight distinct geographic regions in the state as shown below in **Figure 3.7**.

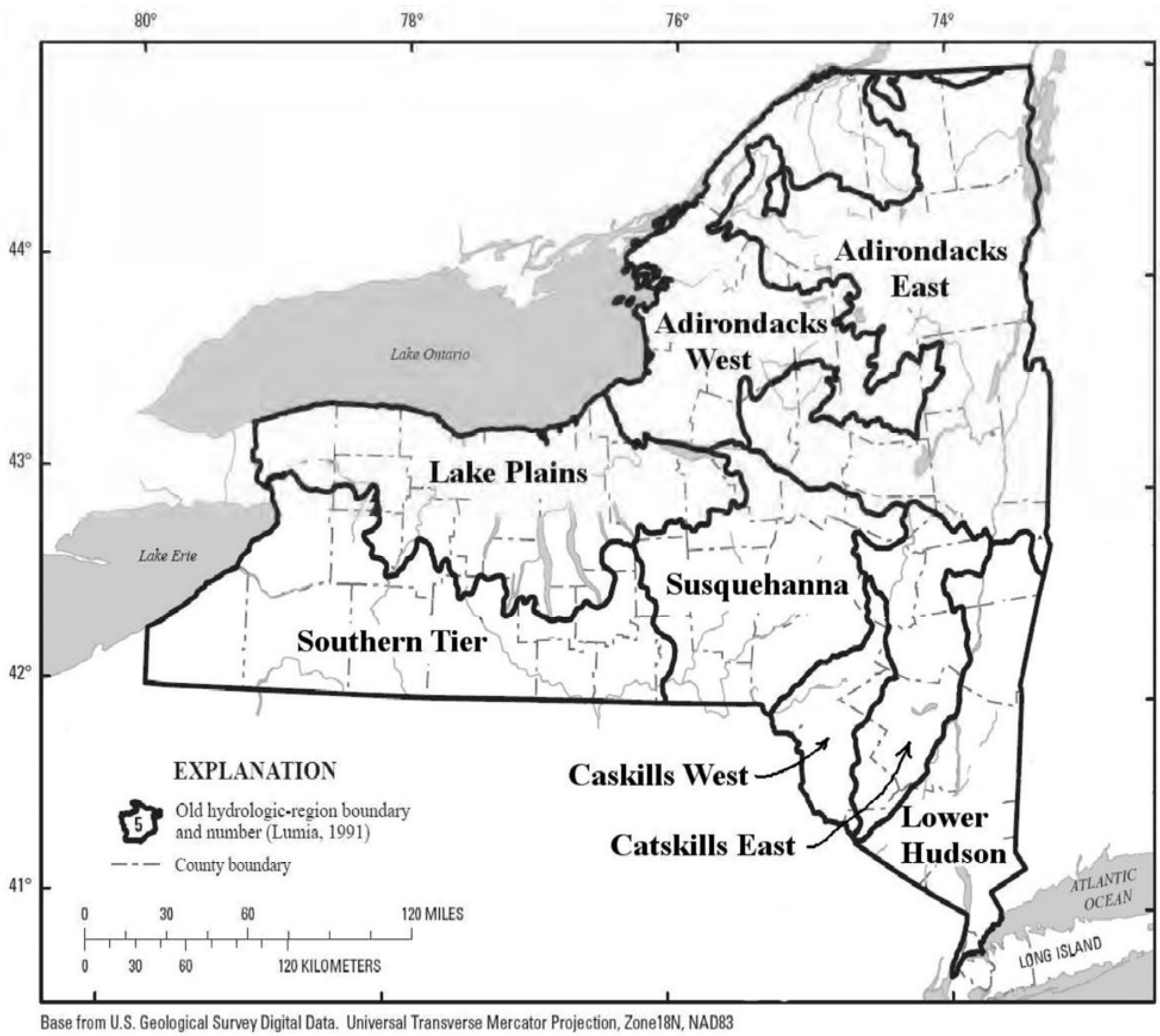


Figure 3.7 Hydrologic Regions in New York State

Bank Full Hydraulic Geometry vs. Drainage Area for Selected Hydrologic Regions

Bank Full Hydraulic Geometry Tables have been produced for each of eight geographic regions of the State: 1) Western Adirondacks, 2) Eastern Adirondacks, 3) Lower Hudson, 4) Catskills East, 4a) Catskills West, 5) Susquehanna, 6) Southern Tier, and 7) Lake Plains. Regional boundaries were established based on variability in the physiographic features and climate between each region. If the drainage area is known, the tables found in Appendix C give dimensions that can be used for the emergency reconstruction of stream channels.

The drainage area (D.A.) and can be found by:

- Using the USGS *StreamStats* website found at: http://water.usgs.gov/osw/streamstats. Instructions for use are found on the left side of the web page. Click on "State

Applications" to access New York. Additional instructions for using the USGS NY State site are in **Appendix D.**

- Using maps created by DEC, available for each county, to be made available on the DEC website.

<u>Note:</u> The Bank Full Stream Channel Statistics can also be calculated using *StreamStats;* however, presently the USGS website does not calculate the necessary construction dimensions that can be found in the Bank Full Hydraulic Geometry Tables found in Appendix C.

Based on the Regional Bank Full Hydraulic Geometry Tables, SWCD staff can design a typical cross section that can be used for the emergency reconstruction of a severely damaged stream. These tables are to be used for <u>emergencies only</u>! An example Regional Bank Full Hydraulic Geometry Table is shown below in **Figure 3.8.** A typical stream channel cross-section would look much like the one shown below in **Figure 3.9**.

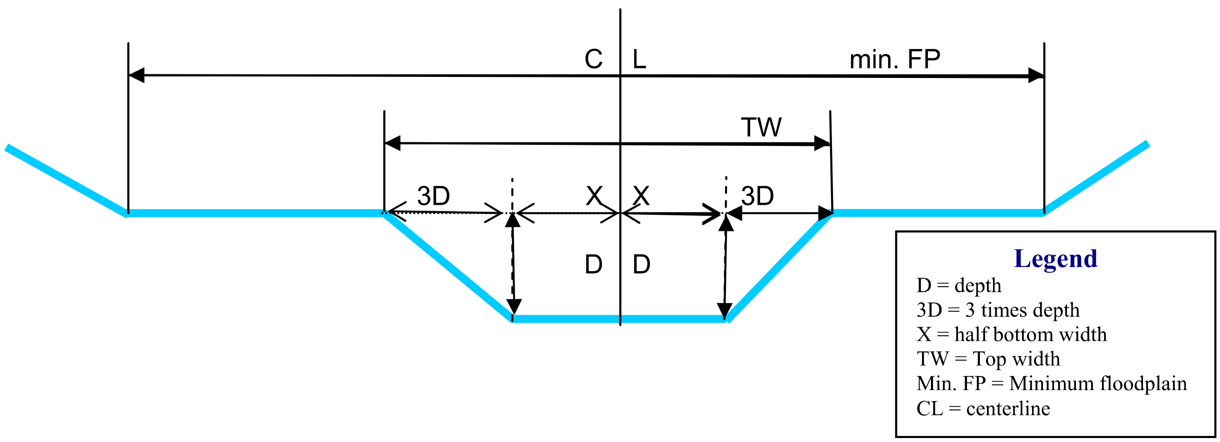
Figure 3.8 Example Regional Bank full Hydraulic Geometry Table

				Construction Dimensions					
DA (sq. mile)	Bank-Full Area (sq. ft)	Bank -Full Width (ft)	Bank-Full Depth (ft)	channel bank side slope	D (ft)	3D (ft)	X (ft)	TW (ft)	Min. FP (ft)
1	7	8.1	0.9	**2:1**	1.3	2.6	1.5	8.1	18
2.5	16	13.9	1.2	**2:1**	1.5	3.0	4.0	13.9	31
5	31	21.1	1.5	3:1	2.1	6.3	4.3	21.1	46
7.5	46	27.0	1.7	3:1	2.3	6.8	6.7	27.0	59
10	60	32.0	1.9	3:1	2.4	7.3	8.7	32.0	70
12.5	73	36.6	2.0	3:1	2.5	7.5	10.8	36.6	81
15	87	40.9	2.1	3:1	2.6	7.9	12.5	40.9	90
17.5	100	44.8	2.2	3:1	2.7	8.2	14.2	44.8	99
20	114	48.6	2.3	3:1	2.8	8.5	15.8	48.6	107
22.5	127	52.1	2.4	3:1	2.9	8.8	17.3	52.1	115
25	140	55.5	2.5	3:1	3.0	9.0	18.7	55.5	122
27.5	153	58.8	2.6	3:1	3.1	9.3	20.1	58.8	129
30	166	62.0	2.7	3:1	3.2	9.5	21.5	62.0	136
32.5	179	65.0	2.7	3:1	3.2	9.7	22.8	65.0	143
35	191	68.0	2.8	3:1	3.3	9.8	24.2	68.0	150
37.5	204	70.8	2.9	3:1	3.4	10.1	25.3	70.8	156
40	217	73.6	2.9	3:1	3.4	10.3	26.5	73.6	162
42.5	229	76.4	3.0	3:1	3.5	10.4	27.8	76.4	168
45	242	79.0	3.1	3:1	3.5	10.6	28.9	79.0	174
47.5	254	81.6	3.1	3:1	3.6	10.8	30.0	81.6	180
50	267	84.2	3.2	3:1	3.6	10.9	31.2	84.2	185

To determine the dimensions of a typical stream cross-section that can be used for the emergency reconstruction:

1) Select the table for the drainage basin that your project is in.
2) Select the drainage area (DA) in the selected table that most closely matches the DA at your project site.
3) Under "Construction Dimensions" read the channel dimensions tabulated.
4) Build the channel to these "approximately bank full" channel dimensions.

Figure 3.9 Typical Stream Cross Section for Emergency Stream Intervention



Classroom Examples on How to Use Bank Full Hydraulic Geometry Tables

Some examples are provided below using the tables. The answers are provided below each example with a detailed explanation.

Example 1:

Flooding has occurred in Woodhull, NY in the south Branch of Tuscarora Creek and repairs work is needed on a small stretch of stream. There is a bridge ¼ mile downstream of the affected area with a drainage area of 19.6 square miles. Using the appropriate Regional Bank Full Hydraulic Geometry Table from Appendix C, find the following:

a) Bank full width b) Bank full depth
c) Bank full area d) Floodplain width

Answer to Example 1:

- Determine the geographic region in which the site is located. In this case, it is in the Southern Tier Region (see figure 3.7). Use the Southern Tier table.
- Locate in the table the drainage area (DA) for the site. If there isn't an exact match, use the table value that is slightly higher than the actual site value. In this case, the closest DA is 20.0 square miles.
- The answers are highlighted in the table below:
  - Bank full width = 59.3 ft. Bank full depth = 2.47 ft.
  - Bank full area = 127.88 ft^2 Floodplain width (FP) = 130.45 ft.

Southern Tier Region

Bank Full Hydraulic Geometry vs. Drainage Area for Selected Hydrologic Regions

				Construction Dimensions					
DA (sq. mile)	Bank-Full Area (sq. ft)	Bank -Full Width (ft)	Bank-Full Depth (ft)	channel side slope	D (ft)	3D (ft)	X (ft)	TW (ft)	Min. FP (ft)
1.0	17.60	16.90	1.04	3:1	1.38	4.13	4.32	16.90	37.18
2.5	32.28	24.81	1.30	3:1	1.62	4.85	7.56	24.81	54.58
5.0	51.08	33.17	1.54	3:1	1.85	5.55	11.04	33.17	72.98
7.5	66.80	39.31	1.70	3:1	2.01	6.02	13.63	39.31	86.49
10.0	80.82	44.35	1.82	3:1	2.13	6.39	15.78	44.35	97.57
12.5	93.68	48.70	1.93	3:1	2.23	6.70	17.65	48.70	107.13
15.0	105.70	52.56	2.01	3:1	2.32	6.96	19.32	52.56	115.64
17.5	117.06	56.07	2.09	3:1	2.40	7.20	20.84	56.07	123.35
20.0	127.88	59.30	2.16	3:1	2.47	7.41	22.24	59.30	130.45

Example 2:

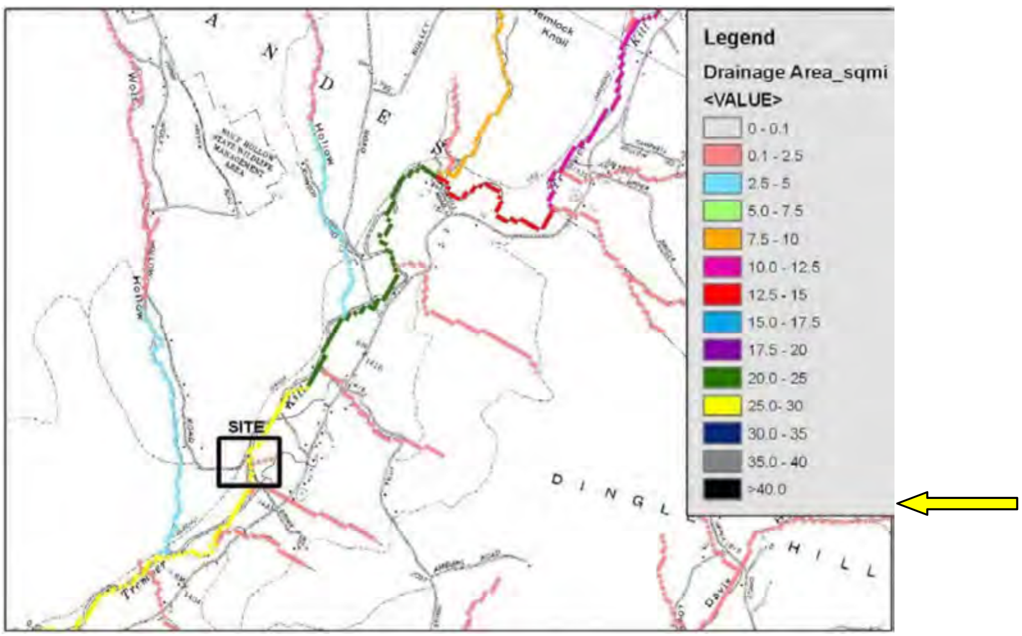
Flooding has occurred in Andes, NY on a portion of the Tremper Kill stream near Wolf Hollow Road. From the map provided below, determine the approximate Drainage Area (DA), then use the appropriate table to determine the approximate construction dimensions.

Answer to Example 2:

- On the map below, the reach in question is color-coded yellow. The key tells us that this means that the DA is between 25 and 30 square miles; therefore we will use the values for the 30 square mile drainage area.
- The project is located in the East Branch Delaware River basin, and falls within the "Catskill West" region. Use the table for this physiographic region.

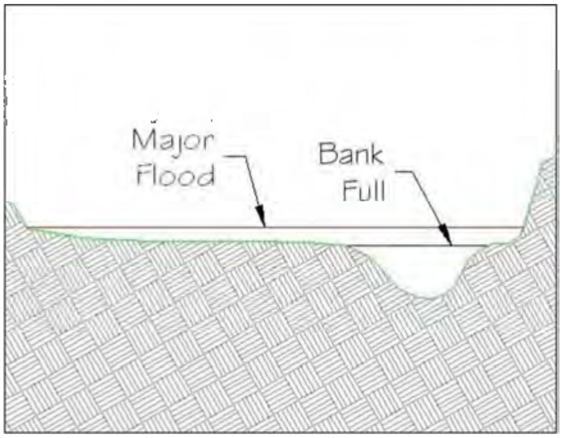
- Under D.A. we find 30, then reading across under the heading Construction Dimensions we get the following answers:
    - D = 3.1 ft
    - 3D = 9.3 ft
    - X = 19.8 ft
    - TW (top width) = 58.1 ft
    - Min. FP (minimum floodplain) = 127.8 ft

It is best practice to make a sketch of the cross section using these dimensions, and then refer to the sketch during stakeout and construction.



Re-connecting Floodplains

When streams are disconnected from floodplains by berming or dredging, the natural balance is disrupted – often with undesirable impacts. Berms are described as an earthen embankment or wall, usually built to provide protection or a result of side casting during stream channel dredging. **Figure 3.10** shows the same flood event occurring in both diagrams. The diagram on the left depicts slow, shallow water on the floodplain. The diagram on the right shows the same water volume, but the floodplain access has been blocked with a berm. There is a lot of water and energy that is stored behind the berm. If the structure fails it could cause devastation in its path. It is, therefore, an important component of any long-term restoration project to give prioritization to floodplain re-connection.



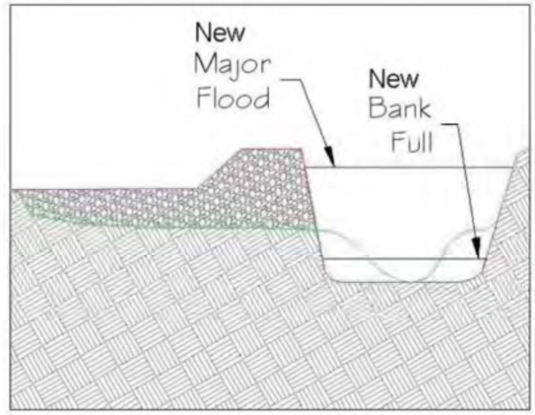


Figure 3.10 Shows the same flood situation on a fully functional floodplain vs. a filled in floodplain and berm.

Figure 3.11 is picture of a functioning floodplain during a storm event. Notice the slow moving water with low energy moving on the floodplain. **Figure 3.12** is picture of a berm protecting a corn field that was breached during a storm event. Notice the high energy that was released when the berm was compromised and destroyed the field.

Figure 3.11 Functioning Floodplain

Figure 3.12 Berm that was breached in 2005 storm event

Post-Flood Intervention using Bank Full Hydraulic Geometry Tables

SWCD utilized the Regional Tables during the 2006 flood event in the Town of Walton. The photographs below are before and after channel re-construction efforts.

Figure 3.13 is a picture taken after the flood and before any stream construction has begun. The stream was filled with debris and sediment. Construction consisted of excavating the stream channel using dimensions determined from the Regional Tables.

Figure 3.13 Shows stream channel after flood event.

Figure 3.14 is a picture at the same location taken after stream channel construction. Notice a floodplain was constructed.

Figure 3.14 Stream channel after Post Flood Intervention.

Figure 3.15 was taken two years later at the same location. The stream has kept the general form of the cross section with a few natural adjustments. The stream is stable with minimum efforts.

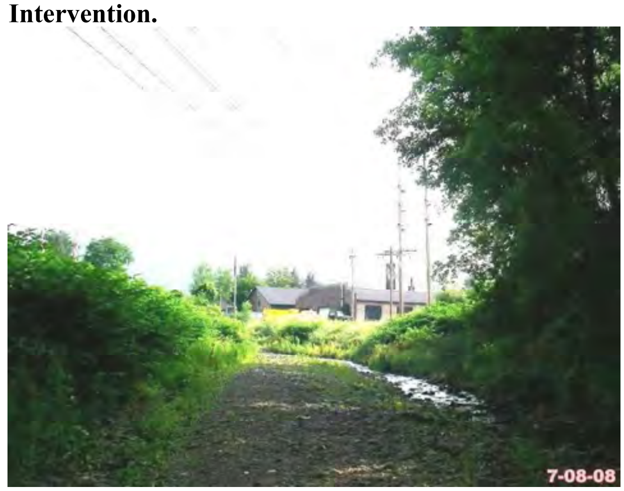


Figure 3.15 Two years after Post Flood Intervention.

Effect of Slope on Post-flood Emergency Reconstruction

If the stream slope is found to be 4% or greater in the mountainous regions of New York, the stream *will* almost inevitably have a step-pool sequence. If the stream slope is 2% - 4% the stream *could* be a step-pool sequence. Step-pool sequence requires special construction measures and designs, such as cross-vanes or other structures designed to mimic the operation of step-pools. In post-flood emergencies, there is not enough time for such design and implementation. In an emergency, immediate priority requires the channel be constructed as has been previously described using the Regional Tables. Stream work on a steep grade will require careful monitoring. Contact SWCD or DEC to monitor the repair work, and if necessary, devise and implement a long-term stabilization program. If it is not an immediate priority or you are not sure how to proceed, please contact SWCD or DEC.

Consideration of Upstream and Downstream Impacts

Impacts upstream and downstream of a stream restoration project always need to be considered. For example, if a streambank is to be armored with rip rap or other hard material, consideration must be given to increased velocities and erosion potential on an opposing downstream bank. Likewise, if a restoration project is designed to improve sediment transport through a reach, deposition potential downstream must be assessed. It is a goal with natural stream channel design to not only repair an impacted reach but to *not* create undue stress elsewhere in the stream system.

Using Vegetation and Natural Channel Design Structures

Woody debris can be found in abundance after a flooding event. The large amount of debris poses huge problems such as difficulty removing the debris from the stream, disposal once removed, and the cost of disposal. The simplest solution is to utilize the woody debris onsite for streambank stabilization.

Figure 3.16 Root wads were placed in two layers with large boulders or logs to hold them in place

Woody debris can be utilized in post-flood intervention saving time and money to implement additional projects. Placing a large tree into the streambank oriented so that the root mass is facing the water pointing upstream and the trunk is buried into the bank, is referred to as a root wad (see **Figure 3.16**). The bottom of the root ball should be below the channel grade to avoid the toe of the root wad to be washed out and be braced with boulders or crisscrossed with other logs. Several layers maybe necessary to get the depth of the structure below the stream channel bed. The exposed root mass dissipates water, protects the streambank and provides good aquatic habitat. Root wad details can be found in **Appendix-E**.

Figure 3.17 shows a stream that has been impacted by the 2006 flood event. The stream's original channel was to the left of the willow tree and an agricultural field is located on the right where the stream is now flowing. Note the location of the willow in both pictures. **Figure 3.18** shows the stream placed back into the original channel using the Regional Hydraulic Geometry Tables and typical cross-sections. The large woody debris found on-site was used as root wads to protect the streambank and newly formed floodplain.

Figure 3.17 Stream impacted by the 2006 Flood.

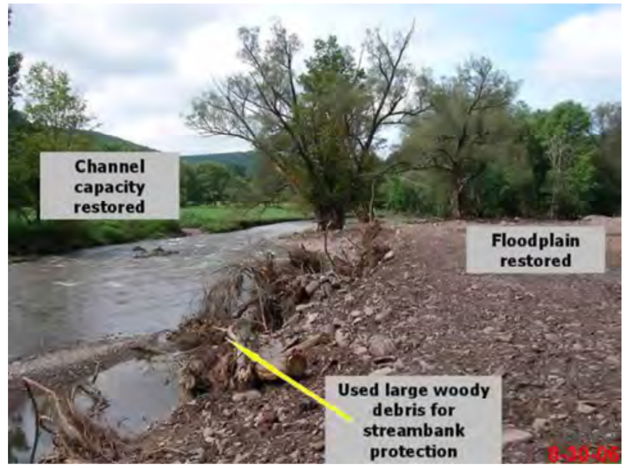


Figure 3.18 Stream construction using Regional Bank full Hydraulic Geometry values, typical cross-section and root wad.

Natural channel structures can be used to reduce stress on the streambank by re-directing stream flow toward the center of the stream. These typically include single arm vanes or cross-vanes that are made out of large rocks but logs maybe used in some small streams. Rock vane structures are built with layers of large rocks, one layer that is well-footed below the stream bed, and well-tied into the stream bank. The vane arm slopes from the top of the stream bank to the stream bed. A rock cross-vane is simply two single arm vanes with a throat in the center (**Figure 3.19**). Vegetative plantings are done around both at the ends of the vane arms (where they are tied into the stream bank). There is, however, a standard design for using them in restoration projects requiring technical data and they are expensive to be placed, so this option may not be feasible without funding.

Figure 3.19 Rock Cross-Vane

Limiting Gravel Removal

As storm flows subside, bed material overlaps and becomes wedged together like shingles; this process is called imbrication. Bed material mobilizes during high water events, and when the water velocity slows down, the material drops out. This interlocking material becomes less mobile. Rearranging the stream bed and banks loosens the interlocking material, and allows the material to become more transportable in the next highwater event. **Figure 3.20** is an example of imbrication after the June 2006 food. Gravel removal at a project site should be given careful consideration. Some gravel bars, such as transverse bars (those bars across a stream that direct flow toward a stream bank), center bars (those in the center of a stream with flow on both sides), or deposition near drainage structures should be considered for removal. Point bars (those on the inside of a bend) actually serve a hydraulic function (**Figure 3.21**). Point bars are formed by lack of stream energy on the inside of a bend and are partially eroded away during flood events, then are re-deposited as flood flows subside. Removing point bars will reduce stream energy at low flows, thereby creating potential for increased deposition in the form of transverse and/or center bars.

Figure 3.20 shows imbrication after the 2006 flood.

Figure 3.22 shows downcutting after dredging.

A straightened stream will also adjust itself. Notice in **Figure 3.22**, how the stream was manipulated into the classic parabolic shape. This adjustment was made after the June 2006 flood event, and this photo was taken in October 2006. The stream has adjusted itself by downcutting approximately 6 feet and eroding the streambanks. The stream will continue to adjust by transporting loosened sediment downstream until it reaches equilibrium and re-builds a floodplain at a new elevation.

Figure 3.21 Looking upstream at a point bar in the Tremper Kill Sub-basin

Environmental Permitting

Compliance with State and Federal Environmental Permitting Laws will need to be established before work can commence. This compliance will need to be documented prior to receiving any Federal Emergency Management Agency (FEMA) or State Office of Emergency Management (SOEM) disaster relief funds. Work without the necessary permits can lead to significant fines and the need to redo the project and possible no reimbursement from funding agencies.

The DEC regulates activities in and around the water resources of New York State pursuant to the Environmental Conservation Law (ECL) Article 15, Title 5, Protection of Waters Program and the federal Clean Water Act, Section 401 Water Quality Certification (WQC) Program. An Article 15 Permit is required for temporary or permanent disturbances to the bed or banks of a stream with a classification and standard of C(T) or higher and for excavation and fill in Navigable Waters. An Article 24 Freshwater wetland permit may also be needed if State protected Wetlands are present.

Examples of activities requiring this permit are:

- Placement of structures in or across a stream (i.e., bridges, culverts or pipelines);
- Fill placement for bank stabilization or to isolate a work area (i.e., riprap or other forms of revetment);
- Excavations for gravel removal or as part of a construction activity;
- Lowering streambanks to establish a stream crossing;
- Use of heavy equipment in a stream to remove debris or to assist in-stream construction.

A state Water Quality Certification is required for any project that required Federal permitting or funding (*e.g.* FEMA funds).

DEC Permit Procedures

In addition to normal permitting procedures, the DEC has two expedited permitting processes available to respond to emergency and disaster situations.

<u>Emergency Authorizations (EA)</u>

- Issued for emergency actions to protect life, health, property and natural resources
- Written pre-notification & plan required (For municipalities, notification within 24 hours if pre-notification is not possible)
- DEC must certify or deny the EA within 2 business days
- Expire in 30 days; ca be renewed for an additional 30 days

<u>General Permits for Disaster Recovery</u>

- Expedited review process
- Valid for all restoration work not just Emergencies
- Available for a set period after a Natural Disaster (i.e. 6 months)
- Expiration date is variable
- These permits can be issued during a site visit or in response to an application received at the DEC office

- For more information see **Appendix F** – Stream Disturbance Permit Regulations in Natural Disasters

Emergency Authorizations (EA) and Permit Conditions

All Emergency Authorizations and Permits will contain enforceable conditions designed to ensure that the project will not impact adjacent landowners, protect natural resources and maintain state water quality standards. These conditions will include:

- Isolating and dewatering the work area
- June 15 – September 30 work windows for trout waters where practicable
- Proper bedding of culverts
- No discharge of turbid waters
- Proper stabilization and re-vegetation of work site

For permit applications and any questions regarding the permit process, contact the Regional Permit Administrator at your local regional DEC office as listed on the DEC website at: http://www.dec.ny.gov/about/39381.html.

Protection of Waters permit information is also available on the DEC website: http://www.dec.ny.gov/permits/6042.html.

Local Municipal Floodplain Development Permits

Nearly every municipality in New York State participates in the National Flood Insurance Program. A condition of program participation is that any development within a mapped Special Flood Hazard Area (area that has a one percent or greater chance of being flooded every year, often called the 100-year floodplain) must receive a floodplain development permit from the municipality. The definition of "development" is:

"any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials." (FEMA regulations, 44 CFR 59.1)

Prior to any excavation, dredging, or grading, the local floodplain administrator, usually a building code or zoning official, must approve the plan. Approval is based on a determination that the development will not result in physical damage to other property, such as stream bank erosion and increased flood velocities.

Some locations have detailed flood maps that include regulatory floodways. The floodway is a narrower portion of the floodplain that must be kept free of encroachment in order to pass the base flood flow without causing any increase in flood elevations. They are shown on Flood Insurance Rate Maps as cross hatched areas within the floodplain, or for maps published prior to 1988, they are shown on separate Flood Boundary and Floodway Maps. No encroachment into any regulatory floodway is allowed by local laws passed to comply with FEMA regulations unless an engineering analysis is performed that concludes that the encroachment will not increase the base flood elevation (elevation of the one percent annual chance flood) by any measurable amount.

The Department of Environmental Conservation serves as the state National Flood Insurance Program coordinating agency and in the role, provides technical assistance to local communities and others on how to comply with floodplain development requirements. The Floodplain Management Section of DEC can be reached the DEC's regional offices, or at 518-402-8185, or by e-mail at fldplain@gw.dec.state.ny.us.

U. S. Army Corps of Engineers (USACE) Permit Requirements

Section 10 of the Rivers and Harbors Act requires a permit from the USACE for any work (including structures) in or affecting navigable waters of the United States.

Section 404 of the Clean Waters Act requires a permit for any activities that involve or result in the discharge of fill material into waters of the United States. Waters of the United States include: 1) navigable waters and adjacent wetlands, 2) tributaries to navigable waters and wetlands, regardless of their DEC classification.

Typical flood response actions that require a permit are:

- Channel shaping
- Sediment removal
- Bank stabilization
- Culvert and bridge repair or replacement
- Road repair or replacement that takes place in water
- Cofferdams or temporary fills required to complete the work

Minor projects with minimal individual and cumulative impacts may be authorized under general permits including Nationwide Permits. Many Nationwide Permits require pre-construction notification to the USACE prior to the commencement of work, especially if the activities:

- Are located in or near wetlands
- Are located in or near riffle pool complexes
- May affect historic property
- May affect endangered species

All terms and conditions of the Nationwide Permit must be complied with even if pre-construction notification or prior written approval of the USACE is not required. Special conditions, such as monitoring requirements, may be added to a permit by the USACE to assure that impacts are minimal.

The U.S. Army Corps of Engineers also has emergency procedures (33 CFR Part 325.2), which may be used to authorize work when their existing permit processing procedures are not timely enough for responding to emergency work.

DEC ***no longer forwards permit applications to the Army Corps***. The applicant must send a copy of the application to the Army Corps. If the emergency is a federal declared disaster, the

USACE will accept complete jurisdictional inquiry forms which are available from State Office of Emergency Management (SOEM).

Nationwide permits may be used to authorize the types of activities typically done in response to flooding events:

- Nationwide Permits 3 – Maintenance
- Nationwide Permit 13 – Bank Stabilization
- Nationwide Permit 27 – Aquatic Habitat Restoration, Establishment, and Enhancement Activities
- Nationwide Permit 33 – Temporary Construction, Access and Dewatering
- Nationwide Permit 37 – Emergency Watershed Protection and Rehabilitation
- Nationwide Permit 45 – Repair of Uplands Damaged by Discrete Events

Nationwide Permits, like all permits from the USACE, require compliance with:

- Wild and Scenic River Act (Delaware River)
- Section 7 of the Endangered Species Act
- Section 106 of the National Historic Preservation Act

If a project would affect any of these conditions then notification will be triggered.

For more information contact the regional USACE office at:

For DEC Regions 1, 2 and 3
US Army Corps of Engineers NY District
ATTN: Regulatory Branch
26 Federal Plaza, Room 1937
New York, NY 10278-0090
email: CENAN.PublicNotice@usace.army.mil

For DEC Regions 1, 2,
Westchester County and
Rockland County - (917) 790-8511

For the other counties
of DEC Region 3 -(917) 790-8411

For DEC Regions 4, 5
Department of the Army
ATTN: CENAN-OP-R
NY District, Corps of Engineers
1 Buffington Street
Building 10, 3rd Floor
Watervliet, NY 12189-4000
(518) 266-6350 - Permits team
(518) 266-6360 - Compliance Team
email: cenan.rfo@usace.army.mil

For DEC Regions 6, 7, 8, 9
US Army Corps of Engineers
Buffalo District
ATTN: Regulatory Branch
1776 Niagara Street
Buffalo, NY 14207-3199
(716) 879-4330
email: LRB.Regulatory@usace.army.mil

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