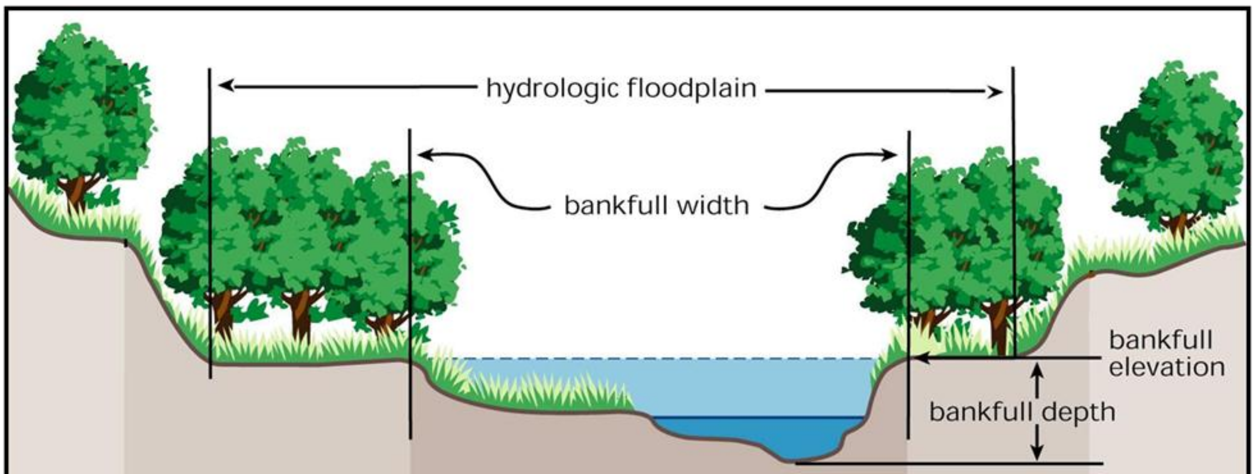
April 12, 2011

AN INTRODUCTION TO RIVER CHANNEL EVOLUTION

Rivers are complex systems that respond to many variable, ever-changing forces that interact temporally and spatially over broad scales. Rivers evolve over time to develop and maintain the shape that will most efficiently move water, sediment and debris in response to constant changes in the environment including its contributing watershed. This most efficient form is called a state of dynamic equilibrium. See Figure 1.



Natural Equilibrium Conditions of a Stream Channel: Floodplain and Bankfull Width and Depth

Figure 1

Since Euro-American settlement, profound land use changes, flood plain and riparian corridor encroachments and stream channel modification, including ditching, dredging and armoring, have led to widespread loss of both floodplain function and the riparian corridor within which dynamic equilibrium may be accommodated. Changes to the shape of river channels or changes in the inputs of water and sediment have led to imbalance, causing physical adjustments in river and floodplain geometry until dynamic equilibrium is re-established. Adjustments resulting from natural changes have been largely magnified during the past two centuries by human-imposed alterations to the depth and slope of rivers, related to intensive watershed and riparian land uses.

Alluvial channels (stream channels formed in stream-deposited sediments), in response to external stressors such as changes in watershed hydrology, gravel mining, straightening, and armoring, evolve through predictable stages as the river adjusts (i.e., eroding and depositing) to re-establish its dynamic equilibrium. This channel evolution process was originally modeled by Schumm in 1984. See Figure 2.

Understanding river channel evolution processes and recognizing the stage of evolution of a particular stream reach can bring important insights for river management and the evaluation of stream alteration project design alternatives.

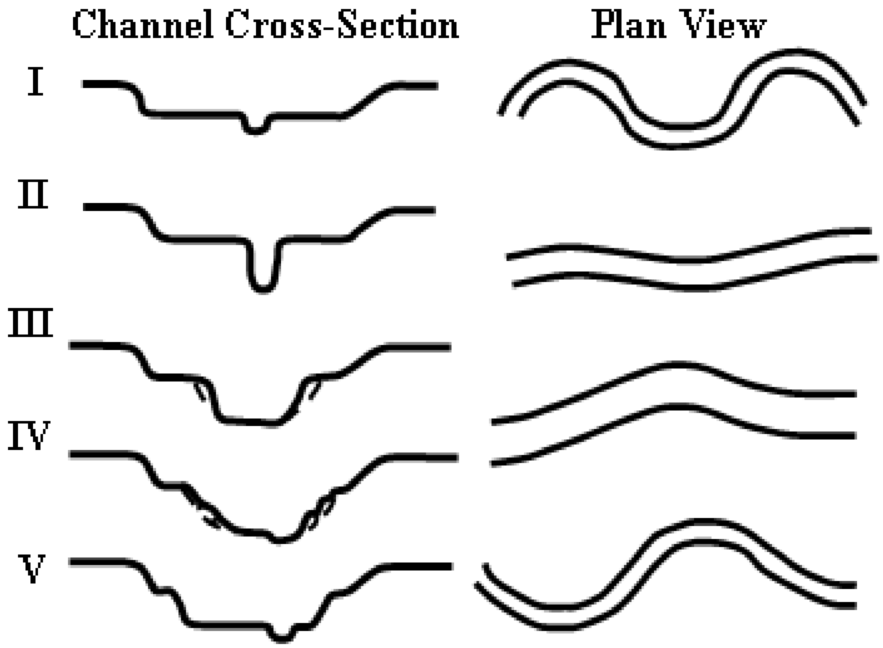


Figure 2: Channel Evolution Process

STAGE I: NATURAL EQULIBRIUM A channel evolution model begins with an undisturbed river in which natural channel forming processes are in dynamic equilibrium. The channel flow has access to flood-plain or flood prone areas at discharges at and above the average annual high flow. The river plan form is moderate to highly sinuous and supports energy dissipating bed features (steps, riffles, runs, pools) that are essential to channel stability. Channel slope (vertical drop in relation to length) generates flow velocities and stream power in balance with the resistance of stream bed and bank materials, and sediment transport capacity is in equilibrium with sediment load.

STAGE II: CHANNEL INCISION The natural balance in dynamic equilibrium is disturbed and channel down cutting begins after the stream becomes more energized with increased flows, or with the steepening that comes about when channels are straightened, bermed and rip-rapped to make way for flood control, farming, houses, driveways, and culverts. At Stage II the stream channel is deeply incised with steep banks that prevent floodplain access at discharges at and above the average annual high flow.

STAGE III: WIDENING The channel down cutting continues, greater flows are contained within the channel and widening ensues with repeated bank failures on both sides of the river. The channel becomes a featureless plane bed without the riffles and pools that dissipate the erosive energy of water.

STAGE IV: AGGRADATION The channel widening continues with severe erosion. In a wider channel the water is more spread out and less powerful and so the bed begins to aggrade with depositing sediments. Bar features develop to the sides and the narrower channel begins to shift back and forth. The different flood chutes in the channel continue to erode terrace side slopes as a juvenile floodplain widens and forms. See Figure 3. Historically in Stage IV, channels were dredged, bermed and armored, which served to push the process back to Stage II or Stage III.

STAGE V: FLOODPLAIN RE-ESTABLISHMENT The new floodplains are established and the channel adjustment process is complete. Channel dimension, pattern, and profile are similar to the pre-adjustment form in Stage I but typically at a lower elevation in the landscape. Planform geometry, longitudinal profile, channel depth, and bed features produce the energy necessary to move the quantity and size of sediment produced by the stream's watershed. At this dynamic equilibrium, the river has regained a natural balance of water flow and sediment flow and the rate of bed scour and bank erosion is diminished.

Figure 3 West Branch, Stowe: Channel Evolution Stage IV. Channel incised, old flood plain abandoned now as a terrace, channel widening and forming a new flood plain at a lower elevation.

A large proportion (74%) of alluvial streams in Vermont is in stages II-IV of active channel adjustment in the channel evolution process. See Figure 4. Vermont River Management Engineers apply the river channel evolution model to evaluate stream reaches in the field to assess the likelihood of success or any proposed stream alteration project. If the project design does not accommodate or is not compatible or consistent with the channel evolution process, the project is either likely to fail, or will transfer the conflict to another location along the stream. The Vermont Rivers Program will work with property owners and towns to resolve conflicts between human investments and the dynamics of streams in a manner that promotes stream equilibrium conditions.

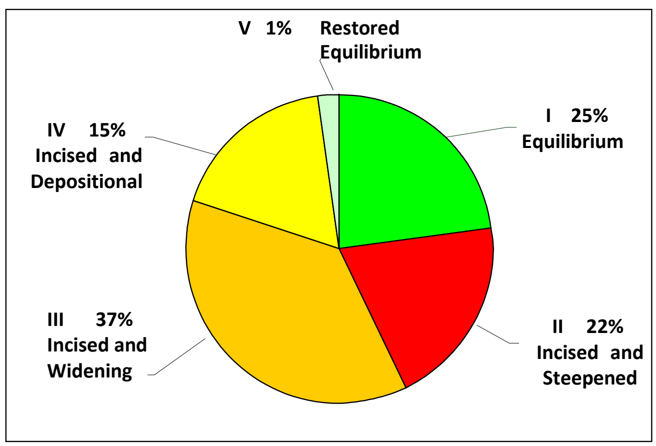


Figure 4

Rivers Program Engineers are available to evaluate and provide technical assistance for new projects, as well as the repair, replacement or retrofit of instream structures that require permitting. **Please contact the Vermont Rivers Program** to discuss stream equilibrium and your project options. Please visit our web site at: www.anr.state.vt.us/dec/waterq/rivers.htm