INTRODUCTION TO DYNAMIC EQUILIBRIUM

Starting in the spring of 2011, at the direction of the Vermont legislature, the Vermont Rivers Program will expand its responsibility for managing stream alteration activities to cover all perennial streams in the state. As part of this change, the Agency of Natural Resources has adopted a Stream Alteration General Permit to assist in the increased regulatory requirements associated with the jurisdictional expansion, and to enable and support the continuation of technical services historically provided to the public by Agency River Management Engineers.

The primary goal of the Rivers Program is to manage conflict between the dynamic nature of rivers and streams (fluvial systems) and human investments along stream corridors, avoid the exacerbation of existing and the creation of new conflicts, and support the reduction of existing conflict.

The cornerstone supporting the accomplishment of state river management objectives is the concept of natural or dynamic equilibrium. Stream equilibrium, as described here, is a balancing process associated with set of inter-related stream physical adjustments that naturally maintain stream channels in their most efficient and least erosive form. The term “dynamic” is important, as the energy of a stream is always at work sustaining or re-establishing its equilibrium condition. Our human impacts at site-specific or watershed scales can upset the dynamic equilibrium thereby triggering a process of stream adjustments as the system attempts to re-establish balance. Stream Equilibrium as illustrated by Lane is shown in Figure 1.

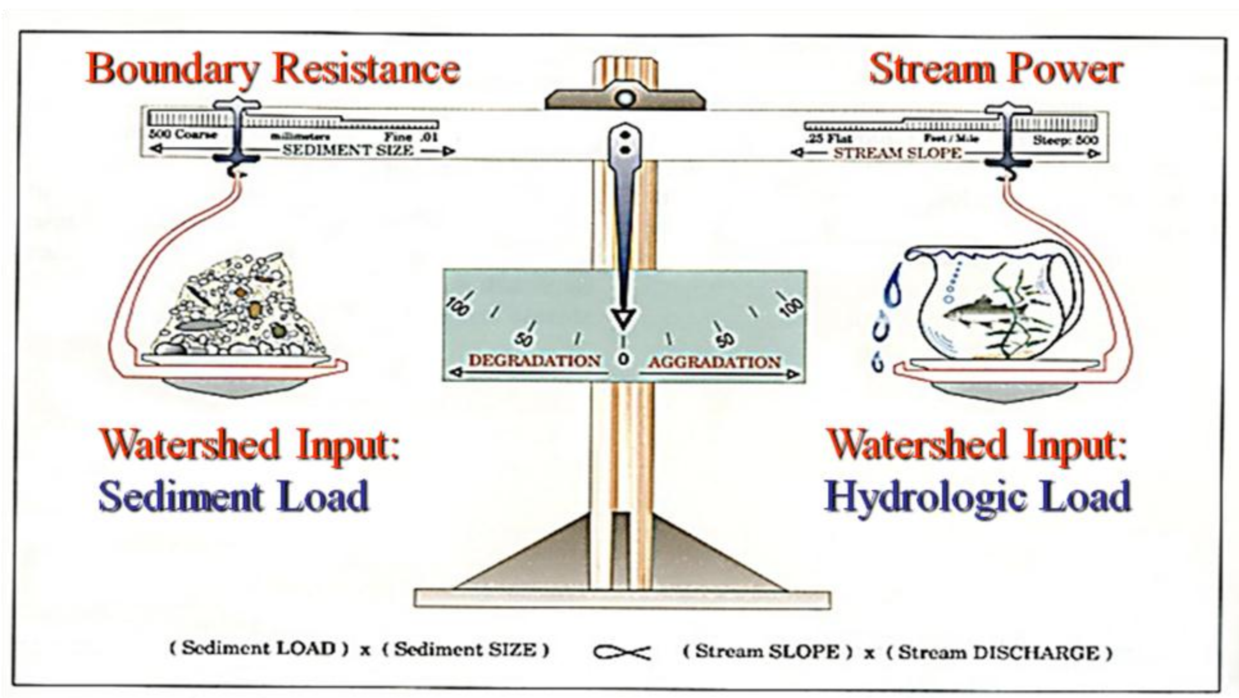

Figure 1 Lane’s Balance illustrating stream equilibrium conditions.

It is important to note that most streams in Vermont, in response to historic intensive channel management, flood plain and riparian corridor encroachments, and watershed land use change are actively adjusting their width, depth, longitudinal slope, bed elevation, and plan form, as they seek to re-establish equilibrium. This process can take many decades and over this time, the stream can manifest dramatically different forms. See an *Introduction to Channel Evolution*.

It is also important to note that development within riparian corridors such as residential and commercial development, roads and railroads, and other public infrastructure may be so extensive as to preclude a stream from ever again achieving equilibrium. The most significant consequence of this is the loss of the resilience, energy attenuation capacity, and ecosystem services provided by fluvial systems able to fully express their dynamic equilibrium. Flood inundation and fluvial erosion hazards are exacerbated, flood-related economic losses are perpetuated and public safety is endangered.

Act 110, which passed in 2010, recognizes the importance of equilibrium conditions and the need to provide streams with a protected corridor wherein natural adjustments may occur. In mandating the establishment of a state River Corridor Management Program, Act 110 defines a public interest in promoting natural stream stability. Therefore, regulating stream alterations and addressing fluvial erosion hazards requires an understanding of stream and river dynamics. Considering any activity that may alter a stream, we must ask: what processes are forming this stream and its floodplain; what is a naturally stable condition at this location; and how will the proposed activity affect the attainment and maintenance of dynamic equilibrium conditions?

The science of fluvial geomorphology involves how rivers shape and interact with the elements of their watershed and landscape setting. The water flow erodes the land and stream channel and moves sediment downstream creating deposits in the stream channel and on the floodplain. We see the erosion, movement and deposits of sediment over time as the stream shifts course and the river meanders side to side within the valley. Vermont's stream geomorphic assessment protocols describe the **four fluvial processes** that may represent natural adjustments in streams and rivers: they are degradation, aggradation, widening, and planform change. A dynamic equilibrium or balance of erosion and depositional processes means that the four fluvial processes are in a mature stage of development as an overall natural adjustment process. When the river reaches its least erosive form, there is a balance of fluvial processes, and we tend to see slow, natural meandering rivers. We notice dramatic channel adjustments and increased flood damage when fluvial processes are not in balance. This imbalance or disequilibrium is most often seen as the long-term effect or our activities on the land and in the stream channel.

Degradation is the incision or downcutting process whereby the stream bed lowers in elevation through erosion of bed material or channel scour. Channel degradation may occur when there has been a significant increase in flows, a significant decrease in sediment supply, or a significant increase in slope due to a loss of channel sinuosity or floodplain access; typically associated with channelization. Incision occurs quickly during periods of high storm water runoff. Some streams incise so deeply that they become entrenched streams. Other streams, in more confined valleys,

Degraded channel and loss of floodplain access are naturally entrenched and are not characterized as degraded unless evidence of the downcutting process is observed, such as a stream headcut working upstream. Bedrock outcrops significantly slow headcut incisions and are considered “control points” in the channel forming process. Degradation can be seen as freshly eroded, steep stream banks, gravel bars eroding on the downstream end and as scour at bridge footings.

Aggradation is the raising of the bed elevation through an accumulation of sediment. Channel aggradation may occur when there has been a significant decrease in flows, a significant increase in sediment supply (upland erosion), or a significant decrease in slope due to transitions in valley slope or natural or human imposed constrictions such as a bridge, culvert or fill encroachment.

Channel widening is often caused by the containment of higher flows within an incised, usually straightened channel. After the initial channel degradation process, the resultant over-steepened banks, and the confinement of flood flows due to loss of flood plain access, generate higher velocities leading to stream bank erosion. Bank failure leads to a widening of the channel cross section as a balance between the increased energy and the resistance of the channel boundaries is re-established. Ultimately, if adequate space is available within the riparian corridor and human intervention is absent, a new flood plain will form within the active channel at a lower elevation than historically, and an equilibrium longitudinal channel slope will be achieved through plan form adjustment to greater sinuosity.

Widening related to aggradation and the formation of a mid-channel bar.

Planform Change is often associated with channel adjustment toward equilibrium through increasing or decreasing the longitudinal slope. The longer, or more sinuous the channel in relation to its rate of change in bed elevation, the less energy the river has to erode bed and bank and transport sediment. The opposite relationship is true for shorter, steeper channels. Active plan form change is the physical response of the system to re-establish dynamic equilibrium when changes in slope, sediment, or watershed hydrology are pushed out of balance.

New channel meanders in Randolph after the 1927 flood

Plan form change is a natural process in response to other adjustment processes, but too often is from our misguided efforts to straighten the river through different channel management activities. A channel avulsion is an abrupt, catastrophic change in course that may come about from a log debris jam, an undersized road crossing, a discontinuity in sediment transport, or bank instability. When a river changes planform and cuts a new channel, a change in channel slope usually results, sometimes initiating another set of channel adjustment processes, starting with degradation if the channel slope is increased, or with aggradation if the slope is decreased, and leading to channel widening and planform change. Adjustments continue until equilibrium condition is achieved and the river settles into the least erosive form.

Dynamic equilibrium can look very different from stream reach to stream reach depending on the dominant sediment regime. The sediment regime exerts a significant influence upon whether the equilibrium state tends to be degradational, vertically stable, or aggradational. Stream reaches can be classified into three dominant sediment regimes.

Source reaches, typically located in valley-confined headwater areas, produce more sediment than is captured or stored within the reach. Source reaches therefore tend to degrade or scour down into the landscape over time and are often associated with steep, unstable stream banks that frequently fail catastrophically as landslides.

Transport reaches, typically located in moderate gradient, semi-confined to unconfined valley locations, achieve a balance in the volume of sediment transported into and through to downstream reaches. When In equilibrium, transport reaches are vertically and laterally stable because of the balance of sediment input and output. However, transport reaches are often seen as highly unstable because they have typically suffered the greatest amount of human manipulation and are attempting to evolve into the form that re-establishes dynamic equilibrium.

Storage reaches are typically associated with low gradient, meandering rivers in unconfined valley locations. Storage reaches receive a greater volume of sediment from upstream than they are able to transport to downstream reaches. Zones of transition from transport to storage reaches are highly dynamic as the channel responds to the sediment supply through aggradation and lateral migration.

Rivers Program Engineers are available to evaluate 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 to balance social, economic and environmental impacts for all of us and future generations. Please visit our web site at: www.anr.state.vt.us/dec/waterq/rivers.htm