CHAPTER TWO: THE CONCEPTUAL FRAMEWORK: NATURALLY STABLE STREAMS ADDRESS MULTIPLE NEEDS

Avoiding Excessive Erosion and Deposition

The purpose of this document is to provide a consistent, logical and easily understood system for government personnel and project sponsors and consultants to evaluate proposed projects which may affect stream corridors. The conceptual framework which provides this consistency is the recognition that we attain the goal of healthy, non-degraded stream systems by protecting and restoring a balance among the naturally occurring variables which affect or determine the stability of the stream corridor. The variables we are most concerned with here involve the proper width of the channel, the proper depth, a functioning corridor of plants and a channel slope in balance with the valley slope and channel sinuosity (channel length). These variables are all affected by the sediment supply to the streams. An easily discernible condition of “destabilization” is a stream corridor that is or is about to be subject to excessive erosion and/or excessive deposition and has or will have a degraded vegetative corridor along the stream banks, floodplain and terrace slopes.

Potential watershed and or stream channel disturbance activities can be linked to specific reactions which watersheds and streams make in response to them, thereby causing a predictably undesirable environmental degradation. A simple and common example of an activity that destabilizes a stream channel is the narrowing of a channel by adding riprap, retaining walls or some other “hardscape” to the stream banks. The channel, which is now too narrow, will compensate by eroding deeper, with the frequent consequence of eroding the streambed out from under “hardscapes” placed on stream banks to protect them. The hard materials, such as rock and concrete, then collapse into the channel. This commonly occurring situation would of course, represent excessive erosion. The condition of excessive deposition can be caused by a number of watershed and channel conditions but a common example is represented with the situation where a culvert is placed too high in a stream channel crossing and it acts as a partial dam, slowing and trapping the sediment being transported by the stream and filling the culvert and stream channel.

Regulatory, restoration, stream protection and grant programs have the common objectives of preventing impacts to stream stability and/or restoring stream stability. This circular, then, directs its user to avoidance and corrective measures which can be applied in order to prevent or reverse the degradations. It is important to repeat that this guide does not intend to provide specific design solutions to replace or modify project proposals. This document is intended to provide a step by step project evaluation process and step by step planning process to avoid unnecessary impacts to stream corridors and prevent well intentioned but counter productive stream modifications.

Integrating River Science and Engineering

Many Engineers and environmental planners are familiar with what is being referred to as “the geomorphic” approach to stream and river management. The term “geomorphic” is derived from the discipline of fluvial geomorphology which is concerned with the study of how water forms the physical features of the earth. An easy to use “short-hand” for “geomorphic approach” is “river science” approach which recognizes how the behavior of streams is related to watershed, streamside and in-stream channel conditions. In the past two decades river engineering, or the modification of streams and rivers for flood, erosion control, and stormwater management has undergone a substantial advancement. This advancement has involved improving the conventional tools used in the past by hydraulic engineers who specialized in converting natural river systems into engineered canals, by combining the analytical concepts contained in hydraulic models with natural river science.

The river scientists understand how the natural components of river systems including watershed conditions, valley and channel slopes, low water discharges as well as flood discharges, channel meanders, riparian vegetation, sediment loads and transport affect the outcomes of human interventions on rivers, their floodplains and watersheds.

Federal water project planning and design documents have provided a new set of design criteria for river management projects on the basis of the integration of the two fields of hydraulic engineering and fluvial geomorphology. This represents a major engineering design paradigm shift in which the old assumption was that environmental features of rivers such as streamside vegetation, meanders and floodplains conflicted with hydraulic engineering practices and objectives. The newer current river project design context is that natural stream dynamics and features are not in conflict with the hydraulic engineer's objectives of flood and erosion control but that these environmental components when integrated with hydraulic engineering produce the best engineering.

The hydraulic engineers and river scientists have arrived at a mutually supporting definition of channel stability which is the overall principle supporting this circular. A channel is considered to be in balance –or in "equilibrium" when the sediment supply entering a stream channel is approximately equal to the sediment supply exiting the stream system. This is another way of expressing the concept that there is not excessive erosion or excessive deposition. At the same time different "schools" of river planning and management have developed to help guide management and design practices to meet this equilibrium objective. Some practitioners emphasize or are more comfortable with one or more schools but they can all be successfully combined and work in a complementary manner.

These "schools" or approaches to river protection, management and restoration include those who apply regional information on the "hydraulic geometry of river channels" to arrive at stable channel designs. This is often referred to as the "empirical school" because it is based on field observations and measurements of river channels, their discharges and shapes. This school recognizes, for example, the physical relationships between the stable dimensions of river channels and their discharges and the sizes of drainage areas of the rivers. It recognizes other physical relationships such as the widths of stream channels with the lengths of channel meanders, the spacing of pools and riffles and shapes of meanders.

Another "school" of river study and management focuses on watershed processes and relies on an understanding of how the changing relationships between stream discharges, sediment quantities and sizes interact to affect the degradation or aggregation of channels and stream slopes. This school can develop simple or complex models of how watershed conditions such as precipitation, discharge, sediment, geology, soils, slopes, vegetation, land use changes and channel modifications can affect river channel reactions over time.

A third school applies quantitative analytical models to estimate flood discharge and stage relationships, the sediment budgets affecting river channels, and sediment transport conditions. This is the domain of hydraulic engineers who apply continuity, flow resistance and sediment transport equations to describe the forces operating on river dynamics. This discipline is creating a new generation of more complex models that help support the new paradigm of returning the natural functions and features of rivers. For example, new modeling tools such as two-dimensional models are helping us understand more about the interactions of flows between river channels and floodplains.

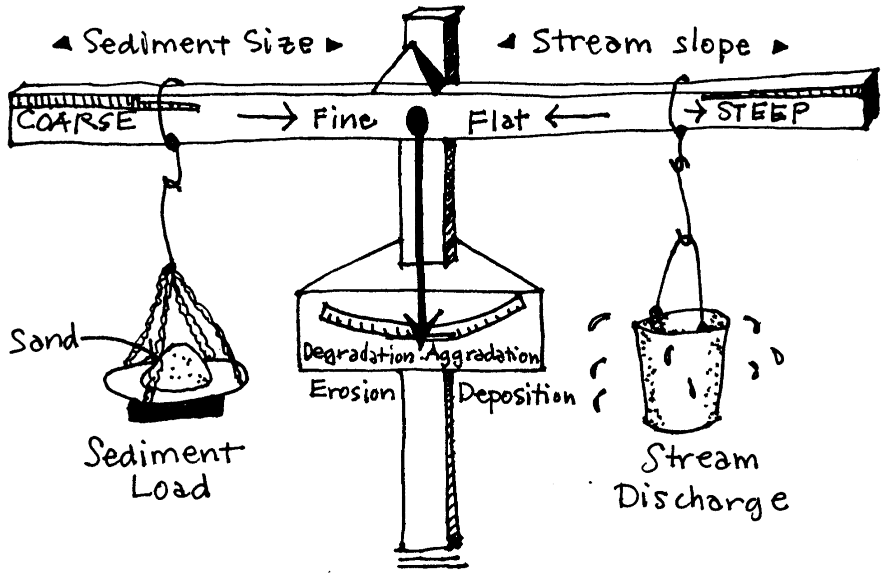
Finally, a fourth evolving "school" entails the classification of watershed or river types to help organize information on river channels to better apply it to the design of healthy in-balance river systems. Classification schemes are applying information from the empirical and watershed processes schools to address river restoration and management problems. A concept widely in use that is derived from this school is the use of information from stable channels to correct the instabilities of the same kind of channel which is in degradation condition. This is referred to as the use of "reference" channels.

This circular is intended to support without prejudice recognition of the positive contributions of all these schools of river management. The planning processes described by this circular can employ one or all of these schools in any combination.

The Concept of Stable Channels

The stability of stream channels is directly linked to the water quality of our waterways. The first task therefore, is to describe what is meant by the concept of "stability." The term "stability" as it is used by this document describes a condition in which the sediment sizes and loads, water discharges, and channel shapes and slopes are in balance. This balance is often referred to as an "equilibrium" condition among the variables which interact to determine the stream system. These variables include the stream valley slope, stream channel slope, sediment loads, sediment sizes, discharges, roughness of the stream channel, and bankfull channel widths and depths. Figure #1 shows an illustration frequently used to describe this concept of equilibrium, called Lane's scale.

FIGURE 1 LANE'S SCALE



Lane's Scale
A.W. Lane, "The Importance of Fluvial Morphology in Hydraulic Engineering"

As mentioned, a widely accepted way to apply the concept of equilibrium to a stream or river channel is to establish that the sediment loads entering a channel are equal to those leaving it. The term "graded stream" is often used interchangeably with the phrase "a stream in equilibrium", and refers to a stream, for which over a period of time, its slope and channel characteristics are adjusted so that the available water discharges have just the energy and velocity required for the transportation of the sediment load from the drainage basin. The condition of this equilibrium or stability can be viewed over a long time scale in which channels take years to make adjustments to ever changing watershed conditions. Equilibrium can also be viewed as a short-term objective, in which we define the management task at hand as avoiding excessive erosional and depositional instabilities. In this short-term context it is easy to define the channel that is unstable and not in equilibrium. An unstable channel is one in which deposition requires regular removal and dredging maintenance programs to protect channel capacities and habitat or fish passage. An unstable channel is also one in which its banks are collapsing, or the bed is eroding down at a rapid rate.

In the recent past, conventional engineering practices have attempted to attain "stable" channels by using channelization, levees, floodwalls, concrete or gabion retaining walls, riprap, rock, sheet piling, rubble, weirs and grade control structures. The logic of "locking" the channels into an immobile condition to avoid the influence of the natural forces and variables acting on the behavior of streams has been reevaluated as a result of observing several decades of stream and river responses to this concept of stream channel control. The natural response of channels in reaction to these controls has been to undermine the very structures meant to accomplish the stabilizing. Concrete has cracked and failed, grade control structures have induced erosion and collapsed and streams have eroded around bank protections. The steam responses have been consistent enough over time to now understand how conventional engineering such as channel straightening, culverting, grade control structures, vegetation removal, floodplain encroachment, riprap, etc., can in fact lead to unintended and undesirable steam instabilities. The system described here therefore recognizes a more sophisticated and effective path to "stream stability" that works with the inclination of the natural variables to create stability as opposed to employing the counter-productive strategy of trying to overcome the natural processes of streams.

The conceptual framework for the criteria contained in this document follows the guidance provided by a coordinated effort of 15 federal agencies which produced a stream restoration manual in 1998 ("Stream Corridor Restoration, Principles, Processes and Practices," by a Federal Interagency Stream Restoration Working Group, coordinated by Natural Resources Conservation Service) and guidance from recent Army Corps of Engineers engineering memoranda and reports (among them:" Stream Management," by J. Craig Fischenick and Hollis, April, March 2000, US Army Corps of Engineers). Please refer to Appendix A for a more complete list of supporting publications.