How Streams Work

Streams and rivers are integral parts of the landscape that carry water and sediment from high elevations to downstream lakes, estuaries, and oceans. Healthy streams migrate laterally over time and maintain a "dynamic equilibrium" with their contributing watershed. When that "dynamic equilibrium" is upset, such as by rapid changes in development patterns, streams cannot respond quickly enough to adjust the other physical processes to accommodate increased runoff or sediment loads. Instead they experience extensive – and undesirable – erosion and sedimentation that sets off a sequence of undesired consequences. Thus, it is important to understand how streams work so that watershed management and land use decisions can support the natural characteristics of the receiving streams and maintain their "dynamic equilibrium".

When rain falls in a watershed, it either runs off the land surface into streams or lakes, infiltrates into the soil or evaporates. As surface runoff moves downslope, it concentrates in low areas and forms small stream channels. These are referred to as "ephemeral" channels that only carry water during rainfall runoff. Downstream from ephemeral channels are "intermittent" streams, which carry water during wet periods of the year. These streams are partially supplied by ground water rising to the surface as stream baseflow. Intermittent streams dry up periodically as ground water levels decline in drier seasons. Further downstream where baseflow is large enough to sustain stream flow throughout the year, "perennial" streams are formed.

The size and flow of a stream are directly related to its watershed area and geology. Other factors which affect channel size and stream flow are land use, soil types, topography, and climate. The "geomorphology" (or size and shape) of the channel reflects all of these factors.

One way of categorizing stream size is by "stream order". "First order" streams are the uppermost perennial tributaries in the watershed and have not yet intersected another perennial stream. When two "first order streams" intersect, they form a "second order" stream; when two "second order" streams intersect, they form a third order stream and so on. The first order figure illustrates how the streams that make up a small watershed would be categorized by stream order. In the study area, 54% of the land area drains to first order streams, and 53% of the total stream miles are comprised of first order streams. First order streams are very small in size and in flow volume and, therefore, are much more vulnerable to impacts on water quality and quantity than larger streams.

While streams and rivers vary greatly in size, shape, slope, and bed material, all streams have common characteristics. Streams have left and right streambanks (looking downstream) and streambeds consist of mixtures of bedrock, boulders, cobble, gravel, sand, or silt and clay. Other physical characteristics of streams include pools, riffles, steps, point bars, meanders, floodplains, and terraces. All of these characteristics are related to the interactions among climate, geology, topography, vegetation and land use of the watershed. The study of these interactions and the resulting streams and rivers is called "stream (or fluvial) geomorphology."

Stable streams migrate across the landscape slowly over long periods of geologic time while maintaining their form and function. Naturally stable streams must be able to transport the sediment load supplied by the watershed. Stream instability occurs when increased runoff and scouring causes the channel to incise (downcut or degrade) or when increased sediment load and excessive deposition causes the channel bed to rise (aggrade). The product of sediment load and sediment size is proportional to the product of stream slope and discharge (or stream power). A change in any one of these variables causes a rapid – and usually undesirable - physical adjustment in the stream channel.

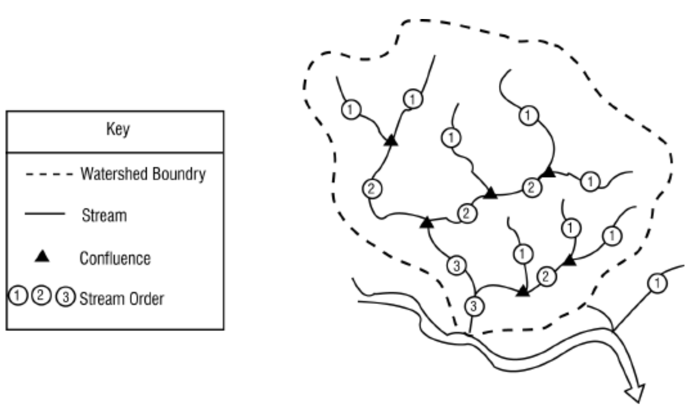
The most important stream process in defining channel form is the "bankfull discharge". Bankfull discharge is the flow that transports the majority of the stream's sediment load over time and thereby forms the channel. The bankfull stage, during bankfull flow, is the point at which flooding may begin to escape the stream channel and enter the floodplain. On average, bankfull discharge occurs approximately every 1.5 years. In other words, each year there is about a 67 percent chance of having a bankfull streamflow event. Because of its important role in maintaining the form and function of stable streams, it is important to manage watersheds to maintain a stable bankfull streamflow. In affected channels, flooding may occur before bankfull stage, if the channel is aggraded, and may not occur at bankfull stage is the channel is degraded.

Stream width generally increases in the downstream direction in proportion to the square root of discharge. Stream width is a function of discharge, sediment transport, bed and bank material, and vegetation along the riparian edge of the stream. Vegetation along the stream corridor provides resistance to erosion, food for aquatic species, shade to moderate stream water temperature, and filtering of sediments and pollutants prior to reaching the stream.

Natural streams have sequences of riffles and pools or steps and pools that maintain the channel slope and stability (see figure). The riffle is a bed feature with gravel or larger size rocks. The water depth is relatively shallow and the slope is steeper than the average slope of the channel. At low flows, water moves faster over riffles, which provides oxygen to the stream for fish and aquatic insects. Riffles are found entering and exiting meanders and control the bottom elevation of the stream. Pools are located on the outside bends of meanders between riffles. The pool has a flat slope and is much deeper than the average depth of the stream.

A stream and its floodplain comprise a dynamic environment where the floodplain, channel and bedforms evolve through natural processes that erode, transport, sort and deposit alluvial materials. The result is a "dynamic equilibrium" where the stream maintains its natural dimension pattern and profile over time, neither "downcutting" or "aggrading". Land use changes in the watershed and channelization can dramatically upset this balance. A new equilibrium may eventually result, but not before large adjustments occur in the channel form, such as extreme bank erosion or channel downcutting. By understanding and applying natural stream processes to stream and watershed management, land uses within the watershed can be accommodated while maximizing the stream's natural flow-carrying ability and its biological potential. (adapted from NC Cooperative Extension Service 1999)

Illustration of first order streams and the stream order concept. (Schueler , 1995(a))



Hydrologic cycle showing rainfall, runoff, infiltration, ground water flow, and stream network (taken from North Carolina Cooperative Extension Service, 1999)

Riffles and pools in the stream (Adapted from North Carolina Cooperative Extension Service, 1999)