Some Effects of Channel Roughness on Stream Flow

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A boundary layer exists between any surface and the fluid with which it comes in contact, and between which there is relative velocity. It has been observed on many streams that a thin layer of water adjacent to the channel walls does not move with the same velocity as the main flow. This layer may be thought of as consisting of a number of thin parallel bands each having a slightly higher velocity than its inner neighbor. Finally a band is reached that has the same velocity as does the main flow. This layer is known as the boundary layer. It has been observed on many streams, but more especially on those which have very rough channel walls and whose beds are boulder strewn. Many of these streams studied are in the Duluth, Minnesota area, some are in the vicinity of Lander, Wyoming, and in Yellowstone Park.

Close observation will show that even streams flowing through alluvium have a thin layer of water adjacent to the channel walls that does not move at all, but instead clings to the slightly roughened walls. Water very near the wall may be seen to move slowly downstream, but it may move upstream, even when the main flow is going over a cascade or fall. The upstream movement of water is not general over any great length of wall, instead it may be seen for a few inches here and there. If the velocity of the stream is very great, the boundary layer will leave the channel wall for a short distance. This may be seen when a stream has a very steep gradient. The narrow band of foaming water on each side of the channel is the boundary layer. The boundary layer may grow in width so much that the main flow is squeezed so as to be invisible. Commonly the boundary layer is not foamy.

A turbulent boundary layer develops from a laminar one, but it has a laminar sub-layer. If channel roughness is such that the projections due to roughness extend beyond the laminar sub-layer into the turbulent layer, there is a thickening of the turbulent layer and a corresponding increase in frictional resistance. Downstream from each protuberance the boundary layer increases in width, thus it will have a jagged edge along a very rough wall.

Boulders jutting above the water in the main flow, divide it, but it unites immediately downstream from the wake, an area of so-called "dead water" that forms behind an obstruction. If stream velocity is low the boundary layer adheres to the boulder. With an increase in velocity the boundary layer leaves the surface of the boulder and two vortices form at the downstream end of the boulder and are opposite each other. The boundary layer is beginning to break away from the boulder. A further increase in velocity makes the break away more noticeable. The vortices at this stage are larger and better developed. They extend their bounds and, eventually break away. They die out a little farther downstream in the main flow. Other vortices grow and follow them so that there is a regular procession of vortices leaving the "vortex street". The vortices are detached periodically, either in pairs or alternately from each side.

Because of the gradient in the boundary layer, the velocity on the underside of, for instance, a grain of sand on the stream bed, is less than that on top. It is because of this Magnus effect, that the sand grain which lies a little higher on the bed than those near it, is lifted up through the boundary layer. If the grain is small it will be held in suspension by the stream, but if it larger it will fall back on the bed as soon as it has risen above the boundary layer for it has then lost its lift. The velocity gradient near the bed may be changed if water seeps down into the bed.

The boundary layer is of importance in the study of the suspended load of a stream for it explains saltation. Turbulence is said to arise in the boundary layer in most instances, and it is associated with difussion.

Literature Cited

1. Jones, Melville. 1937. Profile Drag. Proc. Royal Aeronautical Society.