

New Gaging Station for Mountain Streams

Forest Service Installation Combines a San Dimas Flume with Two Broad-Crested Weirs

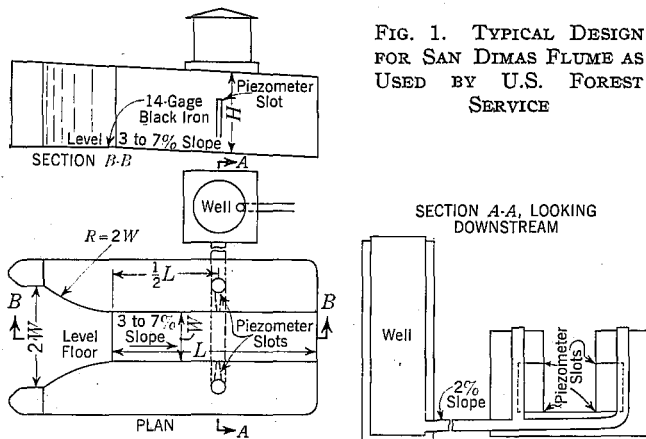
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ONE of the many duties of the Forest Service of the U.S. Department of Agriculture is the investigation of watershed management. A phase of this subject is the measurement of the flow of mountain streams, which varies through a wide range. To measure and record these varying quantities, a type of gaging sta-

tion which combines a flume and two broad-crested weirs has been developed at the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colo. Mr. Wilm discusses the accuracy with which extremes of flow in flashy mountain streams may be measured by this type of installation.

As a part of its investigations in watershed management, the Forest Service is having to make accurate measurement of the flow of mountain



streams, usually small in size, but subject to wide ranges of flow. On many streams ordinary stream-gaging stations, sharp-edged weirs, or flumes have not proved satisfactory because of the influence of unstable stream beds and moving bed-loads on the relation of discharge to depth.

Experience in measuring mountain streams for experimental purposes has shown that the following requirements must be met by any gaging station designed for this purpose:

1. Adaptability to a wide range in flow. Protracted ground-water flow should be measured within a range of 5% above or below the true discharge. At the same time the station must be capable of handling with reasonable accuracy, peak discharges up to several hundred times the ordinary minimum.
2. Stable and easily determined "rating" characteristics. The cross-section should be simple and regular, to facilitate calibration in field or laboratory.
3. Relatively high flow velocities in the measuring section. Velocities must be high enough so that any debris or bed-load reaching the station is carried through the measuring section rapidly and without deposition.

A stream-gaging station designed to meet these requirements is now in

operation in the Manitou Experimental Forest in Colorado. The measuring section for normal flow consists of a 2-ft wide San Dimas flume made of reinforced concrete, with a floor of 14-gage iron to minimize erosion by bed-load material and to insure a stable friction factor for the flume. Placed on bedrock in the stream channel, this flume collects and measures discharges ranging from 0.75 to 30.0 cu ft per sec.

SUPERCritical VELOCITIES WITHIN THE FLUME

In principle the flume resembles a broad-crested weir, with pressure measurements taken at the longitudinal midpoint of the weir (Fig. 1). To obviate the removal of contractions by silting, the ordinary bottom contraction is entirely replaced by a cylindrical transition of 4-ft radius, as shown in an accompanying photograph. Approaching this channel constriction the stream, if flowing rapidly, passes through a hydraulic jump and enters the transition at a velocity below the "critical." Then, leaving the transition and entering a rectangular channel set at a grade of 5%, the flow drops through Belanger's "critical" depth and proceeds through the flume at a shooting velocity.

The width and depth of the San Dimas flume are designed for accurate measurement of the normal range



GAGING STATION IN MANITOU EXPERIMENTAL FOREST, COLORADO, FROM DOWNSTREAM
Normal Flow Measured in 2-Ft Flume, Peak Discharges Over One or Both of Adjacent Broad-Crested Weirs

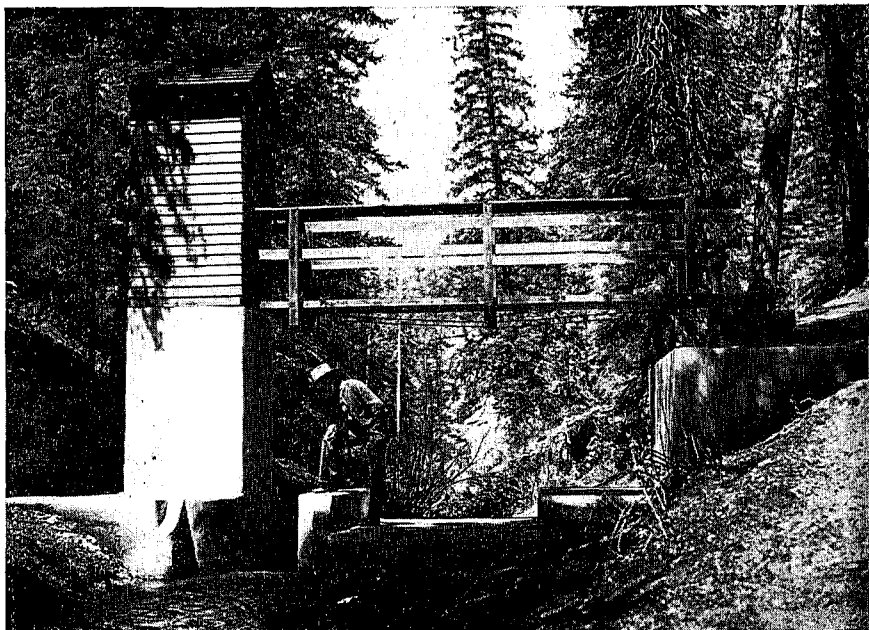
of stream flow, which prevails perhaps 90% of the time. Excessive rates, which occur rarely and need not be measured with great accuracy, are handled by broad-crested weirs adjacent to the flume. One of these, 6 ft wide and 1 ft deep, is placed at an elevation of 2 ft above the flume floor, with a wall separating it from the flume. After water depths in the pool upstream of the structure exceed 2 ft (about 1.18 ft in the flume at the piezometers), flow is measured in both flume and weir, a single depth being recorded in the stilling well. A second weir, simply a broad step at a higher elevation, is designed to handle the possible maximum flood—about 600 cu ft per sec in the station illustrated. These weirs must of course be calibrated in the field. Discharges for the whole structure are rated for depths in the single stilling well.

Since March 1940, when this gaging station was installed, the recorded stream flow has not been great enough to permit complete calibration of the broadcrested-weirs. Some discharges have been measured through the lower weir, however, and ample data have been obtained for the flume to bear out the results of laboratory model tests and to demonstrate the accuracy with which discharges may be computed from recorded water depths.

CLOSE COMPARISON OF RATING FORMULAS

Field rating data for the flume have agreed very closely with figures obtained by extrapolation of model results. A "field" formula for the flume, $Q = 13.95 H^{1.276}$, was derived by fitting a logarithmic straight line by "least squares" to 10 measurements of depth and discharge obtained in July 1940. Subsequently 12 other measurements were made over a period of about 21 months. The measured discharges were compared with values computed from the original least-squares formula. All field measurements were made by means of a velocity-head rod operated by several different observers. The model formula, $Q = 14.20 H^{1.28}$, was computed from laboratory observations of depth and discharge obtained in 1937 on a one-quarter scale model of the San Dimas flume. In both these formulas Q = discharge in cu ft per sec, and H = depth in ft, measured in the stilling well.

Considering the long period of time over which the field data were taken, these figures conform with pleasing accuracy to both field and model formulas. The model formula appears high; still, the greatest deviation of field discharges from this formula was under $4\frac{1}{2}\%$. As compared to the field formula, 11 observed discharges fell below, and 11 above, the computed values, and the greatest deviation of ob-

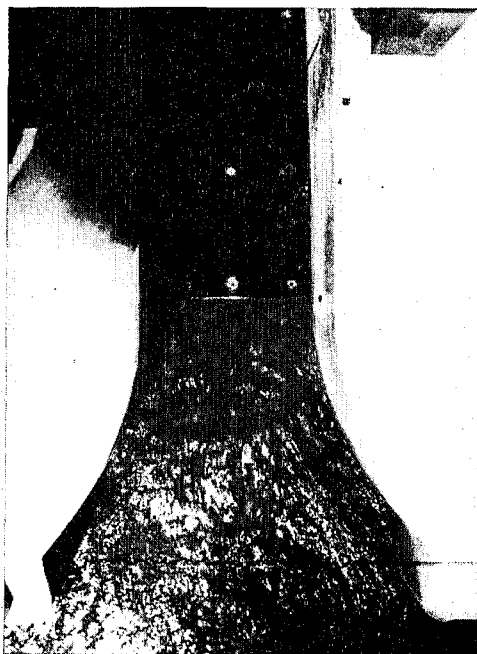


GAGING STATION FROM UPSTREAM

Cylindrical Flume Transition Appears at Left

served from computed values was 4.27%. A new rating formula, $Q = 13.953 H^{1.276}$, fitted to all 22 points, conforms almost exactly to the original field formula. The standard error of estimate for the new formula is $\pm 2.00\%$, and the correlation coefficient is $+0.9999$. These results seem to indicate quite conclusively that the San Dimas flume, as installed in this station, is satisfactorily accurate and stable in its discharge characteristics over a considerable range in both time and rate of flow.

Sufficient data have been obtained on discharges over the 6-ft broad-crested weir to demonstrate the approximate relation of discharges through the flume and weir to depths measured in the single well. To fit the observed values, a rating formula was prepared by the method of least squares. This formula is $Q = 9.7035 H^{2.8477}$, in which Q is the discharge for the flume and the weir together, and H is the depth of water in the flume. The errors of these discharges are somewhat greater than those of the flume alone (standard error of estimate $= \pm 4.56\%$), largely, it is believed, because of small variations in depth of water in the flume corresponding to a given depth on the weir. Such variations are to be expected and the resulting errors in discharge are a necessary sacrifice, offset by the need for only a single record of water depths. To obtain more precise data on depths and discharges over the weir, a second recorder and piezometer well would be required. At this particular station the additional precision is unnecessary, since up to August 1942, flow had passed over the broad-crested weir during only 2 of the 28 months that the station had been in operation.



VIEW OF FLUME FROM ABOVE

Note Smooth Sloping Floor and 4-Ft Entrance Width, Twice That of Flume Proper