HIGHWAY BRIDGES AND CULVERTS*

By M. A. Lyons
Chief Engineer, Good Roads Board, Manitoba

WHEN should a bridge be built, and if it should be built at all, how large should the opening be? These are the most difficult of the problems to be solved in connection with any bridge project.

It is evident that a bridge must effect some real saving to economically justify its construction. This saving may be one of distance over which loads must be hauled, or persons must travel, or it may be a saving effected by an increase in the size of the load which may be hauled, due to its construction. As it costs about 35 cents per team-mile to haul a load, it is seen that the money in cents which can be spent on a bridge in order to save distance is thirty-five times the team-mile saved. For example, if the construction of a bridge will save a haul of five miles to five persons who have forty loads to send to market each year, the total justifiable yearly expenditure would be $350. On a wooden bridge this would justify the expenditure of about $2,500, or on a permanent bridge of about $4,500. Likewise, when the cost of auto traffic is 15 cents per mile, a saving of two miles for an average traffic of four cars per day for 200 days per year would effect a yearly saving of $240, or, taking the two suppositions together, an annual saving of $570, which would justify the expenditure of $8,000 on a bridge lasting thirty years. The amount of justifiable expenditure due to a saving effected by an increase in the weight of the load which can be hauled by the construction of the bridge will also vary as the traffic, and, when the amount of the traffic is known, the economical expenditure can be ascertained.

This, however, is only the economic side, and is, perhaps, not so important as the social or sentimental side, which cannot be estimated in concrete units, but must remain a matter of judgment or sentiment. The economic consideration is, however, generally the one on which the engineer must base his decision. Sometimes, however, neither economy nor sentiment is the deciding factor, but vested rights or orders of courts may compel the construction of a bridge.

Determination of Clear Opening

The determination of the area of waterway required is quite often a difficult matter. Various methods may be employed for finding this approximately. It may be found, (1) by a consideration of the manner in which the present structure (if one already exists) has fulfilled its duty; (2) by the evidence of men who are acquainted with water conditions at the proposed bridge site; (3) by an examination of water levels as shown on the surrounding objects; (4) by an examination of run-off data supplied by the Hydrometric Survey; (5) by an examination of rainfall data supplied by the Meteorological Service; (6) by means of a formula; (7), and best of all, by means of one or several of these methods and common sense.

Where there are existing structures the problem is somewhat simplified, but not solved. On small creeks there is a tendency to under-estimate rather than over-estimate the size of waterway required, especially if some years have elapsed since a season of heavy run-off. Where only temporary structures are being placed, this is, perhaps, not so important, but where the structure is to be a permanent one, care must be taken that the area is sufficient to provide for the greatest run-off which may take place. Too much dependence cannot, then, be placed on the size of the existing structure, but information must be obtained as to the area required under greatest flood conditions. If a structure has successfully passed all water for a considerable number of years, including years of excessive run-off, we know that it is at least large enough, and information must be obtained as to actual flood conditions in order to determine whether or not the waterway area can be reduced, should this reduction prove economical. On the other hand, on large streams the high-water mark has a tendency to move up a little beyond where the other man saw it. If definite marks of flood-water elevation recorded by men living in the vicinity at the time of flood can be obtained, these are generally to be depended upon. From cross-section measurements of the valley and known flood elevations the area of the required waterway can be estimated.

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Ascertaining Maximum Run-Off

The use of water marks on surrounding objects is not a very accurate method of determining flood-water elevations. If a few years have elapsed since the season of heavy run-off, these marks may have been entirely obliterated, and any marks found be quite misleading. They are really only one indication to assist in determining the area required. The most valuable and dependable records of all are those supplied by the Hydrographic Survey, where these go back a sufficient number of years. Unfortunately, these records cover comparatively few streams, and on most streams cover only recent years. They do, however, form a valuable guide in determining the run-off on streams other than the ones which are covered by their records. While not numerous, the Hydrometric stations are fairly well distributed and the run-off of typical streams in various parts of the country has been recorded. Knowing the maximum run-off, the drainage area and the type of country constituting the drainage basin, it is a simple matter to arrive at an estimate of the discharge of a stream of similar drainage basin. This estimate will be of assistance in determining the proper waterway. As an example, from the discharge record of the Valley River for 1913 (a year of heavy run-off in this portion of the country), the maximum discharge is found to be 3,500 cu. ft. per sec. The discharge, divided by the mean velocity of 4 ft. per sec., gives the area of the required waterway, and this, divided by the drainage area of 1,028 sq. mi., gives as the waterway required an area of .85 sq. ft. per sq. mile of drainage basin for this particular stream. Knowing the drainage area of a similar stream, and multiplying this area in square miles by .85, would give some idea of the area of waterway required for this stream. The Valley River rises in the southerly slopes of the Duck Mountains, and runs fairly rapidly to Lake Dauphin, the discharge fluctuating rapidly. From a similar record of the Rat River, which flows through a comparatively level country, the discharge is found to be 1,030 cu. ft. per sec., mean velocity 1.63 cu. ft. per sec. and drainage area 650 sq. mi., requiring a waterway of .98 sq. ft. per sq. mi. of drainage area.

It is important to know that the records cover greatest flood periods, and an accurate knowledge of the drainage basins is necessary. The drainage area of the larger streams can be ascertained from present maps with sufficient accuracy, but sufficient topographic information is not always available to apply this to smaller streams. The Topographical Surveys' Branch is, however, undertaking to secure information which will be very valuable for future studies along this line. A study of the records of the Meteorological Service will also guide the judgment in selecting a proper area of waterway. Reasoning from one drainage basin, where total maximum precipitation and maximum percentage of run-off are known, to a similar drainage basin for which meteorological records can be obtained, a comparative estimate of the maximum run-off of this basin can be made. There are also a number of formulas which can be applied under certain conditions to drainage areas that are useful also as a guide to the judgment. With the exception of the testimony of dependable observances of flood conditions and the actual record of the Hydrometric Surveys, the various methods mentioned serve only as guides for the judgment in selecting a proper waterway, and all must be applied with common sense.

Selection of Type of Structure

In selecting the type of structure three factors will influence this choice, viz, economy, service and appearance, and of these the first two will generally, but not always rightly, be the deciding factors. It is impossible to estimate the value of the æsthetic in design, and, as this value cannot be expressed in concrete symbols, it is frequently not understood,