REPUBLIEK VAN SUID-AFRIKA—REPUBLIC OF SOUTH AFRICA

Tegniese Verslag
Technical Report No. 10

Departement van Waterwese
Department of Water Affairs

PROBLEMS ENCOUNTERED IN CONNECTION WITH STREAM FLOW MEASUREMENTS IN SOUTH AFRICA.

DEUR/BY: A.L. RABIE

AFDELING/DIVISION: HYDROLOGICAL RESEARCH

DATUM/DATE: 1960

Opgestel en gepubliseer op gesag van—
Die Sekretaris van Waterwese
Privaatsak X313
Pretoria

Prepared and published under the authority of—
The Secretary for Water Affairs
Private Bag X313
Pretoria

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS

PROBLEMS ENCOUNTERED IN CONNECTION WITH STREAM-FLOW MEASUREMENT IN SOUTH AFRICA

BY A.L. RABIE HYDROLOGIST

DIVISION OF HYDROLOGICAL RESEARCH

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS

PROBLEMS ENCOUNTERED IN CONNECTION WITH STREAM-FLOW MEASUREMENT IN SOUTH AFRICA

BY A.L. RABIE HYDROLOGIST

HYDROLOGICAL RESEARCH DIVISION

Throughout South Africa considerable seasonal climatic changes occur and the river flow pattern likewise varies from very low or zero flow to floods of magnitudes which are not measureable by means of weirs or inexpensive controls.

RESERVOIRS AS FLOW MEASURING STATIONS.

Existing storage dams are suitable for measuring the total river yield by means of the inflow-evaporation-outflow water balance.

Transported sediment complicates this method as sediment deposited in a reservoir is not necessarily in direct ratio to inflow, and periodic silt surveys of the reservoir basins are essential to determine the loss in capacity of dams.

The gradual compaction of sediment deposits affects the useful quantity of water available in reservoirs particularly those subject to periodic drying out. Previously surveyed reservoir floors have been found to have dropped a few feet when dry, due to the consolidation of the previously loosely compacted sediment.

Reasonably accurate determination of flood peak flows can be made from the basin absorption and spillway discharge measurements, but additional gaugings are necessary if accurate low flow figures are required at reservoir statinns.

NATURAL RIVER CHANNEL MEASURING STATIONS.

Where no dams or similar structures exist, flood flows can only be measured by calibrating a stretch of natural river channel, preferably by means of velocity measurements while floods are in progress.

All rivers are subject to continuous changes both with regard to their cross-section and their slope during floods, as well as through seasonal vegetation growth, and continued calibration measurements are therefore required.

Where no rock outcrop or other natural or artificial stabilising control exists the river shape may change during the course of each flood through successive scouring out of the river bed and subsequent deposition of sediment. This change

in bed ..../2

in bed level can be of the order of 10 feet or more for the bigger rivers. Often there is a predominant tendency towards silt de= position or scour depending on the river bed gradient and the climatic, topographical and land-use conditions in the catchment area.

The more gradual changes through tree, reed and related water plant growth constricting the flow channel can be effectively controlled by mechanical means or through treatment with chemical herbicides, but the removal of vegetation can often aggravate scouring of the river channel and the two problems have to be weighed together.

It is clear that no initial calibration can be regarded as permanent for the river-run type of measuring section. It has been found in practice, however, that major changes in river channels occur in most cases during periodic damaging floods, usually but not necessarily, several seasons or floods apart and recalibration is carried out accordingly.

It is often not possible to measure extreme floods while they are in progress especially in fast-flowing rivers which subside rapidly. Flood gradients and river channel sections are then measured from debris and water marks left on the banks over a suitable stretch of river.

The length of river channel thus used should be sufficiently long that the estimated effective height of the waves lapping the banks at the time of the floodpeak be only a small percentage of the total fall in flood surface gradient over the river stretch used and a sufficiently large number of points on both banks and a minimum of 3 cross-sections should be taken in order to minimise the effect of observational and topographical irregularities.

Rapid changes in river section or direction of flow as at bends, in which case the cross-sectional water surface will not be level, must be taken into account. River reaches where transitional flow stages occur may give a completely wrong picture if insufficient allowance is made for the increase or decrease in velocities. This can be prevented by surveying a sufficient number of points on both banks and selecting the cross-sections with care so that changes in sectional area and thus velocity can be obtained.

To minimise the necessity of continual recalibration of flow measuring stations, flow controls are selected where natural rock bars, causeways or bridges cross the river and wherever possible unstable measuring sections are replaced by stable controls.

The above applies to natural river flow sections and to flood flow stages at weirs and controls. For accurate low flow measurement controls are essential.

MEASURING WEIRS AND FLUMES.

Over 90% of the gauging stations at present in operation in South Africa are equipped with weirs and flumes or similar controls for measuring normal and low-flow discharges. These stations are usually designed to measure up to 80% of the annual run-off

accurately ..../3

accurately and calibrated by current meter gaugings and/or surface velocity measurements for flood peaks. By drawing comparable duration of flow curves (rate of flow vs. time) for adjacent gauging stations the rate of flow below which 80% of the run-off takes place is obtained and this figure is used as the basis for design of new gauging stations. The 20% of the run-off which is not accurately gauged, is measured by calibrating the river section, and errors in this calibration can only be responsible for a small error in the total run-off computation.

Due to economic considerations weirs are built where suitable rock foundation exists. For accurate and continuous observations and maintenance of gauges it is necessary that the sites should be reasonably accessible and near suitable observers. Often measuring devices are required where there is no rock foundation in the flow channel. A short stretch of river channel is then stabilised by the construction of a concrete control or similar stabilised section resembling a causeway but conforming to the natural river cross section with cut-off walls to prevent excessive seepage underneath, and a weir or flume built on the upstream end of the control. As little deviation as possible from the natural river profile ensures less danger of scouring and outflanking.

The most important factors causing inaccuracies in river flow measurement by means of weirs are:-

1. CREST SHAPE AND DEPTH OF FLOW.

Sharp-crested aerated weirs are normally used in South Africa. In practice the sharp edge has a thickness of $\frac{1}{4}$" to $\frac{1}{2}$", to provide strength in order to eliminate even greater errors due to the edge becoming dented or flattened by floating debris, by corrosion, or abrasion by sediment in the water.

To reduce the error inherent in this minimum width of the crest, the gauge is designed with sills at varying levels so that the minimum flow depth to be measured over the low notch is more than $1\frac{1}{2}$ times the thickness of the edge, and higher notches are likewise designed to be at such levels that the resultant error is negligible.

2. AERATION OF FLOW OVER A SHARP CREST.

Aerated flow conditions are essential for sharp crested weirs and the height of the steel plate or angle iron crest and downstream shape of the concrete profile is designed to provide this requirement. Although weir notches up to 100' wide have been built, sharp crested notch widths are not being limited to 50' to ensure a sufficient air supply to the notch and 4" minimum angle iron is used to provide a sharp crest. Notches are separated by piers which in older type weirs were provided with streamlined upstream projections, but complete streamlined conditions are difficult to obtain unless a fairly elaborate and thus expensive pier is built. Recent weirs have sharp upstream edges provided by means of steel plate or angle iron to ensure full side contraction.

3. APPROACH ..../4

3. APPROACH VELOCITIES AND SUBMERGENCE.

Weirs are normally low structures and approach velocities occur which may contribute a large percentage to the dis= charge. To reduce the effect of velocity on the low flow stages to a minimum, weirs are built to a height related to the depth to be measured, the upstream face of weirs are made vertical and allowance is made for the approach velocity in calibration calculations.

At higher flow stages most weirs start to submerge due to the downstream water backing up to weir crest level. Sub= mergence gauges are erected and the submergence effect all allowed for.

4. SILT UPSTREAM OF WEIRS.

In some rivers sediment is a major problem, especially sand and the coarser sediment which is not carried over the weir in suspension but is deposited upstream thus causing high approach velocities, altering the discharge coefficient, silting up of the area around the gaugeplates and clogging of recorder sump pipes.

The discharge over a weir which is completely silted up to its crest is increased considerably for the same head, and the effect continually changes, since the sediment is carried over the crest during floods and fresh deposits are left behind as the flood subsides. An early attempt to incorporate permanently open sediment scours in weirs was not very successful as these get blocked by branches and vegetal matter brought down by the water. Sluices were provided in the past, but periodic scouring by opening gates has proved to be ineffective in almost all cases and especially in large rivers where the effective scour is too localised. Recently measuring troughs or flumes with their floors level for ease of calibration and in the interests of standardisation, have been incorporated in weirs. A flume is used instead of a low notch, because a definite bed-level at its entrance can be ensured as against a varying sediment level for a weir notch and the flume can operate under a large degree of submergence. These measuring flumes have proved to be effective in eliminating most of the sediment deposits upstream of weir notches. The troughs are set at various levels for accuracy in measurement, with their sills a few feet below the weir notch crests. The trough openings have to be wide enough, completely unobstructed and provided with streamlined entrance in order not to act as debris traps during floods and freshets. About 15 to 20 feet appears to be the minimum flume width suitable in this country, depending on the size of floating material brought down by the river.

The flumes are calibrated by means of current meter gaugings.

To avoid continual cleaning round gaugeplates, they are sited, apart from other basic considerations, where they have the least chance of getting silted up and are stepped up the river bank with the lower ones near the flowing current.

Recorder ..../5

Recorder sump pipes are kept as short as possible and where the river profile necessitates long sump pipes, manholes for cleaning sediment from the pipes are provided. In addition to the one nearly horizontal pipe connecting the recorder sump to the river upstream of the weir, an additional scour pipe for draining the recorder sump by means of a valve dicharging downstream of the weir has lately been incorporated in recorder installations on very silty rivers. This allows easier periodic flushing of the recorder sump pipe.

5. AQUATIC GROWTHS.

Aquatic growths, especially reeds, are given an excellent opportunity for growth in the sediment deposits accumlating in the comparatively quiet pools formed by weirs. The vegetation must be continually removed in the effective vicinity of the measuring notches. In the past the plants, mostly reeds, were removed by mechanical means only. Recently experiments with chemical or hormone compounds sprayed on the leaves have been carried out and encouraging results are being obtained.

6. OBSERVATIONS.

One of the main possible sources of error in flow measure= ment, in common with most fields of visual observation, is the human element. Observations are usually performed by part-time employees and although the majority are conscientious and do excellent work, there are exceptions whose readings are estimated or interpolated between a few infrequent actual observations, also continual visual observations are not practical for 24 hours each day. Official checks and adjustments are continually made, but the only satisfactory solution is automation. Consequently automatic recorders are erected to measure all variations in river stage, and although there are still some problems, the possibility of guesswork in readings is largely eliminated.

Most of the automatic recorders commercially available have a limited range and those suitable for accurate low flow measurement are often not capable of measuring total flood flow in rivers where great variations in flow depth occur. A few manufacturers have overcome this problem however and the float operated instruments now used in the Republic as standard equipment are completely satisfactory. These are of the type which reverse or invert the height when either end of the chart is reached. To eliminate errors in inter= pretation reverse movement indicators and zero stops are fitted. The zero stop on the counterweight cable is especially necessary for recorders on rivers that stop flowing completely for a time such as those in semi-arid areas. In such cases, in addition to fitting a zero stop, observers have been instructed to use the same chart more than once when there is no flow.

FLOOD ..../6

FLOOD WARNINGS.

In intensively cultivated and densely populated areas it is essential that timely flood warnings be given should it not be possible to control the river flow by means of existing storage dams. Severe storms which cause the most damage often break telephonic contact lines, and radio communication with key flood measuring points appears to be the only satisfactory solution. In the Republic there are few rivers long or slow flowing enough for flood warnings to be practical. Where it is possible to give advance warning of approaching floods use has been made of radio equipped vans.