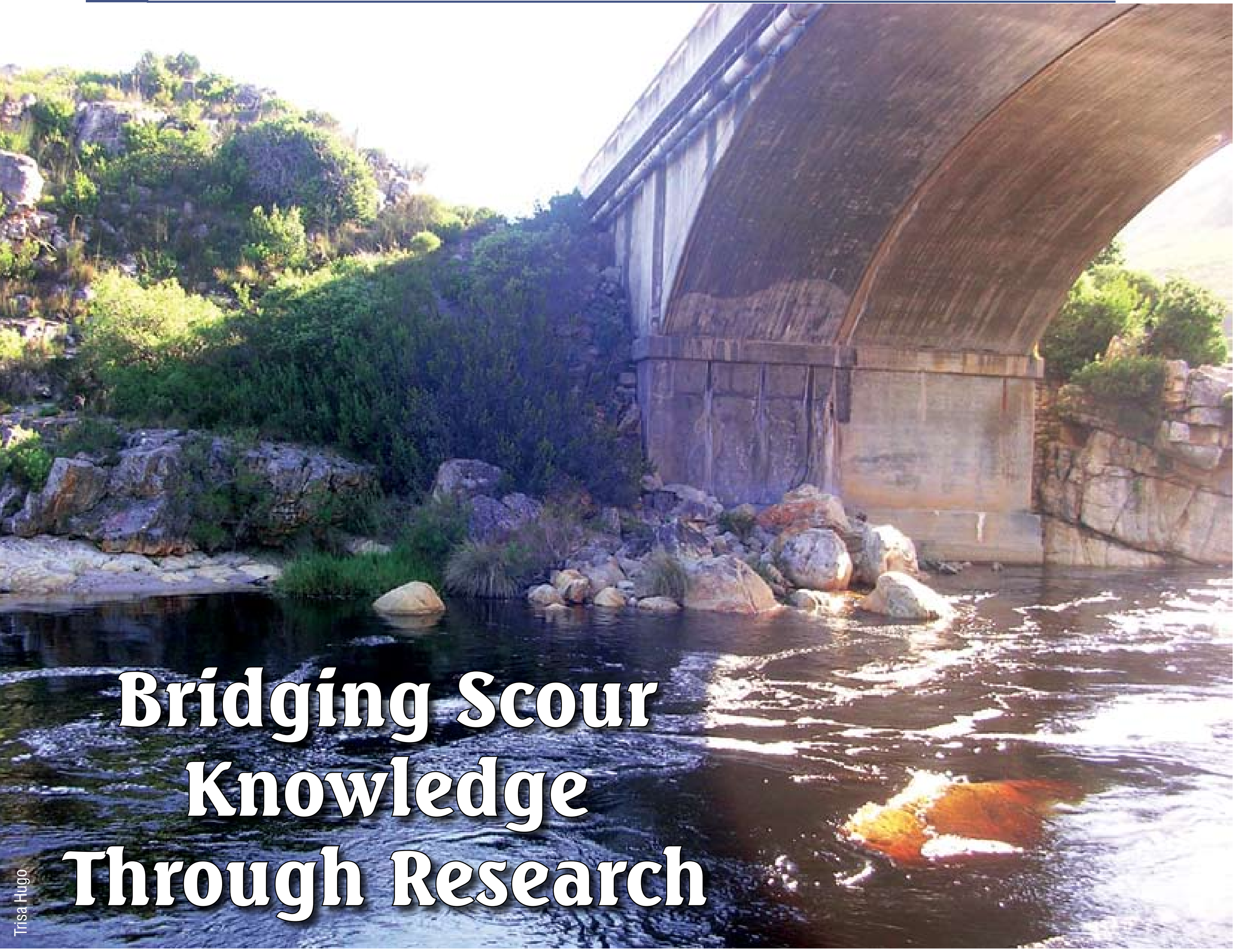


Trisa Hugo

Bridging Scour Knowledge Through Research

Mounting evidence suggests that South Africa should prepare itself for more extreme weather events, such as floods, in future due to global climate change. This could lead to increased erosion or scouring of riverbeds at engineering structures – a major cause of structural damage to bridges and fluvial structures in South Africa. Lani van Vuuren reports.

Scour is a worldwide phenomenon and of great concern especially to civil engineers. Any structure placed in a river, whether of natural or human origin, will tend to promote scour and deposition due to a sudden change in the flow direction or high velocity flow. Such obstacles can include a boulder, an island, a sharp bend, or a pipe or road bridge pier.

Local scour causes holes to be dug around structures – such as bridge piers and abutments – which are built on or below the riverbed. These holes can be exceptionally deep, e.g. they can easily run to 20 m to 30 m. Scour can also result in the sand around the pier being removed to such a depth that the pier ends up being supported on nothing. Because of this the pier will fail and the structure will collapse.

Unfortunately, designing for scour is not a mature science. Scour is difficult to detect and the maximum scour depths attained under peak flood conditions cannot be measured with ease. This is mainly due to the complexity and, thus, unpredictability, of the natural river system. As a result, there is still no universally agreed design procedure that can cope with all the observed scour and deposition phenomena.

The Water Research Commission (WRC) recently published a report on the extent of local scour in rivers in South Africa. This report is based on years of research by the University of Cape Town's Department of Civil Engineering. The report provides a snapshot of the present status of local scour in South Africa.

As project leader Prof Neil Armitage points out, in general, because rivers in South Africa tend to be relatively small, scour tends to be more of a maintenance issue rather than a serious hazard. Severe scour damage is seldom evident at bridges under normal flow conditions. "There are exceptions; major floods will almost always cause scour around bridge piers and abutments – unless they are founded on extremely hard material such as rock or concrete. The undermining of bridges due to scour is a common failure mechanism," he tells *the Water Wheel*. Still, the potential cost of maintenance should not be underestimated, as this is another expense provincial and local authorities would have to budget for.

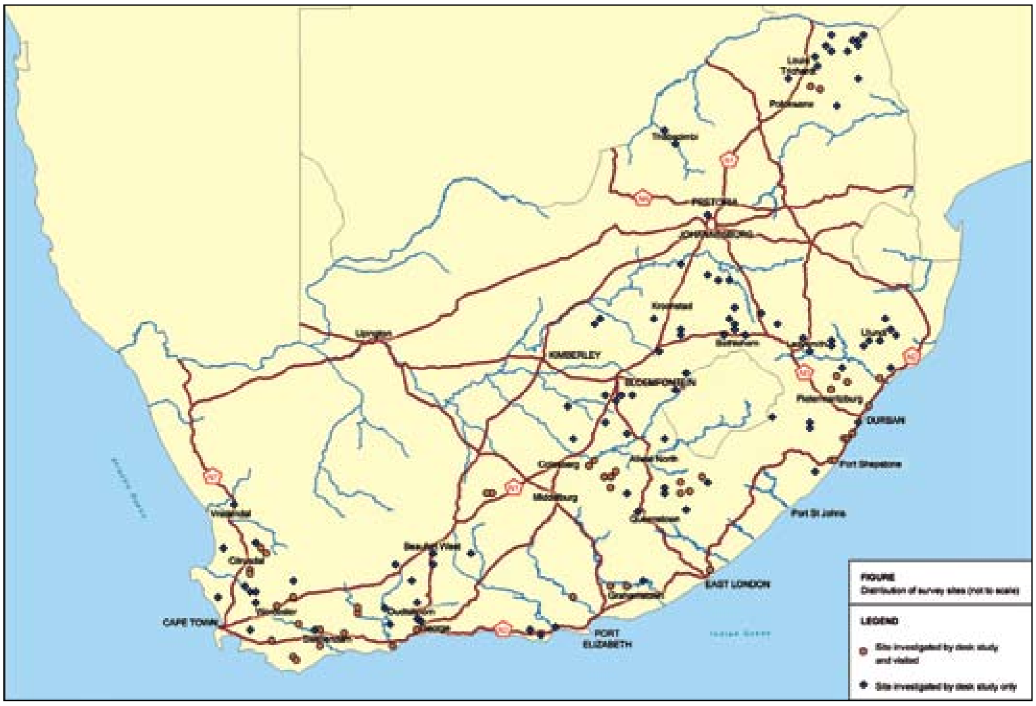
EXTENT OF THE PROBLEM

An investigation into present local scour (due to the sudden change in the flow direction around a solid obstruction in the river) and constriction scour (erosion due to the fact that the flow has to speed up to get through a smaller flow area) damage was undertaken at 105 provincially maintained road bridges across the country. Local scour was observed at 60% of the bridges while constriction scour was observed at 44% of them. The local and constriction scouring were combined at 37% of the sites investigated.

An estimate of the direct cost of repair to scour-related damage at these bridges is about R22-million a year. This cost excludes the damage incurred in extreme flood events and the economic costs associated with the disruption caused by the failure of major transport links. Inclusion of scour damage during extreme flood events may increase the estimate to more than R25-million a year.

"Major floods will almost always cause scour around bridge piers and abutments – unless they are founded on extremely hard material such as rock or concrete."

The problem was found to be most acute in KwaZulu-Natal, which has the largest number of fast-flowing rivers. Probably the best known example of a bridge failure due to scour was the collapse of the John Ross Bridge on the N2 over the Tukhela River in the 1987 Natal floods. Interestingly, about 120 bridges were destroyed or severely damaged during these floods, causing substantial losses to the economy. About 42% of the calculated annual repair costs in the country are on bridges in this province.



Distribution of survey sites

This bridge in the town of Heidelberg, Western Cape, failed as the foundations were undermined. The fact that piers on the upstream side failed suggests that local scour was responsible.

HISTORICAL SCOUR-RELATED BRIDGE FAILURES IN SOUTH AFRICA

- In 1868, floods caused the failure of the iron plate girder Queens Bridge over the Umgeni River near Durban.
- During the 1959 floods in Natal, one pier on the Lovu River sank by 2,74 m and three bridge spans were destroyed.
- The damage caused to bridges by the 1976 Natal floods was estimated at R50-million (R1 020-million in 2005 values).
- Scour at the Pondoland Bridge on the Mzimvubu River at Port St Johns due to the 1978 flood caused the failure of one pier and the collapse of two spans.
- The N1 Route from Cape Town to Beit Bridge has been seriously disrupted by floods on five occasions over the past 42 years.
- About 200 bridges and other drainage structures were washed away or severely damaged during floods in Limpopo in 2000. The value of damage to provincial roads and bridges in the province was estimated at R1 269-million.

Scour damage to bridge foundations is certainly not limited to structures in rural areas. Urban streams receiving fast-flowing water from impermeable surfaces, concrete pipes and lined channels also encounter scour problems. During the February 2000 floods, for example, bridges in many golf courses in Gauteng were affected by flood damage.

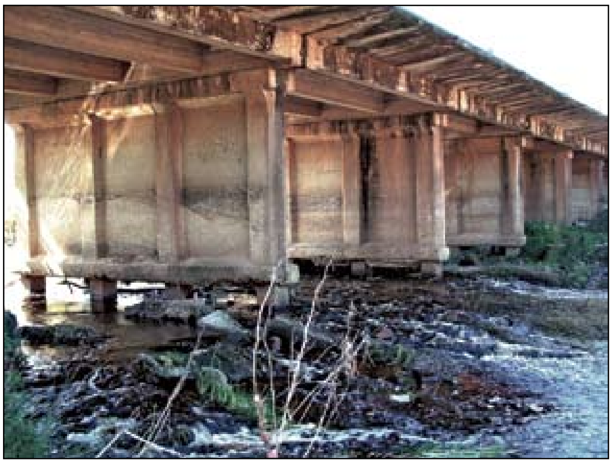
Pipelines attached to road and rail bridges are also affected by damage associated by bridges. Basic water supply to rural communities, particularly in Limpopo and Mpumalanga, was severely disrupted by the February 2000 floods.

DESIGNING FOR SCOUR

Prof Armitage points out that there are three basic methods to predict scour in a river system. The first is through empirical relationships developed by river observations of data collected in the field – or from simple physical models in the laboratory. The second is from scale (physical) models in the laboratory while the third is through numerical modelling using Computational Fluid Dynamics (CFD).

"The cheapest is using empirical relationships, however, real rivers seldom look like the ones from which the data was gathered, so this leads to great inaccuracies (greater than 100% error is common). On the other hand, scale models are expensive to set up and run, require a lot of space, suffer from scale effects (e.g. surface tension may cause distortions in the model but not in the full scale)," he explains.

Constriction of the flow at this culvert near Riebeeck East, northwest of Grahamstown, in the Eastern Cape, has led to high velocity water exiting the downstream end. The riverbed has been severely scoured for a long distance downstream.



The Palmiet River in the main stream of Grabouw, in the Western Cape, no longer flows parallel to the bridge piers. This may have initiated scouring under the bridge and exposure of the piles.

The piles of this bridge near the Mzimkulu River mouth have been exposed to a significant depth.

As a result CFD is rapidly gaining ground, especially due to the rapid increase in computing power. CFD is a computer program that attempts to model the behaviour of water by solving the basic equations of motion at every point (or surface) on a grid that encompasses the entire river volume. Ideally, the equations are simultaneously solved in all three directions (forwards, sideways and downwards). Often, to make the computations simpler, they are only solved in two dimensions – usually forwards and sideways.

"There is a pressing need for the development of appropriate tools to enable the designers of the future to make the optimal use of limited resources."

While reality remains so complicated that it is unlikely that any computer will ever be able to perfectly simulate it, it is now possible to get a reasonable prediction of the sort of behaviour one can expect under a variety of conditions, without leaving one's desk. "One great advantage of numerical modelling is that it is possible to see the likely effect of small changes by simply making small changes in the data set. There is no need to reconstruct a large physical model," explains Prof Armitage.

Running times will, however, remain long for the foreseeable future. Most models take several hours to run to completion; many take days. Faster computers – with more memory – theoretically help, but usually this additional capacity is put to use to improve the accuracy of the model. "In the end, it becomes a trade off between run time and accuracy," says Prof Armitage. The hope remains, however, that numerical modelling will soon become a viable option to model the scouring processes around engineering structures.

DEALING WITH CAPACITY CONSTRAINTS

The need for appropriate modelling tools is especially important considering that the role of engineering departments in many government institutions is changing from design to regulatory. This means that they are employing fewer and possibly less experienced engineers, resulting in years of accumulated wisdom in design being gradually lost. This has resulted in a pressing need for the development of appropriate tools to enable the designers of the future to make the optimal use of limited resources.

Unfortunately, these capacity constraints have left many government departments without adequate personnel who understand the problem of scouring. According to Prof Armitage, there is a need to ensure that bridge foundations are designed very conservatively. "In the end, it is the bridge designers who have to ensure that bridges will stand up in flood conditions, however, very few bridge designers nowadays have more than an elementary knowledge of scour."

While international interest in the scouring phenomenon is gaining, the waning of local interest and, as a result, decreased research support, has steered experts such as Prof Armitage in other research directions. It is hoped that it will not take a spectacular failure for decision makers to realise the importance of tackling the challenge of river scouring.

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