**Managing Bridge Scour:**

**Abstract**

(125 - 150 words/min: 20min, 2000 to 3000 words)

Bridge scour is a truly complex phenomenon and the following barely does the subject any justice. I would like to provide a broad overview of bridge scour, its types and introduce the theory. Next I will outline the methods for assessing scour using hydraulic principles.

The aim is to help you identify problems early and where to get more information.

l aspects of hydraulic design and advice for infrastructure projects.

So why is Bridge Scour important? Well bridge scour isn’t new or unexpected, it has vexed bridge builders for centuries. History is replete with incidences of failed bridges where the design did not adequately account for the capacity of rivers to scour away channel beds and banks. The first third of this presentation includes examples of undermined and washed out bridges that must keep the bridge designers awake at night.

Understanding bridge scour helps us to avoid these nightmares. It will reduce the disruption and economic costs of flood events. Recent flood events have demonstrated that the loss of bridge approaches and the uncertainty relating to a bridge’s integrity slowed the immediate recovery efforts. Identifying scour prone bridges is a key component in providing cost effective transport solutions for the community.

**Abutment Scour**

Flooding and scour results in a direct repair cost of around quarter of billion dollars in damaged bridges. But the real cost is the loss of key transport links during disaster recovery. Scour of the abutments had a significant impact on flood recovery efforts. Abutment scour at bridges on critical infrastructure links, must be serviceable once flood waters recede.

traditional stone pitched spill-through abutments are not serviceable for overtopping flow. If a road approach embankment is overtopped, scour will occur on the downstream face unless the downstream face is protected against scour.

An example of this problem was at the Burke and Wills Bridge on the Cooper Ck near the South Australian border. This bridge was overtopped for over a week and lost significant portion of both bridge approaches. This flood shown here was assessed as having between a 5 and 10% Annual Exceedance Probability.

Scour is relevant to transport solutions because there is no other crossing for hundreds of kilometres.

**11 Abutment Repairs**

Repairing the abutment using gabions provides a means of achieving a heavy duty abutment protection at rock spill throughs. What will happen during another overtopping event?

**13 Overview of Bridge Scour Theory.**

As noted at the beginning, I only have limited time to outline why scour occurs and what should be considered during bridge design. I won’t dwell on the hydraulic theory that underpins this or go heavily into any formulas. As noted, this only provides a sample of how the problem should be considered.

**14 Step 1 – General Scour Analysis**

Scour analysis should be broken into three stages. Step 1 – Stream Stability, Step 2 – Hydrologic/Hydraulic Analysis and Step 3 – Design of Countermeasures for new or existing. I won’t go into step three today. This step links in with the overall whole of life cost and asset management.

Traditionally we have done half of the second step well – hydrologic and some hydraulic analysis. This resulted in good outcomes for Local Scour at Piers but General Scour and Contraction Scour was not understood. Skipping Step 1 is the primary cause of the abutment scour problems illustrated earlier. More sophisticated software has also allowed for a more sophisticated appreciation of debris loadings and velocities.

**15. Geomorphic Analysis**

How stable is the stream? Step one involves a more considered approach for all bridge design involves examining the context of the bridge site – both for new bridges and countermeasure options at existing bridges.

Is it sited on a stream bend or in an unstable channel?

Is it likely that there will be significant changes to the catchment – rapid urbanisation or production of debris loading?

The whole process is inclusive of all disciplines and is methodical. We now have greater access to aerial survey and imagery to produce two dimensional hydraulic models. I will talk about 2D models later. Accessing aerial imagery has never been easier – as you will see it is the first step in understanding stream stability.

**16. Channels in Floodplains**

By definition, bridges exist within floodplains - crossing the river at a convenient location. All scour analysis should begin by giving due consideration to the stability of the river and floodplain. This slide shows the range of stream characteristics and how they differ. Key ones being discharge variability and bedload. Queensland possesses some of the most variable streams in the world. Understanding the inherent instability of Qld streams will improve scour outcomes. Channels can and will change their location overtime, either naturally or as a response to changes in the built environment. Note that scour of a bridge can occur at any of these channels.

**17. Mississippi**

Here is an example of a how a river can change its course over 170 year period. The river moved from its original 1765 alignment, 60 years later it had shifted (red line). Another 60 years it had moved westwards (purple line), cutting off the oxbow. By 1930 it had reverted eastwards (black hatching). A bridge located anywhere on the 1765 course would have experienced a lifetime of scour problems. This illustrates the importance of understanding the context of the floodplain.

**18. Scour Analysis**

To just briefly recap – I have outlined the first step in scour analysis.

Step 1 – assess the streams stability, consider the site of the bridge, use aerial imagery and so on

Step 2 – undertake hydrologic/hydraulic analysis. Some of you may be familiar with hydrology and hydraulic principles. This establishes the baseline variables that dictate local scour.

**19. Scour characteristics summary**

As most people would be aware, scour is the erosion of material. Ultimately, the presence of a bridge will lead to some level of contraction and local scour. The severity and frequency relates to the hydrologic and hydraulic studies that underpin a scour assessment.

**20. Hydraulic considerations**

A hydrologic study will determine the flood flows for the bridge’s location. These flows can be input into a steady or unsteady state hydraulic model. The hydraulic model will provide, among others, information on the stream’s velocity, tailwater level and time of submergence at a bridge.

**21. Flow velocity considerations**

Modelling allows us to examine the existing, pre-existing/natural velocities and then find a solution related to the bed shear stress. Steps can be taken to examine high velocities and accommodate mitigation measures within the design.

**22. Types of Bridge scour**

The hydraulic modelling undertaken as part of Step 2 will identify the types of bridge scour. Scour can be categorised into local scour at piers, local scour at abutments and contraction scour. Step 1 is important as it will identify the geomorphology of streams and identify general scour and sediment transportation problems. Identifying the extent of scour in live beds can be difficult as the evidence of scour is refilled as the flood waters recede.

**23. Contraction scour**

This image helps explain contraction scour. Similar to the Burke and Wills Bridge, the bridge embankments project well into the floodplain. The floodplain flow contracts and the flow regime develops into turbulent flow. This results in eddies and wakes which increase shear on the bed. The loss of this underlying material weakens the structure. This will occur as part of prolonged exposure to low modelled velocities. This was the case on the Cooper Creek and elsewhere.

**24. Local scour at abutments.**

In addition to contraction scour, there is more localised scour effect that occurs at the abutment’s leading edge and along the toe. Local scour at the abutment is the result of a flow forced down the leading face of the abutment and a vortex forming along the toe. The wake vortex again forms due to the lower pressure at the downstream face. These local scour effect are in addition to the eddies and vortices that form due to contraction scour.

Live bed scour can result in deep scour holes being formed at the peak of flood. These holes are then re-filled as the high sediment load is depositing out after a flood event. This makes monitoring and detecting these scour prone bridges problematic. undertaken real-time scour measurement in Mackay for the tidally influenced Ron Camm bridge.

**25. Local scour at piers**

The turbulent and unstable flow observed around a pier can be simplified into horseshoe and wake vortices. A scour hole results from the flow being forced down the leading edge of a pier and then abrading the stream bed. The relatively lower pressure on the trailing edge of a pier results in the unstable wake vortex that shears against the stream bed.

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In some cases detecting a scour problem is simple.

**27 Flow chart**

The calculations that underlie my earlier slides on contraction and local scour are cumulative. The scour depth is calculated for each category and then added together. This is complicated and iterative when done by hand.

**28 Computer Models**

However, the HEC RAS 1D modelling software provides a module that allows this to be done on a software platform. Note that the earlier examples I showed were using 2D software which do not have scour modules included.

**29 HEC RAS**

All of the step 2 hydraulic analysis can be done within HEC RAS and then the bridge scour module can be run. A better understanding of contraction scour can occur by using 2D software. Good modelling practice then involves using HEC RAS for a more detailed assessment and verification of the 2D results.

**30 Approach to Bridge design for Total Scour**

Using the HEC RAS bridge scour module, some of the complex iteration work can be processed to identify scour at a bridge. The individual components of scour (local and contraction scour) can be separated to aid in visualisation and comparison with bridge soundings post scour event.

**31. Keelbottom Creek,**

This bridge, near Townsville experienced ongoing maintenance and costly repair works since its construction. Extensive optioneering was undertaken following flooding in 2007. MikeFlood and Mike21 models were constructed to examine the peak velocities, velocity vectors and scour impacts.

**32. MIKE Flood 2D Model**

Using 2D hydrodynamic modelling allows the problem to be understood and impacts from the longer solutions. The velocities were much lower and therefore scour problems could be avoided.

**33. Option – Scour Protection**

The 2D Model was used to test the bridge with gabion reinforcement. This found unacceptably high velocities.

**34 Option – Lengthen Bridge**

The original construction avoided the high cost of the longer bridge. However, has all the inconvenience, ongoing maintenance costs and regular loss of connectivity negated any savings that the narrower bridge may have provided?

**35 Bridge scour challenge**

Here is the caveat - Whilst we have more computing power and more formulae available, there has been very little field verification. The formulae contained within books and computer models are based on very simple laboratory models that generally over-predict what is observed in the field. There is still much more work to be done and is not a simplistic exercise.

As always, scour analysis remains a complex interaction between:

River flow, Channel boundary materials, Bridge structure configuration,

The uncertainty of analysis is compounded by: River hydrology, Sediment transport and Hydraulic analysis

**36 Summary**

Thank you for your attention today and I hope that you now have a greater understanding of the bridge scour process. Bridge scour is a truly complex phenomenon and I hope I haven’t lost too many of you with this very truncated presentation. I hope that you know understand why scour analysis is important to the community and transport solutions. I have provided an overview of the components of scour and where uncertainty exists. I have not had the time to do this subject justice. I do hope that you have all obtained a greater understanding of the complexity of this subject.

**. Assessing Bridges for scour susceptibility and screening**

As outlined today, scour assessment is a process. A bridge cannot be assessed in isolation or without a complete picture. GIS software and aerial imagery are being used to understand the catchment. The 2D modelling software can identify areas of stream instability and higher velocities. HEC RAS 1D modelling is used to calculate the components of total scour. Bridge inspections and soundings provide a real world measurement and documentation of the impact of flood events and scour. Identifying the early signs of scour prone bridges will lead to more effective counter measures and enhanced bridge design.

**Cost of 2010/2011 Event**

* $4.5 Billion dollars – $3b in summer
* $225M repairing bridges
* Permanent scour over 3m at bridges
* Replace 2 timber bridges
* 1 bridge 70mm pier settlement
* 1 bridge closed with 3m scour
* Many scoured abutments
* Many bridge approaches washed out