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**GUIDELINES FOR THE HYDRAULIC
DESIGN AND MAINTENANCE OF
RIVER CROSSINGS**

**VOLUME V : BRIDGE MANAGEMENT
FOR RIVER BRIDGES**

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PREFACE

At the rate at which new information is generated and made available it is becoming increasingly difficult for the practising civil engineer to decide on the appropriate norms and analytical methods to be used in designs. Although there will always be cases necessitating a comprehensive independent literature study to ascertain the best suited norms and methods to achieve a sound solution, it is recognised that they tend to be the exception rather than the rule. The designer cannot be expected to undertake such detailed studies for each case as this would become impractical. Consequently the need for practical guidelines.

The main aims of these guidelines are to make recommendations on methods of calculation, design norms as well as legal and other issues which need to be taken into consideration in the pursuit of providing safe, economical and viable river crossings. The intention is not to stifle original thinking and new development, and thus designers are expected to deviate from the general recommendations where optimum solutions clearly fall outside the general applicable norms. The guidelines are furthermore intended to serve as a basis for governing bodies to formulate their policies on design standards with due consideration of legal and other risks.

These guidelines comprise seven volumes each dealing with a particular subject or related subjects.

SYNOPSIS

During the 1970s and 1980s a number of major floods caused serious damage to the road and rail infrastructure in southern Africa. These events underlined the need for a structured management programme to ensure that preventative maintenance will minimize similar losses in future.

This volume outlines the objectives of such a management system and then discusses the development of a database, bridge inspections and remedial actions which form the backbone of such a management system. Specific attention is given to the aspects unique to river bridges.

Keywords : Bridge management, river bridges, database development, bridge inspection, remedial actions.

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By

Dr. D J W Wium and W le Roux

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1. INTRODUCTION

1.1 Background: Bridge management

When roads and bridges approach the end of their design life, an increase in maintenance activities may be expected. Furthermore, river bridges are often subjected to severe flood conditions, which result in damage to, or even failure of a significant number of bridges. The rehabilitation of these bridges would require extensive funding.

In an effort to utilize the available funds in the most effective way, management systems have been developed to provide rational programmes for maintaining the infrastructure. The relatively large number of river bridge failures in the past clearly indicate a need for applying these principles to maintaining such bridges.

1.2 Scope of the document

River crossings differ from other bridges in that the feature being spanned may impose extremely destructive forces on the bridge. This volume of the guidelines addresses waterway-related aspects which could affect the safety of a bridge, and proposes a method for incorporating these aspects into a bridge management system.

The aspects of bridge management that are common to other types of bridges are not covered here. The reader is referred to documents such as the Bridge Inspection Manual, the Bridge Management System Technical Report and the Guidelines for Maintenance and Repair of Bridges, issued by the Department of Transport.

2. BRIDGE MANAGEMENT

2.1 Scope of a bridge management system

2.1.1 Scope

The cost of bridges represents a significant proportion of the investment in the road infrastructure of the country and proper planning is therefore needed to manage these assets. Such planning should be based on the full history of bridges, from their inception to their eventual demolition or decommissioning.

Various phases in the life of a bridge can be identified, as presented in Figure 2.1.

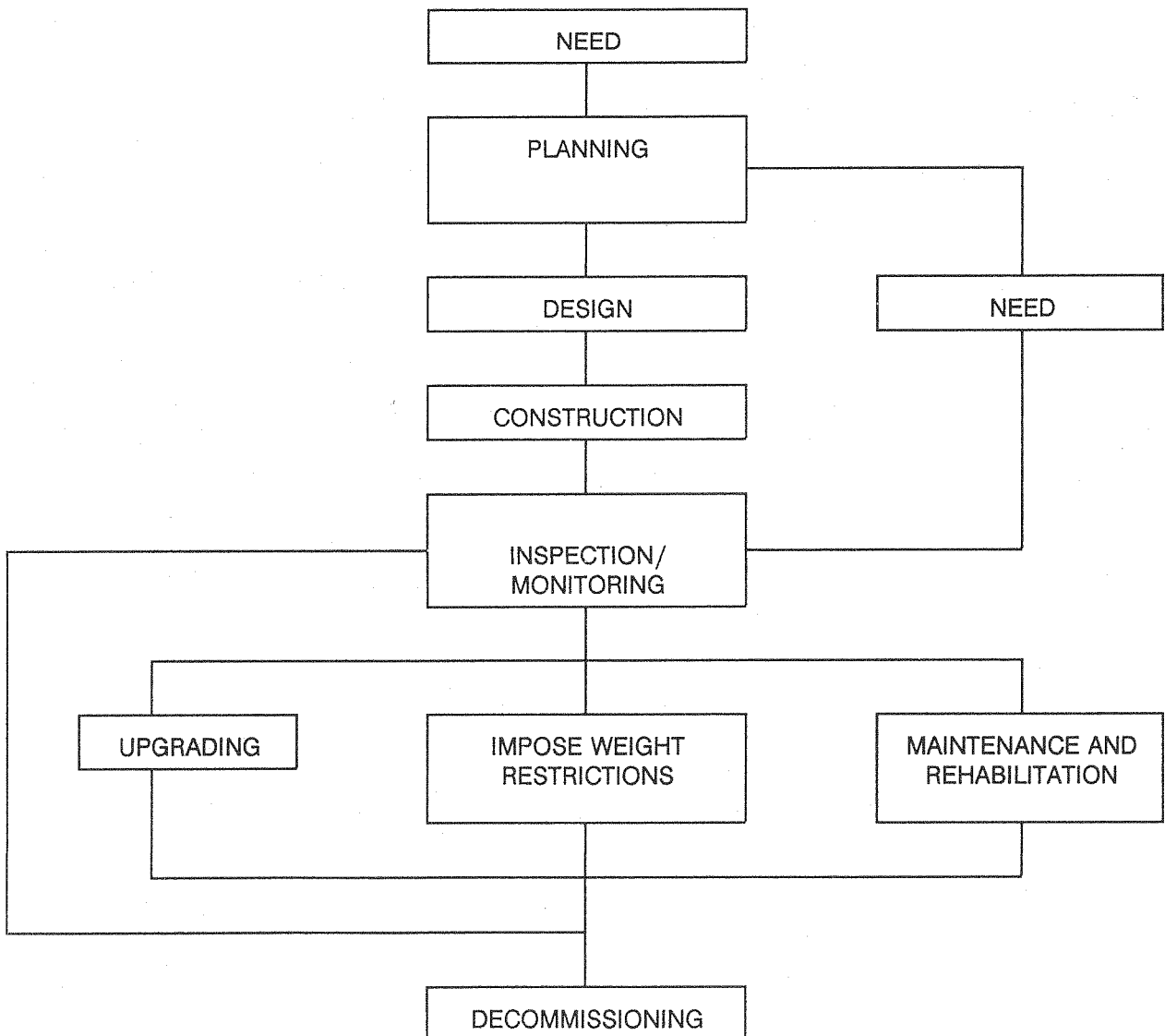


FIGURE 2.1 : PHASES IN THE LIFE OF A BRIDGE

Although bridge management encompasses all the aspects indicated in Figure 2.1, the bulk of the work is inspection, rehabilitation, and maintenance once the initial bridge inventory records have been recorded. Proper records should therefore be kept of all related costs in these fields throughout the serviceable life of the structure up to its eventual decommissioning.

2.1.2 Objectives

The ultimate objective of using a bridge management system is to ensure that all bridges provide an acceptable and safe level of service to the public. However, other factors also influence the level of service that can be achieved: This level of service is usually subject to budgetary constraints, while certain minimum environmental concerns must be addressed, and ecological balances must be maintained.

This objective of optimal level of service (subject to the above constraints) may be achieved by using an approach which assists the road authority in the following functions:

- Identifying all bridges that need maintenance, upgrading or replacement to provide the required level of service
- Planning and prioritizing all maintenance or rehabilitation work on bridges
- Estimating the long-term budgetary requirements to maintain the bridge inventory at the required level of service.

Johnston (1988) proposed the "level of service" concept as a basis for making decisions on appropriate expenditure levels for bridges. The level of service provided by a bridge is an indication of the degree to which it provides an acceptable and safe facility to the general public. This can be qualified by comparing the bridge with acceptable standards (eg. traffic safety, strength, state of deterioration, comfort, aesthetics, etc).

Failure to meet an acceptable level of service could result in costs to the user due to loss of or damage to property or life, or costs associated with delays due to not being able to use the bridge (these costs have to be borne by the individual users). On the other hand, the authorities have to maintain these structures at an acceptable level of service, which are financed through taxation of the general public. A bridge management system should therefore minimize the total cost to the general public by finding an optimum balance between acceptable levels of service and the costs to provide these levels of service.

The acceptable level of service differs from one bridge to the next. Funds should therefore be allocated in such a way that all bridges provide an acceptable level of service. The first step towards this goal is to rank bridges according to the level of service provided by each bridge. This ranking process is discussed in the next section.

2.2 Criteria for allocation of funds

Various parameters need to be considered in both the immediate and long-term planning of bridge maintenance and rehabilitation. Numerical models have been developed to rank bridges according to

their current conditions. These models can be used to decide which bridges require immediate attention. The ranking should reflect the need of the community for an appropriate level of safety on bridges. The same criteria should in principle apply to all bridges. However, after recent incidences of bridges collapsing, river bridges appear to be less safe than others, and there seems to be an increased awareness of this by the public. River bridges may therefore require a somewhat more detailed attention.

The different parameters to be considered are briefly discussed below.

2.2.1 User costs

One of the major advantages of many bridges is the fact that they reduce travelling time for the user (by providing a more direct route), thereby saving the public costs they would have incurred had they been forced to travel over longer routes or on roads that are in a poorer condition. Such costs (or savings) therefore represent one aspect of the level of service provided by a bridge. In the case of river bridges, the costs incurred by the user may include the cost of not being able to use the bridge during and after a flood (either due to collapse or to damage), as well as delays during a flood when the public has to wait for the water-level to subside.

2.2.2 Safety

Safety may be defined as freedom from danger or risk. In the case of bridges, such danger or risk to both life and property should be kept within acceptable limits. Since risk or danger affects the willingness of the public to use a facility, it also has a negative impact on the level of service provided by that facility. People are reluctant to use a bridge that is perceived to be not safe, and this can entail costs which can otherwise be saved. Several factors enter into creating an acceptable level of safety.

Once bridges have been designed and constructed, they should be maintained in order that floods cannot cause damage to their substructures or their approaches (except for bridges that have specifically been designed with weak approaches which are supposed to fail under heavy flooding). However, in extreme cases some damage or collapse may occur. A well-established risk analysis approach for assessing such conditions is to consider the risk cost of each event. The risk cost may be defined as the consequences of an event (eg the number of fatalities or the cost of failure), multiplied by the probability of that event occurring. The risk cost is then compared with the expenditure needed to improve the bridge to prevent such failure. Should the risk cost exceed the cost of improving the bridge, it is judged beneficial to perform the work.

Since larger floods (causing potentially more severe damage) have a very low probability of occurrence, they very often also have a low risk cost. It may therefore not be worthwhile to improve a bridge to prevent a remote mode of failure. No acceptable basis has as yet been found to allocate a monetary value to the life of a person. The result is that large sums of money are often spent to prevent a single fatality, while many other suspect bridges do not receive attention. Therefore, an acceptable balance is needed to allocate funds for improving safety. A further complicating factor must be taken into account: those events which result in extreme consequences generate much more public awareness than a number of small events with the same total damage or number of fatalities. People are generally averse to risk, and more emphasis may have to be placed on preventing the damage to those bridges which would result in severe consequences, even though the risk cost may not justify it.

The public's perception of safety (or risk) is greatly influenced by the degree to which they can control their exposure to danger, and by the available information regarding the perceived danger. Some bridges may therefore be regarded as more dangerous than others. These include bridges which may fail suddenly without prior warning, and bridges which pose significant danger to the public, due to the fact that a failed member may be obscured from the public.

In Volume VI (Risk Analysis of River Crossing Failure) the aspects related to the safety aspects of river bridges are discussed in detail.

2.2.3 Strategic considerations

During and immediately after a flood, emergency services usually operate at a peak. Bridges often form key links between different communities, and it is of the utmost importance to ensure that these bridges are operational at all times. Alternative routes and the type of traffic expected at a bridge during and after a flood will determine the strategic importance of that bridge, as will the average daily traffic and the role of the bridge in the road network as a whole.

2.3 Scope of maintenance and improvement

The degree to which a bridge should be repaired or maintained would differ from one case to the next. One option is to do sufficient work on an existing bridge to ensure that it will perform satisfactorily for the next 20 to 25 years, after which it will again require a considerable degree of improvement. Alternatively, it may be less expensive in the long term to repair a bridge at more regular intervals. Research to compare these options was carried out by Johnston (1987), and the results indicate that the approach differs from one case to the next. However, since river bridges may be subjected to severe floods, the extent of deterioration may be difficult to predict. It may therefore be necessary to perform remedial work at shorter intervals to prevent catastrophic failures.

Once the condition of a bridge has been established, a decision must be made whether to maintain, rehabilitate or replace the bridge. In general terms, maintenance involves activities to retard the further deterioration of a structure, while rehabilitation involves activities to upgrade the condition of a structure.

Finally it is important to keep a record of all the costs incurred on a bridge to assist in predicting future funding requirements.

3. DEVELOPMENT OF A DATABASE FOR RIVER BRIDGES

The key to the successful management of bridges lies in the availability to relevant information on the condition and importance of all bridges in the inventory. It is therefore suggested that details regarding the physical configuration and condition of bridges be stored in a central data base, from which the bridge engineer can retrieve the required information to make sound decisions. Although such decisions are only as good as the information on which they are based, a limited number of significant data items is often preferable to a large number of general data items.

This section describes the general categories of variables (data items) and lists items that should specifically be included in a data base for river bridges. A list of variables that should be included in a comprehensive data base for bridges is included as Appendices 7.1 and 7.2.

3.1 Inventory variables

Inventory variables describe the bridge in terms of location, type, design criteria, geometry and strategic importance. These variables seldom change, but changes such as the construction of a new adjacent route might for instance change the strategic importance of a bridge.

Variables such as the average daily traffic over a bridge, and the length of the detour required when a bridge is closed (as well as the additional travel time) provide information regarding the relative importance of a bridge within the road network. These and other inventory variables such as horizontal and vertical clearances can be used for ranking bridges according to the level of service provided to the public.

3.2 Bridge condition variables

This group includes variables reflecting the condition and appraisal of the bridge. A condition rating represents the condition of a bridge relative to that when it was constructed, while an appraisal rating gives an indication of how the bridge compares with current standards.

The condition and appraisal ratings are based upon field inspections which are discussed in Chapter 4. All bridges should be inspected on a regular basis. The degree of detail required on these inspections may vary from a rating of the global condition, to a detailed breakdown of each subcomponent, indicating the rating, extent and distress of each component.

These condition and appraisal variables are used to prioritize and optimize the repair of individual bridges, while existing preventative bridge maintenance and rehabilitation strategies can also be adapted to prevent future problems.

3.3 Planning of improvements

It is important that the findings of a bridge inspection program be implemented by a maintenance, rehabilitation and replacement program. Guidelines based on evaluation of the bridge condition, the level of service provided by the bridge (e.g. vertical clearance under the bridge) and the strategic importance (e.g. traffic volumes over or under the bridge, length of detour, importance of the route), should be

developed to select the most cost-effective remedial actions. One way to prioritize the remedial work is to calculate a deficiency index for each bridge, based on the deficiencies in terms of condition and level of service and to weight the index in relation to the strategic importance of the bridge.

Details of the required remedial actions, their urgency and the estimated costs should be used to plan future maintenance, rehabilitation and replacement, as well as for making budget predictions.

Remedial work for river bridges is discussed in Chapter 5.

3.4 Historical variables

A management system should be able to determine two important parameters:

- The rate of deterioration of bridges under various conditions, and
- The cost of improvements for any degree of distress.

Such a system can be developed by keeping a record of bridge conditions and appraisal ratings over a period of time, the corresponding information on remedial actions taken and the costs involved. With the aid of statistical methods, this historical data can be used to predict future conditions and repair costs.

A second field of application of historical data relevant to river bridges is hydrological information which is used for calculating design floods. This subject is treated in Volumes I and VI.

4. INSPECTION OF RIVER BRIDGES

4.1 Objectives of bridge inspection

As maintenance and rehabilitation are essential to maintain an acceptable level of service, it is essential that decisions in this regard be based on the actual condition of the structure, supported by data from regular inspections. The objectives of such inspections should be:

- To identify potential problem areas as early as possible.
- To assess the effectiveness of protective works.
- To enable the bridge manager to evaluate the safety of a bridge.
- To record and verify the condition of the structure.
- To provide feedback on the design, construction and remedial work, as well as on the behaviour of structures and the performance of new projects.
- Clogging and aggradation.

This section briefly deals with the inspection of bridges and a systematic approach to attain the above objectives. Typical problems at river crossings are reviewed and inspection methods summarized. A method for reporting defects is proposed and the requirements for inspectors listed. Finally, guidelines are proposed for the frequency of inspections.

4.2 Problems at river bridges

A wide range of problems which could either damage or destroy the bridge, occur at river crossings. Typical problems include the following:

- Loss of or settlement at supports
- Floatation of deck
- Impact damage to piers and decks
- Lateral displacement of deck
- Breaching of approach road embankment
- Inaccessibility during floods

Many of these problems may have been caused by poor design practice and incorrect siting, but these aspects are not being addressed here.

More details are provided in the Bridge Inspection Manual.

4.3 Causes of problems at river bridges

In general, the failure of river bridges may be ascribed to two primary causes, viz, a variation in the flow path of the river and lack of sufficient flow capacity through the bridge opening. The result of the latter is twofold: The water level in the river rises (possibly resulting in floatation of the deck, or debris may collect against the deck causing a build up of hydrostatic pressure) and the flow velocity increases (which could result in scour, causing the loss or failure of a substructure member especially where foundations have been placed relatively shallow). It is often a combination of these occurrences that lead to problems at river bridges). The causes of problems at river bridges are also discussed in Volume II (Structural Aspects, Bridge Configurations and Foundations).

4.3.1 Changes in channel alignment

The position of the main river channel relative to the bridge opening may change for a number of reasons (eg developments upstream or downstream of the bridge, natural vegetation e.g. reed growth and natural erosion, etc). This may cause the water to be redirected against the substructure or the road approaches. This problem is aggravated by flood conditions, and may result in approaches being eroded and washed away.

4.3.2 Debris

Debris that collects against a bridge substructure or in close proximity to the bridge, or vegetation in the river bed may restrict the flow of water through the bridge opening.

Restrictions cause water levels to rise, or result in localized increases in flow velocity which, under flood conditions, may lead to damage.

4.3.3 Scour

Comprehensive studies have been conducted on the causes and effects of scour and is discussed in more detail in Volume I (Hydraulics, Hydrology and Ecology) of these guidelines. Only a brief review of this topic is given here.

Scour may be defined as the loss of material in the river bed, caused by the flow of water. For scour to occur, the velocity of the water must be sufficient to transport the material. It may therefore be expected at those bridges where the flow velocity of the water is high and where the material is loose. Various factors contribute to the extent of scour:

- Slope and natural alignment of the channel
- Type and amount of bed material in suspension
- Extent of previous scour damage to the river bed
- Accumulation of debris
- Flow constriction
- River realignment
- Layout and geometry of training works
- Protective measures

- Shape and configuration of the structure.

Scour can generally be divided into four main categories:

- General scour occurs across the width of the waterway and results in a general lowering of the river bed. It usually occurs when the waterway is restricted by the bridge opening, which results in increased flow velocities during flood conditions.
- Local scour occurs around piers, abutments, the noses of guide banks and various other locations where these obstructions induce vortex flow conditions.
- Natural scour occurs in alluvial and tidal channels associated with variations in flow conditions. This involves the transportation of bed material, migration of the bed-shape and channel shifting.
- Progressive channel degradation is associated with geological processes or man-made regime changes, either upstream or downstream. The extent of this type of scour mostly extends beyond the bridge site.

4.3.4 Material defects

Defects in the materials used to protect the river banks or the substructure against erosion and scour may cause premature deterioration of these protective systems, and accelerate scour. Typical problems include poorly constructed gabions, rip-rap or steel sheet piling.

4.3.5 Channel aggradation

Aggradation of the river bed occurs when additional material is deposited on the river bed, usually due to a drop in the velocity of the water. In most cases this does not pose a direct threat to the safety of the bridge, but such additional material may affect the flow pattern of the river, which may in turn affect the bridge. This is especially true when vegetation establishes itself on the new deposits, thus preventing erosion to re-establish the balance during future floods.

4.4 Bridge inspection programme

Although some authorities conduct bridge inspections based on a structured inspection programme, many do it on an ad hoc basis when problems are reported.

It is important to have a structured inspection programme whereby all bridges are inspected on a regular basis. All bridges need not be inspected at the same frequency. Surface or conventional (conducted from above the water surface), and underwater inspections need not be performed at the same intervals. The frequency and extent of these two types of inspections are briefly discussed in this section.

4.4.1 Surface (conventional) inspections

Surface inspections (conducted without diving equipment) should be performed on all bridges using conventional methods, which will involve visual inspection of all components.

(i) Frequency of inspections

The first step in implementing an inspection programme consists of conducting an initial round of inspections to establish the general state of the bridges and to update the existing bridge inventory. These inspections should be visual and aided by checklists to evaluate bridge conditions.

On completion of the initial round of inspections a list should be compiled of bridges requiring more detailed inspection. These bridges should then be inspected in more detail to assess the need and implementation of remedial action.

The initial inspections must then be followed up by a regular inspection programme, the frequency of which would be dictated by:

- Condition of the bridge
- Type of bridge
- Traffic volume carried by the bridge
- Strategic importance of the route
- Environmental conditions
- Age of the bridge
- Risk to the public

Generally, bridges should be inspected every two to three years, while certain inclement bridges require more frequent inspections:

Bridges could be classified according to the importance of the route on which they are situated, and more regular attention can be given to those on the important routes.

(ii) Levels of inspection

Three basic levels of inspection can be identified:

- Superficial inspections are cursory, visual checks of the condition of structures, persons with a good practical knowledge of road structures, such as bridge and roads maintenance personnel, could conduct these inspections. No formal standardized reporting format is required. The main purpose of these inspections is to report obvious defects that would otherwise only be identified during formal inspections of the bridge.
- Detailed inspections are regular inspections carried out by experienced bridge inspectors or experienced structural technicians, under the general supervision of a structural engineer. It involves a thorough examination of all the components of a bridge. Although mainly visual, it could include the measurement of crack widths, deflections, levels etc. These inspections form the basis of the inspection programme. Standardized inspection sheets and checklists should be used to record the inspection results, supplemented by written reports and photographs where necessary.
- A special inspection is performed for unusual circumstances or if the principal inspection identified

the need for further investigation into a certain aspect. Since specific details will receive detailed attention, no standard format can be prescribed in such cases. More advanced methods such as non-destructive testing methods, long term monitoring, underwater inspection, core drilling, etc, may be required to assess specific problems.

The format of reporting depends on the nature and extent of the inspection methods.

4.4.2 Underwater inspections

An underwater inspection is a specialised application and falls within the ambit of professional divers and contractors, requiring special equipment and workmen. Being a very specialised work, each structure having its own specific problems, it is essential to liaise in detail with experienced divers for each problem. Whereas most other special inspections may be conducted on an *ad hoc* basis, underwater inspections should form part of a regular inspection programme.

(i) Frequency of inspections

Underwater inspections are necessary when surface inspections (using probing or other method) do not provide adequate information regarding the condition of the foundations or other submerged members of a river bridge. These inspections should supplement the surface inspection, and ideally be conducted at the same frequency as the surface inspections, since the factors that influence the frequency of surface inspections also apply to underwater inspections. It is advisable to conduct underwater inspections after severe floods, or after reports of scour observed during a visual inspection, or after other events which may have caused damage to the substructure (such as impact damage due to a vessel).

(ii) Levels of inspection

Underwater inspections may be classified in three levels:

- Level I inspections involve a visual inspection and evaluation of the substructure under water or the probing (using long probing rods) in turbid waters where visibility is very poor. This inspection is intended to detect obvious damage, or problem areas that may require a Level II inspection to evaluate conditions more closely.
- In a Level II inspection the aim is to search for less obvious defects, which may require that areas be cleaned and inspected. Assessment of defects using a hammer to evaluate the extent of deterioration or damage, and to achieve greater accuracy than obtained with a Level I inspection.
- Level III inspections are highly specialised inspections to investigate specific problems or expected hidden damage. Due to the detailed nature and high cost of these inspections, these inspections are usually limited to relatively small areas.

Level I and some Level II inspections should be performed on a regular basis, and Level III inspections only when a problem is suspected.

4.5 Inspection procedures

Rivers can impose destructive forces on bridges. It is therefore important to inspect the waterway in the vicinity of the bridge in addition to the bridge itself, to address the following possible problems:

- To identify damage to the foundations (eg. the loss of founding material), which may cause the bridge to settle or collapse.
- To identify changes in the channel condition, as these changes are often the result of some underlying problem. Warning signs of scour may be noted and attended to before the bridge structure has suffered damage.
- To establish scour potential so that it can be monitored more closely, and for corrective measures to be applied to the bridge or waterway.

This section highlights some aspects regarding the inspection of the waterway and the effect thereof on the bridge. For comprehensive information about inspection procedures covering these aspects, the reader is referred to the Bridge Inspection Manual.

4.5.1 Inspecting the waterway

(i) Preparation

Proper preparation and planning to determine the scope of the work are essential to ensure good results. The original site plan (as reference), the available scour evaluations and reports should be examined and the type of stream-bed material assessed so that areas where there is a potential for scour damage can be identified. The inspector should familiarize himself with the site conditions and a summary of this information should be available.

The site conditions and type of inspection dictates the equipment that will be required. If access is a problem, a special mobile crane unit, or a rubber boat may be required to gain access to the particular supports.

(ii) Procedure

Three main elements of the waterway that are to be inspected are briefly discussed below.

(a) Waterway at the bridge

The waterway should be inspected for the following:

- Scour of the banks
- Debris that may restrict the flow under flood conditions
- The channel alignment relative to the bridge opening
- Development of islands.

The condition of the protective aprons at guide banks or spur dikes should be inspected for material loss. The area around the substructure should be inspected for the following:

- Accumulation of debris
- Evidence of lateral channel movement
- Changes in the elevation or cross-section of the river-bed
- Local scour around foundations
- Damage to scour counter-measures.

(b) Bridge

The bridge should be inspected for the following signs of an inadequate waterway opening:

- Evidence of overtopping
- Accumulation of debris or other restrictions to the river flow
- Evidence of lateral movement of the deck due to floatation.

(c) Waterway upstream and downstream of the bridge

The waterway banks should be checked for:

- Evidence of scour
- Stable vegetation on the banks.

The main channel should be checked for:

- Obstructions in the channel, eg. trees, islands, etc.
- Evidence of lateral movement of the stream-bed.

The flood-plain should be checked for:

- High water marks
- Developments (agriculture, plantations, housing settlements, etc) or other obstructions on the flood-plain
- Roads below the flood-line (the road embankment may affect the flow of water during a flood).

Other features such as dams or other restrictions that may have an influence on the flow pattern should also be noted.

4.5.2 Underwater inspections

(i) Preparation

It is important to be well prepared for an underwater inspection. These inspections are usually conducted by a team of divers who should familiarize themselves with their respective duties, with the equipment, and with the site itself.

The following is a list of some of the items with which the inspectors should acquaint themselves beforehand:

- The nature and level of detail required from the inspection should be determined beforehand.
- Examination of all pertinent and previous inspection reports should be available. Familiarization with the site conditions. Study the drawings, since visibility is often very poor and the inspector then has to rely on drawings for guidance through the structure.
- Workmen, equipment and material (films, batteries, writing material, etc) requirements.
- Establish the diving technique to be used eg. SCUBA, surface-supported air supply etc.
- Determine the most suitable communications system, comprising pull line, radio communications, closed-circuit TV, etc.
- Recording equipment such as slates, notebooks, video cameras, etc.

It is therefore evident that the inspection team must allow adequate time to prepare for the planning and inspection.

(ii) Cleaning

An underwater inspection often involves cleaning of structural member of any growth, or the accumulation of mud etc. The extent of the cleaning operation depends on the amount of such growth and the type of inspection. Unnecessary cleaning should be avoided because this growth may offer some form of protection to the member.

(iii) Detection

The following methods apply to underwater inspections:

- Visual examinations with the aid of lighting, diver's slate and tools for scraping, probing and cleaning as required.
- Tactile examination especially under conditions of severely limited visibility which is restrictive with regard to qualitative assessment of the defects. (Under these conditions, it is important that the diver is well prepared and familiar with the structure and assisted by a good communication link to the support team).
- Support testing to obtain specific details and which comprises:
 - Core drilling
 - Optical scans
 - Acoustic scans
 - Ultrasonic tests
 - Voltage-potential tests
 - Computer-assisted photography
 - Polarization-resistance tests.

These testing methods have specific fields of application, and should be used accordingly. For accurate interpretation of the results, the testing methods should be calibrated against known conditions.

(iv) Diving techniques, equipment and safety

Information on the above topics are covered in the references: The engineer in charge should be familiar with the applications and limitations of the various techniques prior to conducting an underwater inspection. It is therefore important that inspections be conducted by a qualified diver under the supervision of an engineer.

4.6 Inspection reports

4.6.1 Evaluation

Bridge inspection reports should be passed on to the departmental bridge engineer for his assessment and decisions on maintenance, rehabilitation or replacement. It is therefore prudent to standardize bridge inspection reports and evaluation methods where possible.

A summary report on the most critical aspects should be prepared if many bridges have been inspected.

4.6.2 Condition ratings

An effective method of comparing bridge conditions is to convert the condition evaluations into corresponding numerical values or ratings. A typical rating scale, applicable to waterway evaluation, is given in Table 4.1.

RATING	CONDITIONS	DETAILED DESCRIPTION
9	Excellent	No noticeable or noteworthy deficiencies which affect the condition of the channel.
8	Very Good	Banks are well protected or vegetated.
7	Good	Little damage to bank protection. Banks and/or channels have minor amounts of drift.
6	Satisfactory	Banks are beginning to slump. Bank protection has widespread minor damage. Minor stream-bed movement evident. Debris is affecting the waterway slightly.
5	Fair	Bank protection is being eroded. River control structures and/or embankment protection shows major damage. Trees and brush restrict the channel.
4	Marginal	Bank and embankment protection is severely undermined damaged. Large deposits of debris in the waterway.
3	Poor	Bank protection has failed. Stream-bed aggradation, degradation or lateral movement has changed the waterway.
2	Very poor	The waterway has changed and the bridge and/or approach is threatened.
1	Critical	Bridge and/or approach damaged due to problems in the channel. Corrective action may put it back into light service.
0	Beyond repair	Bridge collapsed due to the problems in the waterway. Replacement necessary.

TABLE 4.1 : WATERWAY CONDITION RATINGS

4.7 Bridge inspectors

4.7.1 Personnel

Due to the considerable knowledge required for the management of an inspection programme, persons with appropriate structural and bridge background should be in charge thereof.

Experienced bridge designers should be used for inspections (where possible), as they are capable of interpreting the data and making recommendations. This would facilitate follow-up inspections to verify special problems and remedial actions.

Alternatively, trained bridge inspectors could be used: they are more cost effective to employ. With time, teams of inspectors can be established resulting in the efficient execution of programmes.

4.7.2 Training programme

An efficient training programme for personnel is essential to ensure uniform and correct reporting. The training programme should entail a basic understanding of the structural behaviour of a bridge, the causes of distress and their potential effects. The programme should be supplemented by case studies or typical examples to highlight problem areas, and should also be supplemented with an illustrated inspection manual and standardized reporting sheets (see Appendices).

4.8 Analytical evaluation of river bridges

Improved theoretical models for the prediction of flood magnitudes and the probability of these floods occurring should be used to re-assess the risk on strategically important existing structures so that preventative measures can be taken in good time.

5. REMEDIAL ACTION

5.1 Structural and functional

The degree of structural and functional remedial work will depend on the state of the structure, the need for affecting repairs in terms of the priority assessment emanating from the bridge management system and the availability of funds.

5.2 Waterway

The most common problems associated with the waterway area have been listed in Section 4.2. However, each bridge site will have a unique set of factors contributing to problems that are present and it is important to identify these, rather than to merely treat the symptoms. In some cases, the major contributor may be remote from the bridge site such as a bend in the river upstream of the bridge. The bridge engineer will have to assess the problem and decide upon appropriate actions to be taken to rectify the problem. The more common preventative and remedial measures are briefly discussed below. Although some of these measures have not been applied locally, they have been used successfully in other countries. Detailed descriptions of these methods are available in the references.

5.2.1 Removal and cleaning of debris

Debris and excessive vegetation should be removed on a regular basis to ensure an unrestricted flow of water under the bridge. This operation can be carried out by road maintenance teams.

5.2.2 Protective aprons and scour protection

These measures serve as protection to foundations and structural members, and are generally placed around piers or abutments located in the river, along river banks and around the ends of training banks.

The most common protection measures include the following:

- Dump rock or Riprap
- Gabions
- Dolos blocks
- Concrete slabs with adequate drop panels.

Use of the appropriate systems is dependent on the severity of flow conditions, the extent of the areas to be protected, the availability of materials and the cost of the particular system. The system adopted should be designed and constructed according to sound engineering practices.

5.2.3 Training works

Training works are used to alter the flow pattern of water courses and to arrest problems due to the secondary effects. The following are typical examples of their application:

- To direct the channel flow

- To stabilize the channel position
- To stabilize river banks and protect them against scour
- To improve the hydraulic efficiency of the channel
- To economize on bridge lengths
- To protect the road approaches to the bridge from attack
- To prevent meanders from folding into approaches
- To facilitate the passage of debris.

The two basic types of training works are:

- Guide banks
- Dykes

These training works should be adequate in length and width, and at the correct angles to achieve the desired effect. Refer to Volume III (Embankment and Bank Protection) of this guideline for a more detailed discussion.

5.2.4 Sheet piling

Sheet piling may be used as a protective apron to prevent scour of river banks, to retain the material behind it and to protect foundations. (See also Volume III).

5.2.5 Foundation reinforcement

Undermined or scoured foundations can be repaired by filling of the voids under the bases or by the installations of foundation piles and the extension of bases. Filling of the voids can entail the placing of concrete under water or the use of prepacked concrete.

5.3 Substructure

Those parts of the substructure that are under water or close to the waterline are often subjected to a greater degree of deterioration due to adverse conditions created by the flow of water. The deterioration is primarily due to

- Chemical attack
- Leaching
- Corrosion of reinforcement
- Abrasion.

The following measures may be taken to arrest or correct the above-mentioned problems.

5.3.1 Deflectors and dolphins

These comprise shields constructed around the piers to protect them against impact damage, to guide debris around it and to reduce abrasion.

5.3.2 Surface coatings

Surface coatings consists mainly of bitumen based or epoxy products and are intended to render protection to the concrete against chemical and atmospheric attack. The bitumen based coatings have a high acid resistance and are used in various formulations depending on the application. A large range of epoxies are available from which the appropriate product for the particular application should be selected.

5.3.3 Veneers

Veneers consisting of bricks or tiles affixed to the member with special mortars are used under conditions of extreme chemical attack.

5.2.4 Wraps

Wraps consisting of special chemically-resistant plastic or rubber sheets that are wrapped around the member may be used as an alternative to veneers.

5.3.5 Jackets

Jackets to protect members against abrasion and chemical attack, to strengthen deteriorated elements or to repair damaged elements are constructed by fixing formwork around the member and filling the cavity between the pier and the formwork with grout or an epoxy mortar. Depending on the material used for the formwork it could be left in position to form a permanent outer protective layer. Sheet piling could be used to form the outer part of the jacket.

5.3.6 Crack-sealing

Cracks may be sealed and structural integrity restored by injecting the crack with a specially formulated epoxy resin. This is a specialised operation and the work should be carried out by experienced personnel.

5.3.7 Cathodic protection

Cathodic protection is an effective method of stopping corrosion damage to ferrous metals. Protection is achieved by introducing an external direct electrical current to the member by installing an electrode in the concrete near the reinforcement and connecting it to the positive terminal of an electrical source and connecting the reinforcement to the negative terminal. This is a very specialised method and various commercial systems are available.

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7. APPENDICES

7.1 Proposed list of variables

The following is an example of a data collection form containing the variables included in a comprehensive bridge data base. Such a form should be supplemented with detailed definitions of each data field. Some examples are included.

[illegible]

Type bridge:

Type deck:

Type deck material:

Type traffic barrier/railing:

Type wearing surface:

Type abutment (Left):

Type abutment (Right):

Type abutment foundation (L):

Type abutment foundation (R):

Screen 2

Design approval date (yy/mm):				
Design firm code:				
Completion date (yy/mm):				
Date major rehabilitation (yy/mm):				
Design load:				
Super load route:		Y	N	U
Design return period (years):				
Design freeboard (m):			.	
Design flood discharge (m ³ /s):				
Skew angle (Degrees)			,	
Radius (m):				

FIGURE 7.1.1: EXAMPLE BMS INVENTORY DATA SHEET

Overall bridge length (metres):									
Approach roadway width (metres):									
Min overall width (metres):									
Min bridge roadway width (metres):									
Number of lanes:									
Traffic flow directions:									
Number of sidewalks:									
Width of sidewalk (m):									
Vertical clearance (principal):									
Vertical clearance (secondary):									
Horizontal clearance (principal):									
Horizontal clearance (secondary):									
ADT (principal):									
ADT (secondary):									
Year of count:									
Truck factor (%):									
Visibility classification:									
Detour impact (minutes):									
Detour length (kilometres):									

Screen 4

COMMENTS

FIGURE 7.1.1 CONT. EXAMPLE BMS INVENTORY DATA SHEET

TYPE CROSSING																															
DESCRIPTION :	This item describes the intersecting features.																														
FORMAT:	INTEGER STRING: The crossing type is described by a two digit code.																														
EXAMPLE :	(i) 01 (ii) 02, 03																														
NOTES:	If more than two features intersect, then both crossing types must be entered, separated by a comma (',') as shown in example (ii).																														
CODES:	The following codes are used to describe the different crossing types. <table><tr><td>01</td><td>-</td><td>Road over River</td></tr><tr><td>02</td><td>-</td><td>Road over Rail</td></tr><tr><td>03</td><td>-</td><td>Road over Road</td></tr><tr><td>04</td><td>-</td><td>Road over Canal</td></tr><tr><td>05</td><td>-</td><td>Rail over Road</td></tr><tr><td>06</td><td>-</td><td>Canal/Pipe over Road</td></tr><tr><td>07</td><td>-</td><td>Pedestrian over Road</td></tr><tr><td>08</td><td>-</td><td>Road over Pedestrian</td></tr><tr><td>98</td><td>-</td><td>Other</td></tr><tr><td>99</td><td>-</td><td>Unknown</td></tr></table>	01	-	Road over River	02	-	Road over Rail	03	-	Road over Road	04	-	Road over Canal	05	-	Rail over Road	06	-	Canal/Pipe over Road	07	-	Pedestrian over Road	08	-	Road over Pedestrian	98	-	Other	99	-	Unknown
01	-	Road over River																													
02	-	Road over Rail																													
03	-	Road over Road																													
04	-	Road over Canal																													
05	-	Rail over Road																													
06	-	Canal/Pipe over Road																													
07	-	Pedestrian over Road																													
08	-	Road over Pedestrian																													
98	-	Other																													
99	-	Unknown																													

TABLE 7.1.1 : EXAMPLE DATA FIELD DEFINITION : TYPE CROSSINGS

BRIDGE #	
DESCRIPTION :	This is a unique number assigned to each bridge.
FORMAT:	CHARACTER STRING: The bridge number consists of a combination of alphanumerics and numerics. Max length : 6 characters.
EXAMPLES :	B443; IB99
NOTES:	This is a mandatory item. It is absolutely important that the bridge number used is correct because the bridge number is the primary identification item in the BMS. The bridge number must be entered without any spaces between numerics and/or alpha numerics.

TABLE 7.1.2 : EXAMPLE DATA FIELD DEFINITION : BRIDGE NUMBER

OVERALL BRIDGE LENGTH (m)	
DESCRIPTION :	This item gives the overall length of the bridge.
FORMAT:	DECIMAL STRING: The overall bridge length must be given to the nearest tenth of a meter, indicated by a decimal point.
EXAMPLE :	117.0; 100.0
NOTES:	The bridge length should be measured between joint centrelines, along the bridge centre line. For cell structures, the length is measured between the middle of the outer walls, perpendicular to the walls. An unknown item must be indicated with a question mark.

TABLE 7.1.3 : EXAMPLE DATA FIELD DEFINITION : BRIDGE LENGTH

COLUMN HEIGHT (m)	
DESCRIPTION :	This item gives the height of each column at a support.
FORMAT:	DECIMAL STRING: The height of each pier must be given to the nearest tenth of a meter.
EXAMPLE :	12.7; 13.5
NOTES:	An unknown item must be indicated with a question mark. The height of a pier column is measured from the top of the footing or pile cap to the top of the pier.

TABLE 7.1.4 : EXAMPLE DATA FIELD DEFINITION : COLUMN HEIGHT

7.2 Proposed set of bridge inspection sheets

The following is an example of bridge inspection sheets.

DEPARTMENT OF TRANSPORT

BRIDGE INSPECTION REPORT

BRIDGE NUMBER:.....

BRIDGE NAME:.....

ROUTE:.....

DISTRICT:.....

DATE:.....

INSPECTOR:.....

ITEM	RATING	REMARKS	MR & R ref
1 APPROACHES			
1.1 Approach Embankments			
1.2 Approach Roadway			
1.3 Approach Guardrails			
1.4 Road signs (Related to bridge)			
1.5 Embankment protection			
2 WATERWAY			
2.1 Stream Bed & Banks			
2.2 Erosion Protection			
3. SUBSTRUCTURE			
3.1 Foundations			
3.2 Abutments			
3.3 Wing Walls/Return Walls			
3.4 Retaining Walls			
3.5 Piers & Columns			
3.6 Drainage			
3.7 Bearings			
4. SUPERSTRUCTURE			
4.1 Longitudinal members			
4.2 Transverse members & diaphragms			
4.3 Deck slab			
4.4 Other types of decks			
5. ROADWAY			
5.1 Surfacing			
5.2 Expansion joints			
5.3 Drainage			
5.4 Traffic barriers			
5.5 Railings			
5.6 Guardrails			
5.7 Kerbs & Sidewalks			

ADDITIONAL REMARKS: 1. Vertical clearance

2. Surfacing depth (mm)

3. Tell - tales attached? (Y/N)(Give details)

SIGNED: _____

NOTE: Attach separate sheets with additional remarks, sketches, photographs if necessary.
 Mark rating with "*" eg. "8*" if inspector cannot draw conclusion without further investigation (eg. structural or nonstructural cracks).

DEPARTMENT OF TRANSPORT
MAINTENANCE & REHABILITATION REPORT

BRIDGE NUMBER: _____

DATE: _____

ITEM	UNIT	QUANT	PRIORITY
APPROACHES / ROADWAY			
1. Surfacing (patch)	m ²		
2. Surfacing (reseal)	m ²		
3. Guardrails (align & tighten)	m		
4. Guardrails (new/replace)	m		
5. End units (new/replace)	No		
6. Downchutes (new/replace)	m		
7. Downchutes (repair)	m		
8. Downchutes (clean)	m		
9. Inlets / Outlets (new/replace)	No		
10. Drainage berm (new/replace)	m		
WATERWAY / EMBANKMENTS			
11. Erosion damage (backfill)	m ³		
12. Gabion boxes 1m x 1m (new / repair)	m ³		
13. Gabion mattresses (new / repair)	m ³		
14. Stone pitching (new / repair)	m ²		
SUBSTRUCTURE			
15. Foundation loss (underpin / backfill)	m ³		
16. Spalling concrete (repair)	m ²		
17. Cracks (seal / repair)	m		
18. Weepholes (new)	No		
19. Retaining wall (new)	m ²		
20. Pier jackets (new)	m ²		
21. Sandblast / Waterjet	m ²		
22. Surface sealer / Paint	m ²		
BEARINGS			
23. Clean / Lubricate	No		
24. Reset	No		
25. Replace with Elastomeric bearing	No		
26. Replace with Steel bearing	No		

PRIORITY CODES		
CODE	DESCRIPTION	URGENCY
0	Critical	As soon as possible
1	Urgent	Within 12 months
2	Priority	Within 3 - 4 years
3	Future	When funds are available
4	Upgrade to standard	To be determined by DOT

DEPARTMENT OF TRANSPORT

MAINTENANCE & REHABILITATION REPORT (CONT.)

ITEM	UNIT	QUANT	PRIORITY
SUPERSTRUCTURE			
27. Spalling concrete (repair)	m ²		
28. Cracks (seal / repair)	m		
29. Surface sealer / Paint	m ²		
30. Sidewalk paving (replace)	m ²		
31. Resurface deck	m ²		
32. Drainage holes (enlarge / new extend)	No		
33. Drainage holes (clean)	No		
EXPANSION JOINTS			
34. Joint filler (replace)	m		
35. Replace concrete nose & seal	m		
36. Replace rubberized bitumen	m		
37. Replace elastomeric conc. nose & seal	m		
38. Replace modular / steel joint	m		
RAILINGS / BALUSTRADES			
39. Steel / Aluminium railings (replace)	m		
40. Steel / Aluminium railings (re-align)	m		
41. NJ type balustrade (replace)	m		
42. Spalls / damage (major repair)	m ²		
43. Spalls / damage (minor repairs)	m ²		
MR & R NOT LISTED ABOVE	RATE	UNIT	QUANT

PRIORITY CODES		
CODE	DESCRIPTION	URGENCY
0	Critical	As soon as possible
1	Urgent	Within 12 months
2	Priority	Within 3 - 4 years
3	Future	When funds are available
4	Upgrade to standard	To be determined by DOT

CONDITION RATING FOR APPROACHES

RATING		GUIDELINES
9	EXCELLENT	New condition.
8	VERY GOOD	No noteworthy problems.
7	GOOD	Some minor problems. Minor erosion damage to embankments.
6	SATISFACTORY	Slight bump before bridge. Some material loss on shoulders and embankments. Safety features still intact.
5	FAIR	Bump before bridge causes some discomfort when driving over. Safety features loose but still intact.
4	MARGINAL	Bump before bridge causes significant discomfort when driving over. Cracks in embankments on shoulder. Loss of embankment material due to erosion. Guardrails damaged or loose.
3	POOR	Bump before bridge requires significant speed reduction for safe passage on to bridge. Wide cracks in embankments on shoulder. Severe material loss due to erosion. Guardrails missing.
2	VERY POOR	Bump before bridge causes serious safety hazard. Signs of embankment slip movement.
1	CRITICAL	Bridge should be closed due to failure of approaches.
0	BEYOND REPAIR	Completely non functional.

CONDITION RATINGS FOR WATERWAY

RATING		GUIDELINES
9	EXCELLENT	No noticeable or noteworthy deficiencies which affect the condition of the channel.
8	VERY GOOD	Banks are well protected or vegetated. River control devices and bank protection are not required or are in a very good condition.
7	GOOD	Bank protection has little damage. Banks and/or channel have minor amounts of drifts.
6	SATISFACTORY	Bank is beginning to slump. Control devices and bank protection has widespread minor damage. There is minor stream bed movement evident. Debris is affecting the waterway slightly.
5	FAIR	Bank protection is being eroded. River control devices and/or bank protection have major damage. Trees and brush restrict the channel.
4	MARGINAL	Bank protection is severely undermined. Large deposits of debris are in the waterway.
3	POOR	Bank protection has failed. Stream bed aggradation, degradation or lateral movement has changed the waterway to now threaten the bridge and/or approach roadway.
2	VERY POOR	The waterway has changed to the extent that the bridge is near a state of collapse.
1	CRITICAL	Bridge closed due to channel failure. Corrective action may put it back in service.
0	BEYOND REPAIR	Bridge closed because of channel failure. Replacement necessary.

CONDITION RATING FOR STRUCTURAL ELEMENTS

RATING		GUIDELINES
9	EXCELLENT	New condition
8	VERY GOOD	No signs of distress or deterioration. Possibly some minor shrinkage or temperature cracks in concrete. No rust on steel members.
7	GOOD	Some minor problems. Nonstructural cracks in concrete. Light spalling. No rust stains through cracks. Some light rust formation on steel members, pitting the paint surface.
6	SATISFACTORY	Structural elements show some minor deterioration. More significant nonstructural cracks in concrete. Moderate spalling. No rust stains visible. Moderate rust formation on steel members. No measurable section loss.
5	FAIR	Structural elements are sound but have some section loss due to deterioration, spalling or scour. Structural cracks with light rust staining. Stratified rust flakes with some measurable section loss for steel members.
4	MARGINAL	More general section loss due to deterioration, spalling or scour. Structural cracks with moderate rust staining visible. Heavy stratified rusting resulting in advanced section loss for steel members.
3	POOR	Advanced deterioration, spalling or scour, exposing reinforcing steel. Structural cracks with severe rust staining. Rust has caused holes in structural steel members. Loose connections, buckled or bowed steel members.
2	VERY POOR	Advanced deterioration of structural elements. Significant structural cracks visible. Reinforcing exposed and rusted. Holes rusted through steel members. Fatigue cracks. Scour has severely undermined supports. Unless closely monitored, bridge should be closed.
1	CRITICAL	Bridge closed. Study required to determine the feasibility of repairs.
0	BEYOND REPAIR	Permanently closed till replaced.

CONDITION RATING FOR ROADWAY SURFACING, KERBS & SIDEWALKS

RATING		GUIDELINES
9	EXCELLENT	New condition
8	VERY GOOD	No noteworthy problems
7	GOOD	Minor localized cracks. Generally a smooth ride over bridge deck. Kerbs and sidewalk generally smooth.
6	SATISFACTORY	Light cracking over most of area. Light rutting or bleeding. Minor unevenness when driving over bridge deck, or walking over sidewalk.
5	FAIR	More general cracking. Minor ravelling or section loss. More visible rutting or bleeding. Ride over bridge deck fairly uneven. No speed reduction required. Kerbs and sidewalk fairly uneven.
4	MARGINAL	General cracking, some ravelling and section loss. Rutting clearly visible. Bleeding reduces skid resistance significantly. Unevenness calls for slight speed reduction. Kerbs or sidewalk elements significantly displaced or settled.
3	POOR	Cracking with more general ravelling and section loss. Pot holes forming. Extent of bleeding such that very little skid resistance remains. Speed reduction required to drive over bridge deck. Kerb or sidewalk elements broken but still in place, very uneven.
2	VERY POOR	Cracking and section loss. Pot holes could cause damage to vehicles driving over bridge deck. Significant speed reduction required. Kerb or sidewalk element missing, otherwise very uneven.
1	CRITICAL	Pot holes or other section loss pose serious safety hazard.
0	BEYOND REPAIR	Completely non functional.

CONDITION RATINGS FOR EXPANSION JOINTS

RATING		GUIDELINES
9	EXCELLENT	New condition
8	VERY GOOD	No noteworthy problems
7	GOOD	Minor cracking. Smooth ride over. All elements tight. No sign of leakage. Free movement.
6	SATISFACTORY	More widespread cracking. Slight bump when driving over. Seal intact but some signs of little leakage. Free movement of the joint.
5	FAIR	Widespread cracking with some isolated spalling. Bump when driving over. Seal protrudes slightly and/or shows some signs of damage. More significant signs of leakage. Free movement.
4	MARGINAL	Cracking with spalling at edges of joint. Significant bump when driving over. Seal loose or protrudes significantly. Leakage stains visible. Bolted down or cast in elements loose. Joint strained to it's extreme reaches.
3	POOR	Cracking and spalling over whole length of nosing. Speed reduction required when driving over. Seal missing or completely damaged. Very prominent leakage stains. Free movement restricted.
2	VERY POOR	Cracking and spalling over whole length. Rust stains visible. Significant speed reduction required. Seal missing or completely non functional. Very prominent leakage stains. Cracking in deck or abutment wall due to movement restriction.
1	CRITICAL	Same symptoms as above except that the degree is such that vehicles could be damaged when driving over or safety hazard.
0	BEYOND REPAIR	Completely non functional.

CONDITION RATINGS FOR DRAINAGE

RATING		GUIDELINES
9	EXCELLENT	New condition
8	VERY GOOD	No noteworthy problems
7	GOOD	Some debris collected in scupper. No silting or ponding evident.
6	SATISFACTORY	Some debris collected in scupper. Minor silting or ponding evident. No scuppers provided but little evidence of silting or ponding.
5	FAIR	Debris in scuppers with more noticeable signs of ponding and silting. Some silt build up on bridges with no scuppers.
4	MARGINAL	Scuppers only marginally functional due to silting or debris. More significant silting or signs of ponding on bridges with no scuppers.
3	POOR	Scuppers blocked. Leakage around scuppers. Spalling concrete around scupper. Silting on deck encroaches roadway.
2	VERY POOR	Scuppers blocked. Leakage and spalling around scuppers with rust stains visible. Vegetation growing out of scuppers or silted areas. Extensive signs of ponding.
1	CRITICAL	Drainage system non functional and could lead to dangerous situations due to ponding or roadway encroachment.
0	BEYOND REPAIR	Completely non functional.

CONDITION RATINGS FOR TRAFFIC BARRIERS

RATING		GUIDELINES
9	EXCELLENT	New condition
8	VERY GOOD	No noteworthy problems
7	GOOD	Localized minor accident damage. Some nonstructural cracking.
6	SATISFACTORY	General minor accident damage. Light general nonstructural cracking. No rust stains.
5	FAIR	General accident damage. More significant non structural cracking. Light rust stains visible.
4	MARGINAL	More serious accident damage. Spalling and cracking clearly visible. Significant rust stains.
3	POOR	Serious accident damage. Significant spalling and cracking with severe rust staining.
2	VERY POOR	Elements loose or missing which could pose safety hazard. Reinforcement visible and corroded.
1	CRITICAL	Condition poses serious safety hazard.
0	BEYOND REPAIR	Completely non functional.

CONDITION RATINGS FOR GUARDRAILS AND RAILINGS

RATING		GUIDELINES
9	EXCELLENT	New condition.
8	VERY GOOD	No noteworthy problems.
7	GOOD	Minor accident damage. All components tight. Some light rust.
6	SATISFACTORY	More general minor accident damage. Most components tight. Light rust.
5	FAIR	General moderate accident damage. More elements loose but still intact. Safety not affected. Moderate rust.
4	MARGINAL	More serious accident damage. Most elements loose, some missing but railing can still function as a safety feature. Moderate to severe rust.
3	POOR	Components loose or accident damage to the extent that railing can not perform function any more. Severe rust.
2	VERY POOR	Railing components missing. Could pose safety hazard. Corrosion causes section loss.
1	CRITICAL	Serious safety hazard due to lack of guardrails or railing.
0	BEYOND REPAIR	Completely non functional.