Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa

Visual Assessment Manual

Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd

ReCAP Project GEN2014C

August 2019

Preferred citation: Paige-Green, P., Verhaeghe, B., Roux, M.P. Council for Scientific and Industrial Research (CSIR), Paige-Green Consulting (Pty) Ltd and St Helens Consulting Ltd (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa, Visual Assessment Manual, GEN2014C. London: ReCAP for DFID.

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Quality assurance and review table

Version	Author(s)	Reviewer(s)	Date
1	P Paige-Green, B Verhaeghe	N Leta, ReCAP PMU Dr J Cook, ReCAP TP	November 2018
2	P Paige-Green, B Verhaeghe	Prof R Wilby	July 2019
3	P Paige-Green, B Verhaeghe, M Roux	N Leta, ReCAP PMU	September 2019

ReCAP Database Details: Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa

Reference No:	GEN2014C	Location	Sub-Saharan Africa
Source of Proposal	DFID/ReCAP	Procurement Method	Tender
Theme	Sustainability of access	Sub-Theme	Climate resilience
Lead Implementation Organisation	CSIR	Partner Organisation	Paige-Green Consulting St Helens Consulting
Start Date	April 2017	End Date	September 2019
Report Due Date	August 2019	Date Received	August 2019

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Abstract

The impact of climate change on roads may require that vulnerable sections of the road infrastructure are identified and adaptations made to minimise potential future climate-related damage. These climate changes include changes in temperature and precipitation, increased windiness, sea-level fluctuations and the likely occurrence of increased numbers and frequencies of extreme events. Currently, for road management and maintenance and rehabilitation planning purposes, visual condition assessments of the road network are usually routinely carried out at specified frequencies. These normally look at the road condition, classifying problems such as cracking, deformation, rutting, potholing, etc. by degree and extent to prioritise and budget for follow-up management operations. Generally, only the road carriageway area is assessed. Similar assessments for Bridge Management Systems are also carried out in certain countries, and these are mostly related to the planning and management of maintenance and repairs of structures (including bridges and culverts). It is, however, necessary to add to this information to provide the required inputs for climate resilience assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure. This manual describes the nature and collection of this type of data, which is normally not part of the routine data collection for asset management purposes. This includes issues such as erosion, problem soils, drainage from the road and its near environment as well as from outside the road reserve, instability of embankments and cuttings, construction issues and maintenance problems. For expedience and to minimise costs, this should be done during the routine visual condition assessments, by the assessment teams or others trained specifically for the purpose. Based on the typical problems expected, the assessments are probably best done by those with a geotechnical, engineering geological or geomorphological background. A standard form for recording the data is provided with a worked example and photos of the rated distresses.

Key words

Climate change; road infrastructure; low volume roads; vulnerability; visual assessment manual.

Acknowledgements

The authors wish to thank the delegates from the AFCAP partners in Mozambique (ANE), Ethiopia (ERA) and Ghana (DFR and MoH) who assisted with inputs into this manual during field trials in each of the countries.

Research for Community Access Partnership (ReCAP)

Safe and sustainable transport for rural communities

ReCAP is a research programme, funded by UK Aid, with the aim of promoting safe and sustainable transport for rural communities in Africa and Asia. ReCAP comprises the Africa Community Access Partnership (AfCAP) and the Asia Community Access Partnership (AsCAP). These partnerships support knowledge sharing between participating countries in order to enhance the uptake of low cost, proven solutions for rural access that maximise the use of local resources. The ReCAP programme is managed by Cardno Emerging Markets (UK) Ltd.

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Acronyms, Units and Currencies

$	United States Dollar (US$ 1.00 ≈ provide conversion to local currencies)
ADB	Asian Development Bank
AfCAP	Africa Community Access Partnership
AsCAP	Asia Community Access Partnership
GPS	Global positioning system
ReCAP	Research for Community Access Partnership
UK	United Kingdom (of Great Britain and Northern Ireland)
UKAid	United Kingdom Aid (Department for International Development, UK)

Executive summary

This manual is aimed at road authority staff in general and in particular persons responsible for assessing the vulnerability of road infrastructure to the impact of climate change. These could be road authority staff or staff from consulting engineering firms.

The impact of climate variability and change on roads may require that vulnerable sections of the road infrastructure are identified and adaptations made to minimise potential future climate-related damage. These climate changes include changes in temperature and precipitation, increased windiness, sea-level fluctuations and the likely occurrence of increased numbers and frequencies of extreme events.

Currently, for road management and maintenance and rehabilitation planning purposes, visual condition assessments of the road network are usually routinely carried out at specified frequencies. These normally look at the road condition, classifying problems such as cracking, deformation, rutting, potholing, etc. by degree and extent to prioritise and budget for follow-up management operations. Generally, only the road carriageway area is assessed. Similar assessments for Bridge Management Systems are also carried out in certain countries, and these are mostly related to the planning and management of maintenance and repairs of structures (which include bridges and culverts). It is, however, necessary to add to this information to provide the required inputs for climate resilience assessments and the implementation of appropriate adaptation techniques to improve the climate resilience of the infrastructure.

The manual describes the nature and collection of this type of data, which is normally not part of the routine data collection for asset management purposes. This includes issues such as erosion, problem soils, drainage from the road and its near environment as well as from outside the road reserve, instability of embankments and cuttings, construction issues and maintenance problems. For expedience and to minimise costs, this should be done during the routine visual condition assessments, by the assessment teams or others trained specifically for the purpose. Based on the typical problems expected, the assessments are probably best done by those with a geotechnical, engineering geological or geomorphological background. A standard form for recording the data is provided with a worked example and photos of the rated distresses.

This Manual is an accompanying document to the *Engineering Adaptation Guidelines*[1] as well as to the *Climate Threats and Vulnerability Assessment Guidelines*[2], and support the adaptation methodology outlined in the *Climate Adaptation Handbook*[3].

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[1] Paige-Green, P., Verhaeghe, B. and Head, M. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Engineering Adaptation Guidelines,* GEN2014C. London: ReCAP for DFID.

[2] Le Roux, A., Makhanya, S., Arnold, K. and Roux, M. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Threats and Vulnerability Assessment Guidelines,* GEN2014C. London: ReCAP for DFID.

[3] Head, M., Verhaeghe, B., Paige-Green, P., le Roux, A., Makhanya, S. and Arnold, K. (2019). Climate Adaptation: Risk Management and Resilience Optimisation for Vulnerable Road Access in Africa: *Climate Adaptation Handbook,* GEN2014C. London: ReCAP for DFID.

1 Background

It is clear that the earth's climate is changing and this is likely to have several significant effects on the road infrastructure of most countries, but particularly on the low volume rural access road network. These roads are often constructed to lower standards using local materials and labour including low cost structures and are thus more susceptible to climate damage than higher order roads carrying higher traffic volumes and constructed to higher standards.

New roads should be designed incorporating the necessary climate adaptation measures but it is not practical or economic to make every existing road resilient to climatic effects. Thus, it is important to identify those roads that are not resilient and prioritise them for adaptation measures. The priority would be based on the road classification and purpose, the number of people affected and the availability of alternative routes, discussed in other documents related to the AfCAP climate change project. To implement the necessary adaptations to make roads more climate resilient and assist with the prioritisation, it is necessary to carry out visual assessments (in addition to the conventional routine assessments for pavement and bridge management purposes) of existing roads with particular attention being paid to those problems specifically related to climatic effects.

This manual summarises the important potential climate-related problems and indicates the method of assessing them, with pointers that can assist with the observations and interpreting the visual assessments.

It is important that all assessors understand the reasons for the visual assessment and how the data collected will be incorporated into the implementation of adaptation measures. During the assessment of each of the issues addressed, the assessor should try and answer the question "Can the existing situation cope with the projected changes in climate without severe damage or collapse within the assessment cycle?".

While it is acknowledged that the collection of this information ostensibly appears to overlap with the visual assessment data collected for Asset Management (roads and structures) purposes, there are significant differences. The assessment for climate resilience differs from the existing pavement and structure assessment used for routine Asset management purposes in the following ways:

- This is carried out only once for each road during an assessment cycle. As climate change is a relatively slow process over decades, an assessment cycle of not shorter than 10 years is recommended. There may, however, be occasional localised areas such as drainage or slope stability issues that indicate possible "warning" situations, which need to be monitored periodically to ensure that no progressive damage or weakening leads to larger unexpected failures.
- It requires significantly more detailed observations, done at walking pace, unlike routine asset management visual inspections mostly carried out from a moving vehicle.
- Assessment for asset management is based solely on what is observed at the time of the inspection, whereas for climate resilience, the impact of the expected future climatic changes must be interpreted or inferred from the observations made.
- These assessments should be up-dated periodically in line with the pace of climate change.

2 Data to be collected

For the design of climate resilience of roads, various issues need to be assessed. These include:

- Erosion potential;
- Subgrade material problems;
- Drainage efficiency in the road reserve;
- Drainage from outside the road reserve;
- Slope stability (embankments and cuttings);
- Construction quality; and
- Maintenance effectiveness.

Other indications of possible problems may be observed on certain sites, such as the accumulation of sand and debris (due to wind and flooding), excessive vegetation caused by increased rainfall and high temperatures, leading to sight-distance and passability problems, etc.

The cells in the assessment form should be completed as discussed in the following sections. In most cells, a degree and an extent rating will be entered. These will be determined on a 5-point scale where they exist (0 is entered if there is no evidence of the distress as discussed below). A typical input would thus be 3/2 for a degree 3 and extent 2 problem. It should be noted that the majority of vulnerabilities will be related to changes in precipitation, but issues such as temperature changes, increased windiness, etc. should be borne in mind during the field assessments. If any facilities (e.g. culvert, drains, etc.) are not present within the assessed section, the cell on the assessment form will remain blank. In a few cases a Yes/No response is required

It is important that the assessment of any condition only be recorded once (i.e. no double accounting). For example, side-drains may not be functioning properly as a result of severe erosion. This should be recorded as either an erosion problem or an effectiveness problem, depending on the assessment, but not as both an erosion and a drainage effectiveness problem.

2.1 Degree

The degree of a particular type of distress is a measure of its severity. Since the degree of distress can vary over the segment assessed, the degree must be recorded in conjunction with the extent of occurrence for most parameters; this will provide the best average assessment of the seriousness of a particular type of distress. The length of a segment is usually 100 m.

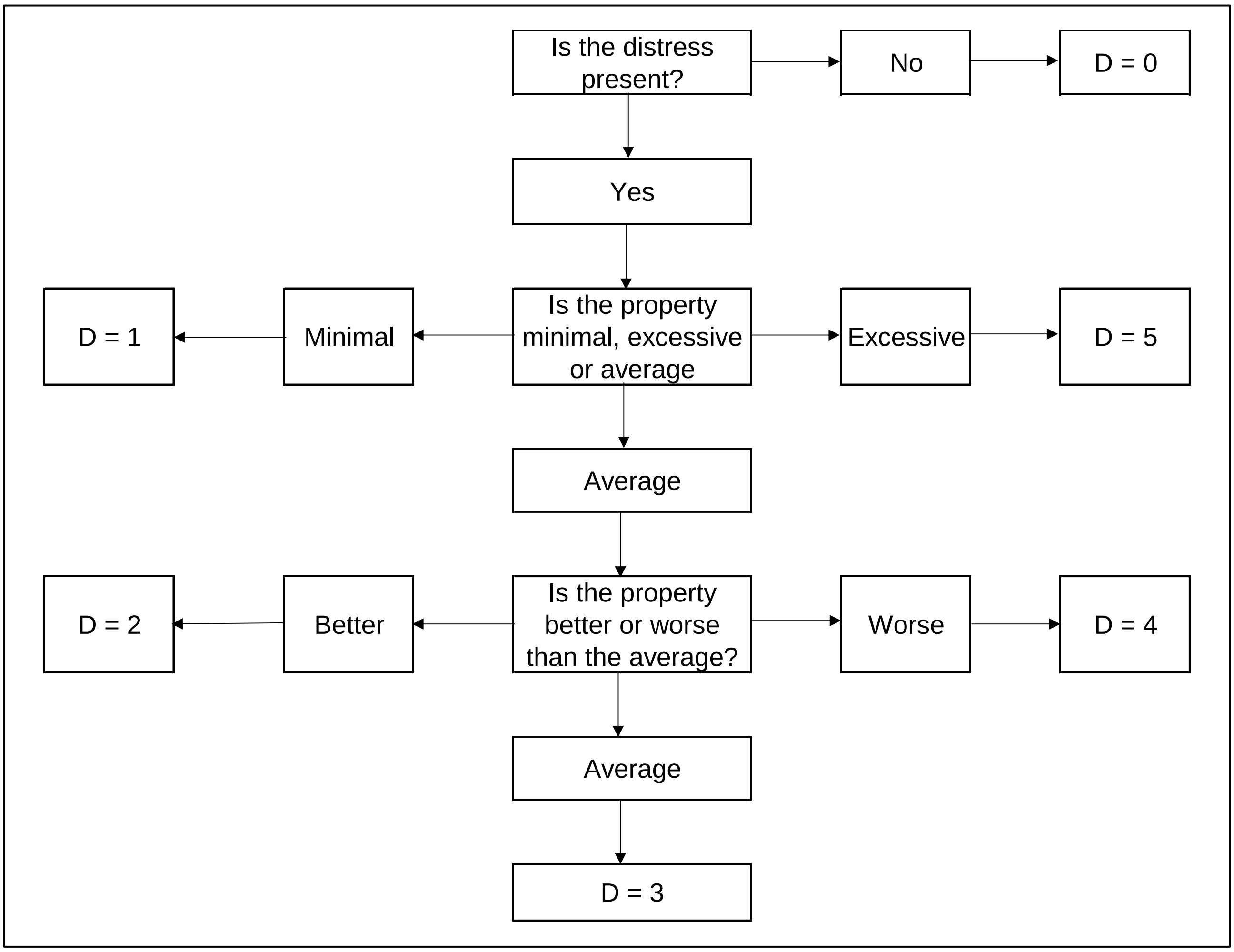
The general descriptions of degree of each type of distress are presented in Table 1.

Table 1 General description of degree classification

Degree	Severity	Description
0	-	No potential vulnerabilities visible
1	Slight	Only the first signs of distress are visible but these are difficult to discern. No adaptation measures necessary
2	Slight to warning	Distress obvious but not at degree 3
3	Warning	Start of secondary defects. (Distress notable with respect to possible consequences). Adaptation in the medium term may be necessary. Usually requires repair
4	Warning to severe	Secondary defects clearly visible but not at degree 5 yet
5	Severe	Secondary defects are well developed (high degree of secondary defects) and/or extreme severity of primary defect. Adaptation measures should be implemented immediately. Usually requires reconstruction

A flow diagram illustrating the use of the five-point classification system is shown in Figure 1. The most important categories of degree are 1, 3 and 5. If there is any uncertainly regarding the condition between degrees 1 and 3 or 3 and 5, the defect may be assessed as 2 or 4, respectively.

Figure 1 Flow diagram for assessing the degree of a distress



2.2 Extent

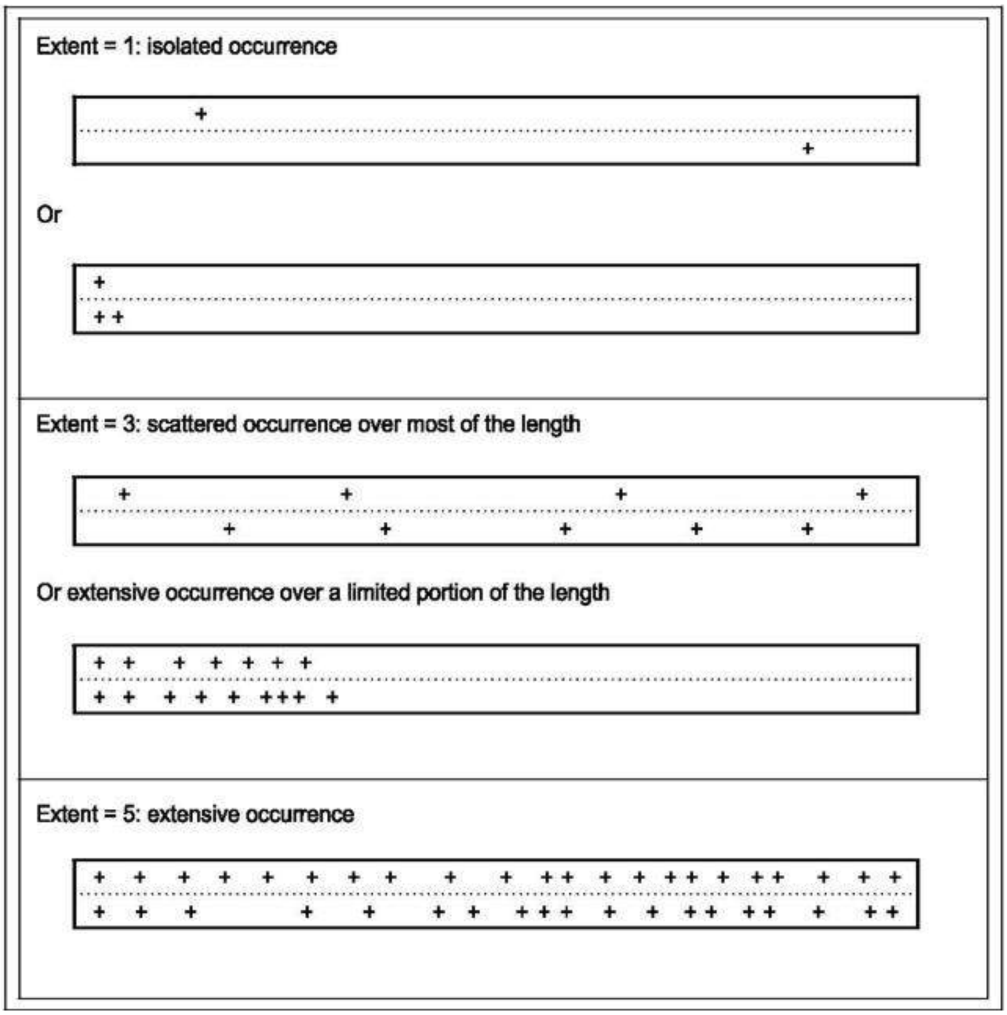
The extent of any distress is a measure of how widespread the distress is over the length of the road segment. This is summarised in Table 2 and illustrated in Figure 2.

Table 2 General description of the extent classification of a distress

Extent	Description	Percentage of length*
1	Isolated occurrence	< 5
2	Occurs over parts of the segment length More than isolated	5 - 10
3	Intermittent (scattered) occurrence over most of the segment length (general), or Extensive occurrence over a limited portion of the segment length.	10 - 25
4	More frequent occurrence over a major portion of the segment length	25 - 50
5	Extensive occurrence over the entire segment	>50

*The percentage of extent is only a guide-line for the assessors and should not be literally interpreted

Figure 2 Illustration of the extent rating of a distress



The individual descriptors of the potential climatic effects on the roads are best obtained based on experience, but several indicators can be used to assist with early identifications of potential problems. These are discussed below relevant to each of the potential problems outlined in Section 2.

Assessments should be done on a planned basis, but could be reactionary in some cases, especially if a climate change related event happens on a section of road or in a certain region. In such cases it might be necessary to assess the rest of the road or roads in the specific region. It should be borne in mind that, although assessments are best done during or shortly after wet weather, they will often through necessity be carried out in the dry season and many of the tell-tale signs may not be present or clearly visible at the time of the assessment.

It is frequently observed that most of a road is affected by, for instance, a degree 3 severity but a degree 5 occurs over portion of the road. In these cases, the higher of the product of the degree and extent would be recorded. For example, a road that has degree 3 cracking over 70% of the area and degree 5 over 7% of the area would be recorded as a 3/5 (product of 15) and not a 5/2 (product of 10). However, if there were degree 3 cracking over 60% of the area and degree 5 over 30% of the area, the recording would be 5/4 (product of 20) and not 3/5 (product of 15).

2.3 Climatic factors

The following main climatic factors may affect different parts of any country in future:

- Increased or decreased average temperatures;
- Increase or decrease in number of very hot days (> 35°C);

- Increased or decreased annual precipitation;
- Increase or decrease in number of extreme events;
- Increased windiness; and
- Increased sea level and coastal erosion.

It is important before making any assessment to identify the expected climatic changes along the road (or in the general area and associated catchments) being assessed and to be particularly aware of the consequences of these expected changes over the design life of the facilities along the road (paved or unpaved road surface, earthworks and small and large structures). General indications of future climate changes in the area are available on the internet but greater detail specifically related to the area required should be available through local meteorological, disaster planning or agricultural departments. Ideally, assessors would refer to a central source of national climate scenarios to ensure consistency around the assumed conditions faced by the road segments.

3 Assessment Criteria

3.1 General information

The top of the assessment form has various "boxes" to capture the overall assessment conditions. These include:

- Road number;
- Date;
- Assessors names;
- Weather - circle relevant symbol – Sunny (S) Partly cloudy (PC) Cloudy (C) Raining (R) Hot (H) Cold;
- Topography - circle relevant symbol – Flat (F) Rolling (R) Hilly (H) Mountainous (M);
- Landcover and use - circle relevant symbol used to identify the impact of precipitation on the natural soil and run-off capacity -– Symbols as follows:
    - A (Agriculture) typical food crops – maize, vegetables, small bush crops;
    - (F) Forest and/or dense vegetation – plantations of timber, tree crops (e.g. cocoa, citrus, etc.);
    - (N) Natural landscape, grasslands or savanna;
    - (PU) Peri-urban or urban – built up areas alongside road;
    - (D) Degraded – badly eroded, overgrazed, minimal plant growth;
    - (O) Other - any other landcover not included above;
- Chainage – distance along road (determined with measuring wheel);
- Grade – indication of grade of road - Flat (F), downhill (D) uphill (U) – estimate of grade in % if possible;
- Access to facilities – provide an indication of whether the road accesses border posts, schools, health centres, market/town, etc. A road provides access to a facility if the facility takes direct access from the road or from a side road that only intersects with the road being assessed;
- No. of alternative roads – indicate (mostly from maps and local consultations) how many alternative routes to the road being assessed exist;
- Common vehicle types – an indication of the dominant traffic types using the road – bicycles, carts, motorcycles, cars, light utility vehicles, trucks, etc. – usually determined by observing traffic while assessing the road; and
- GPS and photo – GPS coordinates at start and end of section and periodically along section – numbers of photographs taken (as recorded by the camera).

3.2 Erodibility

The erodibility of the road surface, embankment slopes and side drains can result in significant problems, not only aesthetic and environmental, but more importantly in the road management context, leading to excessive maintenance requirements (both road surface and drains) and potentially to complete failure of the infrastructure facility. Surface damage caused by erosion leads to concentrations of water, excessive loss of material as silt and increased water flow velocities. Uncontrolled erosion of the road support layers can eventually lead to collapse of the pavement or structure as well as excessive siltation of drainage structures. Changes in the rainfall volume or intensity will normally compound any problems noted during the assessment.

During assessment of the erosion potential of various components of the road and associated structures, the following need to be identified:

- Is the soil material comprising the subgrade and areas adjacent to the road obviously susceptible to erosion? Typically, single sized materials, fine sands and silts and non-cohesive materials are most prone to erosion. Poor compaction of constructed materials also encourages erosion. Erodible soils in the area usually make up the subgrade and would probably have been used in formations and embankments, leading to possible problems under future high-water regimes.
- Does the road surface (carriageway and shoulders) show any evidence of scouring or precipitation-related material loss? Erosion of the road surface applies only to unpaved roads and paved roads should be indicated as such on the assessment form and recorded as a blank.
- Are the side and mitre drains smooth and even or has erosion affected their shape and effectiveness? Lined drains will be indicated on the form and shown as a blank.
- Are there any run-off channels or signs of erosion damage on embankment or cutting slopes? Erosion on slopes must be differentiated from minor slope failures or surface sloughing.

Any significant positive responses to these questions will require some action to be taken to ensure climate resilience of the road as these areas will lead to concentration of water and accelerated erosion. Most of these adaptation/control techniques are relatively inexpensive, and include reshaping and grading of drains and surfaces, bio-engineering techniques, erosion control and protection measures (e.g. check dams), etc.

Any indication of channelling and material loss on unpaved road surfaces or shoulders must be noted. The intensity of the erosion should be described with an indication of the cause, where possible, i.e. poor compaction, long slopes, transverse or longitudinal, etc. This information should be sufficient to identify the expected adaptation or remedial measures by the designer. It is also necessary to identify the type of wearing course and nature of unpaved roads (i.e. gravel, earth or track). Wearing course materials selected according to recognised specifications and properly compacted will usually resist erosion, except on the steepest grades.

The descriptions of degrees of the various types of erosion are presented in Table 3 to Table 6 with degrees 2 and 4 being interpolated between 1 and 3 and 3 and 5 respectively and illustrated in Figure 3 to Figure 6 respectively.

3.2.1 Erosion of the road surround

Table 3 Degrees of erosion of the road surround

Degree	Description
1	Evidence of localised and minor material loss due to channelized water flows
3	Obvious surface erosion and channelling of water – regular inspection necessary
5	Severe loss of material and formation of deep erosion gullies – requires urgent adaptation measures

Figure 3 Erosion of areas around the road

	1 [✓ 1] 2 3 4 5 Evidence of localised material loss due to channelized water flows
	3 1 2 [✓ 3] 4 5 Obvious surface erosion and channelling of water
	5 1 2 3 4 [✓ 5] Severe loss of material and formation of deep erosion gullies

3.2.2 Erosion of the road surface

Table 4 Degrees of erosion of the road surface (and shoulders of unpaved roads)

Degree	Description
1	Evidence of minor water damage
3	Material loss can be easily seen – speed reduction necessary. Channels > 30 mm deep x 75 mm wide
5	Severe loss of material and road shape – vehicles avoid these areas. Channels > 60 mm deep x 250 mm wide – urgent improvement of drainage and material quality required

Figure 4 Degrees of erosion of the road surface (and shoulders of unpaved roads)

	1 [✓ 1] 2 3 4 5 Evidence of minor water damage and loss of material
	3 1 2 [✓ 3] 4 5 Material loss easily seen – speed reduction necessary. Channels > 30 mm deep x 75 mm wide.
	5 1 2 3 4 [✓ 5] Severe loss of material and road shape – vehicles avoid these areas. Channels > 60 mm deep x 250 mm wide

3.2.3 Erosion of side and mitre drains

Erosion of the side drains is usually evident as exposed soil, deep channels and poor flow characteristics. The potential erodibility of the soil and causes of erosion (high water velocities, inadequate drain capacity, steep slopes, etc.) should be noted together with the associated deposition (of the eroded material) locations and problems. The presence of vegetation in side- and mitre-drains normally indicates that no erosion is taking place.

Table 5 Degrees of erosion of side and mitre drains

Degree	Description
1	Minor evidence of material loss and damage due to water.
3	Erosion of drains requiring periodic maintenance and reshaping to restore flow - still functional
5	Severe loss of material and deformation of drains – dangerous to traffic and causing severe siltation “down-stream” – urgent adaptation measures required – impaired drain performance

Figure 5 Erosion of side and mitre drains

	1 [✓ 1] 2 3 4 5 Minor evidence of material loss due to water.
	3 1 2 [✓ 3] 4 5 Erosion of drains requiring periodic maintenance and reshaping to restore flow - still functional
	5 1 2 3 4 [✓ 5] Severe loss of material and deformation of drains - dangerous to traffic and causing severe siltation “down-stream”

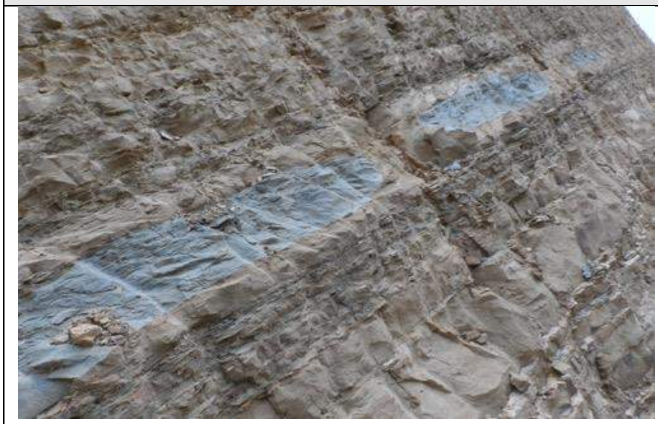
3.2.4 Erosion of embankments and cut slopes

The erosion of embankments and cut slopes is manifested as channels that allow uncontrolled water to flow down the slope, usually with siltation in the drains at the base of the slope or at the base of the slope where no drains exist. The need for water-chutes originating from a surface cut-off drain at the crest of the slope to control water flows in these areas should be assessed to minimise the problems.

Table 6 Degrees of erosion of embankments and cut slopes

Degree	Description
1	Minor evidence of water damage
3	Can be easily seen – protection measures should be considered. Channels >75 mm deep x 300 mm wide
5	Severe loss of vegetation and material and deposition in drains. Channels > 200 mm deep x > 300 mm wide – adaptation measures urgently required

Figure 6 Erosion of cut slopes

	1 [✓ 1] 2 3 4 5 Minor evidence of water damage
	3 1 2 [✓ 3] 4 5 Channels on slopes and notable loss of slope material. Channels >75 mm deep x 300 mm wide
	5 1 2 3 4 [✓ 5] Severe loss of material and development of deep channels (> 200 mm deep x >300 mm wide)

3.3 Subgrade problems

3.3.1 Materials

Changes in precipitation and/or temperature over time will result in larger moisture fluctuations in subgrade materials. Most problematic soils such as expansive clays, dispersive clays, collapsible sands, saline materials, etc. will be affected by both wetting up of subgrades due to increased precipitation or more extreme events and drying out of the soils caused by longer dry periods, increased temperatures and windiness and drought conditions.

During the assessment of climate resilience, particular note should be made of the presence of such materials, as described below. Cognisance should also be taken of areas where the pavement structure is deteriorating (cracks, potholes and deformation) due to subgrade conditions, particularly weak materials. This is usually associated with localised drainage problems and the distress would normally be recorded during the routine visual assessment for Asset Management.

The assessor should look at the exposed soil adjacent to the road and in the side drains for evidence of expansive, collapsible, saline, dispersive or slaking materials. Some of these materials are often associated with other problems such as erosion (collapsible soils).

The following issues should be checked:

Expansive soil:

Usually black, dark grey or red. Shows distinctive cracking with wide, open cracks. May be masked by vegetation and so one needs to look for open exposed areas. If no cracks are observed the material will be identified as non-expansive. If wide cracks (Degree 5 in Figure 7) are observed, the material should be identified as highly expansive. These materials also tend to slake (disintegrate to clay) when placed in water.

Figure 7 Expansive clays

	3 Moderately expansive clays – cracks 5 – 10 mm wide				
	1	2	[✓ 3]	4	5
	5 Highly expansive clays – cracks > 10 mm wide				
	1	2	3	4	[✓ 5]

Collapsible soils

Collapsible soils are difficult to identify in the field without very close inspection. These soils consist of individual particles of hard sands that are supported by clay, iron or calcite “bridges” and often contain obvious voids (pinholes). When these materials are loaded under wet conditions, the “bridges” collapse and the material decreases in volume, usually manifested as distinctive rutting in the wheel tracks (Figure 8). Most collapsible soils consist of highly weathered granites or sandstones, or else transported sandy soils, although various other materials may have a collapsible structure. In the field, it is thus important to identify the type of material and look for signs of collapse on similar materials in the area. Local engineering knowledge will often be available if collapsible soils are present.

Figure 8 Typical manifestation of collapsible soils in paved road

Saline soils

Saline soils contain salts that may or may not be deleterious, but those containing specifically sulphides often present problems, should the salt be in sufficient quantity. Salts are usually observed as deposits or encrustations on the surface after water has evaporated, particularly at the edges of bituminous surfacing and on embankment slopes when the salts are incorporated into the materials or construction water. Particular care should be observed in areas close to oceans or saline lagoons and where materials have been obtained from evaporation pans and enclosed (i.e. where the water does not drain away from the water body) water areas. In marine areas, sea water may have been used for compaction and this could introduce high salt contents. Saline ground-water can also cause problems and discussions with local residents and pastoralists will usually indicate the quality/potability of local ground waters.

Saline materials are often difficult to identify, but past experience in the area is useful. Yellow/brown staining of local structures often indicates the presence of sulphides. Many salt deposits can be identified by licking them lightly and tasting for salts. Figure 9 shows an example of a side drain with staining from sulphuric acid generated from the oxidation of sulphides in coal used in support layers.

Figure 9: An example of yellow/brown staining of a concrete side drain due to the presence of sulphides

Dispersive soils

Dispersive materials can cause severe problems as they (i.e. the fine clays) are leached out of embankments and subgrade areas leading to the formation of tunnels and "pipes" which then collapse. Dispersive soils in the area are usually indicated by what appear to be highly eroded areas, but specifically with the presence of the pipes and tunnels (Figure 10). Such soils are best identified as potential problems by placing small clods of the soil in pure (drinking) water and checking the state of the clay suspension after 24 hours. The clods may stay intact or slake, but dispersive clays go into suspension and do not settle out (Figure 10).

<table>
<tr><th colspan="2">Figure 10 Dispersive soils</th></tr>
<tr><td></td><td>Dispersive soil showing typical erosion-like features with tunnels in lower central area</td></tr>
</table>

	Three soils showing slaking but no dispersion (left) and slight dispersion in two samples on right
	Two soils showing slight dispersiveness (left) and highly dispersive (right)

Other potentially problematic soils

Such materials include dolomites or other soluble materials that could be indicative of karst (sinkhole) problems; soft clays or waste materials (particularly old landfills), industrial waste or mine dumps; and fine soils prone to liquefaction. Evidence of these should be noted in the Comments area of the assessment form.

3.3.2 Moisture

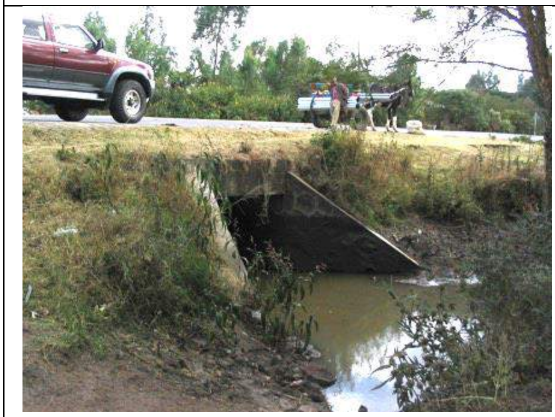
The second potential subgrade problem is the presence of excessive moisture in the subgrade, resulting from localised natural water sources and not specifically drainage problems that can be rectified by good control of periodic water. If there is excessive moisture present due to springs, high water tables or marshy areas, this should be recorded as well as the cause of the moisture where it can be determined. During the wet season, it is usually plainly obvious if the subgrade materials are affected by high moisture conditions. However, if the assessment is being carried out in the dry season indicators such as reed beds, dry marshy areas, evidence of aquatic animals, etc., adjacent to the road indicate potential water problems. Clayey soils (possibly expansive) are often present in these areas.

This issue is of particular importance in terms of climate change as moist areas are expected to change significantly with time, either by drying out with concomitant shrinkage and cracking or by becoming wetter for longer periods. Both of these scenarios will result in significant impacts on the overlying road.

Table 7 Wet areas

Degree	Description
1	Minor evidence of localised, but controllable water problem or seepage
3	Standing water adjacent to road surface or evidence of prolonged perennial water accumulation or standing water
5	Marshy areas or areas with permanent high water tables

Figure 11 Wet areas

	1 [✓ 1] 2 3 4 5 Minor evidence of localised, but controllable water problems
	3 1 2 [✓ 3] 4 5 Standing water adjacent to road surface or evidence of perennial water accumulation
	5 1 2 3 4 [✓ 5] Permanent high water-tables

3.4 Drainage (in road reserve)

The main objective of this rating is to identify whether water is moved away from the road surface and sides effectively so that it will not affect the pavement structure. Various issues need to be assessed under the following categories:

- Road shape;
- Shoulders;
- Side slopes;
- Side drains; and
- Mitre drains.

It is essential that water is moved from the road surface and close vicinity into suitable side drains and then removed from the road reserve by mitre drains (turn-outs) or culverts, where necessary, as quickly and effectively as possible. During the assessment, this efficiency needs to be estimated with respect to whether precipitation remains on the road long-enough to cause potential structural damage to the road. Many of these problems are related to poor road shape/profile exhibited by ruts, potholes and depressions (often with associated cracking) on paved roads and lack of camber, potholes and ruts on unpaved roads. These problems are often caused by a lack of (or just poor) maintenance and this should be noted under the maintenance category during assessment. However, where the problem is one of design, performance or construction this should be highlighted under this section for rectification.

Ponding of water adjacent to the road, whether unpaved or paved, can result in localised pavement failures and such areas should be noted. Similarly, shoulders that are higher than the edge of paved road surfaces will cause water to be retained on the road surface, potentially leading to saturation of the vulnerable outer wheel track areas. Shoulders should be well compacted and graded to shed water into the side drains. Depressions in the shoulders and particularly adjacent to the surfacing on paved roads must be recorded. Any side slopes away from the shoulders (formation or embankments) must be free of excessive vegetation and lead into the side-drains. The differentiation between shoulders and side-slopes (particularly on unpaved roads) in flat terrain is often difficult and in these cases one or the other should be filled in only.

The presence of accumulations of fine silty/clayey material and trash in drains is indicative of poor maintenance or drain design. This is usually prevalent in low areas where water is not removed from the side drains by adequate cross drains/culverts.

Side drains should be at least 3 m from the road and at least 250 mm (dry areas) and 350 mm (wet areas) below the top of the formation and 650 – 750 mm below the crown of the road. They must be shaped to ensure that water flows freely in them towards nearby mitre-drains or culverts. Vegetation growth should not be such that flow of water is impeded or sufficient to cause ponding (an indication of insufficient maintenance). Signs of surface silt and clay deposits (often with associated drying cracking) usually indicate that water has ponded in these areas.

Mitre-drains should conduct the water collected in the side-drains sufficiently distant from the road so that there will be no ponding that will affect the road. These should be open and lead into steam courses or open fields where the water can drain away. During assessment, the lack of sufficient mitre-drains should be noted as a problem – in these areas the water volume will build up, with increased velocities and greater potential for erosion.

It is often necessary to construct culverts to convey the water collected in side-drains from the road across (under) the road to avoid damage to the road and ensure that the water is moved away from the road. The effectiveness of these needs to be ascertained – this should include both their positioning with respect to the lowest point in the road as well as their grade and surroundings, to ensure that water is not permitted to accumulate near the pavement structure. This is normally plain to see, but the presence of silt and clay deposits with associated drying cracking should be looked for when assessing the road in the dry season (Figure 12). Assessment should include issues such as the adequacy of culvert numbers and apertures, the effectiveness and indications of silting and recording of damage to pipes and head- and wing-walls. It is often seen that the low points in roads move laterally along the road with time (particularly related to flooding and sedimentation) and culverts are no longer in the correct places. This should be noted where observed.

Figure 12 Evidence of ponding of water in side drain

Any damage to structures and/or their associated erosion protection works resulting from flooding or overtopping should be noted in this category. If the damage to erosion protection structures is the result of poor design or construction e.g. lack of founding beams), this should be noted under the construction category, as detailed in section 3.4.4.

3.4.1 Road shape

The shape of the road will dictate whether water is removed rapidly from the road surface. This is more critical for unpaved roads where retained surface water softens the wearing course material and results in deformation of the road surface and the rapid formation of potholes.

For paved roads, potholes, ruts and deformation will result in water ponding on the surface. However, provided the bituminous surfacing remains intact (i.e. no cracks or deep potholes) and the depressions are not too deep (< 25 mm), water will usually not be retained long enough to cause any severe distress.

Table 8 Road shape (unpaved and paved roads)

Degree	Description
1	Good shape and cross-fall - minor susceptibility to retaining shallow water on the surface.
3	Uneven road with poor camber leading to ponding of water on road surface
5	Road is below surrounding ground level and water will not be removed before distress is caused

Figure 13 Road shape (unpaved roads)

	1 [✓ 1] 2 3 4 5 Good shape and crossfall - minor susceptibility to retaining shallow water on the surface
	3 1 2 [✓ 3] 4 5 Uneven road with poor camber leading to ponding of water
 09/08/2017 12:34 PM	5 1 2 3 4 [✓ 5] Road is below surrounding ground level and water will not be removed before distress is caused

Figure 14 Road shape (paved roads)

	1 [✓ 1] 2 3 4 5 Good shape and crossfall - minor susceptibility to retaining shallow water on the surface
	3 1 2 [✓ 3] 4 5 Uneven road with poor camber leading to ponding of water
	5 1 2 3 4 [✓ 5] Road is below surrounding ground level and water will not be removed before distress is caused

3.4.2 Shoulders

The assessment should indicate whether the shoulders are shaped to remove water from the road surface towards the side slopes and side-drains. A common observation is the presence of unpaved areas between the sealed road pavement and the lined side-drains, which is considered unacceptable (Figure 16) as water will penetrate through these areas into the pavement layers.

Table 9 Shoulder condition

Degree	Description
1	Shoulders allow flow of most water with minor ponding
3	Significant ponding of water occurs on shoulders – could lead to structural failure of pavement
5	Water retained on shoulders for extended periods allowing weakening of carriage-way materials

Figure 15 Shoulders

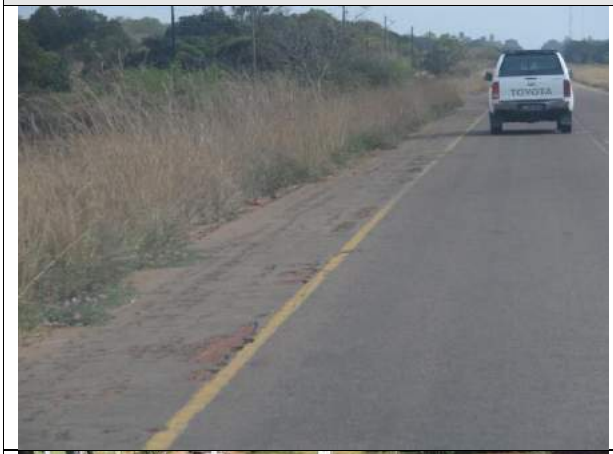
	1 [✓ 1] 2 3 4 5 Shoulders allow flow of most water with minor ponding
	3 1 2 [✓ 3] 4 5 Significant ponding of water occurs on shoulders
	5 1 2 3 4 [✓ 5] Water retained on shoulders for extended periods allowing weakening of carriage-way materials

Figure 16 Unpaved area between impervious seal and lined drain allowing access of water into the pavement (Note poor maintenance of side drain as well)

3.4.3 Side slopes

The side-slopes in this case are normal formation (up to 750 mm high) and embankments (> 750 mm) constructed to raise the road, provide for culverts, etc. Poorly shaped side slopes will usually result in erosion and undercutting of the shoulders and even the road structure if not repaired properly. Side slopes that allow accumulation of water are not common but may occur and should be recorded.

Table 10 Drainage effectiveness of side slopes

Degree	Description
1	Slopes remove water with minimal ponding or erosion damage
3	Poor removal of water from road and shoulders into side drains – may be erosion that could block drains
5	Uneven slopes with severe loss of shape and development of deep channels (> 400 mm deep x 400 mm wide)

Figure 17 Drainage effectiveness of side slopes

	1 ☒1 · 2 · 3 · 4 · 5 Slopes remove water with minimal ponding or erosion damage
	3 1 · 2 · ☒3 · 4 · 5 Poor removal of water from road and shoulders into side drains – may be erosion that could block drains
	5 1 · 2 · 3 · 4 · ☒5 Uneven slopes with severe loss of shape and development of deep channels (> 400 mm deep x 40 mm wide)

3.4.4 Side drains

Erosion of side drains is covered in Section 3.1. Their effectiveness in removing water rapidly and effectively from the side of the road is assessed under this criterion and is essentially related to their shape (cross-section) and grade. Badly eroded drains will usually rate poorly as their effectiveness will be compromised.

Table 11 Effectiveness of side drains

Degree	Description
1	Most water is effectively removed but localised ponding of short duration may occur
3	Drains are incorrectly graded or have uneven surfaces, that retain water for prolonged periods
5	No effective drains or else water is not removed from road side

Figure 18 Effectiveness of side drains

	1 [✓ 1] 2 3 4 5 Most water is effectively removed but localised ponding of short duration may occur
	3 1 2 [✓ 3] 4 5 Drains are incorrectly graded or have uneven surfaces that retain water for prolonged periods.
	5 1 2 3 4 [✓ 5] No effective drains or else water is not removed from road side

3.4.5 Mitre drains

Sufficient mitre drains should be constructed to remove water from the side drains so as to avoid accumulation of water or the build-up of excessive water velocities such that erosion of the side-drains becomes a problem. The mitre drains should also be sufficiently long to remove water far enough from the road not to affect the road structure. It is important that maintenance grading does not leave windrows blocking access into the mitre drains.

Table 12 Effectiveness of mitre drains

Degree	Description
1	Mitre drains mostly effective but localised ponding
3	Mitre drains poorly graded or too short
5	Insufficient mitre drains or totally ineffective

Figure 19 Effectiveness of mitre drains

	1 [✓ 1] 2 3 4 5 Mitre drains mostly effective but localised ponding
	3 1 2 [✓ 3] 4 5 Mitre drains poorly graded or too short
	5 1 2 3 4 [✓ 5] Insufficient mitre drains or totally ineffective

3.5 Drainage from outside the road reserve (streams)

This section describes the drainage of water collected outside the road reserve in larger catchment areas, which has to cross the road through bridges or major culverts. If possible, the catchment area should be determined/estimated as a guide to possible water flows[4]. Good observation of the bridge or culvert structure should be carried out to determine high water levels, whether any damage has been done to the structure by past water flows, the presence of any damage to wing-walls, erosion protection measures, erosion of the river bank near the structure or the presence of any debris reducing capacity of the bridge. During the dry season, the foundations of the abutments and piers may be visible and can be inspected for scouring or damage. Parts of the structure such as drainage pipes, bearings and expansion joint seals should also be inspected for wear or damage, although this would normally be done during assessments for Bridge Management Systems (BMS). It should be noted that the purpose of this evaluation is not to add to the routine bridge assessment data, but to determine whether future changes in climate could have a detrimental effect on the structures and their immediate environments.

Although in many areas of sub-Saharan Africa, the precipitation is expected to decrease over time, the likelihood of more frequent and more severe extreme events is much higher. This is expected to increase water flows in valleys requiring greater capacity of the culverts and bridges to handle the increased flows without being damaged.

Approach embankments and fills around the abutments should be inspected for any settlement, erosion, undermining or likely saturation.

3.5.1 Structures

Most bridges and culverts are assessed during routine asset management inspections. However, this assessment is mostly related to their condition in terms of structural integrity and operational effectiveness under prevailing conditions. The capacity and protection requirements would have been considered by the design/structural engineer. During the vulnerability assessment inspections, the evaluation should be more directed towards whether the structure would perform adequately under changing precipitation, temperature or wind conditions, not anticipated at the time of design of existing (especially older) structures.

Table 13 Damage to large drainage structures

Degree	Description
1	Minor evidence of localised damage
3	Obvious damage to the bridge or culvert structure, but which can be repaired
5	Severe damage to the structure that requires reconstruction of the bridge

---

[4] Topographical maps (1:50 000 or 1:10 000, if available) are normally used to determine the area of a catchment. Orto-photographs, if available could also be used. The catchment boundary is demarcated on the map based on the contours. Graph paper or a planimeter can then be used to determine the catchment area. GIS software packages could also be used.

Figure 20 Damage to large drainage structures

	1 [✓ 1] 2 3 4 5 Minor evidence of localised damage
	3 1 2 [✓ 3] 4 5 Obvious damage to the bridge or culvert structure, but which can be repaired
	5 1 2 3 4 [✓ 5] Severe damage to the structure that requires reconstruction of the bridge

3.5.2 Approach fills/embankments

The approach fills and embankments associated with structures must be assessed for any damage caused by flood waters or waters flowing away from or around the structures.

Table 14 Damage to approach fills/embankments

Degree	Description
1	Minor evidence of water damage
3	Localised loss of material from embankment. Can be repaired
5	Severe loss of fill material - closure of road – needs reconstruction

Figure 21 Embankment damage

	1 [✓ 1] 2 3 4 5 Minor evidence of water damage
	3 1 2 [✓ 3] 4 5 Loss of material from embankment. Can be repaired
	5 1 2 3 4 [✓ 5] Severe loss of material - closure of road – needs reconstruction

3.5.3 Erosion of stream banks

Any erosion of the stream banks in the vicinity of the structure indicating potential for future damage to the structure or embankments under high water levels and strong flows should be assessed.

Table 15 Erosion of stream banks

Degree	Description
1	Minor evidence of stream erosion
3	Loss of material from river banks. Signs of erodibility
5	Severe erosion and loss of material from river/stream banks near structure

Figure 22 Erosion of river/stream banks

	1 [✓ 1] 2 3 4 5 Minor evidence of stream erosion
	3 1 2 [✓ 3] 4 5 Loss of material from river bank. Signs of erodibility
	5 1 2 3 4 [✓ 5] Severe erosion of river banks near structure

3.5.4 Protection works

Damage to protection works (gabions, stone pitching, rip-rap, etc.) associated with drainage structures caused by high water levels can be expected to increase under more extreme events and these works should be assessed in terms of their capacity to resist future damage.

Table 16 Damage to protection works

Degree	Description
1	Minor evidence of water damage
3	Damage to protection works requiring significant repairs
5	Damage to protection works requiring reconstruction and/or replacement

Figure 23 Damage to protection works

	1 [✓ 1] 2 3 4 5 Minor evidence of water damage
	3 1 2 [✓ 3] 4 5 Damage to protection works requiring significant repairs
	5 1 2 3 4 [✓ 5] Damage to protection works requiring reconstruction and/or replacement

3.5.5 Flood plain

If the area being assessed is a flood plain (or likely to be flooded by rivers in the area not directly crossing the road, which are often not seen from the road), the indication of Yes or No should be included on the assessment form. This could also apply to low lying areas close to the sea that could be flooded as a result of a rise in sea levels

3.6 Slope stability

Slope failures, especially in the case of major slopes, could lead to the loss of life. It is important to ensure that cuts and embankments are stable enough to resist changes in precipitation. This involves a close inspection for any signs of instability. Cut slopes should be inspected for any signs of movement behind the slope (tension cracks or subsidence) or at the toe of the slope (bulging or deformation of side-drains). Signs such as movement of trees, or fences, minor cracking, seepage of water from out of the slope, etc. are all indicative of potential instability. Signs of instability in embankments are usually seen as the presence of arcuate cracks in the shoulders or the road surface, unusual settlement of parts of the fill, bulging at the base of the fill and periodic seepage of water from beneath the fill. Most properly designed and constructed fills fail through a lack of shear resistance in the subgrade materials, particularly when these are in a saturated or excessively moist condition.

The stability of embankments and cuttings should be assessed and indications as to whether slope failure is likely to occur under extreme precipitation events made. Indicators for this are discussed in detail in the following section.

3.6.1 Cut slopes

Most cut slope problems affecting low volume roads generally affect only the shallow soil mantle unless the cuts include deep excavations, in which case the hill-slope above the cut could become unstable as the “toe“ is removed. However, in order to reduce the cost of such excavations for low volume roads, excavation is usually limited as far as possible.

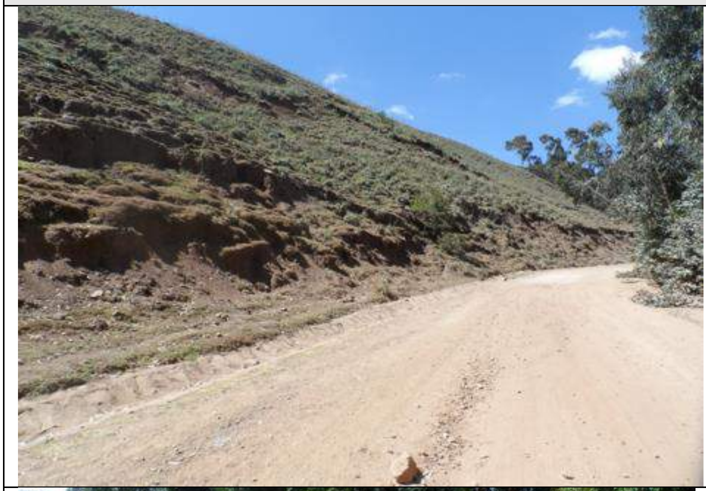
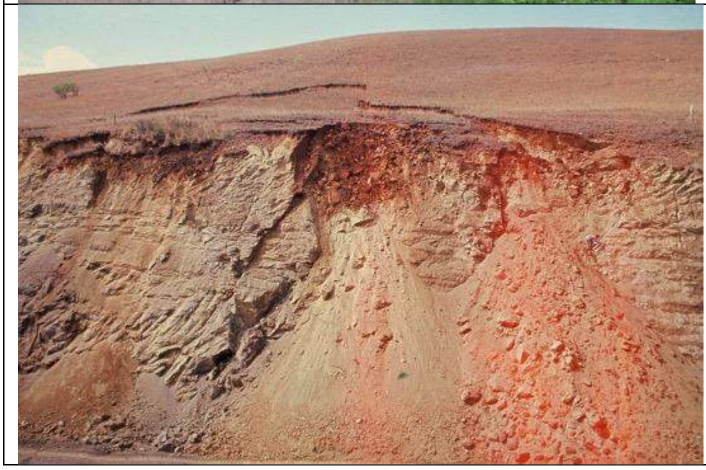
Where excavation is extensive, it is usually outside the expertise of general road engineers to assess the stability of the slope, and geotechnical specialist input should be obtained. Even then, it is often necessary to carry out expensive subsoil investigations to determine the potential and mode of possible failures.

During the assessment exercise, it is thus necessary to look at the overall stability of the area surrounding the cut slopes as well as any evidence of instability directly affecting the individual slopes. Figure 24 illustrates typical unstable terrain, in which any interference with the natural stability (e.g. by undercutting slopes during road excavations) could lead to large slope failures.

Table 17 Cut slope stability

Degree	Description
1	Minor evidence of surface instability – major failures unlikely – shallow cuttings below small slopes
3	Evidence of slump or localised movement of material on slope – failure likely to cause short disruptions to traffic flow
5	Major slope failure likely – long-term closure of roads caused by slope failure and expensive rehabilitation

Figure 24 Stability of cut slopes

	1	☒ 1	2	3	4	5	Minor evidence of surface instability – major failures unlikely
	3	1	2	☒ 3	4	5	Evidence of movement of material on slope – failure likely to cause short disruptions to traffic flow
	5	1	2	3	4	☒ 5	Major slope failure likely – long-term closure of roads caused by slope failure

3.6.2 Embankments

The stability of embankments must be assessed. Unlike cuts, there is usually evidence of arcuate cracking on the surface of the embankment prior to failure and evidence of such cracking should be investigated. Many high embankments develop one or two longitudinal cracks which are indicative of tensile strains in the upper portion of the fill (Figure 25), but provided that they are timeously sealed, will not usually lead to failure.

Figure 25 Cracking of embankment due to overstressing

Table 18 Stability of embankment slopes

Degree	Description
1	Minor evidence of surface instability – localised arcuate cracking of road surface
3	Evidence of widespread or large arcuate cracks with minimal vertical displacement – failure unlikely (restricted to one lane) or will only cause short-term disruptions to traffic flow
5	Evidence of or potential for large failure causing closure of road for extended period

Figure 26 Stability of embankments

	1 [✓ 1] 2 3 4 5 Minor evidence of surface instability
	3 1 2 [✓ 3] 4 5 Evidence of widespread or large arcuate cracks with minimal vertical displacement – short-term disruptions to traffic flow
	5 1 2 3 4 [✓ 5] Evidence of or potential for large failure causing closure of road for extended period

3.7 Construction

The main construction problem affecting the resilience of roads to extreme climatic conditions is the lack of compaction. Poor compaction within the formation/embankment materials, the shoulder materials or even the structural layers is usually manifested as rutting, undulations or excessive vertical deformation in affected areas. These conditions need to be identified, as the permeability of the materials in these areas will be significantly higher than well-compacted materials and the potential for premature failures due to water ingress is increased.

The overall finish of a road is a good indication of the quality of construction and can be used to decide if the construction quality is likely to lead to problems. Poor overall finish include things such as oversize material lying around, poorly rehabilitated deviations, uneven shoulders and poor finishing of the road reserve. A road that looks well-finished is usually an indication that the contractor was diligent and careful. This issue is particularly relevant to new paved roads as most deficiencies in older roads would have been manifested during their service.

Construction problems in unpaved roads are usually more easily observed as the wearing course is typically the most sensitive layer and exposure will highlight any deficiencies.

In addition, erosion protection measures must be continuous and intact and be able to perform as intended, i.e. protect the underlying soil from erosion, without being deformed, cracked or disintegrated.

3.7.1 Overall Finish

The overall finish of the road should be visually assessed in terms of the impression that a good job was done during construction. Typically, poor finishing off and a product that does not look neat is indicative of the possibility that the construction quality was not ideal. Figure 27, for example illustrates a newly constructed road with a poorly finished and uneven shoulder.. A typical example of this on unpaved roads, is the presence of excessive oversize material, when the specification included a limit on the maximum size.

Figure 27 Poor finish of newly constructed road

It is difficult to “visually” assess the compaction in paved roads, but a hollow sound when knocked with a hammer usually indicates poor compaction of the underlying layer, although a weak bond between the base and the surfacing (also often a sign of poor construction) will often produce a similar sound.

Poorly compacted unpaved roads, which are highly susceptible to surface erosion, can usually be identified by being able to easily scratch the material at the surface – it should be checked that this “loose” material is not the result of recent deposited material introduced by grader blading.

3.7.2 Erosion protection measures

All erosion protection measures should be assessed to ensure that they are intact, integral and do not allow water to enter behind or through them. This is normally a simple visual inspection (Figure 28), although the presence of “anchoring beams” may be difficult to observe in some areas.

Figure 28 Poor finish of protection works resulting in failure – no "anchor" beams

3.8 Maintenance

Maintenance is an essential part of preserving any road and should be judiciously carried out. As climatic conditions change, the need for additional and good quality maintenance is going to become increasingly critical. During the assessments, issues such as the retention of shape of shoulders, cutting and clearing of vegetation, removal of termite nests and bushes on embankments (that are likely to induce turbulent flow of water moving over the embankment), cleaning and shaping of side-and mitre drains and ensuring that culverts and drains are not blocked must be noted.

The importance of minimising the risk of wind-induced wild-fires that burn the vegetation and soil cover, allowing exposure of the soil to intense storms (more of these are expected) and consequent erosion cannot be overemphasised. This is particularly relevant on embankment and cut slopes, around drainage structures and in areas where the soils are inherently susceptible to erosion.

It is also essential that potholes are repaired regularly with a well-compacted, high-quality impermeable cold-mix asphalt and all cracks in the road surface are regularly sealed, to avoid the ingress of water into the pavement structure.

In assessing the quality of road maintenance, the shape and evenness of the road surface must be analysed. Any depressions will result in the ponding of water, and if unsealed cracking is present, this will lead to permeation into the pavement and weakening of materials. Excessive vegetation on the shoulders and in side drains interferes with water flow and should not be permitted. This excessive vegetation can also have an impact on fire hazard (expected to increase with longer dry seasons and increased windiness), which should be minimised to reduce soil erosion potential.

Effective drain maintenance is essential and the quality and effectiveness of this must be assessed.

3.8.1 Quality

This can only be assessed if maintenance has been carried out recently before the assessment. Issues to be looked at include vegetation control, cleaning of drains, shaping of gravel shoulders, repair of potholes and cracks in paved roads, grading of unpaved roads, etc. Often it is found that, for instance, potholes may have been repaired but other maintenance (e.g. drain cleaning or vegetation control) was not carried out. In such cases, the quality of the pothole repairs would be assessed and the extent would usually be 1 or 2.

3.8.2 Quantity

This can also only be assessed if maintenance has been carried out recently before the assessment. Issues to be looked at include vegetation control, cleaning of drains, shaping of gravel shoulders, repair of potholes and cracks in paved roads, grading of unpaved roads, etc. The extent rating would normally be 0 or 5 for routine maintenance, excluding pothole patching or crack sealing. It is unusual for vegetation control or shoulder maintenance to be carried out over limited sections, although this is possible.

Figure 29 Thick vegetation alongside road indicating insufficient maintenance (rated at 5/5)

Comments

There are many other issues that may need taking note of and these will usually be identified as the assessment takes place. A typical example of one of these is the presence of ants in the road area. Figure 30 Shows ant "holes" that will allow water to penetrate into the embankment (there is usually an extensive network of tunnels beneath such an area) and these should be taken care of.

Figure 30 Other issues

<table>
<tr><td rowspan="3"></td><td colspan="5">3</td></tr>
<tr><td>1</td><td>2</td><td>[✓ 3]</td><td>4</td><td>5</td></tr>
<tr><td colspan="5">Ant nests allowing water access into embankment</td></tr>
</table>

Recently, the impact of wildfires combined with extremely windy conditions has been noted on guard rail supports (Figure 31). Burning of the wooden supports has resulted in collapse of the guard-rail. In addition, obvious damage to the bitumen seal (on the left side of the photograph) can be clearly noted in Figure 31. Such instances would be recorded under comments.

Figure 31 Damage to guardrail posts and bitumen surfacing caused by wildfire

4 Assessment Procedure

The assessor will usually move along the road (preferably walking but in a slow-moving vehicle if necessary) and assess the features identified in the forgoing text at relevant points along the road. Typically, the data sheet (Annex 1) will be completed after every 100 m (measured with a measuring wheel) with locations of any problems highlighted in the problem row. This differs from routine visual condition assessment for Asset Management purposes, which is generally done from a moving vehicle (up to 80 km/h) over a road link (2 to 5 km) with occasional stops. The assessment of climate resilience requires experience and knowing “what to look for” as described previously and will usually be carried out by different teams. The team for the vulnerability assessment must be trained to look specifically for the geomorphological, hydrological and soil properties highlighted in this Manual.

It must be remembered that the information obtained pertains only to the observations at the time that they are made and it needs to be carefully interpreted to identify potential longer term or more severe problems. Recent maintenance (prior to the visual assessment exercise) may affect the observations by masking potential problems and must be considered, bearing in mind that the objective is to identify areas where adaptation measures are probably necessary to improve the future climate resilience of the road. Similarly, a lack of maintenance or overgrown vegetation may make the observation of certain features difficult. The evidence of potential problems is also different during different seasons and climatic cycles.

The data should be recorded directly onto the field sheet (Annex 1) in the field for later use. All ratings should be on a 0 to 5 scale, where 0 indicates that the “problem” is absent or not visible, 1 indicates that it is present but negligible, 3 indicates a moderately serious problem that should be inspected regularly and 5 is a severe problem requiring urgent adaptation interventions.

The data can then be shaded in the spreadsheet, with for instance no colour for 0, green for ratings of 1 and 2, orange for 3 and red for 4 and 5 (Annex 2). Concentrations of red on the sheet indicate areas needing urgent attention, while orange indicates areas of warning that should be considered after the severe problems have been rectified with appropriate adaptation measures and are expected to be potentially problematic in the medium to long-term.

Annex 1 Data assessment collection form

Road Number:		**Date:**		**Assessors:**		**Weather:**	**S. PC. C. R. H. Cold**	**Topography**	**F. R. H. M.**	**Landcover and use**	A. F. N. PU. D. O.

Chainage	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9		0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	
Grade																				
Access to facilities																				
No. of alternative roads																				
Common vehicle types																				

GPS and photo No																				

Erodibility																				
Sugbrade																				
Road surface - unpaved																				
Side drains - unlined																				
Embankment slopes																				
Cut slopes																				

Subgrade problems																				
Material type																				
Moisture																				

Drainage (in reserve)																				
Road shape																				
Shoulders																				
Side slopes																				
Side drains																				
Mitre drains																				

Drainage (streams)																				
Structure																				
Approach fills																				
Erosion of approach fills																				
Protection works																				
Flood plain																				

Slope stability																				
Cut stability																				
Fill stability																				

Construction																				
Overall finish																				
Erosion protection works																				

Maintenance																				
Quantity																				
Quality																				

COMMENTS:																				

Annex 2 Example of completed field data collection sheet for climate resilience assessments with supporting photos

Road Number: B - G

Date: 2018/08/01

Assessors: PPG

Weather: S. [✓ PC.] C. R. [✓ H.] Cold

Terrain F. [✓ R.] H. M.

Landuse [✓ A.] F. N. [✓ PU.] O.

Chainage	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2
Grade	F	F	F-U	U	U	U	U	U	U - F	F - D	D	D	D	D	D - F	F	F	F	F	F
GPS and photo No	08.1123 38.3535						65													
Erodibility																				
Subgrade	0	0	0	4/4	0	0	0	3/3	0	0	0	0	0	0	0	0	0	0	0	0
Road surface - unpaved	Paved	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Side drains - unlined	2/4	5/1	0	4/5	0	0	4/5	4/3	0	0	0	0	0	0	0	0	0	0	0	0
Embankment slopes	0	0	0	5/4	5/1	0	3/3	3/3	0	2/1	2/1	2/1	3/2	3/5	3/5	0	0	0	0	0
Cut slopes	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Subgrade problems																				
Material type	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moisture	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	Possible	Possible	🟩	🟩	🟩	🟩	🟩
Drainage (in reserve)																				
Road shape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shoulders	0	0	3/3	4/3	4/5	4/5	3/3	2/3	0	0	2/3	2/2	2/2	0	0	1/2	0	0	0	0
Side slopes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Side drains	0	0	5/5	0	0	0	0	5/3	5/3	0	0	0	0	0	0	0	2/1	0	0	0
Mitre drains																				
Drainage (streams)																				
Structure	3/1 - 1	🟩	🟩	🟩	4/1 -2	4/1 -2	🟩	🟩	🟩	🟩	🟩	🟩	🟩	5/1 -2	5/1 -2	5/1 -2	🟩	🟩	🟩	🟩
Embankments	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Erosion	🟩	🟩	🟩	🟩	🟩	🟩	🟩	5/1	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	3/1	🟩	🟩	🟩
Protection works	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Slope stability																				
Cut stability	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Fill stability	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Construction																				
Overall finish	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Erosion protection works	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Maintenance																				
Quantity	3/4	0	5/4	5/4	5/4	5/4	4/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4	5/4
Quality	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5	2/5

COMMENTS:

1\. Culvert silted at inlet

1\. Needs culverts

Supporting Photos

Assessment Item: Erodibility - Side drains, unlined

Distress: Severe erosion of side drains

Chainage: 300 m to 400 m

Degree: 4 Extent: 5

Assessment Item: Drainage (in reserve) – Side drains

Distress: Blockage of side drains by landslide debris

Chainage: 700 m to 800 m

Degree: 5 Extent: 3

Assessment Item: Drainage (in reserve) – Side drain

Distress: Damage to erosion protection in side drain

Chainage: 1 600 m to 1 700 m

Degree: 2 Extent: 1

Assessment Item: Drainage (stream) - Erosion

Distress: Erosion of river bank and damage to protection works

Chainage: 700 m to 800 m

Degree: 5 Extent: 1

Assessment Item: Drainage (in reserve) – Side drains

Distress: Poor maintenance of lined side drain

Chainage: 700 m to 800 m

Degree: 5 Extent: 3

Assessment Item: Drainage (streams) – Erosion of approach fills

Distress: Poor control of water next to road leading to erosion of bridge approach fill

Chainage: 1 600 m to 1 700 m

Degree: 3 Extent: 1

Assessment Item: Drainage (in reserve) - Shoulders

Distress: Poor shoulder maintenance

Chainage: 300 m to 400 m

Degree: 4 Extent: 3