South-East Asia Community Access Programme

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LAO CONSULTING GROUP

SD & XP Consultants Group

SEACAP 21/002: Feasibility Study for a National Programme to Manage Slope Stability

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Abbreviations

AADT	Annual Average Daily Traffic
ADB	Asian Development Bank
BAC	Basic Access Component (of the LSRSP-3)
CRM	Community Road Model
DFID	Department for International Development (UK)
DOR	Department of Roads
DOW	Department of Waterways
DPWT	Department of Public Works and Transport (formerly DCTPC)
EIU	Economist Intelligence Unit
ESD	Environment and Social Division (of MPWT)
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
IRI	International Roughness Index
JICA	Japanese International Co-operation Agency
LRD	Local Roads Division (of MPWT)
LSRSP-3	Lao-Swedish Road Sector Project 3
LTSP	Lao PDR Transport Sector Project (proposed)
MCTPC	Ministry of Communications, Transport, Post and Construction (now MPWT)
NR	National Road
NUOL	National University of Lao PDR
PBMC	Performance-based Maintenance Contract
PMO	Prime Minister's Office
PRoMMS	Provincial Road Maintenance Management System
PTD	Planning and Technical Division (of MPWT)
PTI	Public Works and Transportation Institute (of MPWT) (formerly URI)
RAD	Roads Administration Division (of MPWT)
RMF	Road Maintenance Fund
RMP-2	Road Maintenance Project, Phase 2
RMS	Road Management System (covers national roads)
SEACAP	South-East Asia Community Access Programme
SIDA	Swedish International Development Cooperation Agency
URI	Urban Research Institute (now PTI)
VMC	Village Maintenance Committee
VOC	Vehicle Operating Costs
WB	World Bank

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PART A: INTRODUCTION

1. INTRODUCTION AND SUMMARY

This document provides the in-depth background material that supports the Consultant's report on the Feasibility Study for a National Programme to Manage Slope Stability, and the proposed programme that is contained within that report. Most of the material represents a collection of data and analysis of it, in relation to the technical, economic and organisational aspects of slope management in the Lao road sector.

The material presented may be incomplete, as it is based only on the information that could be gathered and assessed during a very brief, reconnaissance level review. This document should therefore not be considered either exhaustive or definitive.

The first part (after this introduction) provides the technical assessment of slope instability. This puts it into the context of the patterns of mountainous terrain and rainfall found in Laos, which account for the fact that most landslides occur in the north of the country. The common types of slope failure are described, along with details as to how these affect roads in the Lao PDR. Rainfall data are limited in scope, but a certain amount of analysis has been possible, to demonstrate how landslides can be triggered by severe storms arriving in cyclonic weather systems or from the south-west monsoon, during the long wet season. The effects of these can be detected on emergency road maintenance spending, with variations between years.

The economic appraisal examines the implications of various types of costs associated with slope instability. It shows that the clearance and repair costs for landslides runs into millions of US dollars per year, mainly through the MPWT's emergency maintenance budget. The costs of blockages can amount to significant sums, depending on the length of time that traffic is disrupted; but if it is more than three hours, the cost becomes large, especially for roads with traffic levels of 300 AADT or above. Environment costs are also noticeable. The economic implications of large scale engineering works to improve the stability of hazardous slopes is marginal, but well worthwhile if a failure were to occur within a few years. The implications for improved engineering management also seem to be marginal, though worth investing in if the potential costs of traffic disruption are taken into account.

The institutional assessment suggests that the current structure and working arrangements of the road sector are good, though still undergoing re-structuring. The document describes in some detail the organisation and capacity of the Ministry of Public Works and Transport, and its various central and provincial units. It also examines the road management systems, particularly in relation to off-road maintenance. There is no reason why the current arrangement should not be able to support a programme of slope stabilisation, except that technical skills are lacking in engineering geology, in geotechnical and bio-engineering, and in river engineering. This part of the assessment underlies the capacity development described in the proposed programme for slope stability management.

The final part of this Background Paper provides a number of technical items. These include a substantial inventory of current slope instability on National Roads. The study has also produced a summary of the preferred engineering response to slope instability, unit costs and standard design drawings for slope stabilisation engineering works. Further technical materials are due to be completed later in 2008 under the SEACAP 21 slope stabilisation trials programme.

PART B: TECHNICAL APPRAISAL

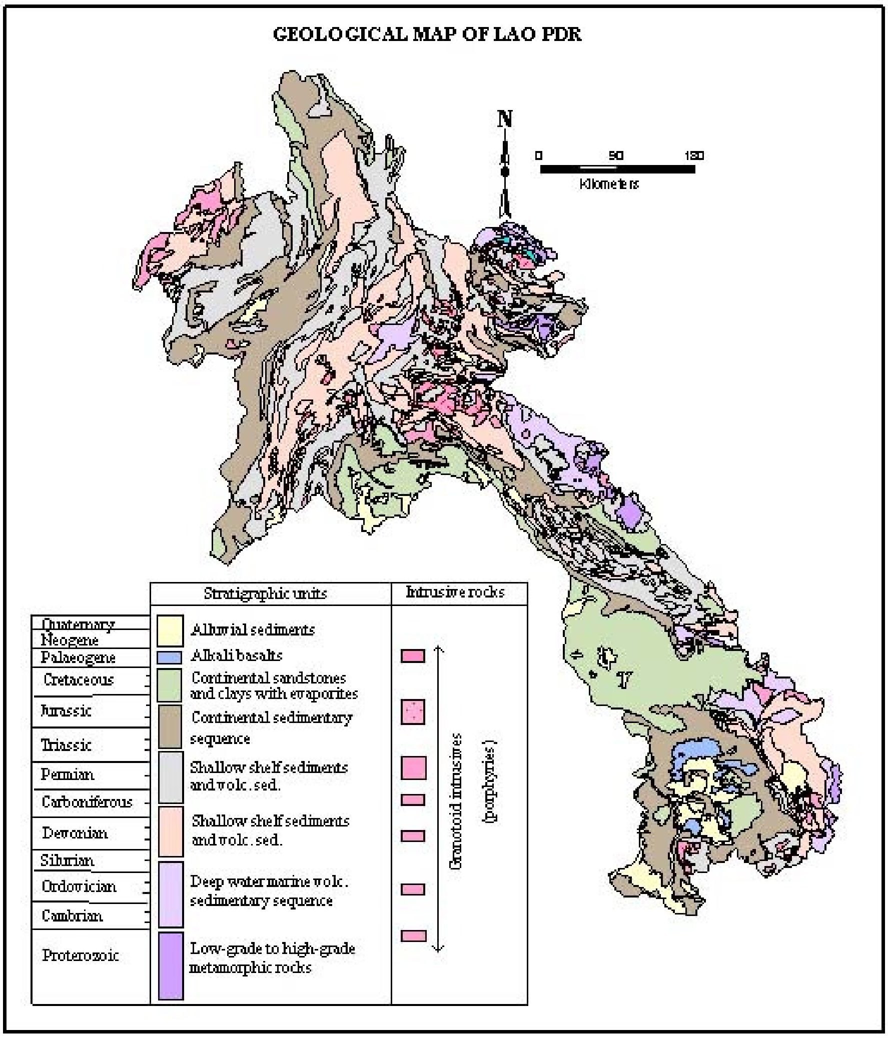
2. LANDFORMS AND GEOLOGY

Ridge and valley terrain is common in Laos. The published topographical maps of the country show a complex assemblage of ridge and valley terrain in many areas, though there is clear structural control where sedimentary sequences dominate the topography, such as for example in parts of the southern region of the country. Slopes are often steep and cut by tributary streams and rivers.

Figure 2.1 shows a map of the geology of Laos published by the Department of Geology and Mines. Parent rocks comprise igneous, metamorphic and sedimentary sequences, and as can be seen, the outcrop pattern is complex. The Consultant has recorded rock types in the landslide inventory collected and reproduced in section 11 of this document. Low grade metamorphic rocks and metasediments form the majority of the underlying materials and were identifiable in the cases observed. These materials were often observed to be closely jointed and tectonically disturbed by folding. Typically, where exposed in road cuttings, they vary in weathering grade from moderately to completely weathered rock, through to residual soil.

The landslide inventory also contains observed failures that have developed in slopes underlain by granitoid rocks (in the case of NR8) and mudstone or sandstone sequences (NR1E). In the latter case, bedding sequences were found to dip unfavourably for slope stability in some of the cutting slopes of the realigned road.

Figure 2.1 Geology of Laos (from Lao PDR Department of Geology and Mines website)



3. SLOPE FAILURE PROCESSES IN RELATION TO ROADS

Slopes adjacent to the road network can be divided into three main categories; cut slopes, fill slopes and natural slopes.

3.1 Characteristics of roadside slopes

3.1.1 Cut slopes

Cut slopes formed during the construction of a road should take into account the nature of the soil or rock they expose. Stable cut slopes can vary from as little as 1V:4H (i.e. vertical: horizontal) to close to vertical, depending on underlying geological conditions, namely rock type and its structure.

For most roads built to a limited budget, cut slopes do not appear to have been designed to take into account the engineering geology of the underlying soil and rock, since this often requires prior ground investigation, especially where deep cuttings are involved. In mountainous areas, access is often made difficult for drilling equipment. Also, since ground conditions are usually very variable, exploration boreholes would need to be placed at close intervals to provide any meaningful data, thus increasing the cost of the investigation. It is likely, however, that cut slopes have been excavated to the steepest angles possible for the materials concerned, and this will have led to assessments being made by site staff based on precedent and experience. This is a reasonable way forward in the absence of engineering geological expertise and ground investigation data.

This situation is not unique to Laos, but applies to most developing countries and to less important roads in many developed countries. The alternative is to use detailed site assessments based on engineering geology, to determine the expected ground conditions.

As a consequence of this, cut slopes are usually designed to set guidelines that are likely to be based on engineering precedent, using broad, though practicable in an engineering sense, differentiation between rocks and soils. As an example, the provisional *Road Design Manual* (MCTPC, 1996) recommends slope angles for cutting depths of up to 8 metres as given in Table 3.1.

Table 3.1. MPWT slope cutting grades

Material	Slope Angle	Depth (d)
Cohesionless sands	1V:2H	
Residual soils	1.5V:1H	For d < 4 m
	1V:1H	For d > 4 m
Weathered rock	2V:1H to 4V:1H	
Sound rock	5V:1H to 10V:1H	

Source: *Road Design Manual* (MCTPC, 1996)

For depths greater than 8 metres, or for situations where material or groundwater may be problematic, the Manual states that an analytical approach, possibly including a ground investigation, may be considered.

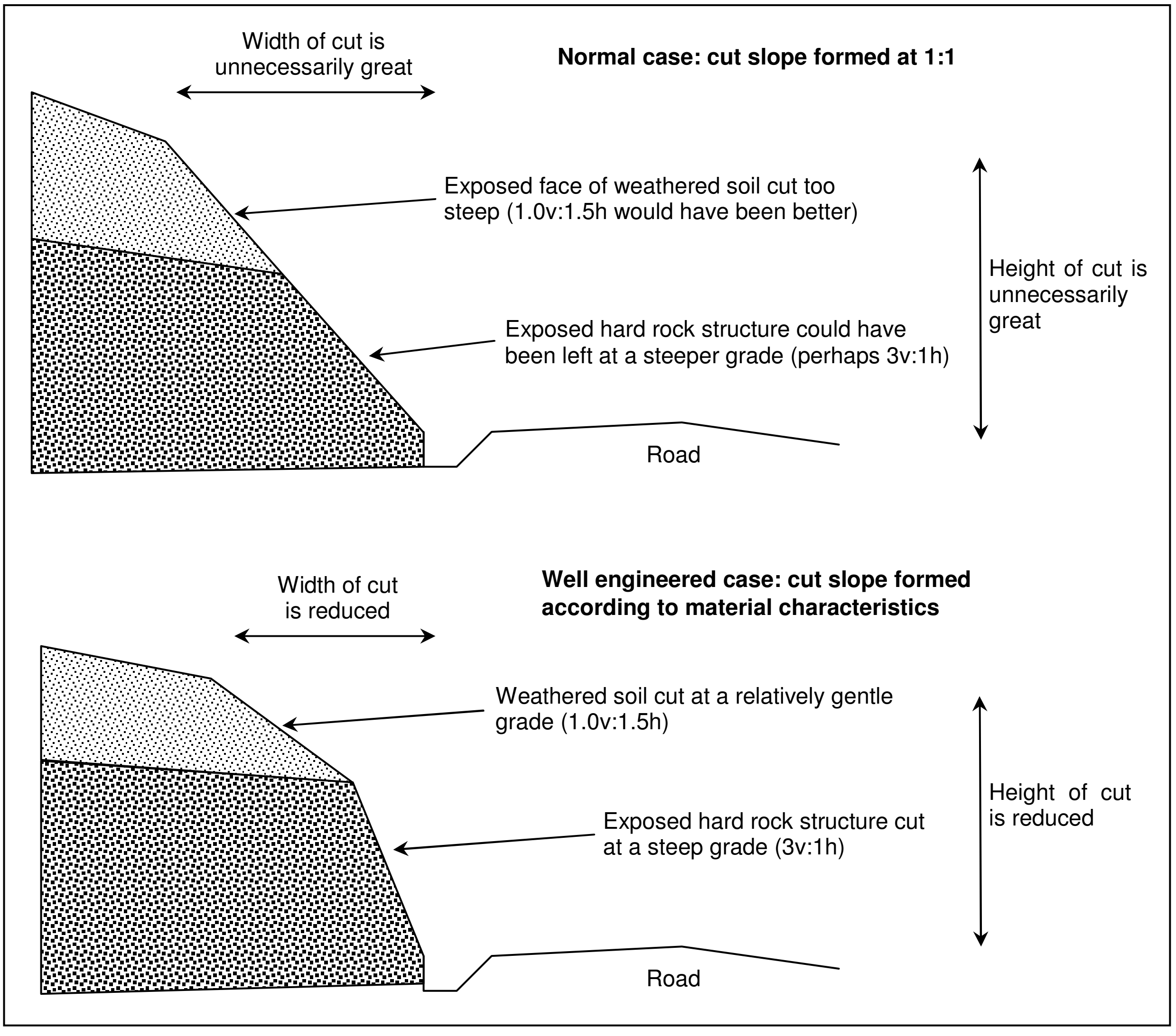
In the absence of any ground investigation, it appears that many road designs in Laos assume a cut slope angle of around 1V:1H, which is then usually steepened if rock is encountered as the excavation proceeds. This has a number of undesirable effects.

- The upper portion of the cut slope where the soils are most weathered is usually cut too steeply, creating the potential for minor instability and erosion. A slope angle of 1V:1.5H is often more appropriate in these circumstances, if the mountainside above allows it to be attained.

- If weathered or sound rock is then encountered lower down during the formation of the slope, then the upper part of the slope could have been placed closer horizontally to the road edge. This would then reduce the cut volume and therefore the volume of spoil to be disposed. If the natural ground is sloping towards the road, as it usually is then the height of the cut slope is reduced as well.

These variations are shown in the sketch in Figure 3.1.

Figure 3.1. Effects of different approaches to slope cutting



3.1.2 Fill slopes

Although fill slopes should also take into account the nature of soil or rock they are founded on, this is less important compared to cut slopes, and fill slope angles are inevitably designed to set guidelines. The *Road Design Manual* recommends the slope angles for heights of up to 10 metres shown in Table 3.2.

Table 3.2. MPWT grades for fill slope formation

Material	Slope Angle	Height (h)
Cohesionless sand	1V:3H	h < 1 m
	1V:2H	h > 1 m
Other materials	1V:3H	h < 1 m
	1V:2H	1 < h < 3 m
	1V:1.5H	3 < h < 10 m

Source: *Road Design Manual* (MCTPC, 1996)

The shallower slope angle at the top of fill slopes is for traffic safety considerations. For the purpose of this report, fill slopes can be taken to be designed and constructed at 1V:1.5H.

Most fill slope failures in Laos appear to be caused by the absence of benching into the underlying ground to 'key' the fill mass into the natural hillside, and the lack of compaction of the fill material. Failures then occur at the interface between the fill and the original ground, or by deep gullying.

3.1.3 Natural slopes

In mountainous terrain the act of cutting a road along a sloping hillside can destabilise the natural slope above and below the road in a number of ways.

- The natural slope may only be marginally stable, so that removal of support by excavating the road may trigger instability up the hillside. Examples of this are found at Road 12 (km 141+500) and Road 13N (km 260+300).
- The surface water drainage regime down the natural slope will be changed by the construction of the road. The surface water will be concentrated into culverts, and unless the outfalls are properly designed, the concentrated flow may cause local erosion and slope failure. Road 13N (km 254) is a good example.
- The dumping of loose fill on the top of an existing hillside slope may then eventually destabilise the natural slope itself. Road 13 North (km 357) appears to be an example of this.

3.2 Slope failure processes

3.2.1 Rock failures

These predominate where bedding, foliation, or tectonic joint sets dip adversely to slope stability. Plane failures and wedge failures are often the most common forms of rock collapse, whereby failure takes place along a single joint or a combination of intersecting joints. In road cuttings and natural slopes adjacent to roads, these failures are relatively infrequent, compared to soil failures (see below) but they are sometimes represented by the presence of rafted boulders and colluvial deposits derived from previous deep-seated rock failures that have since 'broken up' to form deep deposits of rock on hillsides.

3.2.2 Soil failures

Soil failures are the most frequent collapses observed along road lines. They are usually developed in weathered rocks and soils, and often occur in the upper weathered portion of cut slopes. Soil failures also frequently occur in colluvial masses derived from earlier rock failures, especially where ground water levels are high.

Soil failures are typically shallow, perhaps a few metres in depth and usually occur along a planar surface in granular soils.

3.2.3 Complex failures

There are sections of the Laos road network where large, deep-seated and often slow-moving landslides are affecting the stability of the road formation. In these cases, the underlying processes of failure are likely to be a combination of failure planes and materials, and the mechanisms of movement are unknown.

3.2.4 Slope erosion

Slope erosion can be considered to be a form of instability, particularly when the erosion creates gullying and surface instability. The most easily observed roadside erosion in Laos usually takes place on the surface of the cut slopes (although it can also take place on natural slopes as noted above). There are several failures along Road 18b that fall into this category. This erosion is sometimes reduced by the presence of intermediate unsurfaced horizontal benches, of 1-metre in width and spaced at vertical intervals of around 8 metres, formed at the time of construction. Occasionally, crest drains are constructed in an attempt to reduce the flow of water from the natural ground above on to the slope surface itself. Rarely, bio-engineering techniques are used to encourage plant growth to create a more stable surface. Often natural processes take over and in the course of time the slope surface stabilises.

Fill slope erosion can become problematic, particularly if the slope surface has not been protected (e.g. by planting) and/or if the slope has not been adequately compacted. This is particularly the case where the fill is the result of surplus spoil and has been dumped on the hillside with no attempt at any compaction, and is a frequent occurrence in Laos, for example on Roads 12 and 18B.

River bank erosion is a special case and is addressed in the following section.

4. RIVER BANK EROSION

River bank erosion frequently occurs below road lines. Where a road runs along or close to the top of a river bank there are two situations which may occur:

- On a valley floor or on a flood plain where the land beyond the road and river is relatively flat and there is no hill slope in close proximity.
- Where the road is forced close to the river by a hill slope where the road may have been built on a river terrace, on embankment encroaching the river, or cut into the slope above normal river water level.

4.1 Mechanism

4.1.1 Causes

Rivers and streams are products of their catchments. They are dynamic systems because they are in a constant state of change.

The factors controlling river and stream formation are complex and interrelated. These factors include the amount and rate of supply of water and sediment into river systems, catchment geology, and the vegetation and land use in the catchment. As these factors change over time, river systems respond by altering their shape, form and/or location. Whilst all rivers change in the long-term, short term change rates vary significantly.

River banks erode for many reasons. It is a natural process that over time has resulted in the formation of the productive floodplains and alluvial terraces common to the middle and lower reaches of river systems.

Paradoxically, even stable river systems have some eroding banks. However, the rate at which erosion is occurring in stable systems is generally much slower and of a smaller scale than that which occurs in unstable systems.

Events like flooding can trigger dramatic and sudden changes in rivers and streams. However, land use and stream management can also trigger erosion responses. The responses can be complex, often resulting in accelerated rates of erosion and sometimes affecting stability for decades. Deforestation or changed land use within the catchment and removal of bank vegetation, poorly managed sand and gravel extraction, and stream straightening works are examples of management practices which result in accelerated rates of bank erosion. More specifically erosion can also be accelerated by factors such as:

(a) river bed lowering or infill;
(b) inundation of bank soils followed by rapid drops in flow after flooding;
(c) saturation of banks from local run-off;
(d) redirection and acceleration of flow around built structures, obstructions, debris or vegetation within the stream channel;
(e) removal or disturbance of vegetation from river banks as a result of trees falling from banks or through grazing, clearing, farming or fire;
(f) bank soil characteristics such as poor drainage or deposits or outcrop of readily erodible material within the bank profile;
(g) wave action generated by wind or boat wash;
(h) excessive or inappropriate sand and gravel extraction;
(i) intense rainfall events (e.g. heavy monsoon storms and typhoons);

4.1.2 Processes

The various mechanisms of river bank erosion generally fall into two main groups: 'bank scour' and 'mass failure'. In many cases of bank instability both will be evident, often with either scour or mass failure being dominant. By looking carefully at the processes operating at a site it may be possible to narrow down the probable causes of instability. It is very important to correctly diagnose the underlying causes of bank erosion in order to come up with successful and cost-effective solutions.

4.1.3 Bank scour

Bank scour is the direct removal of bank materials by the physical action of flowing water and is often dominant in smaller streams and the upper reaches of larger streams and rivers.

As flow velocity increases, the erosive power of flowing water also increases and scour may occur. Increases in flow velocity can be the result of natural (e.g. from above d, and f) and/or human induced processes (e.g. a and e). Undercutting of the bank toe is an obvious sign of scour processes.

Effective strategies for combating scour are generally aimed at reducing flow velocity and increasing resistance to erosion through re-vegetation and in some cases through strategic bank or channel works.

4.1.4 Mass failure

Mass failure, which includes bank collapse and slumping, is where large masses of bank material become unstable and topple into the stream or river in single events. Mass failure is often dominant in the lower reaches of large streams and often occurs in association with scouring of the lower banks.

Bare and near-vertical banks or areas of slumped bank materials are obvious signs of these processes. The causes of these types of failures are often difficult to determine but can include natural (e.g. b f or j) and/or human factors (e.g. c, e, g, or h).

Collapse following undermining of the bank toe and slumping as a result of saturation after flooding are common examples of mass failure.

Effective strategies for combating slumping or bank collapse are generally aimed at stabilizing the bank toe and restoring bank vegetation.

4.1.5 Stream Types and Characteristics

When considering the risk and occurrence of river bank erosion it is important to understand the characteristics and behaviour of the river in the general vicinity, and to be able to interpret them with the aid of maps, aerial photographs or satellite imagery.

The physical characteristics of a stream are determined by a variety of factors, for example geology, recent geological history, topography, climate, aquatic habitat and land use. For civil engineering purposes, governing factors may be divided into five groups:

- Geographic: including physiographic settings, geological history, channel pattern
- Hydrological: including discharge patterns, water levels
- Hydraulic: including channel slopes and cross-sections, velocities, hydraulic roughness, erosion and sedimentation, scour

- Geotechnical: including bed, bank and underlying materials
- Environmental: including aquatic habitat, surrounding land types and uses.

The complex interactions between these characteristics produce a wide variety of river types. Table 4.1 lists a selection of some common types and problems associated with each. The general patterns of variation in all these characteristics and the relationships between them are sometimes referred to as the river's 'regime', somewhat in the same sense that 'climate' embraces a suite of meteorological variables. With respect to the key factors of erosion and scour, stream types may range from very stable bedrock channels to highly mobile alluvial rivers.

Table 4.1 Some common types of river and their problems with respect to bank erosion

General type of country or slopes	Type of stream or crossing	Typical materials exposed in channel	Dominant channel processes	Possible hydraulic problems
Mountainous; streams with steep slopes	Boulder torrent	Bedrocks and boulders	Pools and rapids; waterfalls	Bank erosion; blockage by debris
	Braided gravel river or outwash valley train (also occurs outside mountains)	Sand, gravel, cobbles	Transport of coarse alluvium; erratic shifting of main channels	Change in location of erosion as channels migrate during times of flood
	Alluvial fan	Sand, gravel, cobbles	Deposition of coarse alluvium; sudden shifting of channel	Change in location of erosion, channel realignment, scour
Hilly; streams with moderate slopes	Entrenched river (also in mountains)	Bedrock, shale, etc.	Minor bank erosion: transport of thin veneer of alluvium	Few problems compared to other types; possible blockage by debris
	Wandering river	Sand, gravel, cobbles	Valley widening by erosion of valley sides and terraces; transport of alluvial and flood plain formation	Bank erosion and scour, particularly on outside of bends.
Plains; streams with flat slopes	Meandering alluvial river	Sand and silt	Reworking of floodplain deposits by systematic migration of meanders; erosion of valley sides and terraces	Bank erosion caused by continual shifting of meanders; sand bed especially susceptible to scour.
	Low-velocity stream in organic terrain, often with contorted windings	Silt and sand	Bank erosion; deep scour holes	Provision for large overbank flows
	Lake or inundated flood plain crossing	Silt, clay, organic material	Wave action	Soft foundations

4.1.6 Channel Adjustment and Response

The dimensions and other characteristics of a stream channel are determined in large part by the higher discharges and by the sediment inflows to which it is subjected. The 'regime' principle of canals postulates that quantitative relationships exist between 'dominant' or channel-forming discharge, channel dimensions, slopes, and boundary materials, and the imposed changes in others. These basic concepts of self-adjustment and response are undoubtedly valid for most natural streams and their recognition is useful for successful control of bank erosion. However, quantitative 'regime' formulas found in the literature were mostly derived from simple artificial channels (usually irrigation canals) and various difficulties arise in applying them to complex natural channels.

As a qualitative guide on channel adjustments to imposed changes, Table 4.2 summarises some approximate relationships among river variables. The dominant or channel-forming discharge is generally considered to correspond approximately to the bank-full discharge, which frequently has a return period of around 2 years – but longer in some cases.

Table 4.2 Qualitative relationships between imposed and consequent changes in river variables

Imposed change	Principal consequent changes	Approx formula to indicate sensitivity to imposed change*
Reduction in width (as by constriction)	Increase in depth of scour	Depth ~ $1/W^{0.75}$
Increase in slope (as by straightening of channel)	Increase in velocity; increase in sediment transport from bed and bank erosion	Velocity ~ $S^{0.5}$ Bed material load ~ S^{3}
Increase in dominant discharge	Increase in width, depth and erosion; reduction in slope by degradation	Width ~ $Q^{0.5}$ Depth ~ $Q^{0.33}$ Slope ~ $1/Q^{0.25}$
Reduction in sediment load (as by damming)	Reduction in slope by degradation	Variable
Increase in sediment load (as by deforestation)	Increase in slope by aggradation; increase in tendency to wander; increase in width	Variable

* The exponents are not universally applicable and are shown to indicate sensitivity only. *W* is channel width, *S* is slope, and *Q* is channel forming discharge.

Erosion and Deposition Processes:

Degradation: Lowering the channel bed on a substantial river length occurring over a relatively long time period in response to disturbances that affect general watershed conditions, such as sediment supply, runoff volume, and artificial channel controls.

Aggradation: Raising the channel bed resulting from disturbances in watershed conditions that produce the opposite effect to those leading to degradation.

General Scour: Lowering the streambed in a general area as a consequence of a short duration event such as a flood. Examples are erosion zones near bridge abutments and scour near sand and gravel extractions from the river bed.

Local Scour: Vortex formations are localized phenomena around obstructions such as bridge piers or rock outcrops which lowers the bed.

Deposition: Raising the streambed due to specific flood episodes. An example is a sand bar during a flood event. Deposition is used in this document as the counterpart of general scour.

Lateral Migration: Stream bank alignment shifting is due to a combination of the above: vertical erosion and deposition processes. The most common example is floodplain river migration or meandering. Another example is a river bank's loss or retreat due to mass failure.

4.1.7 Flood processes

The flood characteristics of a river – the magnitude of floods and the frequency with which they occur – govern all aspects of its channel. By virtue of their energy, flood flows are responsible for erosion, the transport of coarse sediments and, ultimately, for the capacity of the channel. Most river channels are able to accommodate the flow of the average annual peak.

An inverse relationship always exists between flood magnitude and frequency; the largest floods are the rarest. Records made at flow gauging stations, or obtained from historical sources, allow the relationship between magnitude and frequency to be examined and, where required, an experienced hydrologist can assess the likely return period of a flood of a given magnitude. However, return periods can only indicate the average interval between exceedances of a given magnitude and, in reality, unusually large floods can occur within relatively short periods of time.

Most bank erosion occurs during the few largest floods each year. In these events, banks are exposed to the greatest height of floodwater, and the erosive stresses resulting from current velocities and water depth are also at their maximum. As water levels recede, the transported material is deposited in areas of low velocity (principally the insides of bends, thus balancing the erosion taking place immediately opposite). Deposition also occurs whenever the floodplain is inundated, as velocities outside the channel are always relatively low.

The type of channel change which occurs during floods is largely a function of the channel type: in steep, upland streams, much of the erosive energy of a flood is directed in the vertical plane, whereas, in flat areas of floodplain, channel evolution is mostly in a horizontal sense as meander bends migrate across the floodplain. Braided channels often typify the intermediate situation, where floods frequently cause channel switching.

4.1.8 Ecology

The processes of flooding, bank erosion and channel change are in the first instance natural, and are responsible for providing a range of fluvial features and natural habitats. However, human intervention in this system, normally aimed at halting erosion or preventing inundation, is never without impact elsewhere and can often be thwarted by these powerful forces of nature.

From a conservation perspective, there are several fundamental considerations in developing bank erosion protection. These are:

- bank erosion protection should always be based on an understanding of the fluvial system, which requires recognition of the dynamic nature of rivers and the links between rivers and other components of catchment hydrology;
- river management should be planned in a catchment framework to ensure that upstream and downstream effects of particular developments are fully evaluated;
- possible impacts of river management on other aspects of the catchment, such as flora, fauna and habitats should be fully appraised, and
- design of bank erosion protection should be appropriate for the particular circumstances concerned and should include the use of alternative low technology/low impact approaches where possible.

4.2 Extent of problem: Mekong River

The problem of bank erosion along the Mekong River is distinct from its tributaries. The underlying processes are the same but the size of the Mekong channel, the large range of water levels and its status over much of its length as the international boundary between Lao PDR, Myanmar, Thailand and Cambodia are the reasons a distinction is made. Tributary rivers are discussed in the next section.

4.2.1 The Mekong River

The Mekong River in Lao PDR is characterized by its winding course and gradient, its wide channel and particularly the reliable rise in water level >10 m each flood season. A consequence of these characteristics is natural instability and alternating sequences of erosion and sedimentation. Flood conditions in the Mekong River and its tributaries cause progressive erosion and weakening of its banks and create steeply sloping river banks at various locations. This erosion poses a serious threat not only to roads along the river bank but also houses, industrial premises, temples, schools and agricultural land.

The total length of the Mekong River in Lao PDR is 1,898 km but for more than half of this the river is the international boundary with Myanmar, Thailand and Cambodia where only the left bank of the river and some islands are Lao PDR territory. In the north the international boundary is in Bokeo Province (with Thailand and Myanmar) and Luang Nam Tha Province (Myanmar). In the south the boundary is with Thailand in Vientiane Province and Capital, Bolikhamsai, Khammuan, Savannakhet, Salavan Provinces and part of Champasak Province, and also with Cambodia in Champasak Province. Problems with bank erosion are reported to occur mostly where the river is shared with Thailand as explained below.

The northern reach from Chiang Saen in Thailand to Vientiane is almost entirely mountainous and covered with natural forest, although there has been widespread slash and burn agriculture. The hydrology is dominated in both wet and dry seasons by the inflow from the upper Mekong River in China. In terms of the classification in Table 4.1 this reach begins as a hill river with moderate slope, entrenched in the mountains but becoming wandering as the valley opens out; then becoming a plains river with gentle slope and a meandering alluvial channel approaching Vientiane.

The southern reach from Vientiane to the Cambodian border sees a change in hydrology which is increasingly influenced by contributions from the large left bank tributaries in the Lao PDR and from the right bank tributaries in north-east Thailand. The hydrology of sub-reaches in this section is distinct and sensitive to existing and future water resources developments in both countries. In terms of the classification in Table 4.1 this reach is a plains river with gentle slope and meandering alluvial channel.

The Department of Waterways has an inventory made in 2004 of erosion on the Lao PDR (left) bank of the Mekong River for the 991 km where the river forms the international border with Thailand and part with Myanmar (Table 4.3). Erosion was recorded for a total of 167.35 km which is about 17% of the inventoried river. Bank erosion has since occurred in other locations but the inventory has not been updated to include this.

The reason given for not inspecting the 901 km not covered by the inventory is that there is little bank erosion of consequence. This is credible because much of the river entirely in Lao PDR flows between steep sided hills and gorges with many rock islands and rapids, sparse riparian population and few settlements.

This bank erosion is significant and there is a political dimension to the problem. The international boundary with Thailand was agreed in 1926 by the signing of a Memorandum of Understanding between the French Colonial administration of Laos and the Government of Thailand. The boundary was set as the centreline of the deep water navigation channel. However, the Mekong is a natural river and its channel is unstable and shifts from year to year. The perception and opinion of the Department of Waterways is that overall the navigation channel has since moved towards the Lao PDR bank, losing territory but also triggering increased bank erosion as recorded by the 2004 inventory.

Table 4.3 Waterways Department inventory of left bank erosion for Mekong River in 2004

Reach	Length of bank affected (km) Width of erosion per year (m)			
	Normal	Medium	Heavy	Too heavy
	1 to 2 m	2 to 5 m	5 to 10 m	10 to 30 m
Bokeo Province (from Golden Triangle to Phaday)		3.45	9.50	8.70
Vientiane Province (from Nam Heung Mount to Ban Ang Samphanna)	12.00	3.50		
Vientane City (from Sangthong District to Pak Ngum District)		5.00	17.50	29.10
Borikhamxay Province to Khammouan Province	4.30	1.80	31.20	8.40
Khammouan Province to Savannakhet Province	2.00	6.00	7.30	0.80
Savannakhet Province to Champasack Province	1.00	3.60	1.50	
Champasack Province	5.30	0.40		1.00
Totals	**24.60**	**23.75**	**67.00**	**48.00**
Grand total	**167.35**			

It is hard to prove that the movement of the channel and the consequent erosion are anything other than the natural river process or that they are not caused by activities on the Lao PDR side. The equivalent information for the Thai side was not available in Laos. However, on the Thai side there is significantly more hard-engineered bank protection; generally bank slopes have been reduced and protected with rock rip-rap, gabions or concrete revetments. This prevents bank erosion and channel movement on the Thai side so there is greater probability that the river will erode banks on the Lao PDR side. In addition there are significant sand and gravel extractions from the river bed on the Thai side over which the authorities in the Lao PDR have had no control. Both issues have been addressed by recent technical level agreements between the two countries made June 2008 covering sand and gravel extraction and river bank works but it is too soon to know how well this will work.

Clearly only in some places will this bank erosion have potential to affect national roads but overall responsibility for its control rests with the Department of Waterways which is at the same level as the Department of Roads within the MPWT (Section 10).

4.2.2 Sand and Gravel Extraction

Sand and gravel extraction also takes place from the Lao PDR and Thai sides of the Mekong. Currently on the Lao PDR side there are three large operators each taking about 100,000 m^3 per year and about 17 smaller operators extracting 20,000 to 50,000 m^3 per year. Extraction permits are issued by the Department of Geology and Mines with technical advice from the Department of Waterways. There is also some illegal extraction. The operators sometimes build temporary dykes and causeways and leave open excavations in the river bed, all of which disrupt flow and can trigger bank erosion when water levels rise each year. Although most gravel extraction activity is along the Mekong passing Vientiane Capital Province, extraction can and does take place on any accessible reach of the river and from the Thai side, also on tributaries. It is likely that many smaller sites are not properly licensed or controlled.

4.2.3 Road 11

Road 11 runs west along the Mekong from Vientiane. It was inspected from the river engineering perspective on 4 July 2008, travelling about 150 km from the city. This is a gravel road but is being progressively upgraded under ADB funding and with the construction of two new Mekong River bridges will eventually provide a fast link to Luang Prabang in the north and also Thailand.

Initially this road passes through the western suburbs of Vientiane parallel to the river bank and not closer than 50 m. The land between is occupied by houses and various commercial premises, plus a water treatment works. There is little undisturbed or natural river bank and in places the bank has been protected with gabions; the water level was too high to see the lower part of the bank.

After a detour inland the road again follows the Mekong but now along the top of the bank and at the foot of a wooded slope. On the Thai side there is a paved highway also located between the river and a wooded slope. The river banks are steep and one mass failure was seen with the back scar just off the edge of Road 11. In several other places there were small gullies along the road edge caused by road run-off. This section of road is clearly vulnerable to bank erosion and may even require special measures by the time the upgrade construction begins. Across the river in Thailand there were no visible problems but river water level was high and therefore any lower bank protection was submerged.

A few kilometres west the valley opens out on the Lao PDR side and passes through Ban Angsamphanna village. The 2004 inventory recorded bank erosion over a 6 km length of bank and in places in excess of 10 m per year. The road is separated from the river by village houses but if the bank erosion continues eventually the houses could be lost and the road threatened. The Department of Waterways is currently constructing rock groynes over a 7 km section of bank, on the 4 July 2008 one downstream groyne had been completed and a second was under construction. Upstream there is an island and a long section of bank protection was visible at a town on the Thai bank. There has also been sand and gravel extraction on the Thai side. The Department of Waterways believes a combination of these factors has triggered the bank erosion. Groynes are an appropriate response, but even the simple rock groynes being used require significant capital investment.

The final 40 km or so of road visited is under construction as part of the ADB funded improvements for Road 11. The road has long sections of cut slopes above the Mekong River, in places there is a river terrace between the road and the river but elsewhere the slope is continuous into the river bank. In fact the road appears that it will be mostly on a rock shelf above high river levels and therefore not generally vulnerable to river bank erosion. It is understood that the designers did not foresee a need for any river bank protection. However, there is a mass failure over a 1 km length of river terrace which has occurred this year and less than 30 m from the toe of the road in a location where it does not appear to be on rock. Elsewhere because of the ongoing construction the slopes above and below the road appear fresh and devoid of vegetation but no other bank erosion was noticed. Overall this section of road is not imminently threatened by bank erosion but its proximity to the river requires that the situation should be monitored, particularly through the flood season when bank erosion can rapidly advance tens of metres.

4.2.4 Elsewhere on the Mekong River

The study period was too short to visit more locations along the Mekong River. There is a history of bank erosion around Vientiane city although this does not impact national roads but rather property and city roads. The Department of Waterways is the government agency involved.

Road 13S only comes in close proximity to the Mekong River in a few places although there is plenty of river bank erosion affecting property and farmland. Near Paksan there is reported to be some bank erosion near the road but this was not inspected. It is believed to be mass erosion due to channel adjustments as described above. In terms of the classification in Table 4.1 this is a plains river with gentle slope and meandering alluvial channel.

Along Road 3 in Bokeo Province the Department of Road has constructed 400 m of bank protection.

4.3 Extent of problem: Tributary Rivers

Tributary rivers in the Lao PDR are subject to all the mechanism of bank erosion described in Section 4.1. At their confluence with the Mekong River they can also be subject to large seasonal fluctuations in water level due to the annual Mekong flood but the backwater effect reduces upstream and disappears as the tributary gradient steepens moving into the mountains.

Overall there are remarkably few examples of river bank erosion affecting National Roads. They are certainly much less than the locations for slope stability problems described elsewhere in this report. The active examples of bank erosion seen during the course of the river bank field observations undertaken during the Feasibility Study did not appear to have triggered instability above the road. Pre-existing large and deep-seated landslides occupying some valley sides are, however, likely to have been triggered, at least in part, by river erosion.

When bank erosion problems do occur they can be just as serious as any other slope stability problem; they can cause loss of the carriageway and reinstatement costs and river training works can be very expensive.

The following sections illustrate the type of problems which may occur.

4.3.1 Road 13N km 470+500

This is a good example of an active slope failure below the road caused by river bank erosion.

The site was inspected on 6 July 2008. The failure was recent and occurred sometime during June 2008. The back scar has caused loss of about 15 m of the edge of pavement and the road was restricted to a single lane. Further along in the grass verge the back scar had reached one of a pair of electricity poles; if this had been a single post it may have dropped into the river. There is a slope above the road but this is not affected.

The bank erosion is on a tributary of the Nam Sat. The failure has occurred where the outside of a meander bend comes against the toe of the slope below the road. In terms of the classification in Table 4.1 this is a hilly stream with moderate slope and a wandering channel. The river has a flashy flow regime and local people report that it floods several times each year which will be whenever there is heavy monsoon rainfall over the catchment.

There are young but established trees on the opposite bank and a small area of deposition. This indicates that the river has followed the same course for some years although it may have followed the opposite side of the valley in the past. This appears to be a scour failure. This was a predictable location for bank erosion and it was inevitable that the bank would fail at some time.

The DPWT are waiting for the dry season to survey the site, design and cost remedial measures. This is a risky strategy because with several more months of the monsoon season remaining the failure may spread; it would be prudent to execute some temporary emergency repairs. The DWPT will use the Road Maintenance Fund for the works; this should be approved because this is an essential emergency repair.

4.3.2 Road 13N km 366+000 and 368+000

There are two failures in the village of B. Mout, that at about km 366 being the more serious. The site was inspected on 7 July 2007.

At km 366 about 1 km of river bank is being undercut by scour and suffering mass failure. In places the erosion has advanced up to 10 m in two years and bare soil banks are standing vertical more than 6 m high. The immediate threat is to village houses between the top of the river bank and the Road 13N but if the houses fail the slope may extend back to the road.

The river is the Nam Khan. It is far enough upstream from the confluence with the Mekong for there to be no backwater effect. In terms of the classification in Table 4.1 this is an entrenched hill river with moderate slopes. The erosion is occurring on a relatively straight reach about 1 km downstream of a bend. The cause of the erosion is a large shoal on the opposite right bank which has narrowed the channel thereby increasing velocity and eroding the left bank. There is a bridge and a steep tributary entering in the village but this is too small to have supplied the sediment to build up the shoal. More probably the shoal has been cause by sediment settling after the upstream bend in the Nam Khan as velocity slows in the straight reach. Matters have been made worse by removal of material and formation of a cobble weir at the upstream end of the shoal, the objective was to improve matters but the angle of the weir has actually directed more flow against the left bank.

The situation at km 368 is essentially the same but less serious. There is again a shoal on the right bank causing a narrowing of the river channel leading to erosion and steepening of the left bank.

The DPWT is concerned at the situation and has been assisted by JICA who have surveyed the site (JICA has a slope stability trial nearby). However no remedial measures have been designed and no funding secured for any works. Measures may include a gabion toe wall to stabilise the bank, probably with stub groynes to direct flow away and towards the right bank, also some clearing of the shoal to restore the width of the channel. Such works will be expensive.

4.3.3 Road 8 km 118+000 to 128+800

The section of Road 8 between Lak Soa and the Vietnamese border was visited on 1 July 2008. Between km 118+000 and km 128+800 there are major gabion works built for river training and slope stability control following severe damage caused by a large flood in 2000.

Upstream from Lak Soa this is a hill river with moderate gradient but with a wide enough valley for a wandering channel. In one place where the river comes against the toe of the road embankment the road has been protected by a gabion toe wall and sloping mattress.

At about 118+000 the valley narrows and the river becomes entrenched. The valley controls the bends in the river. The inventory at section 12 notes a number of locations where there are major gabion works and for some of these the previous erosion of the river bank is identified as also a trigger for instability above the road.

From about 119+500 the river rapidly changes into a mountain river with a steep channel rocky bed and bolder torrent. The valley sides are steep and there are long sections of gabion work, some founded directly onto rock.

The mountain sections of this road are a high risk location for bank erosion. Particularly the Annamite Mountain Chain is a high risk area for typhoons tracking inland from the South China Sea. The river banks can be stable during floods generated by normal heavy monsoon storms but a typhoon can generate two or three times the rainfall along the centreline of its track. Typhoon tracks are random and many years may separate one tracking over the same catchment. Hence a road can survive many years without significant problems until an exceptional flood occurs, as happened in 2000 for National Road 11. It is very difficult and expensive to protect such a road against every eventuality. It can be better to respond to damage from a major flood, albeit that there is disruption and delay repairing the road.

The gabion river training works on Road 8 are well designed and constructed. They are appropriate to the conditions and are standing up well to the normal annual flood cycle. They have not yet been subjected to a flood of the magnitude 2000 but even if they do sustain damage in such an event there is a good chance that they will provide a level of protection to the road.

4.4 Control measures

Many of the most appropriate control measures for river bank erosion have already been used at various locations in the Lao PDR. There is a core of staff within the MPWT with sufficient understanding and experience to undertake such works, the major constraint is funding.

4.4.1 Retreat and realignment

Where bank erosion is affecting a road the option of ‘retreat’ (move the road away from the river) should always be considered. The major benefits will be avoiding the potentially high construction and maintenance costs of bank protection and river training works and also elimination of the risk of undesirable consequence to other parts of the river system.

However, this option will only be possible where topography allows; either flat land or a suitable slope. In narrow mountain valleys it will often not be tenable. Also there can be issues over land ownership if farmers are displaced from their land, or if houses or other property are affected. This will add land purchase and compensation payments to the engineering costs of building a new section of road.

4.4.2 Engineering Solutions Generally

Where retreat is not possible, bank revetment will usually be the best available engineering response to serious river bank erosion. Along the Mekong River most work has been around Vientiane City, and also other riverside towns and locations where there is infrastructure. On other rivers the works described above for Road 8 are amongst the largest. However, to date cost constraints mean that engineering solutions have only been used in a fraction of the locations where bank erosion has occurred in the Lao PDR. This has generated interest in alternative lower cost bank protection methods such as bio-engineering or the 'soda system' trials undertaken by the JICA around Vientiane and which are described below.

Hard revetments such as wall construction to armour the river bank can actually trigger additional bank erosion and scouring:

- at the toe of revetment;
- immediately downstream of bank protection work (because vortices are generated by rapid divergence and a sudden change in hydraulic roughness if the revetment is not 'feathered in' to the natural river); and
- on the opposite side of the river, downstream from the revetment.

4.4.3 Engineering Materials

The ideal properties of materials used for riverbank protection are:

- flexibility;
- free draining;
- durability;
- easily repaired or replaced; and
- provide protection in all seasons.

Other important factors in the choice of material include:

- cost;
- safety;
- environmental impact; and
- appearance.

Not all materials can provide all the desirable properties and the choice is driven by circumstances, cost, the location and nature of the problem. Some of the materials in common use are described below. A filter is essential for several of the methods.

Rip-Rap

Rip-rap is a layer of heavy stone which protects the softer materials of the riverbed and bank from eroding. The stone must be heavy enough so that it is not moved by the water flow. Therefore heavier stone is required for faster flow velocities. It should be laid over a filter material or filter fabric to protect the underlying material.

Rip-rap has all the required properties and advantages over most other materials in many circumstances because:

- it is flexible and is not impaired by slight movements resulting from settlement;
- local damage is easily repaired;
- no special equipment or construction practices are necessary;
- appearance is natural;
- additional thickness can be provided at the toe to offset possible scour; and
- vegetation will often grow through the rocks, or may be planted to do so.

The major disadvantage of rip-rap is that over time there is often a loss of stone by washing away which must be replenished. Also where flow velocity is high, large size stone is needed which can be difficult to quarry and transport and makes the protection layer very thick.

Numerous guidelines, charts and specifications have been produced for the selection of the stone size for rip-rap. These all require estimation of the flow velocity so the designer must obtain this from direct measurement or calculation.

Gabions

Gabions are stone filled wire baskets. Gabions must always be laid over a filter, geotextile filter fabrics are best.

Gabions have all the required properties, very similar to rip rap with the possible exception of durability:

- they are flexible and their effectiveness is not impaired by slight movement resulting from settlement;
- local damage is easily repaired;
- no special equipment or construction practices are necessary;
- appearance is natural;
- a gabion apron can be provided at the toe to offset possible scour; and
- vegetation will often grow through the gabions, or may be planted to do so.

Gabions have additional advantages over rip-rap because the wire basket holds the stone together:

- preventing it being moved away by water velocity; and
- ensuring the desired thickness of protection at all times by preventing loss of stone.

For a given level of protection a layer of gabions is about only 40% of the thickness of the equivalent layer of rip-rap. This gives a saving in real cost. Also there is a significant benefit in terms of environment and sustainability in that less quarried stone is required.

A gabion basket is made of steel wire mesh in a rectangular box shape. It is strengthened in the corners by heavier wire and by mesh diaphragms that divide it into compartments. The wire is galvanised, and sometimes PVC coated for greater durability.

The baskets usually have a double twisted hexagonal mesh. This is important because it allows the gabion to deform without the box breaking or loosing its strength. Factory or hand woven gabions can be used. If the gabions are hand woven it is important that the correct grade of wire is used and that the twist is tight producing the correct mesh size.

There are two distinct types of gabions with two different uses:

- gabion boxes are the heavier more rigid form with larger stones used in walls, stiff aprons and such like, usually 1.0 m high boxes are used but sometimes 0.5 m boxes are used for rigid aprons.
- gabion mattresses are thinner using smaller stones and mesh and therefore more flexible so that they will fold down to protect scour holes, for this purpose the maximum thickness is 0.3 m.

The size of stone is important, small stones which can fall through the mesh must not be used. Too large stones must not be used in mattresses because they will reduce flexibility.

There is sometimes confusion over this terminology when 0.5 m boxes used as aprons are referred to as mattresses. The definitions above are the correct generic terms.

One disadvantage of gabions is that high bed loads can damage the wire, but this is only usually a problem in upland watercourses where sediment transported is of a large size. Measures to protect the gabions include mastic grouting (which retains some flexibility) or facing with concrete (used on Road 11 where gabions are founded on rock).

Mortared masonry
This common and popular method of protection can work well in road drains but is in general totally unsuitable for use in natural rivers and difficult flood conditions. This is because it lacks two of the required properties: it is rigid and difficult to drain, and will fail from the toe unless protected.

It is important to understand the problem of drainage. During a flood the ground behind the slope protection becomes saturated with water. When the water on the river side drops, water must be allowed to drain from behind the wall through a filter layer and weep hole (drainage pipes). But such drainage is seldom properly provided, and even when it is it will tend to block up over time. If back drainage is poor there will be a high hydrostatic force pushing outwards from behind the lining, which can literally blow apart.

Concrete
Concrete protection can be formed of mass or reinforced concrete. They have the same disadvantages as mortared masonry except that the concrete is much stronger and will accommodate minor failure but still protect the slope. It can be used for bank slopes and river walls, provided that the toe is adequately protected against scour and that there is effective back drainage.

4.4.4 Hard revetment river walls and slope protection

These provide direct protection to a continuous length of river bank. They can be economical for dealing with specific locations such as erosion on the outside of a river bends on a tributary river. However, they can be very expensive for long sections of bank such as the 7 km bank erosion near Road 11 described above.

The sloping revetments can be made with rip-rap, gabions and rigid concrete and masonry. There are many possible arrangements. Some simple examples are illustrated schematically by Figure 4.1 and are suitable for many tributary rivers. For the Mekong River the large variation in water levels means more complex combinations are normally used.

All the examples provide toe protection. For rip-rap, extra stone is laid along the toe of the slope to settle into any scour hole that develops to protect the toe against undermining. For the gabion solutions the same is achieved with a flexible mattress. If the works can be built in the dry season then toe protection can be carried below the bed and buried. Sheet piles can also be used for toe protection but this can only be justified where high value assets are at risk.

4.4.5 Groynes

Groynes are structures that project out from the river bank to deflect strong currents away from the bank and encourage the settling of sediment along the toe of the protected bank.

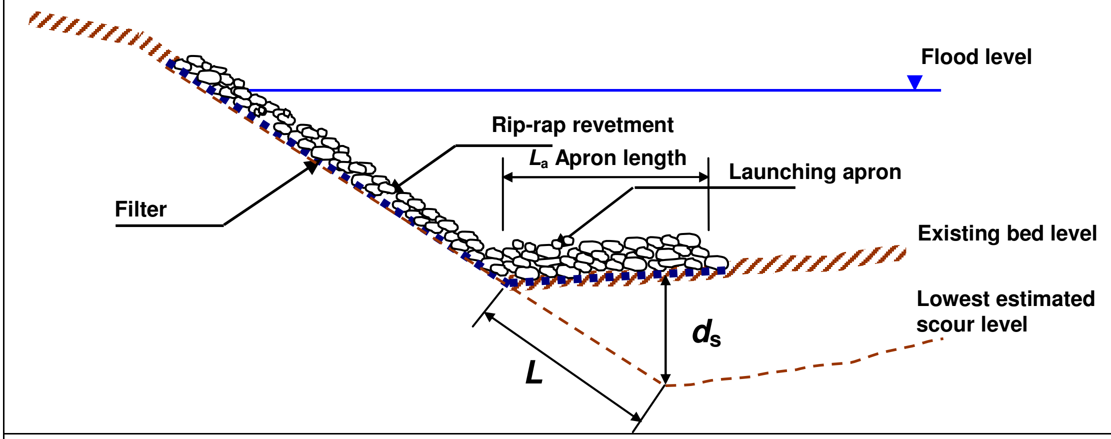
Groynes may be used singly or in groups. They will usually be less costly than continuous bank protection and the river bank between groynes can be undisturbed.

Groynes can consist of:

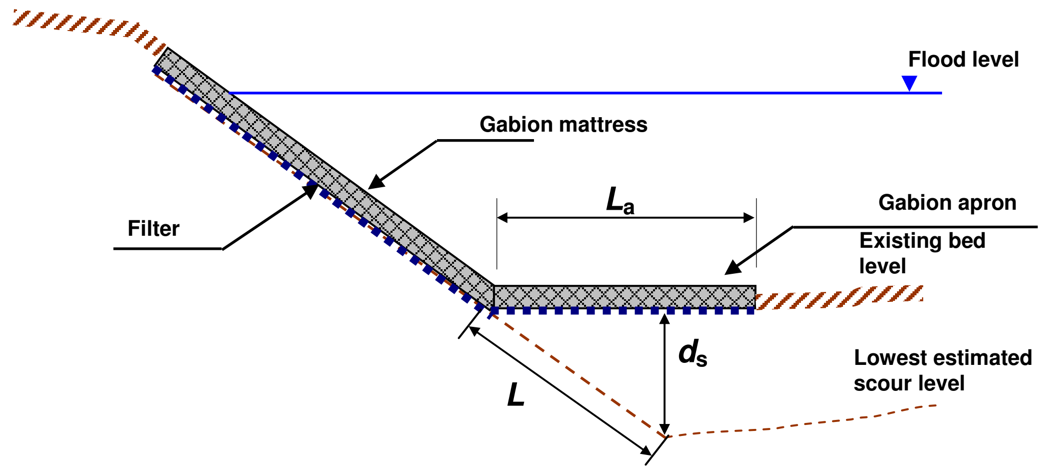
- embankments similar in cross-section and height to a guide bank;
- gabions; or
- permeable structures such as a double row of wooden cribs filled with rocks and brush wood.

Figure 4.1. Typical hard revetment river walls and slope protection

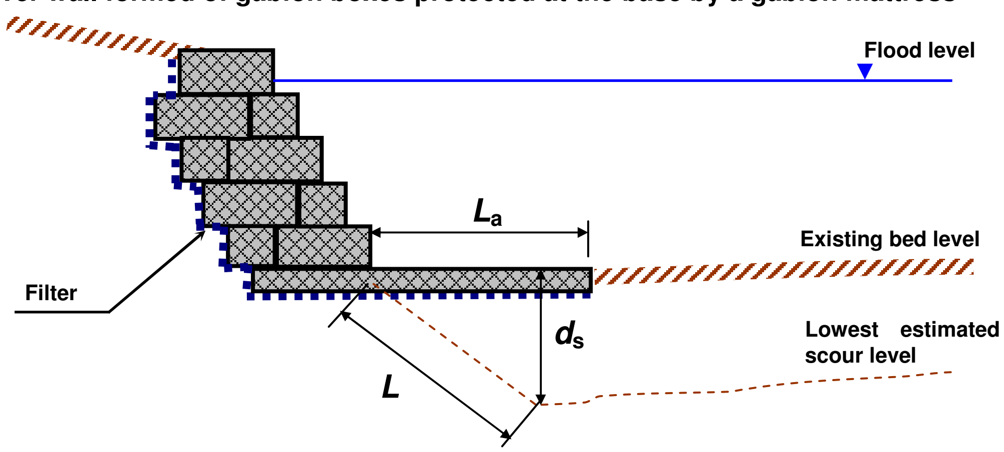
Sloping rip-rap revetment with launching apron on the bed of the river at foot of the slope



Sloping gabion mattress laid over a filter



River wall formed of gabion boxes protected at the base by a gabion mattress



Suitably protected embankments are recommended as the first choice, but cost may well dictate the use of gabions, especially in fast-flowing rivers which require large rip rap stone sizes. Timber or crib groynes can also be used.

A single groyne tends to cause severe flow disturbance and a deep scour hole at its outer end. Groynes should normally be used in groups, and a single groyne should in general be avoided where the main current would impinge against it, although exceptions to this recommendation can be made in certain circumstances.

When constructed in the form of earth embankments, groynes should generally be pointed upstream so as to create a dead water pond which provides a cushion to prevent erosion of the upstream face. It is then necessary to place protection only at the nose of the groyne. If pointed downstream to act as flow deflectors, the upstream faces will require protection against erosion along their full length.

The length of bank protected by each groyne appears to be at least twice its projected length perpendicular to the current, equally spaced about the projection of its outer end. For a group of four or more, the spacing may be up to four times their projected length.

Since groynes deflect flow away from the eroding bank they generally cause sediment transport on the opposite bank. This can be desirable if the objective is to remove a shoal that has caused the bank erosion (as at Road 13N km 366). However it is not desirable if it causes loss of land and property damage on the opposite bank. There are obvious implications in this respect where the Mekong River forms the border with Thailand.

4.4.6 Stub groynes

These are very short groynes along the toe of a river wall or revetment. Typically they can be a gabion box on top of a mattress projecting 2 m out into the river. They are used to correct channel migration and move the channel back towards the opposite bank. Stub groynes could be used at Road 13N km 470+500.

4.4.7 Soda method

The soda method was introduced to the Lao PDR under the JICA Project on River Protection Works for about 60 km of the left river bank centred on Vientiane. The initial Development Study (2001-2004) focused on the development of low cost and effective bank protection works using this traditional Japanese method of river bank protection as an alternative to high cost hard engineered revetments. Several demonstration projects were used to prove the method and a master plan has been prepared for wider scale implementation through to 2020. Follow-up technical assistance has focused on consolidating the expertise and organisation for river protection projects within the MPWT.

The significant output of the project has been the successful introduction and acceptance of the soda mattress, and although the use to date is understood to be limited to the Mekong River around Vientiane it is suitable for use anywhere in Laos. The soda method was introduced and developed in Japan by Dutch engineers in the 19th century. There are many variations but they all share the following features:

- only locally available and assembled materials such as fascine and stones are needed;
- components can be fabricated in various sizes according to the needs at any site; and

- since only natural indigenous materials are used the method is very environment friendly.

A soda-mattress is used on the lower part and toe of a revetment, it is very flexible and can be laid to follow the ground profile and will fold to accommodate settlement and protect against scour – similar to a gabion mattress but at lower cost. Further up the slope another variation is to use cobblestones with willow branch work for slope protection. The system can also be used in combination with hard revetments such as a gabion wall or slope protection, in which case the mattress is used for the toe protection.

4.4.8 Vegetation

The use of vegetation and bio-engineering is covered in detail elsewhere in this Feasibility Study final reporting. They can make significant contribution to restoring a river bank and protecting it against erosion, particularly in combination with many of the measures already described above.

Vegetation can provide excellent short-term protection above normal water level. However, grasses may die back in the dry season or if grazed by domestic animals. Plants with good surface root systems are needed because these will bind the soil. Grasses and bamboo have such root systems. Woody bushes have the benefit off breaking the flow of water at the ground surface in locations where waves or boat wash are a problem, and some species are unpalatable to grazing animals. The most successful plants will probably be those found growing naturally along the river or flood plain that is to be trained and protected.

Vegetation is least effective in situations where it suffers long periods of inundation. Most plants will die back during sustained periods of flooding; even if they regenerate there will be a period when the slope is not protected. Vetiver is proposed by its advocates as a plant that can sustain long periods of inundation. However, trials conducted in the Mekong River Delta in Vietnam and more recently the Tonle Sap in Cambodia have been inconclusive but tend to show that vetiver dies back and is weakened in the long-term by prolonged inundation.

Vegetation can be used on tributary river banks where it is only submerged by floods for short periods. However for banks of the Mekong River and tributary confluences which are submerged several months each year, vegetation is not a tenable means of slope protection other than above flood level.

4.4.9 Reinforced vegetation

Reinforced vegetation on river banks has to be stronger than used for bio-engineering on hill slopes because of high flow velocities during a flood.

For many years in many countries use has been made of geotextile systems to establish and reinforce vegetation root systems. An example of a popular and successful proprietary system is Enkamat; similar products are available from Malaysian suppliers although availability in the Lao PDR has not been investigated.

Enkamat type products are based on an open three-dimensional plastic wire grid, as thin as 10 mm, pegged and laid just below the original ground surface. When fine soil is spread on the mat it fills the open grid and allows roots to pass through binding together to form a dense vegetated mat. The strength can be significantly improved by filling the mat with a gravel and bitumen emulsion. This does not inhibit plant growth and some companies will supply the mats prefilled complete with grass seed. The mats can also be filled in-situ but are not as effective as the factory filled mats. These systems are simple and environmentally friendly to use so the only constraints are the extra cost and availability.

Gabions can also be used for reinforced vegetation. Gabion mattresses and boxes are fundamentally permeable and permit the natural movement and filtration of ground water indispensable for the life of the surrounding area. Moreover, due to this filtration effect, silt is deposited in the stone fill, promoting the growth of native plants which not only reinforce the structure binding it into the underlying soil but will also attract back indigenous fauna, recreating the original eco-system. As with the Enkamat type systems, it is possible to accelerate the vegetation growth by spreading soil over the gabions and seeding or planting as for other vegetated slopes.

4.4.10 Selection and design

The principal quantitative variable in the choice of bank protection is the flow velocity that occurs along the bank. Table 4.4 provides a general comparison of the maximum velocities that can be sustained by bare soil banks and for different types of protection. These values are for information only and reference should be made to the literature for actual design values.

Table 4.4. Comparison of maximum velocity for natural and protected river banks.

Type of protection	Maximum velocity (m/s)	Description	Remarks
Bare soil	0.75	Fine sand	Quoted velocities assume that there is colloidal material in suspension, velocities are 30 to 50% lower for water with no material in suspension.
	0.75	Sandy Clay	
	0.90	Soft clays	
	1.05	Muds	
	1.50	Coarse sand	
	1.50	Medium clay	
	1.85	Gravel	
	1.70	Shingle	
	1.85	Hard clay	
Rip-rap	3.80	d_{50} stone 200 kg	Requires 0.8 m layer
	4.60	d_{50} stone 600 kg	Requires 1.2 m layer
	5.60	d_{50} stone 2,000 kg	Requires 1.8 m layer
0.3 m gabion mattress	5.50	d_{50} stone 100 mm	
	6.40	d_{50} stone 125 mm	
Gabion box	7.60	d_{50} stone 150 mm	
	8.00	d_{50} stone 190 mm	
Unreinforced grass	2.00		
Enkamat 7003	5.20	30 minute, vegetated	Test values
	3.60	50 hour, vegetated	Test values
Enkamat 7920	5.80	30 minute, vegetated	Test values
	4.20	50 hour, vegetated	Test values
Soda mattress	No data		4-5 m/s measured at JICA trial sites in Vientiane
Concrete	>8.00		

The relatively poor performance of rip-rap should be noted.

The most reliable way of determining velocity is by observation at the site. However, for the design case this measurement should be made under flood conditions. This may be hazardous and it is necessary to capture a flood event and know its magnitude. For the Mekong River it is easier because of the reliable and long duration flood peak. The measurements at the JICA trial sites in Vientiane will have been done in this way. For open water reaches of the Mekong River these velocities can be used for design.

For tributary rivers it will generally be necessary to estimate velocity by calculation. A crude but sufficient estimate can be made with Manning's equation, assuming high water level, selecting a suitable value for hydraulic roughness '*n*' from the literature or based on judgement. It will also be necessary to measure channel gradient over sufficient distance to be representative and even out the effects of sudden drops, pools and riffles. Ideally the level difference and channel cross section should be measured by topographical survey. If this is not possible a crude measurement may be made with a clinometer or Abney Level, but only with good line of sight. The gradient may also be estimated from contours on 100;000 scale mapping. The distance between upstream and downstream can be measured from a map or with a hand held GPS track. Unfortunately GPS is insufficiently accurate for level measurements. Cross-section can be measured roughly by tape, line and level.

Velocities estimated by calculation give mean flow velocity. It is necessary to factor this for the channel velocity. The factors in Table 4.5 can be applied to estimate velocity at the bank.

Table 4.5. Factors to obtain velocity at different channel cross-section locations

Location	Factor for mean flow velocity
Straight reach	1.0
Outside bend	1.33
Inside bend	0.67
At bridge abutments, etc	1.50

4.4.11 Construction

Rip-rap, pre-assembled gabion and soda mattress and tremie concrete (i.e. concrete placed in situ under water) can be placed under water but these will all require heavy plant. However in all cases it is preferable to carry out work when water levels are lowest in the dry season. Vegetation is best seeded or planted in the early wet season but this can only be above mean annual flood level.

Many of the operations can be labour intensive such as gabion weaving, assembly and filling, vegetation and reinforced vegetation. Large scale earthworks and rip-rap placing require machinery.

4.5 Suggested approach

4.5.1 Proactive versus reactive

Historically the approach to river bank erosion in the Lao PDR has been reactive. For example the DPWT in Luang Prabang have never executed bank protection works although two of the samples sites described in this report are in that province. The intervention on

Road 8 was only made following extensive damage after an exceptional flood, and then needed donor support.

There is a good argument to continue a reactive approach. Bank protection works are expensive. As explained above, rivers are natural systems that respond to many variables, not least a very unpredictable pattern of floods. To attempt to engineer for every possibility would be unnecessarily demanding on resources and funds and even then would not provide absolute protection against bank erosion.

It is better to be proactive in the identification of sites at risk. It is only necessary to consider those sections of National Road that are close to a river. These should be inspected applying the methodology described in section 14. The initial inspection is best made at the end of the wet season and thereafter annually to monitor any change. The work is best carried out by the provincial DPWT reporting to the MPWT.

4.5.2 Roads most vulnerable to bank erosion.

The time available for the river component of the Feasibility Study has been too short to make comprehensive site visits to establish the most vulnerable National Roads. Instead only a selection of roads has been inspected made on the basis of earlier work and advice from the MPWT on known problem locations. In fact this means they may well be the most vulnerable roads but this cannot be certain; there may be another Road 11 size flood elsewhere in the country that will bring to light another vulnerable location. The approach recommended above would improve knowledge on vulnerability.

At this stage known vulnerable roads are:

- short sections of Road 13S
- short sections of Road 13N
- Road 11 beside the Mekong River
- Road 3 in Bokeo Province
- Road 8 east of Lak Sao (albeit recent measures gave mitigated risk of damage)
- Road 12 between Tha Khaek and Nyommalet, possibly further east

5. RAINFALL

Rainfall patterns in Laos are dominated by the south-west monsoon and the relief of the country. Widespread extreme rainfall events are most often associated with typhoons tracking inland from the South China Sea or Gulf of Thailand

The network of daily (24 hour) rain gauge stations is shown in Figure 5.1 and the years of record available are listed at Section 15. Many of these stations have more than 15 years record and longer. This is sufficient for frequency analysis for rainfall of return period up to 1 in 20 years which is appropriate for the small scale drainage works used for slope stabilisation. Unfortunately the stations are usually located for convenience in provincial and district towns and not at elevation in the hills and upper river catchments. There is significant localized variation in rainfall due to the topography and therefore detailed analyses of a record will only yield a broad indication of actual rainfall at a nearby location.

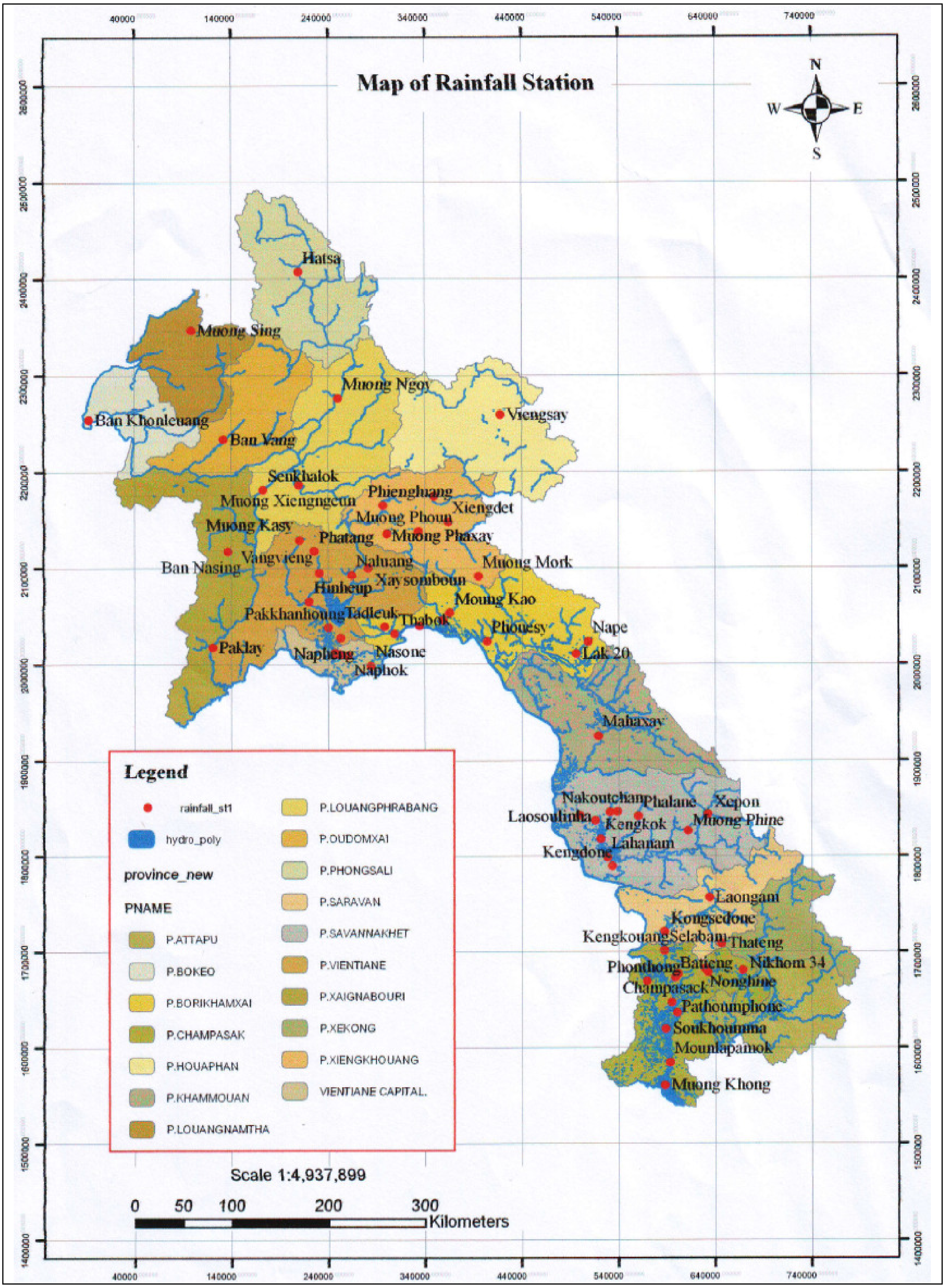
There are few recording rain gauge[1] records. There are several recently installed recording gauges and the network will probably expand in the future but no record was identified sufficient for frequency analysis. When such records exist it is possible to derive short term rainfall-intensity-duration relationships from daily rain gauge records. These relationships are needed for a rigorous drainage design. A detailed rainfall analysis is outside the scope of this Feasibility Study. Therefore at this time drainage design must rely on current MPWT standards or relevant design studies.

In the absence of detailed studies it is difficult to obtain a sound overview of the situation. Figure 5.2 shows two rainfall maps, which show good correspondence in the centre and south of the country, where there is generally high rainfall except across much of Savannakhet Province. For the north the agreement is less precise although both show higher rainfall in Phongsaly; the national map shows an area of higher rainfall in Bokeo, Luang Namtha and Oudomxai which does not feature in the Mekong regional map. The greater rainfall in the central and southern areas is related to cyclonic activity in the South China Sea, and the two main westward tracks of cyclonic storms across Vietnam. These have the effect of extending the wet season beyond the period of the south-west monsoon. Rainfall in the north is also affected by the wider effects of cyclones, but is more dominated by the monsoon. Since the monsoon air mass is affected by its passage from the Bay of Bengal over Thailand and Burma, it becomes somewhat erratic by the time it reaches Laos.

The picture is generally supported by looking at the data supplied from two weather stations in northern Laos. These are given in Table 5.1. The annual total is high at Vang Vieng, with a ten-year average of nearly 3900 mm, and a yearly range between 3150 and 4550 mm. It is much lower in Luang Prabang, where the same ten years showed an average of only 1430 mm, with a range between 1150 and 1800 mm. A glance through the tables shows that the monthly totals can vary considerably at both locations.

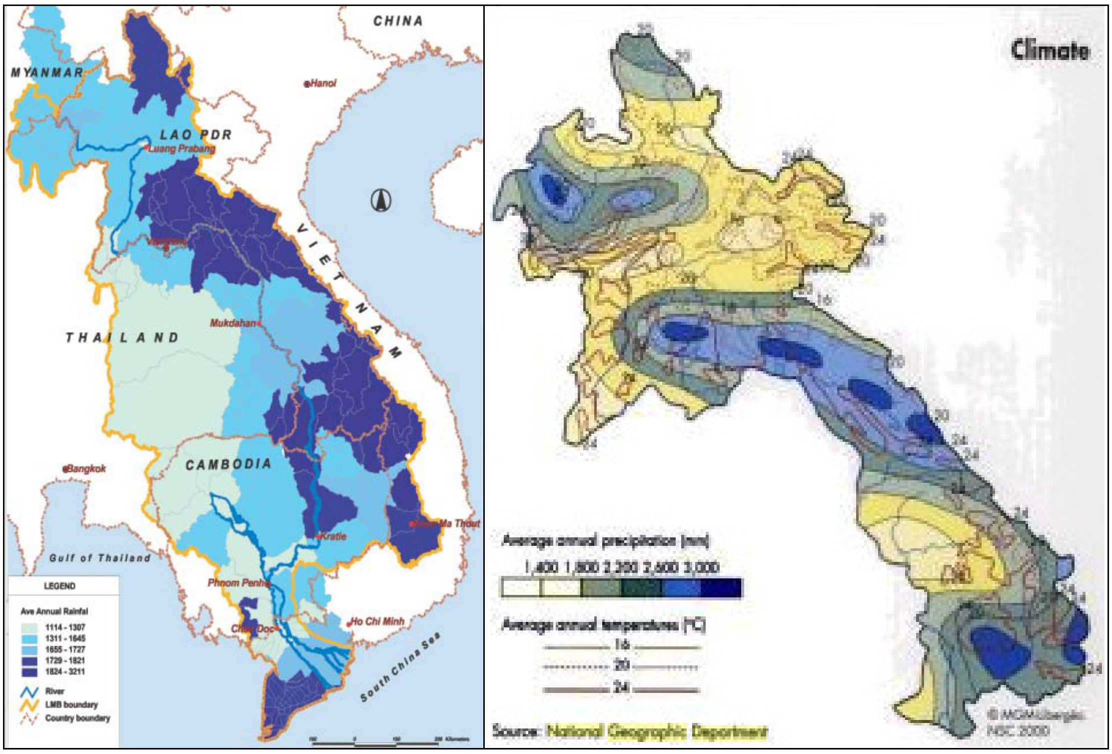
[1] A recording or autographic rain gauge provides a continuous record of variations in rainfall over every 24 hour period. This allows calculation rainfall intensity. For example a monsoon rainstorm recording 50 mm of rainfall on a 24 hour rain gauge may actually peak at an initial intensity >200 mm per hour for 5 minutes and the rain may all fall within one hour.

Figure 5.1. Distribution of daily raingauge stations in Lao PDR



Source: Department of Meteorology, Lao PDR

Figure 5.2. Rainfall maps of (a) the lower Mekong basin and (b) Laos



Sources: (a) Mekong River Commission (2005); (b) Bounthavy and Sisouphanthong (2000).

Table 5.1. Monthly total rainfall for 1996 to 2005

(a) Luang Prabang

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
1996	21	54	76	126	221	136	292	374	203	45	17	46	**1611**
1997	65	25	68	87	89	166	290	176	81	99	19	41	**1206**
1998	78	50	57	130	110	129	152	241	53	136	12	21	**1169**
1999	42	59	85	87	106	166	75	179	243	113	82	111	**1348**
2000	105	138	110	65	241	217	197	112	94	108	55	13	**1455**
2001	45	88	169	194	175	127	349	229	160	169	51	54	**1810**
2002	49	1	24	56	269	156	384	259	161	71	76	97	**1602**
2003	15	20	77	140	68	315	196	314	223	35	0	0	**1401**
2004	15	0	0	143	241	208	287	233	152	166	28	0	**1473**
2005	0	5	89	33	102	238	196	322	183	19	33	0	**1219**
Average	43	44	75	106	162	186	242	244	155	96	37	38	**1429**

(b) Vang Vieng

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
1996	1	15	63	299	376	503	716	1030	472	228	215	6	**3923**
1997	16	0	18	165	387	479	978	753	616	99	0	0	**3512**
1998	0	16	47	239	288	459	780	682	457	102	65	5	**3140**
1999	2	0	87	294	645	750	668	835	473	164	118	55	**4088**
2000	0	118	7	259	742	1047	513	1012	642	166	38	0	**4545**
2001	0	0	248	15	522	888	815	717	448	168	26	1	**3849**
2002	42	0	31	51	742	920	800	743	359	229	24	34	**3975**
2003	24	48	105	78	389	465	931	702	373	95	0	0	**3209**
2004	27	38	22	273	558	671	1087	797	618	10	4	0	**4105**
2005	0	40	8	60	312	1025	1102	1049	690	129	16	3	**4435**
Average	11	28	64	173	496	721	839	832	515	139	51	10	**3878**

Rainfall in mm

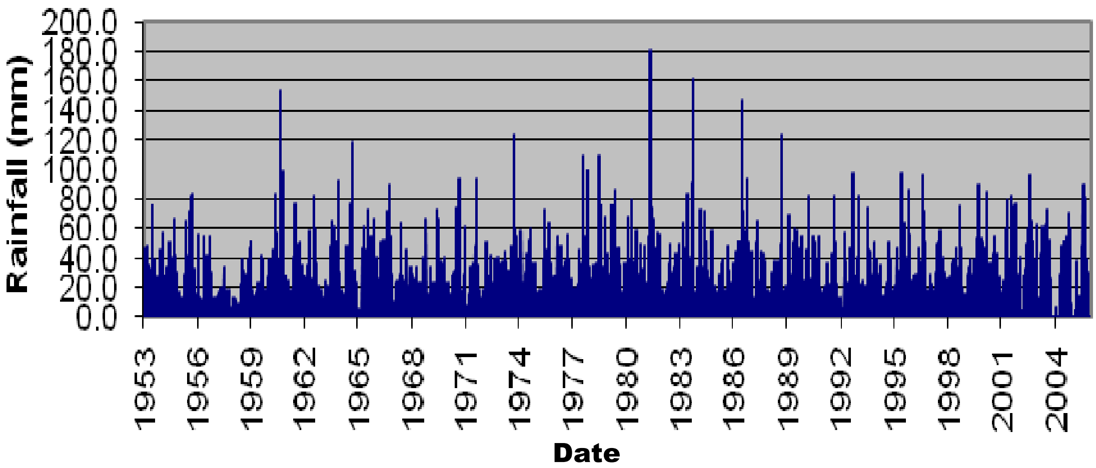
Slope instability can also be related to rainfall, both to the total rainfall (mm) over a period of one to several days, or the rainfall intensity (mm/h) which varies over the duration of the storm. Monsoon thunderstorms are characterised by an initial high intensity which then falls away. Typhoons are characterised by lower intensity but sustained for much longer for the duration of the storm. Often failures occur as a result of a build up of significant rainfall over a period of a few days or even a week, and sometimes it is related to a single particularly intense event.

Luang Prabang has a dataset of fifty years of daily rainfall readings. In that period there have been only twelve occasions when rainfall has been at least 100 mm in one day (see Table 5.2). These have occurred any time between early May and late October, and so can occur as a result of either monsoonal or cyclonic weather systems. The chart in Figure 5.2 gives the complete set of daily rainfall for the fifty year period of records from Luang Prabang. Obviously the printing of over 18,000 individual readings cannot be very clear at this scale, but the chart nevertheless shows that there are relatively very few rain days with more than 60 mm of rain. The twelve high peaks are mainly isolated occurrences, with significant rainfall build-up occurring only in August 1960, August 1973 and September 1983. This rather simplistic assessment of the peak events of course misses other periods of longer rainfall build-up: for example, 141 mm fell in four days at the end of May 1983, and 170 mm fell in five days in August 1983, but not with any single daily total exceeding 100 mm.

Table 5.2. Days with more than 100 mm / day at Luang Prabang (1953 to 2005)

Date	Rainfall (mm)	Comments
27/08/1960	154.0	212 mm between 19 and 24/8, otherwise no rainfall for some days.
26/08/1964	118.0	55 mm in the 2 days before, virtually no rain in the 3 days afterwards.
27/08/1973	124.0	170 mm between 19 and 24/8, otherwise no rainfall for some days.
22/07/1977	109.0	6 mm day before, 38 mm day after.
29/10/1977	100.0	Isolated: virtually no rainfall for 3 days either side.
28/06/1978	109.0	24 mm day before, 2 mm day after.
10/05/1981	181.0	69 mm in 3 days before, 4 mm in 3 days afterwards.
16/09/1983	139.0	This was an extraordinary period (assuming the data to be correct). There was 16 mm of rain in the 3 days before 16/9, 9 mm between 17 and 20/9, no rain on 22/9 and 9 mm in the 3 days after 23/9.
21/09/1983	126.0	
23/09/1983	161.0	
24/06/1986	148.0	Isolated: virtually no rainfall for 3 days either side.
10/09/1988	124.0	Isolated: virtually no rainfall for 3 days either side.

Figure 5.2. Daily rainfall at Luang Prabang, 1953 to 2005



The Vang Vieng station, with its much higher amounts, experienced 36 days with totals between 100 and 200 mm in the ten years from 1996 to 2005, mainly towards the lower end of this range (see Table 5.3). Only on one occasion (in 2005) did the 48-hour total approach 300 mm; and only on three occasions (1998, 2000 and 2005) did the 72-hour total exceed 300 mm.

Table 5.3. Days with more than 100 mm / day at Vang Vieng (1996 to 2005)

Year	Date	Rain (mm)	Year	Date	Rain (mm)	Year	Date	Rain (mm)
1996	12 Aug	147	2001	3 Jun	101	2004	5 Jul	132
1997	21 Jul	138		10 Jun	107		12 Jul	102
	29 Aug	147		27 Jun	184		6 Aug	153
	2 Sep	105		2 Jul	130		31 Aug	119
1998	2 Jul	231		13 Jul	141		8 Sep	132
	22 Sep	115	2002	10 Jun	116	2005	30 Jun	129
1999	20 Jun	150		13 Jun	100		1 Jul	161
	26 Aug	130		17 Aug	111		8 Jul	130
2000	7 Jun	124	2003	21 Jun	100		24 Jul	186
	23 Jun	147		22 Jul	130		12 Aug	161
	26 Jun	138		30 Jul	107		21 Aug	199
	15 Aug	133		22 Aug	121		6 Sep	104
	4 Sep	142						

What this demonstrates is that the large rainfall events likely to trigger significant levels of slope instability are very sporadic and unpredictable. Local effects of terrain on the patterns of air movement almost certainly complicate the situation further, so that the actual rainfall at a particular site 50 km from Luang Prabang may be very different from what is recorded in the raingauge at the weather station. It seems that unusually damaging bursts of rainfall can occur throughout the middle six months of the year, but that they do so only very occasionally.

Fiscal years end on 31 October, which almost coincides with the end of the wet season. In theory, a comparison should be possible between rainfall and expenditure on emergency maintenance. However, even on the very simplifying assumption that rainfall data from a single provincial weather station is representative of the province as a whole, there are two main difficulties in doing this. The first is that the expenditure records are not broken down between the various maintenance items, and so it is not possible to tell how much relates to landslide clearance and how much to subsequent repair works. So in the fiscal year from 1 November 2004 to 31 October 2005, for example, it is not possible to work out how much was spent on repairs to damage from the 2004 monsoon, and how much on landslide clearance in the 2005 monsoon. The second problem is that the Consultant was able to obtain data that overlapped for only two years (2004 and 2005), which were both relatively wet years. Hence an attempt at comparison is inconclusive (see Table 5.4).

Table 5.4. Comparison of annual rainfall and ensuing emergency expenditure

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Emergency expenditure
Luang Prabang (Weather Station and Province)														
2004	15	0	0	143	241	208	287	233	152	166	28	0	**3477**	**2,932**
2005	0	5	89	33	102	238	196	322	183	19	33	0	**3224**	**6,250**
Vang Vieng Weather Station and Vientiane Province														
2004	27	38	22	273	558	671	1087	797	618	10	4	0	**4105**	**14,668**
2005	0	40	8	60	312	1025	1102	1049	690	129	16	3	**4435**	**10,742**

Rainfall in mm, expenditure in million Kip

6. EMERGENCY MAINTENANCE IN RECENT YEARS

An analysis of the financial implications of the MPWT's expenditure on emergency maintenance in recent years is given in section 7. In this section, a more detailed assessment is made of the technical conclusions that can be drawn from the available data.

A summary of emergency maintenance expenditure is provided in Table 6.1, and the full data set in Table 6.4. In fact, expenditure under the emergency budget is mostly not against the emergency maintenance activity codes, which are very limited in number. There are two reasons for this: (a) that although some activities are classed as true emergencies (e.g. landslide clearance and emergency culvert repair), most repairs are the same as for routine maintenance or rehabilitation (e.g. gabion box construction), though they are required as a result of the emergency; and (b) that funds unused in emergencies may be utilised for other key works, such as filling potholes and regrading roads damaged in the wet season, and these also use standard maintenance activity codes. The result of this is that although the works covered by these amounts come out of the emergency budget, they are not all emergency codes. This also makes it difficult to be precise about exactly what constitutes the repair of landslide damage.

Table 6.1. Summary of emergency maintenance expenditure over three recent years (million Kip).

Fiscal Year	Landslide removal and repair	Carriageway repairs and road grading	Total emergency maintenance expenditure
2004-05	44,528	10,280	54,808
2005-06	27,392	29,649	57,041
2006-07	27,136	17,960	45,096

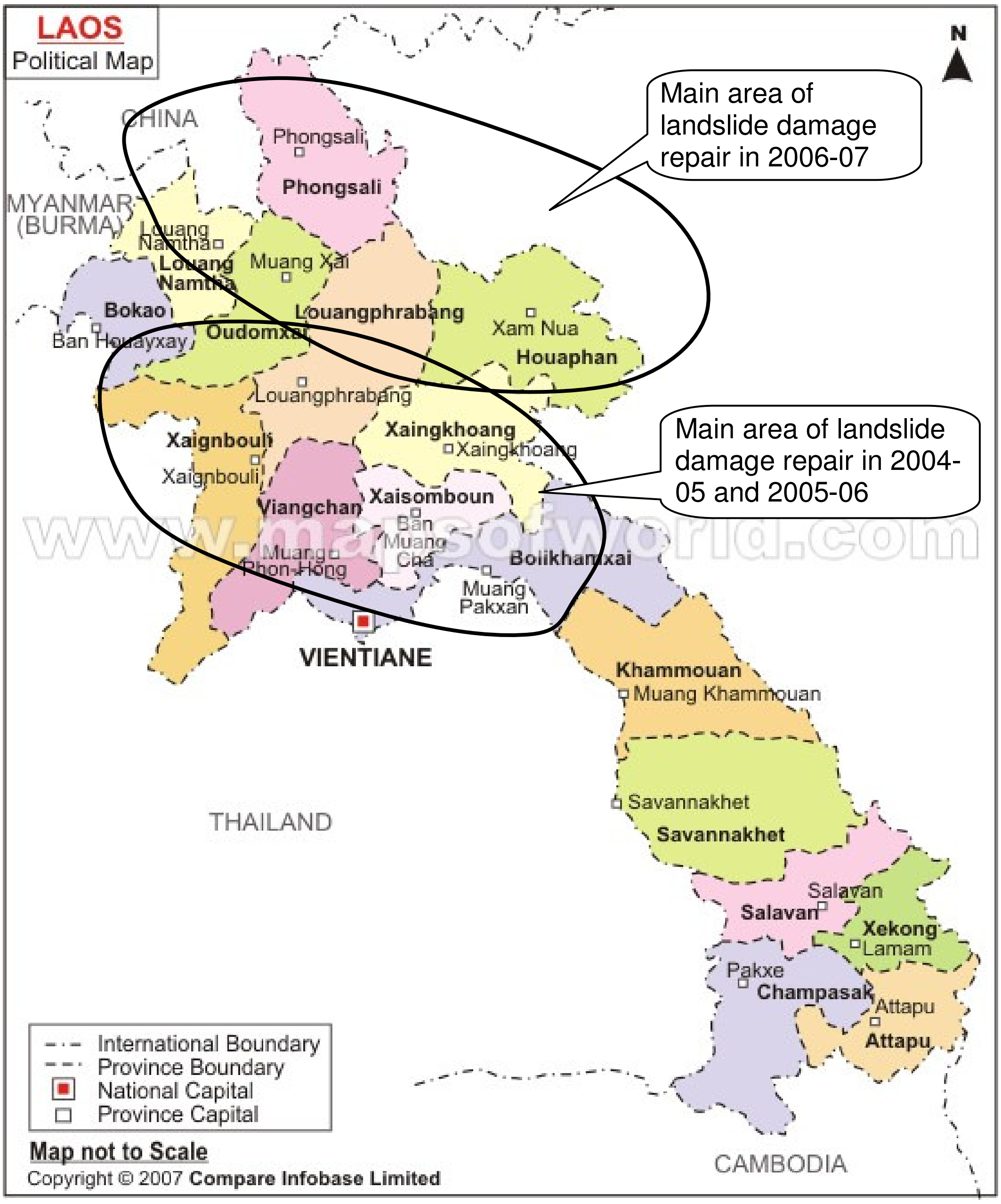
The expenditure of emergency funds on the removal and repair of landslides is very uneven across the country. When the data for the last three years are aggregated by Province (see Table 6.2), it is clear that almost all of the funds are spent in the north of Laos, and none have been spent in the five provinces south of Khammouan in the last three years. It can also be seen that the extreme north-western corner of Laos (Bokeo and Luang Namtha) has also had relatively little expenditure on landslides.

Table 6.2. Summary of emergency expenditure on landslides by Province over three recent years (million Kip).

Province	Annual expenditure, million Kip		
	2004-05	**2005-06**	**2006-07**
Phongsaly	1,083	3,356	7,438
Houaphan	4,462	2,461	7,798
Luang Prabang	2,930	5,418	5,498
Xiangkhouang	9,156	2,985	973
Xaisonboun	4,794	0	0
Borikhamxai	2,472	319	0
Xaignabouli	3,365	2,374	0
Vientiane	14,668	8,927	2,591
Oudomxai	1,317	641	405
Luang Namtha	150	911	853
Bokeo	131	0	0
Khammouan	0	0	1,580
	44,528	**27,392**	**27,136**

The amounts given in Tables 6.1 and 6.2 include not just emergency maintenance from both the Road Maintenance Fund and the Ministry of Finance, but also special governmental funds released at the discretion of the Prime Minister's Office on the declaration of a National Disasters. These events occur every year, but not in the same places and not usually more than twice in a year. The procedure for the declaration of a National Disaster is given in section 11.6. The proportions financed from different sources also varies from year to year. For example, in 2005-06, Kip 22 billion came from the Ministry of Finance and the rest from the RMF, but other years have differed.

Figure 6.1. Main areas of expenditure for landslide damage and repair in different years.



What Table 6.2 also shows is a considerable variation of expenditure between years for each Province. From this it can be seen that the annual pattern of landsliding varies, with some areas requiring considerable expenditure in some years, but very little in others. A basic attempt to show how this is distributed is made in Figure 6.1, where the areas of highest expenditure are marked over a map of the country. In conjunction with Table 6.2, this appears to show that in 2004 there was severe damage over the central-northern

Provinces, whereas in 2006 there was significant damage across the north-eastern-most Provinces. It is not clear what happened in the 2005 wet season: there may not have been exceptional damage at all, but locations triggered in 2004 may have continued to deteriorate; or perhaps there was a backlog of works from 2004 that even the exceptional budget of Kip 44.5 billion had not been able to cover. Table 5.2 shows that rainfall in both years was above average in Vang Vieng, but close to average in Luang Prabang.

The only further information that seems to be worth drawing from these data is revealed most clearly in Table 6.3. This is the expenditure of emergency maintenance funds on landslides, by road section. Most striking is the very high cost of repairs on Road 7 and the Vientiane Province section of Road 13 North in 2004-05, followed by further big spending on 13 North in the following year. Over the three-year period, 33 percent of the total budget for emergency landslide treatment went on Road 13 North. Road 7 absorbed 9 percent, Road 6 required 7 percent, and Roads 1D and 1C took 7 and 6 percent respectively. This means that some 62 percent of the allocation went on only five roads; however, when these amounts are compared with the lengths of the roads, they are in a reasonable proportion.

Table 6.3. Emergency maintenance expenditure on landslide removal and repairs, by road, 2004 to 2007

Road	Length (km)	Province	Annual expenditure, mil. Kip			Total, by road (m Kip)	Percent, by road
			2004-05	2005-06	2006-07		
1A	144	Phongsaly	405	1,027	2,410	3,842	4
1B	109	Phongsaly	602	1,755	2,717	5,074	5
1C	119	Houaphan	1,745	674	906	6,419	6
1C	63	Luang Prabang	520	2,574	0		
1D	77	Xiangkhouang	2,245	2,196	973	7,306	7
1D	30	Xaisonboun	277	0	0		
1D	150	Borikhamxai	1,296	319	0		
2E	120	Phongsaly	0	0	895	895	1
3	68	Bokeo	131	0	0	131	0
4	67	Luang Prabang	467	0	0	1,920	2
4	35	Xaignabouli	972	0	0		
4	76	Xaignabouli	481	0	0		
4A	94	Xaignabouli	1,912	2,374	0	4,286	4
5	130	Xaisonboun	1,891	0	0	1,891	2
5A	12	Vientiane	0	800	889	3,372	3
5A	71	Xaisonboun	1,683	0	0		
5B	78	Xaisonboun	943	1,564	1,702	4,209	4
6	92	Houaphan	447	337	1,671	7,303	7
6	84	Houaphan	1,568	253	3,027		
6A	125	Houaphan	490	907	1,504	2,901	3
6B	25	Houaphan	212	290	690	1,192	1
7	46	Luang Prabang	587	570	0	8,857	9
7	244	Xiangkhouang	6,911	789	0		
8	132	Borikhamxai	1,176	0	0	1,176	1
12	146	Khammouan	0	0	1,580	1,580	2
13 North	30	Luang Namtha	0	159	0	32,881	33
13 North	85	Oudomxai	1,317	641	405		
13 North	433	Luang Prabang	1,356	2,274	5,498		
13 North	203	Vientiane	14,668	6,563	0		
17A	71	Luang Namtha	150	752	0	902	1
17B	70	Luang Namtha	0	0	853	853	1
19	102	Phongsaly	76	574	1,416	2,066	2
	3,331		**44,528**	**27,392**	**27,136**	**99,056**	**100**

The same basic data as in Table 6.3 is presented again in Table 6.4, but this time in combination with the amounts spent on other emergency works. This demonstrates the proportion going to landslide repairs as opposed to on-road repairs in different years. It can be seen that in 2004-05, when there was considerable landslide damage, just over 80 percent of all emergency maintenance funds were required to repair landslide damage. In 2005-06, this was reduced to a little under 50 percent of a similar budget. In the next year, 2006-07, a similar amount was spent overall on landslide damage repairs (Kip 27 billion), but as the overall emergency budget was significantly lower, the proportion rose to 60 percent.

It is important to recognise that, although some trends have been drawn from these data, the total data set is too limited to be certain that what is found here is a true representation of a long-term pattern.

Table 6.4. All emergency maintenance expenditure, by road, 2004 to 2007

Road	Length	Province	Annual expenditure, million Kip			Main activity
			2004-05	2005-06	2006-07	
1A	144	Phongsaly	405	1,027	2,410	Landslide removal and repair
1B	109	Phongsaly	602	1,755	2,717	Landslide removal and repair
1C	119	Houaphan	1,745	674	906	Landslide removal and repair
1C	63	Luang Prabang	520	2,574	-	Landslide removal and repair
1C	84	Xiangkhouang	802	-	-	Carriageway repairs
1D	77	Xiangkhouang	2,245	2,196	973	Landslide removal and repair
1D	30	Xaisonboun	277	-	-	Landslide removal and repair
1D	150	Borikhamxai	1,296	319	-	Landslide removal and repair
1F	96	Khammouan	586	1,496	414	Carriageway repairs
1G		Saravan	-	800	-	Carriageway repairs
1H	30	Sekong	-	1,971	-	Carriageway repairs
1J	95	Attapeu	240	313	-	Carriageway repairs
1L		Attapeu	-	595	-	Carriageway repairs
2E	120	Phongsaly	315	458	-	Carriageway repairs
2E	120	Phongsaly	-	-	895	Landslide removal and repair
2E	52	Oudomxai	1,898	211	83	Carriageway repairs
2W	139	Oudomxai	2,663	2,045	-	Carriageway repairs
3	68	Bokeo	131	-	-	Landslide removal and repair
4	67	Luang Prabang	467	-	-	Landslide removal and repair
4	67	Luang Prabang	-	833	3,662	Carriageway repairs
4	35	Xaignabouli	972	-	-	Landslide removal and repair
4	35	Xaignabouli	-	941	847	Carriageway repairs
4	100	Xaignabouli	1,810	3,394	3,821	Carriageway repairs
4	76	Xaignabouli	481	-	-	Landslide removal and repair
4	76	Xaignabouli	-	1,303	1,861	Carriageway repairs
4		Xaignabouli	-	-	312	Carriageway repairs
4A	94	Xaignabouli	1,912	2,374	-	Landslide removal and repair
4A	94	Xaignabouli	-	-	531	Carriageway repairs
5	130	Xaisonboun	1,891	-	-	Landslide removal and repair
5A	12	Vientiane	-	800	889	Landslide removal and repair
5A	71	Xaisonboun	1,683	-	-	Landslide removal and repair
5B	78	Xaisonboun	943	1,564	1,702	Landslide removal and repair
6	92	Houaphan	447	337	1,671	Landslide removal and repair
6	84	Houaphan	1,568	253	3,027	Landslide removal and repair
6A	125	Houaphan	490	907	1,504	Landslide removal and repair
6B	25	Houaphan	212	290	690	Landslide removal and repair
7	46	Luang Prabang	587	570	-	Landslide removal and repair
7	244	Xiangkhouang	6,911	789	-	Landslide removal and repair
8	132	Borikhamxai	1,176	-	-	Landslide removal and repair
8	132	Borikhamxai	-	2,987	4,460	Carriageway repairs
9		Savannakhet	-	4,557	-	Carriageway repairs
10		Vientiane	-	1,815	-	Carriageway repairs
12	146	Khammouan	-	-	1,580	Landslide removal and repair
13 North	30	Luang Namtha	-	159	-	Landslide removal and repair
13 North		Luang Namtha	-	-	559	Carriageway repairs
13 North	85	Oudomxai	1,317	641	405	Landslide removal and repair
13 North	433	Luang Prabang	1,356	2,274	5,498	Landslide removal and repair
13 North	203	Vientiane	14,668	6,563	-	Landslide removal and repair
13 South	184	Borikhamxai	297	-	-	Carriageway repairs
13 South	237	Khammouan	90	1,325	-	Carriageway repairs
13 South		Savannakhet	-	508	-	Carriageway repairs
13 South		Saravan	-	1,364	-	Carriageway repairs
15B		Saravan	-	878	508	Carriageway repairs
16	44	Champasak	240		-	Carriageway repairs
16A	14	Attapeu	109	179	-	Carriageway repairs
16B	105	Sekong	-	305	-	Carriageway repairs
16E+1L		Sekong	-	208	-	Carriageway repairs
17A	71	Luang Namtha	150	752	-	Landslide removal and repair
17A	71	Luang Namtha	-	-	442	Carriageway repairs
17B	70	Luang Namtha	396	625	-	Carriageway repairs
17B	70	Luang Namtha	-	-	853	Landslide removal and repair
18A	84	Attapeu	834	517	460	Carriageway repairs
18B		Attapeu	-	21	-	Carriageway repairs
19	102	Phongsaly	76	574	1,416	Landslide removal and repair
			54,808	**57,041**	**45,096**	

PART C: ECONOMIC AND SOCIAL APPRAISAL

7. COST IMPLICATIONS OF SLOPE INSTABILITY

7.1 Introduction

The economic consequences of landslides on roads can be assessed by converting the following into monetary terms:

- Costs associated with the clearing of landslide volume and repairs to roads and associated structures;
- Road closures and impacts on vehicle operating costs and the loss of time;
- Loss of lives and livelihoods;
- Negative impacts on utility and other infrastructure; and
- Damage to the wider environment.

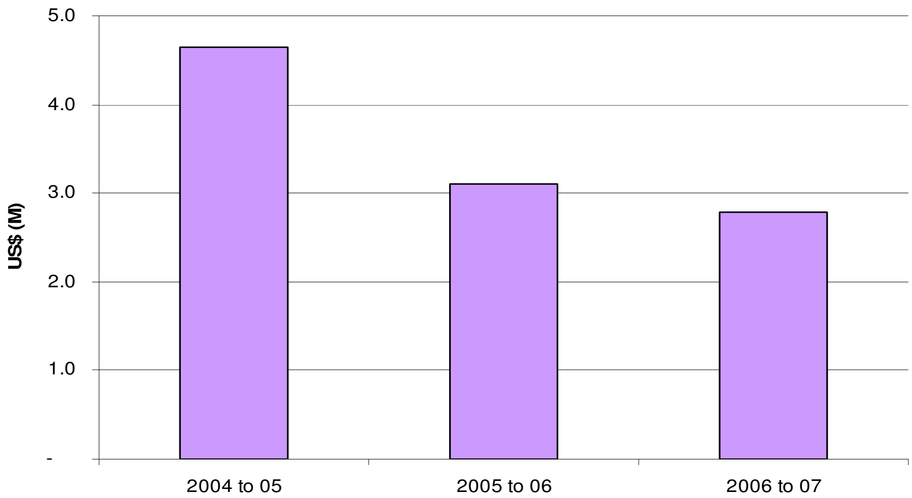
Whilst the relevance and importance of each component of the economic assessment can differ significantly between roads, there are some parameters which apply country-wide e.g. value of life, value of time and vehicle operating costs.

7.2 Cost of landslide clearance and repair

Information was provided by the MPWT on the money spent on national road emergency maintenance during the past three years (see section 6). “Emergency” is defined as a sudden, localised event that is out of the ordinary in scale and expectation.

The three years of data were converted into US dollars (by using Economist Intelligence Unit exchange rates) and filtered to identify the money spent specifically on landslides. Figure 7.1 sets out the overall expenditure on roads affected by landslides over the past three years (including clearing and making necessary repairs).

Figure 7.1. Overall emergency maintenance expenditure on landslides (2004-07)

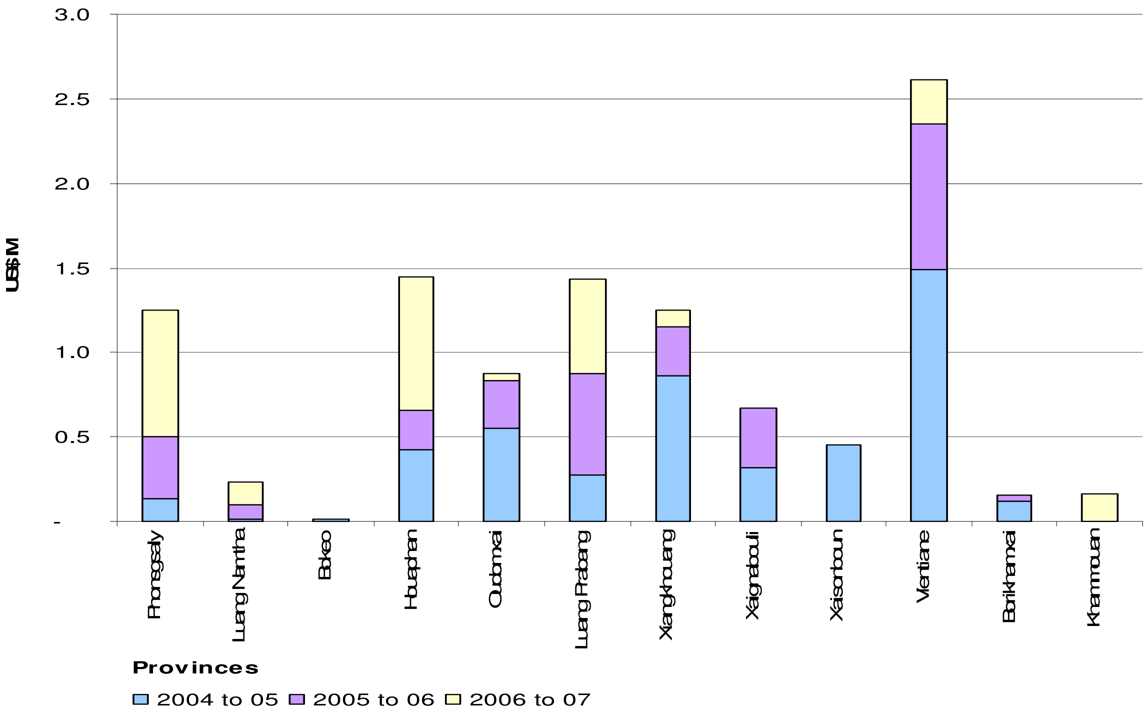


Source: MPWT & Scott Wilson analysis

Expenditure on emergency landslides has declined over the past three years, but the reason for this is uncertain. For example, it could be that the rainfall was lower so there were fewer failures, or that the road stock is maturing and the slopes becoming more stable, or simply that there was a budgetary shortfall. In general it should be supposed that there is a gradually increasing network as the MPWT takes over responsibility for additional roads as they come out of the construction phase: for example, Road 12 in Khammouan Province, in the first year for which MPWT held responsibility, incurred an expenditure of approximately US$160,000 (almost 6 percent of overall landslide expenditure for 2006-07).

Figure 7.2 sets out the expenditure for each province affected during the past three years. Note that during the past three years only 12 out of the 17 rural provinces have been affected by landslide emergencies.

Figure 7.2. Expenditure on emergency maintenance per Province (2004-07)



Source: MPWT & Scott Wilson analysis

There is a significant variance between provinces, with Vientiane appearing to be the most vulnerable, followed by four others with similar expenditure levels over the past three years. At the other end of the scale, Bokeo’s expenditure is insignificant.

Variations in expenditure levels are witnessed not only between but also within provinces over the three-year period analysed (i.e. between the different roads on each Province’s share of the national network). This gives an indication of the difficulties associated with making predictions on future landslides or expenditure requirements.

The length of the road network varies in each of the provinces affected by landslides. A pro-rata calculation was carried out to gain an indication of the average cost per kilometre in the past three years, to provide a crude indication of variance, and is presented in Table 7.1.

Table 7.1. Crude landslide expenditure per kilometre, by Province

Province	Cost (US$M) per province 2004 to 05	2005 to 06	2006 to 07	Three year expenditure US$ (M)	Road Network (KM)	US$/KM
Phonsgsaly	0.1	0.4	**0.8**	1.3	474	7,913
Louang Namtha	0.0	0.1	**0.1**	0.2	302	2,310
Bokeo	0.0	-	**-**	0.0	169	219
Houaphan	0.4	0.2	**0.8**	1.4	446	9,720
Oudomxai	0.6	0.3	**0.0**	0.9	314	8,339
Luang Prabang	0.3	0.6	**0.6**	1.4	610	7,045
Xiangkhouang	0.9	0.3	**0.1**	1.2	464	8,064
Xaignabouli	0.3	0.4	**-**	0.7	540	3,723
Xaisonboun	0.5	-	**-**	0.5		na
Vientiane	1.5	0.9	**0.3**	2.6	650	12,053
Borikhamxai	0.1	0.0	**-**	0.2	510	898
Khammouan	-	-	**0.2**	0.2	422	1,136
Total	4,652	3,098	**2,789**			

Source: MPWT & Scott Wilson analysis

Key observations that may be made from the assessment of these data are as follows.

- Almost all of the expenditure is in the north of Laos. There is virtually no allocation in the hilly provinces in the south.
- There is significant variation within provinces and between years, making predictability difficult.
- The very high budget for Vientiane Province, especially in 2004-05, needs further explanation.
- The statistics do not include newly completed roads, which might be expected to have higher expenditure levels.
- In national terms, the magnitude of the landslide clearing costs is insignificant (representing less than 0.1 percent of GDP).

7.3 Road closure impacts

Interviews were carried out with MPWT staff in Vientiane and with staff from the DPWTs at Khammouan and Attapeu Provinces. The Consultant was informed that national roads would normally be cleared of landslides within a period of six hours. There was a significant landslide in 2006 on the Road 18B, which stopped large trucks for an estimated period of 1.5 months, but this was considered to be a rather unusual case.

The following three roads were considered in relation to the impacts of closure.

- Road 13 North: an arterial road, linking the north and south of Laos, with a variety of trade and moderately busy (based on an estimated AADT of 350). A combination of remedial and preventative measures are being implemented (as part of the SEACAP 21/001 programme).
- Road 12: this has a length of 146 km, but 18 km are perceived to be vulnerable to landslides. The AADT is estimated to be 100, mainly trucks carrying gypsum and logs to Vietnam. Landslides here would typically take less than half a day to clear. There are a number of villages along this road but they are not dependent on the road to have access to basic facilities.
- Road 18B: road completed in 2007 with a length of 112 km. The estimated construction cost was US $ 48 million, but the road is highly vulnerable to landslides, which range in

length from about 20 to more than 100 metres. This road is mainly used for a "one-way" logging trade between Laos and Vietnam (an estimated AADT of 90, mostly trucks). Four villages were identified along the road but, similar to those on Road 12, they are not road dependent.

Since Laos is land-locked, most roads are used for international trade. However, the main types of goods being transported (motorcycles, gypsum, building materials, timber, beer etc.) appears not to be time sensitive; perishable goods, such as agricultural produce, would be time sensitive.

Calculations of vehicle operating costs (VOC) per kilometre were presented in some JICA data dated 2003 on southern Lao roads with varying IRI parameters (leading to variance in speed). The estimated VOC for a car was estimated at US $ 0.26/km, whilst a bus was US $ 0.43/km with an IRI of 15 m/km. This calculation gives an indication of the additional costs per kilometre incurred by commercial vehicles due to diversions as a result of landslides that take longer than a few hours to clear.

Estimates for the value of time were carried out to provide an indication of the average economic costs associated with delays in travelling time due to landslides. Parameters adopted for this were:

- GDP per head;
- Percentage of population within working age;
- Unemployment rates (within the working population); and
- Estimated working hours per annum.

Table 7.2 sets out the parameters that have been adopted, which resulted in a value of time equivalent to US $ 0.55/hour. This result is consistent with those presented in the JICA report of 2003, where the reported value of time estimate was US $ 0.42/hour.

Table 7.2. Value of time estimates

Value of time	Parameter	Source
GDP/c (US$ 2007)	565	EIU
Working Age Population	56.7%	EIU
Unemployment Rate	5%	ADB estimates
Working Hours	1920	Scott Wilson based on weeks/pa, working days/week, hours/day
Value of Time (US$ /hour)	**0.55**	

Source: Scott Wilson calculation

Typical economic costs of road closures due to landslides can be estimated by combining the road users affected (AADT during hours of road closure), re-routing that may take place and its implication (additional distance and time) and the value of time cost implications.

In addition to the value of time, vehicle operating costs need to be considered. This is made through assessment of the cost associated with hiring or purchasing a vehicle, the labour costs associated with a driver and assistant, and fuel costs. Typically vehicles would cost US $ 19,000 and US $ 67,000 for a car and a heavy truck respectively. Assuming that the average life expectancy of a vehicle is ten years, and adopting a weighted average price of US $ 28,000 per vehicle, this would mean an average daily cost of US $ 76/day. Driver and assistant costs are estimated to be US $ 1.2/hour and $ 0.3/hour respectively. Fuel costs linked to the landslide blockages would probably be insignificant as the trucks would typically wait for the landslides to be cleared, with their engines switched off. If landslides are cleared within three hours, the VOC would be in the region of US $ 22.9 per vehicle per hour. This value was adopted for the calculations carried out in Table 7.3.

The costs associated with a hypothetical landslide can be estimated by defining the traffic affected and the resulting implications. The results are given in Table 7.3. For example, if a landslide takes place on a road with an AADT of 300, it takes six hours to clear and there is no re-routing, the costs would be in the region of US $ 8,200, based on the calculations described above and shown in Table 7.3. For longer blockages, the costs become very significant. Note that this is only the economic costs to road users, and does not include landslide clearance and damage repair costs.

The main observations that emerge from this assessment are that landslides must be cleared within a few hours for the cost implications to be small, so that the short disruption and relatively low traffic volumes mean that the indirect cost of landslides (VOC and value of time) is small. Delays of six hours or more start to have a serious impact in terms of high economic costs. These estimates do not take into account the downstream consequences of industrial items. For example, a large number of timber or gypsum trucks delayed for a day could have serious effects if it led to the stoppage of a large sawmill or cement factory; items being transported to a seaport could incur substantial demurrage costs if they caused a delay.

7.4 Loss of lives and livelihoods

Staff were interviewed at both the Ministry of Labour and Social Welfare and the MPWT's Environment and Social Division. In both cases, they considered that landslides do not have a direct impact on lives or indeed, on people's livelihoods. Typically, landslides take place in very steep and mountainous areas, close to the road and are normally caused or aggravated by the construction of the road in areas where villages are few. In the past there has been some resettlement, particularly for villages that were located in the areas affected by hydro-power schemes, but landslides on most roads are far from existing settlements.

According to the Population and Housing Census 2005, approximately 12% of villages are located within urban areas. The vast majority of the settlements are rural and to a great extent self sufficient in terms of foodstuffs (crops and livestock). Permanent settlements tend to be in valleys and plains rather than on steep, landslide-prone mountain slopes.

There is a contrast in that, although some sectoral specialists claim that landslides occur far from villages, it is also commonly stated that landslide remedial works are typically carried out by labourers from villages in the proximity of the landslide. This work provides a source of employment and therefore an economic benefit to some settlements near roads in mountainous areas.

In fact, it would be misleading to assume that landslides have no impact on rural people's livelihoods, particularly in the north of Laos. The reasons for this are considered in the social appraisal (section 9). Certainly our observations on National Roads 7 and 13 North show that there is a loss of economically productive land. Some of this affects shifting cultivators and some affects farmers growing cash crops (such as pineapples in the Phou Khoun area). However, as that appraisal shows, it is likely that the loss of crops is not significant relative to other costs, although an individual poor family might be affected.

The main findings in this respect are therefore that there has been no recorded direct lost of life as a result of a landslide, and that the impact of landslides on rural livelihoods is probably insignificant.

Table 7.3. Landslide costs calculations: implications on road users (see notes on next page)

(a) Blockage time of quarter of the traffic-day (i.e. 3 hours of daylight), AADT of 100 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	100		12.5		
Traffic split					
- cars	20%	5	3	20	
- trucks	65%	2	8	27	557
- others	15%	15	2	46	129
Landslide Blockage (hours)	3				
Total Economic Cost of the landslide (excluding removal & repairs)				93	686

(b) Blockage time of half of the traffic-day (i.e. 6 hours of daylight), AADT of 100 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	100		25		
Traffic split					
- cars	20%	5	5	82	
- trucks	65%	2	16	107	2,228
- others	15%	15	4	184	514
Landslide Blockage (hours)	6				
Total Economic Cost of the landslide (excluding removal & repairs)				373	2,742

(c) Blockage time of a full traffic-day (i.e. 12 hours of daylight), AADT of 100 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	100		50		
Traffic split					
- cars	20%	5	10	328	
- trucks	65%	2	33	426	8,912
- others	15%	15	8	738	2,057
Landslide Blockage (hours)	12				
Total Economic Cost of the landslide (excluding removal & repairs)				1,491	10,969

(d) Blockage time of two full traffic-days (i.e. 24 hours of daylight), AADT of 100 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	100		100		
Traffic split					
- cars	20%	5	20	1,311	
- trucks	65%	2	65	1,704	35,649
- others	15%	15	15	2,950	8,227
Landslide Blockage (hours)	24				
Total Economic Cost of the landslide (excluding removal & repairs)				5,966	43,876

Table 7.3 (continued). Landslide costs calculations: implications on road users

(e) Blockage time of quarter of the traffic-day (i.e. 3 hours of daylight), AADT of 300 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	300		37.5		
Traffic split					
- cars	20%	5	8	61	
- trucks	65%	2	24	80	1,671
- others	15%	15	6	138	386
Landslide Blockage (hours)	3				
Total Economic Cost of the landslide (excluding removal & repairs)				280	2,057

(f) Blockage time of half of the traffic-day (i.e. 6 hours of daylight), AADT of 300 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	300		75		
Traffic split					
- cars	20%	5	15	246	
- trucks	65%	2	49	320	6,684
- others	15%	15	11	553	1,543
Landslide Blockage (hours)	6				
Total Economic Cost of the landslide (excluding removal & repairs)				1,119	8,227

(g) Blockage time of a full traffic-day (i.e. 12 hours of daylight), AADT of 300 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	300		150		
Traffic split					
- cars	20%	5	30	983	
- trucks	65%	2	98	1,278	26,737
- others	15%	15	23	2,213	6,170
Landslide Blockage (hours)	12				
Total Economic Cost of the landslide (excluding removal & repairs)				4,474	32,907

(h) Blockage time of two full traffic-days (i.e. 24 hours of daylight), AADT of 300 vehicles

Item	Parameter	Passengers per vehicle	Vehicles affected number	Value of time US$	VOC US$
AADT	300		300		
Traffic split					
- cars	20%	5	60	3,933	
- trucks	65%	2	195	5,113	106,947
- others	15%	15	45	8,850	24,680
Landslide Blockage (hours)	24				
Total Economic Cost of the landslide (excluding removal & repairs)				17,897	131,627

- Source: Scott Wilson Analysis.
- It is assumed that: (a) effectively all vehicles travel during daylight; (b) landslides are not cleared at night, so all landslides have an impact on traffic during daylight; (c) vehicles are equally spaced and travelling at the same speed, so that the average length of disruption is half of the blockage time (i.e. some vehicles are blocked for nearly the whole time, but others for hardly any time).
- AADT is taken as the total volume of traffic passing a point on a road in both directions for one year divided by the number of days in the year.
- On this basis, the number of vehicles affected is calculated as [AADT] / 12 * [length of blockage] / 2.
- Passengers affected are calculated by multiplying the vehicles affected by the percentage of vehicle type and passengers.
- “Other vehicles” include buses, coaches, minibuses etc.
- Value of time per vehicle is calculated by multiplying the passengers affected by the value of time/hour & number of hours.

7.5 Negative impact on utilities

Access to centralised utility services (sewerage, drinking water and electricity) appears to be limited. Rural settlements have access to water from natural springs in the mountains, and through boreholes in large valleys and plains. Sanitation systems tend to be very localised and basic except in the main towns. The electricity network is well developed. Table 7.4 sets out the results of the Population and Housing Census 2005 for the Provinces understood to be vulnerable to landslides.

Table 7.4. Population and access to basic utilities (by number of villages)

Province	Population (000's)	Households (000's)	Villages (number)	Villages with			
				Water supply	Health Centre	Complete Primary School	Incomplete Primary School
Phonsgsaly	83	29	607	25	68	91	422
Luang Namtha	73	26	380	24	27	89	247
Oudomxai	132	43	587	22	25	135	294
Bokeo	74	26	355	20	43	118	134
Luang Prabang	203	70	855	58	29	308	411
Houaphan	139	43	784	11	55	205	476
Xaignabouli	167	62	487	15	43	326	115
Xiangkhouang	113	36	541	18	43	143	259
Vientiane	190	69	593	34	52	280	197
Borikhamxai	111	38	327	14	40	177	125
Khammouan	171	61	803	39	80	271	320
Xaisonboun	18	6	84	3	16	70	0

Source: Population and Housing Census 2005

Analysis of the statistics presented in Table 7.4 suggests that only 4 percent of villages in rural mountain villages have access to district water supplies. Although 81 percent of villages have primary schools (in a complete or incomplete form), only 8 percent have access to healthcare facilities. The latter could potentially represent a problem where landslides are common and emergency facilities are limited.

Nevertheless, there are a few places where rapid economic development is starting to change the situation. An example is at Phou Khoun, which extends along the ridge on either side of National Road 7. The town water supply runs underneath the road in some sections, and is vulnerable to valley side failures (for example, at Road 7, km 3). So far there is no evidence that there has been an impact on this utility, but as key areas become economically more important, there is an increasing chance of this factor becoming significant.

Power grid cables tend to follow major road alignments, but in areas where the road is vulnerable to landslides the pylons or poles are not necessarily close to the road. There was an unusual example on Road 13 North (km 239), where an electricity pylon was close to the head of a landslide above the road. The electricity authority moved the pylon before an emergency occurred. However, it was not clear whether the pylon was really in danger, or whether it would have been safeguarded by the rehabilitation of the landslide carried out by MPWT with SEACAP support.

This brief assessment therefore suggests that the impact landslides have on utilities is rather limited.

7.6 Costs to the wider environment

A landslide will inevitably cause damage to additional elements of the wider environment. If the landslide is entirely natural, then it might not be appropriate to try to put economic values on the impacts caused. However, if the landslide is at least partly due to the presence of a road, a value might be added for the perceived human consequences of the wider damage. Examples of damage commonly caused by landslides are as follows; for reasons of simplicity in moving towards an estimated value of the environmental damage, these assume that landslides occur in natural forest with exploitative value (which is the case for the majority of slope failures in Laos).

- Loss of trees of commercial value, either for timber or other products such as bamboo, resin, sticklack, orchids, medicines or fibres.
- Permanent loss of topsoil and nutrients, representing the degradation of the overall national land resource.
- Increased suspended sediment in streams and rivers, leading to a degradation of water supplies and fisheries for a considerable downstream distance.
- In extreme cases, downstream sedimentation can cause changes to river beds, leading to altered flood patterns, with additional consequences.
- In the upper catchments of reservoirs, sediment from landslides can gradually reduce the water storage capacity.

In addition, some environmental economists would argue that there is an additional effect in the loss of stored carbon. However, the calculation of carbon fluxes and effects is notoriously difficult and probably of negligible value here.

For the purposes of calculating the costs of environmental damage in the most common landslides, it is assumed that the last two of the bullet points above are only exceptional cases for the worst landslides, or for the accumulated effects of a large number of small failures in a single catchment. In estimating the costs of the damage to the wider environment, it is assumed that the failure is of a size big enough to block a national highway for three hours (the same as for the example used in the economic framework), giving it an areal extent of 1500 square metres of slope surface and a displaced mass of 500 cubic metres of soil and rock. The assumptions used in deriving a value for the environmental damage are given in Table 7.5.

Table 7.5. Cost estimations of the wider environmental damage caused by landslides

Damage type	Assumptions	Value (US$)
Loss of trees and plants of commercial value	2 large timber trees 6 trees of alternative commercial value Herbaceous plants of value	3,000 4,800 100
Permanent loss of topsoil	Equivalent to the lost value of one rotation of an agricultural crop	150
Effects of increased sediment in water courses	Damage to drinking water supplies in terms of blocking intakes and time lost in going to other clear water sources Damage to fish stocks through loss of productivity (reduced fish growth and temporary prevention of fishing)	50 50
Total cost of wider environmental damage		**8,150**

This is based on the following assumptions:

The forest gate price of rosewood is US $ 300/m^3; one large tree is about 5 to 8 m^3.
The forest gate price of a "general tree" is US $ 100/m^3; one large tree is about 8 to 10 m^3.
Topsoil for upland rice cultivation is valued at US $ 100/ha.

These estimates suggest that there is an appreciable environmental cost that can be placed on landslides where they affect both natural forest with commercial value and downstream water courses.

7.7 Conclusion

The economic appraisal presented here is not particularly authoritative because of the scarcity of data on landslides and their associated costs. The figures show that the expenditure is roughly proportional to the lengths of mountain roads. In “better” years, the expenditure has been around Kip 8 million (US $ 960) per kilometre per year across the whole network (see Table 6.3), but was Kip 13.4 million (US $ 1,570) in the bad year of 2004-05; yet within these figures, there is a wide range (see Table 7.1).

Whatever the cost is, it appears that it is the clearing of debris and repair of damage that are a significant part of the cost. However, the impact of temporary road closures seems not to be particularly costly in comparison if landslides are cleared within a few hours. Delays in opening the road start to incur very significant vehicle operating costs, especially if the blockage lasts for a day or more. The economic effects on people’s lives and livelihoods seems not to be large, with no recorded loss of life and mainly the very steep, marginal land affected. Utilities (electricity and water supplies) are so far not much affected, as far as can be ascertained. There is a greater potential effect in environmental costs, mainly because of the very high export value of tropical hardwood timber, so that, as Table 7.5 shows, not many trees need to be lost before a medium-sized landslide has an economic cost of US $ 8,000.

The next section examines various economic scenarios for different approaches to proactive engineering, to test the relative value of landslide damage mitigation.

8. ECONOMIC MODELLING OF SLOPE STABILITY INTERVENTIONS

8.1 Introduction

The economic viability of a slope management programme can be assessed by comparing the socio-economic impact of landslides with and without preventative measures. This requires an assessment of the likelihood of a particular landslide taking place and the level of impact expected on social and economic infrastructure, and people. It also requires the identification of technically feasible preventative measures and their costs, as well as an indication of the extent to which the likelihood of the landslide occurring would be reduced as a direct result of the engineering works. This is provided in section 8.2.

In the context of the Lao road sector, there is another scenario that has been identified. This relates to the adoption of improved engineering standards to reduce the likelihood of landslides occurring in the first place. The underlying assumption is that, if a greater investment is made at the time of initial road construction to ensure better design, with more stable alignment and man-made slopes, then it will subsequently yield economic benefits through reduced disruption and damage, and therefore lower maintenance and vehicle operating costs. This is considered in section 8.3.

8.2 Economic framework for landslide stabilisation works

A formal representation of the economic framework is provided through a series of mathematical equations. The socio-economic impact of landslides on roads is set out in equation 1, below.

Equation 1: Costs associated with landslides on roads

$$LSc(N) = \sum_{t=1}^{n} \frac{R + U}{(1+r)^n}$$

Where:

LSc(N)	Landslide and associated costs if nothing is done
$\sum$	Sum over a period of time (defined as 1 to period n)
R	Remedial costs i.e. clearing the landslide and necessary repairs to the road
U	User-related costs (VOC and value of time)
$(1+r)^n$	Interest or discount factor (defined by parameter r)

Note that in this model variables for loss of life, livelihoods or utilities have not been included, as they are perceived to be insignificant.

Once the likely economic implication of a landslide has been established, the costs associated with possible technically feasible preventative measures (initial construction and ongoing maintenance), need to be considered. In a mathematical form this is represented by equation 2.

Equation 2: Costs associated with landslide preventative measures

$$Mc = I + \sum_{t=1}^{n} \frac{O\&M}{(1+r)^n}$$

Where:

Mc	Total costs of possible preventative measures
I	Initial investment required in infrastructure (e.g. retaining wall, drains, etc.)
∑	Sum over a period of time (defined as 1 to period n)
O&M	Operating and maintenance cost of the infrastructure and associated institutional costs
$(1+r)^n$	Discount factor (defined by parameter r)

The third component of the economic framework is to establish the likely impact that a landslide would have if it occurs even after mitigating measures have been put in place. This is represented by equation 3.

Equation 3: Costs associated with landslides with mitigating measures

$$LSc(W) = \sum_{t=1}^{n} \frac{R + U}{(1+r)^n}$$

Where:

LSc(W)	Landslide and associated costs with mitigating measures in place
∑	Sum over a period of time (defined as 1 to period n)
R	Remedial costs i.e. clearing the landslide and necessary repairs to the road
U	User-related costs (VOC and value of time)
$(1+r)^n$	Discount factor (defined by parameter r)

Note that, as in the “do nothing” scenario (Equation 1), in this equation no variables were included for losses of life, livelihoods or utilities.

The final equation consolidates the various components into an overall socio-economic appraisal of a slope management programme. This is in equation 4.

Equation 4: Overall socio-economic framework

$$EV = Mc + LSc(W) – LSC(N)$$

Where:

EV	Economic Value or particular intervention
Mc	Cost of mitigating measure (as previously defined)
LSc(W)	Landslide costs post mitigating measure
LSc(N)	Landslide costs if nothing is done

The output of the economic framework is a monetary value of the benefits that interventions would have in present value terms (in other words taking into account the relevant discount factors).

To provide a plausible illustration of the economic framework, two assumptions can be made:

- that a mitigating measure could be put in place in 2009 for a particular landslide, which would cost US$100,000 (initial investment) and US$2,500 on an ongoing basis (operating and maintenance costs);
- that a landslide takes place five years later (year 2013) and its associated costs are US$200,000 and US$50,000 without preventative works and with preventative works respectively (the high value attached to the possible failure even with preventative works represents a "worst case" example).

A cash flow profile for the example has been developed together with a net present value (NPV) calculation, using a discount rate of 10 percent. This is presented in Table 8.1.

Table 8.1. Economic framework hypothetical example (US$)

Time period	2009	2010	2011	2012	2013
Mitigating Measure					
- Initial investment	100,000				
- On-going maintenance		2,500	2,500	2,500	2,500
Landslide cost (No action taken)					200,000
Landslide cost (With mitigating measure)					50,000
Cash flow	**-100,000**	**-2,500**	**-2,500**	**-2,500**	**147,500**
Discount Factor	**10%**				
NPV of cash flows	**-4,975**				

Source: Scott Wilson economic model

The results of the example presented suggest a negative economic return of approximately US$5,000 over the five year period if preventative measures are put in place. This means that it would not be worthwhile to construct the proposed measures. However, the results are sensitive to the discount factor (a lower discount factor would make this particular intervention worthwhile), the timing of the landslide (if it happens earlier the mitigating measure would yield a better result) and the estimated extent of damage (without and with preventative measures).

A series of sensitivity analyses were carried out on the hypothetical example presented to illustrate how vulnerable the results are to the inputs for the model. These are shown graphically in Figure 8.1.

Figure 8.1. Sensitivity analysis on results of example.

Source: Scott Wilson Economic Model

The base case result is the net present value presented in Table 8.1. A decrease in the discount factor to 5% leads to an NPV change of approximately US$19,000 (from a negative US$5,000 to a positive NPV of nearly US$14,000). If the anticipated landslide takes place in 2012 instead of 2013, the NPV result again swings from negative to positive. The NPV also becomes positive if the economic impact of the preventative measures is changed by 20% (i.e. the landslide costs US$40,000 instead of US$50,000 to stabilise), although the change is smaller.

When this model is run for three representative landslides on Road 12 and Road 18B, it demonstrates this sensitivity very clearly (see Table 8.2). When a landslide event occurs two years after the initial investment, there is a very good positive NPV. If the event occurs in year five, it is marginal and if it occurs in year seven, it is strongly negative.

This economic modelling is very useful in that it shows how the results of investment can pay off or be partly lost, depending on a wide range of circumstances. However, there are also some shortcomings to these models, the most significant of which are as follows.

- It is not possible to give accurate figures for both the investment cost and the landslide cost with no action taken, for any single landslide. And since every landslide is unique, it is unlikely to be meaningful to compare the investment cost for stabilising one landslide with the removal and repair cost for another untreated landslide. For this reason, one or other of the major cost factors will always be speculative.
- In many cases the preventative measures will be adequate to stabilise the slope, and so there will be no landslide. Therefore it will be impossible to know for certain whether the investment was worthwhile or not. The landslide might have occurred in a particular year if there was no treatment, or it may not have.

These results clearly demonstrate the need to gather and collect accurate data to enable the MPWT to carry out reliable socio-economic assessments of potential landslides, so that this model can be used to prioritise interventions. Without more information, it is not possible for this assessment to move to any further logical conclusions.

Table 8.2. Economic model calculation for three landslides

Time period	NPV	Discount factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Road 18b														
Landslide KM XXX														
- Initial investment			65,000											
- On-going maintenance				2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500	2,500
Landslide cost (no action taken)							150,000							
Landslide cost (with prevention works)							30,000							
Cash flow	**658**	**10%**	**-65,000**	**-2,500**	**-2,500**	**-2,500**	**117,500**	**-2,500**	**-2,500**	**-2,500**	**-2,500**	**-2,500**	**-2,500**	**-2,500**
Landslide KM YYY														
- Initial investment			125,000											
- On-going maintenance				4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500	4,500
Landslide cost (no action taken)					300,000									
Landslide cost (with prevention works)					80,000									
Cash flow	**25,082**	**10%**	**-125,000**	**-4,500**	**215,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**	**-4,500**
Road 12														
Landslide KM AAA														
- Initial investment			80,000											
- On-going maintenance				3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500	3,500
Landslide cost (no action taken)									160,000					
Landslide cost (with prevention works)									45,000					
Cash flow	**-34,380**	**10%**	**-80,000**	**-3,500**	**-3,500**	**-3,500**	**-3,500**	**-3,500**	**111,500**	**-3,500**	**-3,500**	**-3,500**	**-3,500**	**-3,500**

8.3 Economic framework for improved engineering standards

Our assessments of roadside slopes in Laos have led us to identify the following five main areas where approaches to road design and construction could be modified to lead to an overall reduction in slope stability hazards.

- Better alignment design. Increased study of the terrain in the design and fixing of the alignment of a mountain road can often lead to the selection of a more stable route for a road. This takes longer to achieve because of the additional topographical and geological analyses that are required, and greater time needed to verify the selected route on the ground. But it means that, through the selection of the route corridors with lowest relative relief, it is often possible to avoid the most unstable areas of slope and minimise, the need for major cuts and fills.
- Cut slope grades designed according to material characteristics. Road construction projects frequently use a single cut slope grade that is based on a perception of the most common material and the optimisation of earthworks costs, i.e. minimisation of cut. Since the weathered condition of the material varies considerably, both between cut slopes and within individual cut slopes, single standard grades often lead to sections of cut slope being formed that are too steep for weaker materials. Designing to a variety of grades increases costs both because of additional site supervision and material sampling and testing, and because of higher earthworks volumes.
- Fill slopes properly formed. Many fill slopes are formed by side tipping of excavated material over the road edge and allowing it to compact itself over time, with only the final layer at road formation level mechanically compacted. This can produce a fundamentally unstable slope, or at least a slope that is subject to settlement once loaded by traffic. Adequate compaction of all fill embankment layers (to specification) will be more expensive because of the need to bench the original slope surface and compact the fill in layers as it is formed. Also, if a fill slope is to be built according to specification, then there needs to be some control of material grading and water content during filling and compaction, and this is not usually achieved by cut to fill through spoil tipping.
- Increased slope drainage. Many road design and construction projects underestimate the extent and volume of slope drainage required to collect and control discharge of surface water in peak rainfall events, and to ensure that high risk areas of slope do not become saturated to a critical extent by surface water and groundwater during the wet season. This requires careful consideration during design, with provision for sufficient quantities during construction and the availability of resources during operation and maintenance, to ensure a fully functioning drainage system.
- Pro-active slope stability measures (mostly retaining structures), designed to achieve an acceptable slope factor of safety where this cannot be derived from earthworks design alone.
- Pro-active slope protection measures (mostly bio-engineering and related works) designed to achieve an acceptable level of slope protection where this cannot be relied upon to establish naturally, or where there is an anticipated immediate need for slope protection to prevent slope instability from developing.
- The reduction of geometric standards over limited sections of roads. In some locations it may be apparent that there is potential for slope instability that will be made worse by a full width of road or significant cutting or filling to achieve full curvature standards. If the road is made narrower over short critical lengths, or a bend is made sharper (with suitable traffic warnings), then long term instability could be reduced or avoided. This would contribute to a reduction in the need for extensive slope stabilisation and protection costs during design and construction as well as recurring maintenance costs during operation.

Determining how much it would cost to implement each of these modifications is impossible with any accuracy, even with detailed site surveys and assessments. This is because of the difficulty of calculating what they would each contribute in terms of potential benefits, which include reduced construction and maintenance costs, and a lower incidence of road blockages, other traffic hazards and disruptions during operation. The costs and benefits would never be the same on any two roads due to variations in topography, geology, land use and road traffic, and acceptable risk factors, plus the inevitable degree of uncertainty that presides without comprehensive and expensive geotechnical ground investigation. As a hypothetical exercise, however, it is possible to give each factor plausible values even though this requires a large number of assumptions to be made.

Table 8.3 compares the anticipated costs and potential benefits associated with the introduction of the various modifications and measures bullet-pointed above. These are based on the consultant's experience of the design, construction and maintenance of mountain roads in similar terrain. The figures given are not intended to be accurate, but simply to provide a general impression for comparative purposes.

The last column in Table 8.3 essentially relates to the cost of reinstating slopes and sections of road affected once a landslide occurs during operation. The detailed figures available from the designed and costed SEACAP 21 slope stabilisation trials on National Road Nos 13N and 7 in northern Laos provide some data in this regard. The site costs are given in Table 8.4, broken down according to the location of the failure in relation to road chainage, and the type of remedial action that was required (i.e. largely geotechnical (through structural support with masonry, concrete or gabion structures and associated earthworks) or mainly bio-engineering (planting and mostly cosmetic engineering structures).

Table 8.3. Estimated proportions of the additional costs (positive values) versus potential benefits (negative values) during design, construction and operation of a road

Opportunities for Reduced Slope Stability Hazards	Additional cost to initial investment (%)		Potential return through reduced annual maintenance costs (%)	
	Design	Construction	Landslide costs	Other maintenance
Alignment design to avoid instability	10	0	-10	-10
Cut slope grades designed according to materials encountered	3	1	-3	-5
Controlled formation of fill slopes following best principles	0	3	-3	-2
Increased quantities of slope drainage	5	1	-4	2
Pro-active slope stability measures (i.e. civil engineering structures)	10	3	-4	-5
Pro-active bio-engineering measures	1	3	-2	-2
Reduction of geometric standards in unstable sections.	0	-0.5	-5	0
Total estimated change	**29**	**10.5**	**-31**	**-22**

The general conclusions from the data given in Table 8.4 are as follows.

1. Most below-road failures requiring retaining wall stabilisation measures are likely to cost in the region of US $ 30 to 90,000, with the average around $ 50,000.
2. Above-road failures requiring only bio-engineering measures are likely to cost in the region of US $ 15 to 20,000. Of this, approximately half is for small structures, such as drains and check dams.
3. Above-road failures requiring retaining walls as well as bio-engineering measures are likely to cost in the region of US $ 40,000.

4. Measures directed at improving only surface drainage close to the road, per location, are likely to cost in the region of US $ 5 to 10,000.

Table 8.4. Approximate costs of the SEACAP 21 slope stabilisation trials, 2006-07 and 2007-08

Road & location km	Above road US$	Below road US$	Total US$	Type	Comments
13N, 238.0	13,519	6,053	19,573	Bio	Above road failure with loose fill below road, 40m x 25m
316.6	12,466	5,093	17,559	Bio	Above road failure with loose fill below road
337.7	8,001	6,946	14,947	Bio	Above road failure with loose fill below road
242.6		33,506	33,506	Geo	Below road failure 80m x 35m - erosion protection layer
254.0	198	66,173	66,371	Geo	Below road failure, wall 52m long and 6m high
260.3	2,949	4,091	7,040	Geo	Above/below road failure - temporary stabilisation measures
287.2		27,952	27,952	Geo	Below road failure, wall 60m long and 3m high
317.9	14,790		14,790	Geo	Above/below road failure - temporary stabilisation measures
332.7	32,927	5,092	38,019	Geo	Above road failure 50m x 50m, with wall 50m long & 4m high
336.4	2,787		2,787	Geo	Below road failure - improvements to road drainage only
339.9	34,873	2,671	37,544	Geo	Above road failure 40m x 40m, with wall 40m long & 4m high
7, 3.3	1,417	90,780	92,197	Geo	Below road failure, wall 65m long and 6m high
7, 6.1	2,814	51,552	54,366	Geo	Below road failure, wall 40m long and 6m high

From the above, an attempt is made in Table 8.5 to give values to the various options for reduced slope stability hazard that might be made to a "typical" mountain road if the introduced or modified engineering approaches and provisions, bullet-pointed above, were to be incorporated in the design and construction. The large number of assumptions necessary for this are also shown, and it has to be stressed that this is an entirely hypothetical and judgemental assessment because no detailed quantified data are available. What it suggests, however, is that there might be a 10% increase in the initial investment cost, but the annual maintenance cost would reduce by perhaps 28%. This is purely in terms of engineering costs, and does not take into account the implied reliability of service from the road.

To assess this further, the economic framework developed for the assessment of the impact of landslides on existing roads (Table 8.2) has been adapted to evaluate the potential benefits of introducing better designs and construction methods on newly built roads. This is given in Table 8.6. The assumptions adopted are the same as for the other tables, and represent the investment and operating costs associated with a typical road. It is also assumed that the probability of landslides on the road is reduced as a result of the improved design and construction methods, to a quarter of the vulnerability under existing practices. The key assumptions can be summarised as follows

Current circumstances and design parameters:

- Investment costs of US $ 25 million;
- Operating costs of US $ 110,000 per annum; and
- Two major landslides per annum, leading to a blockage of six hours each.

Proposed construction and design improvements:

- Investment costs of US $ 27 million;
- Operating costs of US $ 80,000 per annum; and
- One major landslide per annum, leading to a blockage of three hours.

Table 8.5. Estimated additional costs (positive values) versus potential benefits (negative values) during the construction and operation of a road through the introduction of measures to reduce slope stability hazard

Potential improvement of standards	Additional cost to initial investment (US$)		Annual return in reduced maintenance costs (US$)	
	Design (750,000)	Construction (25 million)	Emergency (75,000)	Routine (35,000)
Better alignment design to avoid instability	75,000	0	-7,500	-3,500
Cut slope grades adapted according to materials	22,500	210,000	-2,250	-1,750
Careful formation of fill slopes following best principles	0	630,000	-2,250	-700
Increased amounts of slope drainage	37,500	250,000	-3,000	700
Pro-active additional slope stabilisation (i.e. retaining walls etc)	75,000	502,500	-3,000	-1,750
Pro-active slope protection measures (i.e. bio-engineering etc)	7,500	530,000	-1,500	-700
Reduction of geometric standards in unstable sections	0	-93,750	-3,750	0
Total estimated change	**217,500**	**2,028,750**	**-23,250**	**-7,700**

On this basis:

- **The initial investment of the road is increased by 10%, from US $ 25.0 million to $ 27.0 million; and**
- **The annual maintenance cost is reduced by 28%, from US $ 110,000 to $ 79,050; so**
- **This implies that improvements in standards are not worthwhile in engineering cost terms: if an additional US $ 2.2 million is spent on design and construction, it would save only $31,000 a year.**

Assumptions forming the basis of calculations.

- The example is based on a National Road of 50 km length entirely in mountainous terrain.
- Range of overall costs for new National Road construction in mountainous terrain: US$ 400 to 500,000/km.
- Cost of 50 km mountain road construction under existing procedures is therefore taken as US $ 18.75 million.
- Design is taken to cost 3% of the construction cost, hence US $ 750,000.
- Routine maintenance costs in the range of US $ 250 to 700/km/yr; mountain roads are at the upper end, so assume $ 35,000/yr for the whole road.
- Emergency maintenance costs in the range of US $ 960 to 1,570 (see Table 5.3); taking a high-end figure, this might amount to $ 75,000/yr for the whole road.
- A better alignment is harder to design but does not increase road length.
- Cut slope changes: 80% of the road is in cut, and along this, half of cut slopes need to be graded more gently. Average cut slope heights in soil are 6 metres and they need to be regraded from 3:1 to 1:1 for half of their height (the weathered soil part). This implies an additional cut cross-section of 3 m^2 of earth to be removed. Along 40% of the road this amounts to a volume of 60,000 m^3. Slope cutting costs Kip 30,000 or US $ 3.5/m^3. It is assumed that the additional volume would be used locally as fill during construction.
- Fill slope changes: 40% of the road has significant fill, all of which needs to be benched in during construction. The benching of fill slopes requires the excavation and compaction of three benches each 1 metre wide, hence requiring 1.5 m^2 cross-section of excavation. Along 40% of the road this amounts to a volume of 90,000 m^3. As for slope cutting, this costs US $ 3.5/m^3. Proper compaction doubles the earthworks cost.
- Slope areas requiring drainage covering 0.5 ha occur every kilometre along the road, each requiring 250 metres of slope drains. Slope drains cost a total of US $ 5,000 per site.
- Slope stabilisation and protection: additional masonry slope retaining structures are required every 2 km and are roughly 50 m long, therefore totalling 1,250 metres. Average cross-section of wall is 6 m^2. Therefore 7,500 m^3 masonry, costed at US $ 67/m^3. Additional slope protection using bio-engineering is required every 2 km and each site covers 1 hectare. Half is grass planting and half brush layering. The unit cost for both is US $ 2.12/m^2.
- Reducing horizontal or vertical geometric standards, or narrowing the road. Using narrowing as a simple example: a length of 50 metres is found every 5 km where the road should be narrowed by 30%; narrowing by this much would reduce earthworks and structures in the critical sections by 40%. Doing this on 50 metres in each of 10 locations equates to 500 metres of the 50 km road. Earthworks and structures are taken as half of the road construction cost but multiplied by a factor of 2.5 for critical sections.

Table 8.6. Economic model calculation to compare current engineering investment approaches with improvements in engineering design and construction over a 50-year timeframe

Time period	NPV	Discount factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Design Improvements												
- Initial investment			25,000									
- On-going maintenance				110	110	110	110	110	110	110	110	110
- Landslide				150	150	150	150	150	150	150	150	150
Cash flow	**-$28,330**	5%	**-25,000**	**-260**	**-260**	**-260**	**-260**	**-260**	**-260**	**-260**	**-260**	**-260**

Time period	NPV	Discount factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Design Improvements												
- Initial investment			27,000									
- On-going maintenance				80	80	80	80	80	80	80	80	80
- Landslide				38	38	38	38	38	38	38	38	38
Cash flow	**-$27,757**	5%	**-27,000**	**-118**	**-118**	**-118**	**-118**	**-118**	**-118**	**-118**	**-118**	**-118**

Notes: All figures in '000s.
Only the first ten years of operation are shown

The economic model in Table 8.6 suggests that the introduction of improved design and construction methods would be marginally beneficial, leading to a 2% lower overall cost in net present value terms over a 50 year time period. But this takes into account only the engineering costs. If the consequences of delay times, vehicle operating costs and reduced environmental damage were to be introduced, there could be very significant differences in the long term advantages of the enhanced geo-engineering approach. Table 7.3 demonstrates that, under the first scenario used above (current practices and two 6-hour blockages per year), there would be costs of US $ 18,700 incurred by road users, whereas under the second scenario (improved practices and one 3-hour blockage per year), there would be costs of US $ 2,300. Clearly this is hypothetical, but the differences are striking. If this happened, there would be an annual reduction of nearly US $ 16,400 per year in the costs to road users, or over $ 0.82 million over a 50-year operating period. Meanwhile it is likely that traffic levels and economic values would increase with national development, giving much greater returns than those at the initial low baseline. Obviously these benefits would be reflected back into the national economy.

9. SOCIAL APPRAISAL

There are two primary stakeholders involved: (a) the people living on and gaining their livelihoods from the land affected by landslides; and (b) the users of the road affected. The impacts of landslides on road users are adequately considered in the economic appraisal in section 7. This section therefore examines in more detail the effects on the rural communities. Since nowhere in Laos are landslides so widespread or destructive that they cause societies to have to move or suffer significant disruption, the appraisal focuses on the possible impacts on household economies that might result through damage to land and vegetation. No gender-related or health issues have been identified.

9.1 Rural livelihoods

The pattern of settlement in the Lao uplands has always been dynamic, dominated by a long tradition of shifting cultivation and disturbances due to war. More recently, a changing socio-economic situation and government policies have started leading to resettlement to permanent villages. As a result, rural communities are not as well established or firmly settled in the environment as is the case in many other parts of Asia. There is also a lower person to land ratio than in many countries, which means that common resources are generally not as intensively used as in regions where community management has necessarily been developed to a considerable extent. Much remains to be understood by government agencies and development workers, of technical issues in both socio-economic and bio-physical systems.

In 2000, some 39 percent of Lao's population depended on shifting cultivation, covering 13 percent of the country's total land area. Although the practice is gradually being reduced as cultivation is stabilised, its effects are still very widespread; this is partly because "stabilised agriculture" often still uses many of the practices of shifting cultivation, but with very much shorter fallow periods. The situation is complex, but the paragraph below summarises the situation, drawing largely on the NAFRI Sourcebook (NAFRI, 2005).

Simply put, shifting cultivation is a practice whereby the forest vegetation is cut and burnt between January and April, and cropped between March and November (an overlap occurs because of varying practices in different areas); it is then left fallow for a long period, traditionally for ten to twenty years. However, there are many variations on this, and for example cleared areas are often cultivated for two or three consecutive years before being left fallow. With changing socio-economic conditions, fallows are tending to become much shorter than is sustainable in the long term using traditional methods and crops alone, and government policies are increasingly helping the move towards sedentary agriculture. Although shifting cultivation is about households producing food for basic subsistence, their income is greatly enhanced by the collection, processing and sale of non-timber forest products, and by livestock. In most ecological areas, if the fallow period is long enough, a forest canopy will eventually reassert itself. This seems to happen even on lands that become infested with a dense grass cover, though it can take ten to fifteen years.

There is a fine dividing line between agriculture and forestry in Laos, largely because most shifting cultivators also rely heavily on the forest, or clear it for cropping. The government's long term forestry strategy (MAF, 2005) makes it very clear that community participation is a key part of the sector's future. It is intended not just to involve rural villagers in the management of forests, but actively to boost their capacity to do so. This applies to a whole range of sectoral objectives, in timber production, utilisation of non-timber forest products, watershed management and biodiversity conservation. A number of mechanisms are being used to achieve this, including a profit sharing-system for plantation establishment on a joint government-farmer arrangement.

Community forestry has been developed along a number of different models in Laos. A useful summary of these is given in NAFRI (2005). Part of the reason for the variation is the involvement of different donors, but the most significant determinant is the difference in the environments in which they have been tried. Two of the four main models have addressed degraded areas in watersheds and the uplands. These have focussed on participatory approaches to the rehabilitation and management of degraded watersheds, mainly through plantation forestry and agroforestry, and a range of livelihood options as an alternative to shifting cultivation.

Tree plantations are common in many parts of Laos, including the mountains. These vary in size from large commercial plantations established by the government, to very small private plots owned by small farmers. The species grown are commonly teak or eucalypt, and the plantations are often considered to be an investment or financial safeguard for the household. They are often on land that is not good enough for regular cultivation, usually because of steepness.

Sedentary agriculture is slowly replacing the mosaic of forest, shifting cultivation and plantations. Where this occurs close to roads, the increased access allows the production of cash crops. Development in this is fast, with a rapidly expanding export market that can still absorb a great deal more production. Crops like coffee and pineapple are therefore becoming more common in the mountains, particularly in areas close to small towns where trading facilities exist. If the current level of change continues, a significant amount of roadside land will be occupied by relatively intensive cash crop farming within the next decade.

9.2 Landslide impacts on rural people and their livelihoods

As the account above demonstrates, there is effectively no land in the mountains of Laos that does not have value in some way to rural people. It is tempting to assume that forest is unused, and that degraded forest has been plundered and abandoned. That is not the case in this society. However good or bad the vegetation may appear, it is likely to be part of an extensive and long term land use strategy, and part of someone's livelihood. Table 9.1 gives details of the land affected by the three landslides treated under the first phase of the SEACAP 21 slope stabilisation trials. At the first sight, none of them were thought to have any significance, and this only became apparent during detailed site investigations. Areas utilised for commercial crops, including timber plantations, are clearly visible and can be appreciated as having an easily calculated value on the basis of area or standing crop, thereby demonstrating a straightforward livelihood element.

What is not so easy is calculating the importance of land that is under forest or shifting agriculture. Certainly, as the discussion in the economic appraisal (section 7) suggested, the economic value is minimal relative to the other costs involved. More significant, perhaps, is the importance of land assets to individual households.

The answer to the question is that there certainly is some social impact for subsistence farmers resulting from roadside landslides, since the households using the land that is lost are adversely affected. The difficulty is to estimate how great might be the consequences, and this would require detailed field surveys to establish: too much depends on the area of land affected relative to the overall land to which the household has access. It is the "stabilised" households with perennial crops who may lose most, since these represent a longer term investment. Shifting cultivation is usually flexible over wide areas, although damage to a portion of land that is currently cropped could have negative short term consequences, as it might well not be possible for the household to replace lost standing crops until the next season. Potentially this could be disastrous for a household if more than about 20 percent of a seasonal crop was affected. Beyond this it is difficult to assess impacts further, without extensive field work, and until more is known about the habits and livelihoods patterns of the different ethnic groups in different parts of upland Laos.

Table 9.1. Summary of land utilisation around three landslides on Road 13 North, 2006.

Location	Land use details
Km 238	Slopes densely vegetated with large grasses, particularly *Imperata cylindrica*. No large trees. No cultivation in the vicinity. To judge from the vegetation indicators, the site was cultivated between about 5 and 10 years ago. It is now about 25 to 30 percent of the way through a 20 year fallow period. There is a small hamlet about 1500 metres down-chainage (at km 236.5, towards Vientiane), called Keokuang, and another, rather smaller, about one kilometre up-chainage (km 239). These both appear to be relatively new and no more than about 5 to 10 years old. They are presumed to be newly established permanent settlements of shifting cultivators. Keokuang has received support from the Lao and French Croix Rouge under EU funding. The presence of these stabilised cultivators means that the nearby land is now likely to come under more intensive pressure, with shorter fallow periods and more animal grazing.
Km 316	There are no settlements of any size in this area, but a number of scattered farms throughout the major hillside above the road. The area directly above the site is cultivated, and the landslide has eaten back into this land. On the main failure there are several "rafts" of debris carrying banana trees, which were part of a plantation that covers several hectares of mountainside. The presence of extensive cultivation and fruit tree plantations suggests that this is a stabilised agricultural area. The risk of burning of the roadside slopes is judged to be low, partly because it seems very unlikely that anyone would encroach on to the very steep slopes alongside the road, and partly because this would almost certainly damage the fruit plantation just above the site. Certainly the settlement and land use appears to be more stable than traditional shifting cultivation. A permanent spring in the re-entrant just up the road from the landslide also seems to be important as a local water source.
Km 339	The forest above the road has obviously been cleared in the past and allowed to regrow. This has led to a vigorous and healthy secondary stand of young *Castanopsis* trees along the top of most of the site, and dense bamboos above the up-chainage end. These are all around 15 to 20 years and look at if they are well protected. They have the appearance of regular management as a private or community forest. The landslide has eaten back into this, causing a considerable number of plants to be lost. There is shifting cultivation across the valley, with steeply sloping fields currently in use. It might be supposed that the area around the site would not be burned intentionally in the future because of the presence of the forest above, unless that were to be cleared for agriculture. The nearest settlement of any size appears to be on the major ridge above. This is about 2 km walking or 6 km by road, and consists of a farming hamlet.

There is anecdotal evidence that the inhabitants of rural settlements benefit economically from landslides, in two possible ways. The first is ephemeral, where they take advantage of a road blockage to sell whatever spare food they can find, especially fruit, to a captive market of stranded road users. The other is by taking up opportunities for casual labour in landslide clearance and repair. Again, these are not quantified, and would need a detailed field survey to establish how widespread the opportunities are.

PART D: ORGANISATIONAL APPRAISAL

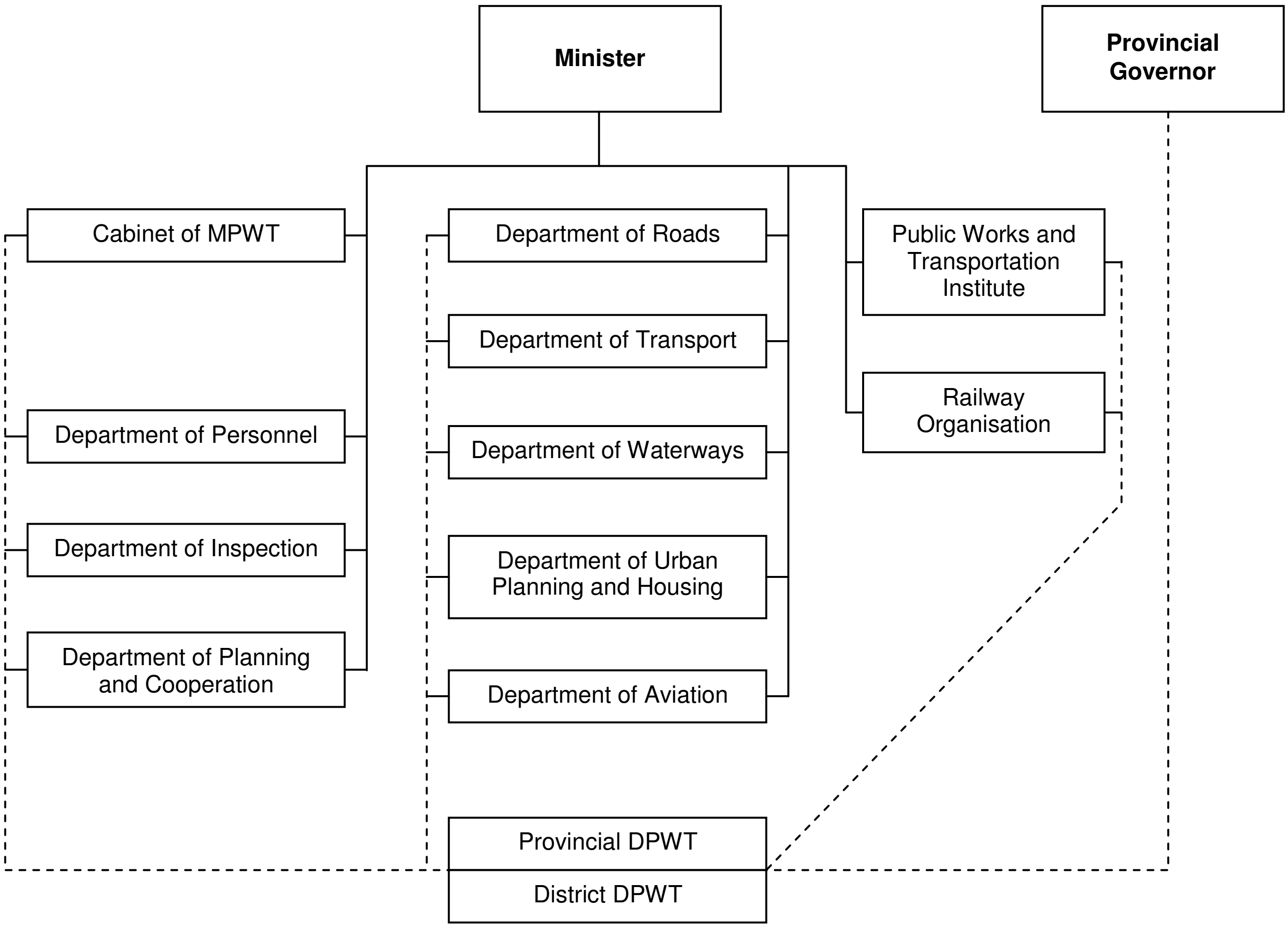
10. ROAD SECTOR ORGANISATION

10.1 The Ministry of Works and Transport

At the time of this feasibility study, the road sector was in the process of re-organisation. In early 2008, the Ministry of Communication, Transport, Post and Construction was changed to the Ministry of Public Works and Transport, mainly by the removal of the telecommunications elements to another part of the government structure. Re-structuring was expected to take at least until mid 2008 at the national level, and then to be followed by further work on the mandates and arrangements of the Provincial and District organisations.

The structure of the MPWT is based on the arrangement shown in Figure 10.1. This shows how the administrative and technical departments come under the direction of the Minister, but also link with the Provincial and District DPWTs; these also have a responsibility to the Provincial Governor.

Figure 10.1. Organisation of the Ministry of Public Works and Transport



The Road Maintenance Fund Board does not appear in this structure because it is not fully part of the ministry organisation. This is because it includes representatives from other governmental agencies, as well as road user groups. However, Gwilliams (2007) questions the RMF's independence, citing an example of a ministerial instruction in 2007 for it to make 10 percent of its revenue available for road safety initiatives.

There are several initiatives underway to support the restructuring of the MPWT, through the Road Maintenance Project-2. The Organisational Capacity Development Component is based in the Department of Personnel. Its role is to assist in corporate planning across the Ministry. It is focussing on helping the MPWT to improve its higher level capacity for planning and implementing enhancements to human resources development and information and communications technology. At the lower levels, it is seeking areas in which to embed new knowledge. It is helping the Ministry to move towards more rational approaches to its organisation, particularly in the separation of planning and implementation. An example is with the Public Works and Transportation Institute (PTI), which has a planning and research capability and can provide important services in these respects to the other sections. It has considerable future value to the overall organisation through possibilities in improving monitoring and review capabilities, and in providing internal consulting and strategic planning services. At present it is drawing up improvements to the practices for road maintenance on national roads. By comparison, the Road Administration Division is very much an implementation body, and needs to focus its work on this aspect.

The Ministry's Organisational Capacity Development Plan promises to provide a robust framework into which can be linked the improvement of sectoral skills in the proposal for a slope stability management programme. This is considered more in the sections below under organisational development.

The responsibilities of the Ministry itself in terms of road maintenance and slope management, is essentially to determine policy and to decide on the allocations of budgets. This is not just in the division of resources between new construction and maintenance of existing assets, but also between the different categories of roads. The detail of preparing and implementing the annual programmes is delegated to the Department of Roads. The Road Maintenance Fund is the MPWT's instrument for channelling funds to the implementing organisations, and also has the responsibility for assessing, approving and monitoring the various maintenance programmes (see section 11.2).

10.2 Department of Roads

10.2.1 Organisational structure

The Department of Roads is split into the following units:

- Personnel and Administration Division;
- Planning and Technical Division;
- Disbursement Division;
- Road Administration Division (RAD);
- Project Monitoring Division;
- Environment and Social Division;
- Local Roads Division (LRD);
- Road Projects Division; and
- Bridge Projects Division.

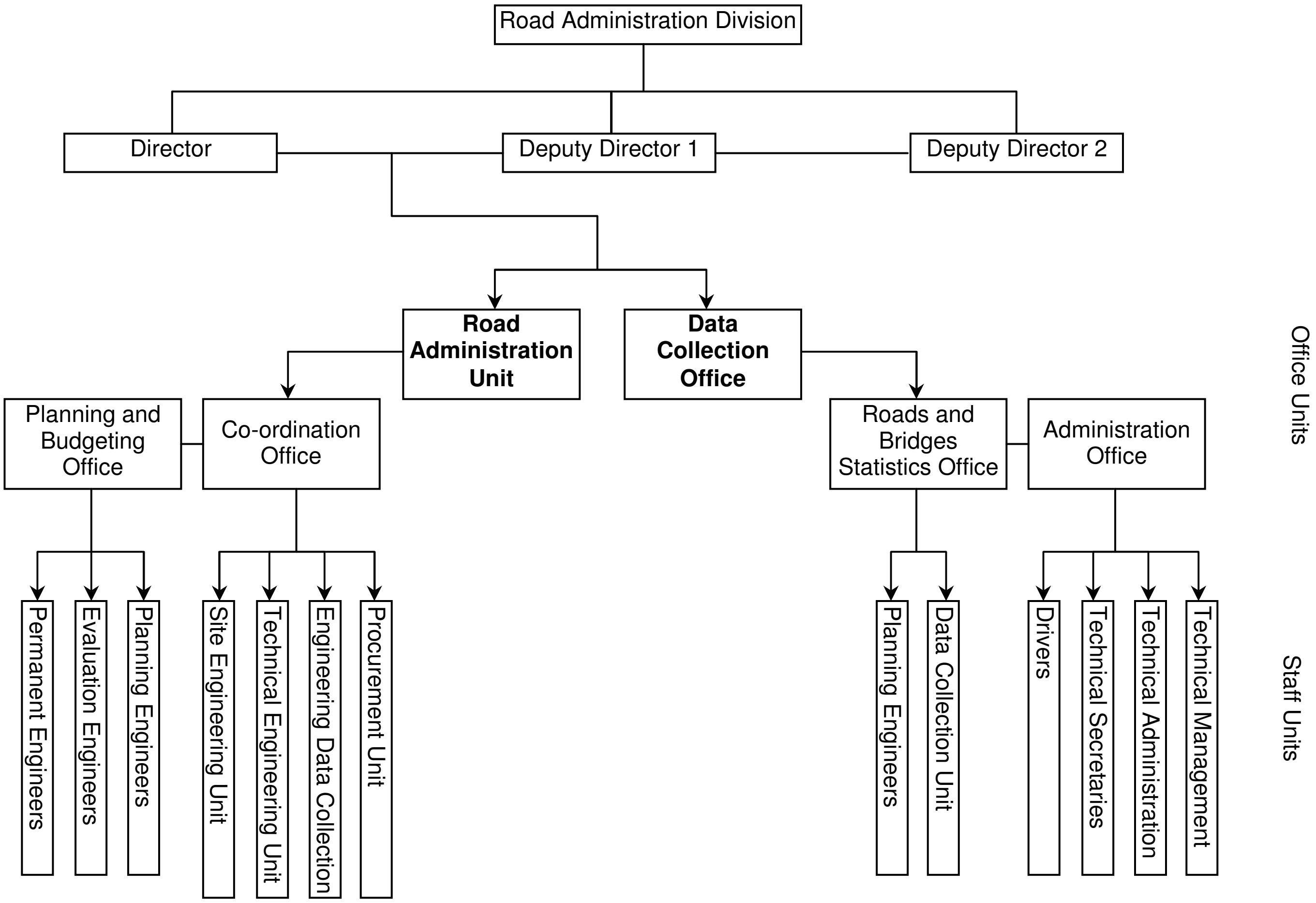
This structure is controlled by a Director General and two Deputies, whose main responsibilities are divided as follows.

- Director General: Overall management of all matters to do with political and technical operation and management of roads.

- Deputy Director General 1: Assist the Director General, with responsibility for construction works on national roads, local roads, waterways and railways; and liaison with the Road Fund Board.
- Deputy Director General 2: Assist the Director General, with responsibility for liaison with the Cabinet, and matters of technical planning, and social and environmental compliance.

Within the DOR, it is the RAD and the LRD that have the practical working relationships with the DPWTs. For National Roads, it is the RAD that provides the overview of the management of roads through the DPWTs, and this division's general organisation is shown in Figure 10.2. The RAD itself is based on a similar structure to other Lao government units, with a Director supported by two Deputies, though there are defined roles for each as well as a hierarchical distinction.

Figure 10.2. Organisation of the Department of Roads



10.2.2 The division of responsibilities

The current division of responsibilities for road maintenance between the various elements of the DOR are as follows.

Planning and Technical Division

- Undertake medium term and long term planning for road construction and maintenance.
- Participate in the strategic expenditure analysis performed by the PTI.

Environmental and Social Division

- Review annual maintenance programmes (and construction programmes) for social and environmental issues.

Road Administration Division

- Participate in the strategic expenditure analysis and multi-year programming performed by the PTI.
- Undertake detailed surveys of road sections included in the annual work programme. This includes condition surveys and detailed design of maintenance works.
- Prepare an annual maintenance works programme for national roads.
- Where PBMCs are in use, prepare a three-year maintenance works programme for specific national roads
- Approve the procurement of maintenance contracts by the DPWTs for national roads.

Local Roads Division

- Provide provincial data to the PTI (merge local PRoMMS databases in a central PRoMMS database).
- Prepare annual works programmes for local roads based on input from the provinces.
- Prepare programmes for road upgrading and bridge replacement for local road classes.
- Monitor road and bridge works implementation.

10.3 Department of Waterways

The main focus of the Department of Waterways is navigation on the Mekong River but because of this it is also responsible for river bank erosion. It has staff with the knowledge, experience and capacity to carry out river engineering works. It was also the department involved with JICA Project on River Protection Works around Vientiane.

The DOW responsibilities include all river bank erosion along the Mekong River covering all types of property and infrastructure, i.e. not just roads.

The organisation of the Department is not fully established at this time following the recent changes at the MPWT.

There is no clear division of responsibility between departments for river bank protection for National Roads. Historically it has depended on the project, for example the Department of Roads carried out 400 m of bank protection works in Bokeo Province. Also the Department of Waterways does not currently get involved with tributary rivers.

Given that the DOW has the best experience and expertise in river engineering it would be sensible for it to provide technical support to the Department of Roads for all matters concerning river bank erosion.

10.3 The Public Works and Transportation Institute

After the re-organisation of the old MCTPC to form the MPWT, the remit of the Urban Research Institute (URI) was changed. The URI was essentially responsible for urban planning, covering the wide range of infrastructure and environmental issues involved in the management of cities. The change has mainly involved adding a transportation capability, and hence the change of name to the Public Works and Transportation Institute (PTI). The first task given to it is the improvement and operation of the Road Management System

(RMS) database, and its use to produce the 2008-09 annual maintenance programme, along with the update three-year rolling plan. The intention is to strengthen the way that this is done, since the limited resources available to the PTD seemed not to be adequate to complete this undertaking to an adequate standard. The PTI may take on additional roles regarding transport in the future.

The Road Management Capacity Component of RMP-2 is supporting the PTI in developing its capacity to provide services in transport management. So far this is being done through the initial task of collecting and processing the data required to update the RMS database, in preparation for the annual programming exercise. The RMS was developed in a previous project phase, ending in 2004. Since then a number of difficulties have become apparent regarding the implementation of the system. The PTI is intended to act as the catalyst needed to overcome the procedures. The main elements that are being built up at present (April-May 2008) are the inventories on the conditions of roads and bridges. A web-based access system is also being devised, to give wide access to it for all personnel in the MPWT who have internet access. The links between the RMS and PRoMMS databases are also being improved, to provide a joined up view of the entire network. This RMP-2 component is also supporting the RAD to improve its capacity to utilise the RMS output, so that the data are used in building up the full annual maintenance programme. This includes help in rationalising the decision-making process, for which a manual is being developed.

The PTI's responsibilities for road maintenance are currently as follows.

- Procure and monitor data collection for national roads and bridges.
- Consolidate all road and bridge information in a central database (i.e. the RMS).
- Perform strategic expenditure analyses for alternative budget scenarios and analyse the road network performance under the budget constraints (using the RMS).
- Perform multi-year (3 years) maintenance programmes analyses for all road classes and submit the results to the operational units (using the RMS).

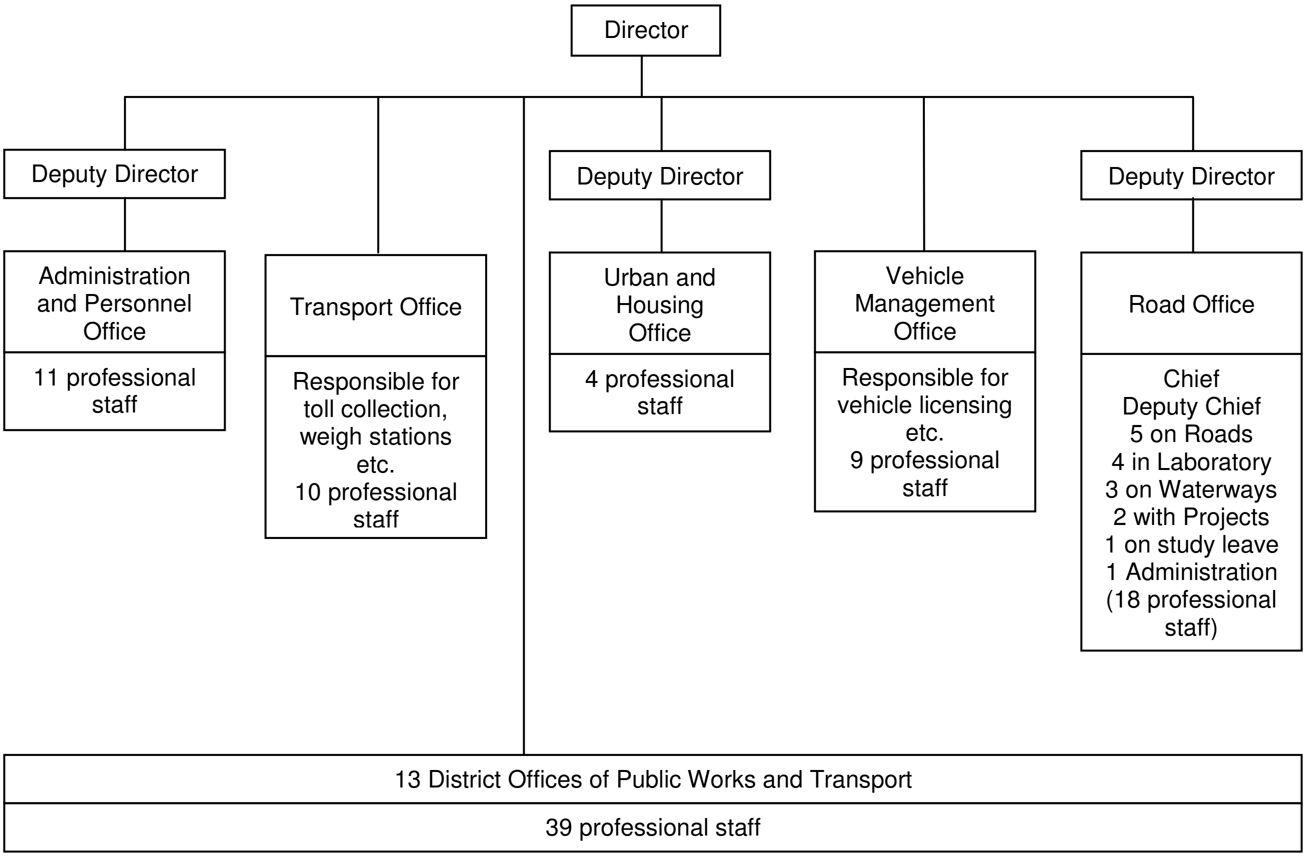
10.4 The Provincial Departments of Public Works and Transport

Each of the provinces has a DPWT, which is responsible for implementing the maintenance of National Roads under central ministry direction, and for managing the various categories of local roads. The structure of DPWTs is a simple arrangement under a Director: the example in Figure 10.3 is from Luang Prabang.

Within this arrangement, the Deputy Director controlling the Roads Office has the overall responsibility for technical and budgetary matters. He is assisted in this by the Chief and Deputy Chief of the Roads Office, according to need. The engineers in the office are responsible for site works, and complete all the checking of roads, drains, landslides and other items. They usually travel together in groups of two or three, to combine their skills when addressing problems. Therefore if a landslide occurs, the response will usually be decided by this group. However, if it is serious, then one of the senior levels of officers will also visit the site in support, to check their proposals and help to seek higher level approval if necessary.

The qualifications of the engineers in the DPWT are mixed, including Technician, Diploma and Bachelor. The more senior tend to be Diploma and Bachelor, but the older ones are more likely to be Diplomas, as the Bachelor degree only became available in Laos in the late 1990s. The qualifications both require four years of university study, and so are considered equivalent. However, most graduates are considered to be general civil engineers, and only a few have had any specialisation in slope stabilisation works; those that have were involved in one of the previous projects working in this technical area.

Figure 10.3. Organisation of a DPWT: Luang Prabang Province



It should be noted that two of the three staff assigned to waterways in the Road Office are in the process of transfer to the new Provincial Department of Meteorology. This is because their expertise is in the use of climate data. The staff member remaining at the DPWT will remain responsible for river water level data plus other activities such as maintenance of navigation monuments along the Mekong River. There has been no requirement to date for the waterway staff members to become involved in river bank protection works. There are waterways staff in all Provincial DPWT along the Mekong River and it can be presumed that the same situation will apply in all these provinces.

The responsibilities of the DPWTs towards road maintenance are as follows.

- Collection of road and bridge inventory and condition data for local roads.
- Analyse maintenance needs and prepare an annual maintenance works programme for local roads and bridges (using PRoMMS).
- Procure and monitor implementation of maintenance works for national roads.
- Procure and implement road and bridge maintenance works for local roads and bridges.

Staff at the Ministry level consider that most of the DPWTs have staff who are already sufficiently capable in project management activities, and that it is simply a lack of budget that is holding them back. However, they also concede that skills are badly lacking in slope management, and need to be improved. Slope failures are considered to be one of the biggest road maintenance problems, and the only skills that exist have been developed through the exposure of a few individuals to work with international consultants. Experience from pilot projects like the JICA trials near Luang Prabang has not been applied elsewhere. Some individuals were sent on a vetiver grass course in Thailand, but have also not applied their new knowledge.

The proposed Lao Transport Sector Project will support the improvement of the DPWTs through two main components, with complementary activities. This will be through both the rural roads and the institutional strengthening components. It is recognised that, while the central level capacity has improved, the provincial level has remained fairly static, but with an increasing burden as more roads are added to the network. Hence there is to be an increasing focus on supporting the DPWTs. However, the details of this still need to be determined.

10.5 Capacity development, skills and training

10.5.1 Capacity development in the road sector

A general review of capacity development in the road sector was undertaken recently (Gwilliams, 2007) and provides a useful summary of the recent history. The Lao PDR's management of the road sector is relatively harder economically than for its neighbours because the low national population make necessary a greater length of road per person. This is reflected in the concern over the long term sustainability of road maintenance, which requires a large share of national resources. But as the review points out, "The history of road transport sector in Lao PDR is one of a progressive shift from the creation of physical infrastructure to the creation of the physical and human resource capacity to sustain that infrastructure". The MPWT has made significant progress in this respect.

Much of the improvement is the result of rationalisation of the sectoral organisation, which has increased efficiency by removing duplicating elements and delegating responsibilities down to the provincial and district levels. More is attributed to the systematic approach to capacity development adopted by the Ministry, based on institutional, organisational and individual levels. This has worked by establishing the policies and roles for the various entities involved, enabling task-oriented organisations in both the public and private sectors, and boosting the skills of individual staff. The result has been considerable progress, particularly at central level.

While the MPWT's donor partners have been instrumental in assisting it to reach its current position, it is clear that harmonisation is still critical to the pulling together of much of its strategic approach to improvement. The governmental needs to increase its central leadership role and ensure that the donor resources are better co-ordinated and more complementary. This applies to skill development as much as to the effective implementation of the RMS and PRoMMS systems for managing road maintenance.

This sets the scene for the next phase of capacity development, which is supported by the Road Maintenance Project-2, under a specific component. At the time of this study, it was still early in the implementation of this component, and the necessary re-organisation at DPWT and other levels was still under discussion, as were key topics such as approaches to human resources management and development. However, it was clear that the strategy to be adopted was to support the MPWT in moving along the following path (MPWT, 2008b).

1. Dependent: establish teams; develop knowledge and skills.

2. Supported: co-delivery of training, workshops etc.; review, discuss and strengthen knowledge and skills.

3. Guided: observed delivery of training, workshops, etc.; review, discuss and fine tune knowledge and skills.

4. Independent: knowledge fully developed.

It is considered that the overall re-organisation of the MCTPC into the MPWT has helped to create an environment of change that makes Ministry staff open to the development of capacity. What this means in practice is the agreeing and implementing of a series of plans for staff management and training, and this initial part of this process was underway in the first half of 2008. The strategy summarised above is underlain by a detailed, though not yet finalised, Capacity Development Plan. This shows how the complex process of developing a sustainable approach to systematic human resource management should be undertaken over the next few years. It is clear from the consultant's report (MPWT, 2008b) that a considerable amount of internal preparation is necessary for the ministry to be able to develop its capacity in a rational and properly structured way. This involves the designating of functions, teams and units within the organisation to ensure that the process is implemented according to plan. The provision of an adequate budget is also identified as a key issue.

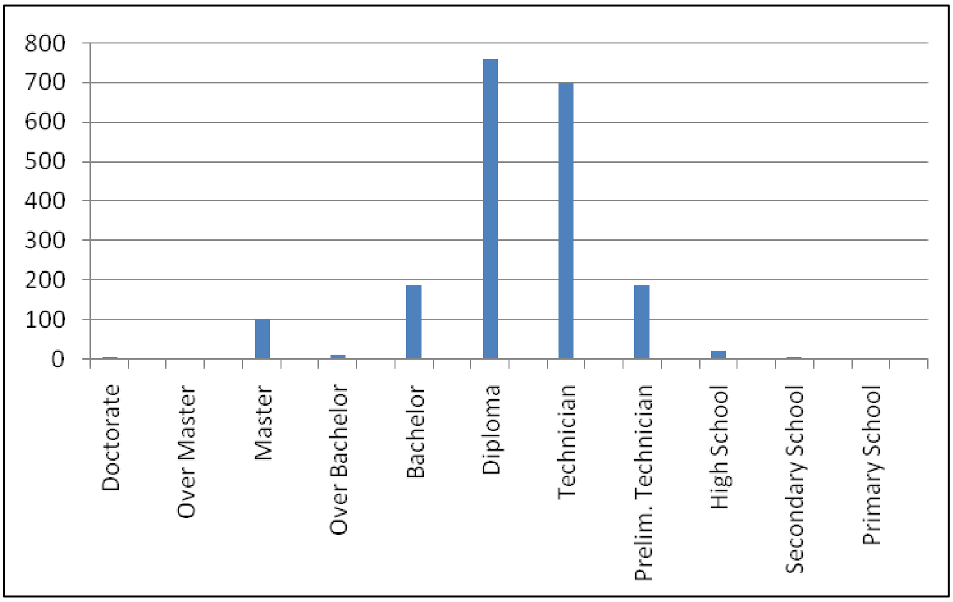
10.5.2 Staff and their skills

The Department of Personnel conducts an annual review of all staff in the Ministry and the Provincial DPWTs, through a series of interviews and questionnaires. The data so gathered are compiled into overall records. An assessment was made for this study of the staff in DOR and the DPWTs, but ignoring the other departments under the ministry. Not all of the DPWT staff work in the road sector, but it was not possible to disaggregate them. The 2008 data for DOR and DPWT staff show the following main attributes.

- In the DOR, there are 155 men and 28 women.
- In the DPWTs, there are 1,587 men and 201 women; the Vientiane Capital DPWT accounted for 11 percent of the men and 21 percent of the women.
- Only 19 of the women have degrees, and of these 10 are in the DOR.
- Only 26 staff members (including 5 women) have only a school qualification.
- Only 13 percent of the DOR staff and 8 percent of DPWT staff are aged over 50 years.

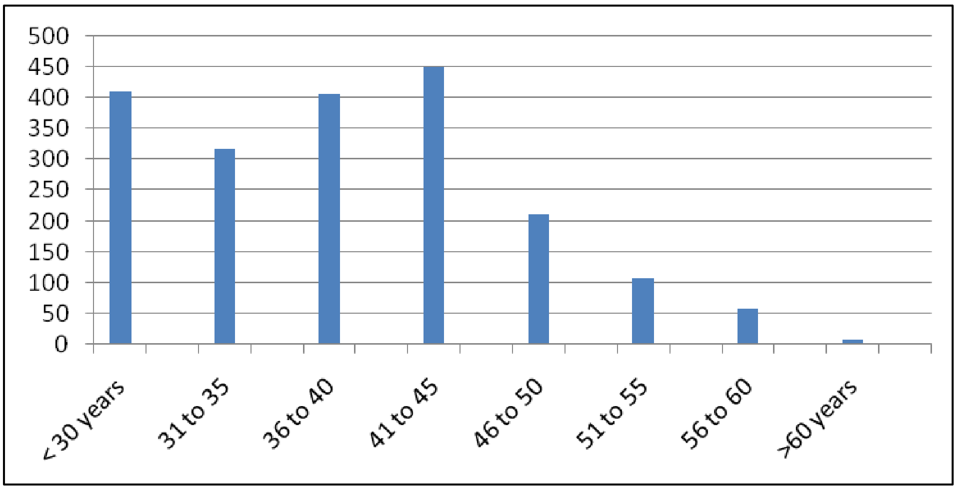
The chart in Figure 10.4 shows the distribution by qualification. Most obvious is the very high proportion of diploma and technician level staff. Although small by comparison, there are still 101 qualified to master level and 185 to bachelor level. The organisations therefore have well qualified managers. The bachelor degree qualification only became available in Laos from the late 1990s. Therefore, for engineers qualifying before that time, the diploma is considered to be equivalent.

Figure 10.4. Number of DOR and Provincial DPWT staff in each qualification class (2008).



The age distribution of the staff is shown in Figure 10.5. This demonstrates a double peak, with the under 30s and 41 to 45 age groups most represented. There is a rapid decline in numbers after 45, although there are still 330 people in this more experienced group. In general, however, the staffing complement is predominantly quite young. Among the graduates, the older group (generally aged over 40) mainly qualified abroad, particularly in the former Soviet bloc countries and China. The younger group, and almost all recent graduates, mainly qualified in Laos.

Figure 10.5. Age distribution of DOR and Provincial DPWT staff (2008).



What is not shown by the level of skill is the type of skill that is held by the staff members. Although the data exist, it was not possible to analyse it in detail in the time available for this study, and so this assessment is based on the informed opinions of a number of ministry staff interviewed. The key findings are as follows.

- The majority of graduates are civil engineers who have a general degree in the subject.
- Few have received more than basic training in geotechnics or any other form of engineering related to slope stabilisation.

- A few people have attended study tours or overseas short courses on the subject, but in general have not had the opportunity to implement new works after their return to Laos.
- The Department of Personnel collects information regarding perceived training needs, but very few individuals perceive slope stability issues as a skill area that they require. Therefore there have so far been no training courses arranged to cover this topic.

There have been several training needs assessments carried out as part of various donor-funded projects, and these have recently been consolidated into a single matrix, which is now incorporated into the draft Capacity Development Plan (MPWT, 2008b). This gives a strong emphasis to administrative and management training, and technical engineering is relegated to the end. There is no mention of slope stability as a specific topic, although it could conceivably be included under the sub-heading of "Environment issues in road maintenance". In any event, under the Plan, the training needs matrix is due to be reviewed and revised, with a current target date of the end of November 2008, and at this stage it will be presumably be much more detailed than the current somewhat generic model.

The question arises as to why there is a perceived need in the Ministry for support in slope stabilisation (leading to the SEACAP 21 trials and then to this study), but it is not followed up by the majority of departmental staff. Among the possible reasons is probably a basic lack of understanding of the subject. A general engineer, suddenly called on to stabilise a slope, undertakes standard practices to the best of his ability. By the time the works are complete, the wet season may be over and the landslide may have become stable in any case. No one apparently appraises the work to see if it has been done logically and economically. If there is further failure in subsequent years, it is in any case difficult to determine whether the design or implementation of the works was faulty, or if the landslide has just become bigger. By contrast, the Ministry personnel have an overall monitoring brief and are able to take a broader view. While they may not understand technical details of slope stability, they gain a view of the costs and effectiveness of the works that are carried out.

The general view is that DOR and the DPWTs have very limited skills for the investigation and design of high standard slope stabilisation measures. Starting with a base of well-qualified engineers, this situation needs to be rectified.

When training is implemented in the MPWT, it can be undertaken in several ways. Much is done through on-the-job training in the provinces. Specialist consultant trainers are sent around the country to work directly with provincial staff. This seems to work well for both technical and certain administrative topics such as financial management. Other courses are held regionally or nationally in a more formal way, with the participants called in from a number of locations. This is preferred for general management training courses.

Some individuals interviewed during the study suggested that self-standing technical training has been effective in boosting the skills of individuals in the past. However, they have not then applied these new skills, and therefore put the investment in the training to any purpose, because the senior staff have not themselves been given orientation in the new options introduced to their subordinates, and therefore remain largely unaware of the need for new approaches. This suggests that any technical training for provincial staff in, for example, slope stabilisation, needs to be accompanied by some form of awareness-raising for senior management staff.

10.5.3 NUOL's rural engineering curriculum

The Local Roads Division has recently developed a curriculum for rural road engineering with the National University of Lao PDR (NUOL) (MPWT, 2008a). The aim is to ensure that the supply of engineering graduates is familiar with the approaches of low cost engineering, to fulfil the technical needs in the construction and maintenance of local roads. It is specifically hosted by the Department of Civil Engineering of the NUOL's Faculty of Engineering. There are three main courses, each divided into a number of modules.

Course	Module
1. Rural Development and Engineering	1.1 Introduction to rural development 1.2 Introduction to rural engineering
2. Rural transport Infrastructure Engineering	2.1 Planning 2.2 Design 2.3 Construction 2.4 Maintenance
3. Rural Engineering Materials and Techniques	3.1 Rural roads and the environment 3.2 Materials 3.3 Techniques for low cost structures 3.4 Techniques for erosion protection works 3.5 Techniques for paving 3.6 Individual assignments

Among these modules, the elements that relate directly or indirectly to slope stability fall into 3.3 and 3.4. These are as follows.

3.3.1 Drainage: covering the drainage of surface water and shallow ground water from both the road itself and the neighbouring slopes.

3.3.2 Small structures and bridges: covering the main types of culverts and other low cost cross-drainage structures. In fact it does not cover bridges.

3.4.1 Slope stability: covering site investigation, surface protection from the cheapest to the most expensive systems, the drainage of steep slopes and gully control.

3.4.2 River protection works: covering site investigation, the use of check dams to reduce river velocities and prevent scour, river bank protection and the control of river courses.

3.4.3 Earthworks: covering the principles of alignment design, managing cut and fill masses, erosion control and embankments.

There is some overlap between 3.4.3 and 3.4.1 in terms of surface protection, and it does not seem particularly logical to have the section on earthworks after that on slope stabilisation, since quite a lot of the slope stabilisation content refers to the resolution of problems on freshly made earthworks.

The advice given for 'Rivers in Mountain Area' is only appropriate to smaller streams and would not address the problems of river bank erosion in rivers or mountain torrents.

The material that has been developed consists of fairly detailed notes on all the topics covered. These are in a form that could be used for handouts. There are module summary sheets that give objectives, further reading and other guidance for each sub-module, but those relating to the modules listed above are somewhat lacking in detail. There are no detailed guidelines for the lecturers as to how to present the subject matter, what emphasis to give each aspect of it or how to cross-reference with other parts of the course.

In general, however, the courses offer very sound knowledge on rural road engineering and will certainly help the graduates to understand the overall processes of planning, designing, constructing and maintaining low cost rural roads. What it will not do is to produce specialists in any aspects of this process. For example, community-based participatory planning is a skill that is often done best by a social scientist than by a civil engineer; good alignment design needs people with a strong understanding of geology and geomorphology; river protection works requires an in-depth understanding of open channel hydraulics and flood hydrology, practical construction on site is a very different skill from designing alignments and cross-sections using computer programs. It seems that the intention is for a large number of individuals to attend the courses so that they understand the broader picture, and then to specialise on the job, according to the role that they are assigned. The LSRSP-3 Basic Access Component will support the attendance of 35 DPWT staff members on a special run of the courses at the NUOL. No other further support is expected from the MPWT for continued development of the curriculum.

Unfortunately this valuable piece of work only has indirect benefit in the development of a national programme for managing slope stability in the road sector. This is because, at the level of understanding that is required, a relatively small number of specialists are needed, rather than general engineers with a broad perspective. While it will help to raise awareness of the issues, it will not in itself provide a means to resolving the current skills gap.

11. ROAD MAINTENANCE IN RELATION TO ROADSIDE SLOPES

11.1 The Road Network and its management

According to the MPWT's latest figures, the Lao road network currently has a total length of about 23,206 km and is classified as follows:

National Roads	7,159 km
Provincial Roads	7,214 km
District Roads	4,987 km
Urban Roads	1,855 km
Rural roads	15,411 km
Special roads	703 km
Total network	*37,323 km*

Out of the total network, only 3,694 km are paved (sealed) roads; 6,738 km are gravelled roads, and the remainder, about 12,775 km, are earth roads or tracks which are trafficable only in the dry season. (Statistics from PTI, dated 2006).

However, there are clearly variations in the classifications and estimations of the network. A more detailed and comprehensive account was given by a statistical document (MCTPC, 2003). According to this, the overall road network amounts to about 32,600 km, comprising 7,160 km of national roads, 8,950 km of Provincial Roads, 6,620 km of District Roads and an estimated 9,800 km of community or access roads (see table below). Of the total road network, some 4,590 km are paved, equating to the length of network that was generally considered to be maintainable and maintained in 2000, though even that was thought to be under-funded (MCTPC, 2000); however, while the position has changed since then, details of the current situation are difficult to find.

Region	National Roads (km)				Provincial Roads (km)				Urban/District/Community (km)			
	Paved	Gravel	Earth	Total	Paved	Gravel	Earth	Total	Paved	Gravel	Earth	Total
North	1,4157	1,061	340	2,816	2	1,119	1,612	2,734	78	735	2,383	3,197
Centre	1,355	578	242	2,175	232	1,571	1,726	3,530	224	2,101	3,514	5,840
South	1,059	478	630	2,168	102	1,256	1,327	2,660	120	757	6,595	7,518
Lao PDR	3,830	2,118	1,212	7,160	337	3.947	4,666	8,952	423	3,595	12,492	16,529

Within the Ministry of Public Works and Transport, all roads are managed by the Department of Roads. National Roads are the responsibility of the Road Administration Division, whereas Provincial Roads come under the Local Roads Division. The latter are sub-divided into Provincial, District, Urban and Rural (or Village, Access or Community) Roads, though the definitions are not entirely clear: these are about to be reviewed and revised with support from another SEACAP project. There is also a separate category of Special Roads, which mainly covers industrial access and army roads.

The practical management of roads, including their maintenance, is administered through a Division of Public Works and Transport (DPWT) in each of the seventeen Provinces. Within each DPWT there are two remits, to cover National and Provincial roads respectively. Responsibilities for District and Rural Roads are delegated to Offices of Public Works and Transport (OPWT) in each District, headed by DPWT staff. These arrangements are governed by the Road Act 1999 and a series of Decrees, Ministerial Decisions and Regulations (see MCTPC, 2000).

In 2003, the main priorities for the transport sector were considered to be the following (Government of the Lao PDR, 2003).

- The need to strengthen linkages between the national and rural road networks.
- For the poorest districts, strengthening of the rural road system so as to give access to markets and critical services (health, education).
- Improvement of road maintenance.

11.2 The Road Maintenance Fund

The Road Maintenance Fund (RMF) was established under Decree No.09/PM in January 2001, with the support of the main sectoral donors (World Bank, SIDA, and Asian Development Bank). It is designed to ensure a sufficient and stable domestic source of revenue for road maintenance. Under the decree, 10 percent of RMF annual revenue is allocated to the local road network (Provincial, District and Rural Roads), 0.5 percent to road safety programmes, and up to 90 percent, after allowing for fund administration costs, to National Roads. The amount allocated to local roads is to be increased once the full cost of maintaining the National Roads network is covered by the fund. Hence the first priority is the maintenance of the all-weather road network, and in turn this is critically linked to the efficient operation of the RMF. Meanwhile the financing of maintenance of the local road network remains weak.

The Road Maintenance Fund is managed by its own seven-member Board under MPWT, which includes three non-governmental representatives from road user organisations. The Board is responsible for overseeing the maintenance operations, recommending user charge levels and publicising the need for the fund. Day-to-day administration is by a Secretariat in the MPWT. This acts as the agency to liaise with the Department of Roads in implementing the Board's policy. Its work includes collation of annual maintenance plans and allocation of budgets according to the agreed programme.

Revenues to the RMF flow into a dedicated bank account and are derived from a fuel levy, heavy vehicles surcharge, international transit fees and other road user charges, together with donor assistance in the medium term. The RMF will gradually increase the domestic funding for road maintenance, supported by annual increases in the fuel levy. The RMF handles local funds as well as support from SIDA. The anticipated budget needs are given in Table 11.1.

The "*Strategic Directions…*" document (MCTPC, 2000) gives more details of the Road Maintenance Fund. The National Growth and Poverty Eradication Strategy identifies the establishment of the Road Maintenance Fund as providing a model of the way in which capital development expenditure should be accompanied by support for the associated recurrent expenditure. The implication is that this was seen as an approach that should be tried in other sectors.

11.3 National Roads: the Road Management System

The MCTPC's (2000) "*Strategic Directions…*" document defines maintenance priorities. The order of importance is as follows.

1. Keep the road open (emergency maintenance).
2. Reduce the rate of pavement deterioration (stop erosion, maintain drainage, surface patching).
3. Improve traffic safety (vegetation control, guard posts, line markings etc).
4. Lower the vehicle operating costs by reducing road roughness (grading, shape correction etc).

Table 11.1. Road Maintenance Fund and Maintenance Budget estimates (Source: National Growth and Poverty Eradication Strategy: Government of Lao PDR, 2003)

Fiscal Year	03/ 04	04/05	05/06	06/07	07/08	08/09	09/10	Total
Maintenance National roads	12.1	9.4	12.5	13.6	14.9	19.5	20.0	102
Maintenance Local roads	7.0	7.8	8.6	9.4	10.2	10.8	11.4	65.2
Total Maintenance	19.1	17.2	21.1	23.0	25.1	30.3	31.4	167.2
External Funding	10.1	6.6	8.0	6.0	6.5	6.0	0	43.2
RMF Income	4.0	5.7	8.6	12.3	18.7	26.0	34.3	109.6
Total	14.1	12.3	16.6	18.3	25.2	32.0	34.3	152.8
National Roads	12.1	10.5	14.4	15.9	22.1	28.1	30.2	133.3
Local Roads (10%)	1.41	1.23	1.66	1.83	2.52	3.20	3.43	15.28
Road Safety (0.5%)	0.07	0.06	0.08	0.09	0.12	0.16	0.17	0.75
Expenses	0.50	0.50	0.50	0.50	0.50	0.50	0.50	3.50
RMF Shortfall/surplus National Roads	*0*	*+1.1*	*-1.9*	*+2.3*	*+7.2*	*+8.5*	*+11.2*	*-1.9*
RMF Shortfall/surplus Local Roads	*-7.0*	*-6.7*	*-10.5*	*-7.1*	*-3.0*	*-2.3*	*-0.2*	*-36.8*

Currency unit not given: Billion Kip? Trillion Kip?

The routine maintenance objective refers to “an efficient way” for it to be conducted. This is explained as involving the use of domestic contractors to carry out routine maintenance, selected through competitive bidding, following specifications and standards provided by the Road Administration Division, and provision of effective and responsible supervision.

Maintenance planning and management is done through the Road Management System (RMS), a computerised system introduced through RMP1 (NDF/World Bank) beginning in 2000. It is now well institutionalised, but it is accepted that some fine-tuning is required to ensure that it runs smoothly from year to year. Currently support is received from the World Bank through the Second Road Maintenance Project.

The yearly cycle of the RMS starts with a road condition survey and inventory on a 2 to 3-year cycle, and is carried out by consultants engaged by MPWT, with support from the central Public Works and Transportation Institute; this was undertaken by the Planning and Technical Division (PTD) up to 2007, but has now been transferred to the PTI. Data collection is done in February and March, and entered into the system in April and May; however, in 2008 the process has been delayed by procurement problems, so that data collection was starting only in May. Priorities are assigned by the Provincial DPWTs as they do so. This leads to the PTI drawing together a consolidated national plan for maintenance of the National Roads over the coming year. It is submitted to the Road Administration Division, which convenes a meeting with the DPWTs to agree final programmes and budgets according to the resources available for the year in the five-year rolling budget. Once this has been done, the annual maintenance plan is submitted to the Department of Roads, and then to the Minister, the Road Maintenance Fund Board and the donors, for approval. Tenders for the provision of maintenance services are then invited during the rainy season, ready for commencement at the start of the new fiscal year, in October.

A modification to this arrangement was being tried out in 2008, at the time of this study. Responsibility for conducting the survey and compiling the inventory was given to the Public Works and Transport Institute (PTI), formerly the Urban Research Institute, which is a semi-independent advisory entity within the MPWT. It had been recognised that there was little incentive for the DPWTs to support this annual exercise, since they do not have direct control of the budgets and are already stretched with work elsewhere. The new arrangement, supported initially by consultants under the Road Maintenance Capacity Component of RMP-2, is intended to build up a transport planning capability in the PTI, which engages consultants to support it in putting together an annual maintenance plan. This plan will then be passed over to the RAD for finalisation and implementation. The inventory and road condition data will also be placed in a web-based database, so that it is easily accessible to anyone in the MPWT with a computer and internet access.

11.4 National Roads: Routine Maintenance

The Road Administration Division has a list of maintenance activities and codes that form part of the road maintenance contract documents (MCTPC, 1999a). The routine off-road activities are listed under two headings. The first is "Drainage and Erosion Protection" and cover the following topics.

- Clearing of ditches by hand tools, defined as removing obstructions (rocks, fallen trees, soil heaps, debris etc.) on shoulders, slopes and in the ditch.
- Clearing of ditches by machine, defined as removing obstructions (rocks, fallen trees, soil heaps, debris etc.) on shoulders, slopes and in the ditch. This is on a larger scale and for bigger areas than the item above.
- Clearing of culverts, defined as the removing of silt, sand and blockages by debris.
- Repair of culverts, defined as the repair of inverts, concrete and steel surfacing, and reconstructing or correcting levels and falls.
- Repair of erosion damage, defined as filling with selected and graded material to repair erosion damage, and the repair of erosion control devices.
- Repair of retaining wall, defined as rebuilding collapsed walls, and repairing and replacing broken blocks or concrete.
- Repair of ditch linings, defined as replacing broken linings and re-aligning the drain, and filling eroded areas with gravel material.

The second heading is "Roadside Maintenance" and covers four categories of vegetation management.

- Grass cutting, defined as all grass to be cut within the road reserve, by hand or machine.
- Bush cutting, defined as all bushes to be cut and removed within the road reserve.
- Bush cutting (thick vegetation), also defined as all bushes to be cut and removed within the road reserve.
- Cleaning of the right of way or road reserve, defined as cleaning of the road reserve and removing of debris.

11.5 National Roads: Periodic Maintenance

Periodic maintenance off the road is covered under the title of "Rehabilitation or Improvement of Drainage and Erosion protection" in the maintenance activities and codes that form part of the contract documents (MCTPC, 1999a). This section covers the following activities.

- Construction of new culverts with headwalls, defined as construction of new culverts as required, with attention to mitres and side drains, and inlet and outlet levels. Attention must also be given to backfill with approved material to specifications.
- Construction of box culvert, defined as construction of new box culverts as required, with attention to mitres and side drains, and inlet and outlet levels. Attention must also be given to backfill with approved material to specifications.

- Construction of new ditches, defined as required where these are missing, with attention to ensure that the ditches have the correct inclination and that the water is directed to go in the desired direction.
- Construction of scour checks, defined as features in ditches, cut off drains etc, where it is important to reduce the water velocity and possibility of erosion. Scour checks can be made of branches, stones or material not easily eroded.
- Erosion protection by gabions, defined as stabilising the base of a slope. A gabion retaining wall may be used, or any other protection structures to prevent erosion.
- Erosion protection by rocks, defined as using rocks to protect slopes and materials which have a tendency to erosion.
- Riprap, protection of banks or bed by stones, defined as the use of stones, usually 5-50 kg, for protection of banks or beds, with or without grouting.
- Erosion protection by vegetation, defined as slopes, shoulders or any surface area within the road reserve which are liable to erosion being protected by planting grass or any plant which provides a soil stabilisation effect.

Standards for the MPWT's periodic maintenance activities are provided in the bidding documents for the Second Road Maintenance Project (MCTPC, 2005a). The latest revision (January 2005) has as Section 8, Technical Specifications for Periodic Maintenance. However, this is restricted to carriageway repairs and covers re-sealing, re-gravelling, rehabilitation and asphalt overlays. There seem to be no specifications for drains or off-road maintenance activities.

There is an element in the RMS that stores information on emergency works, in terms of what has been done, where and when. This can be plotted on GIS-based maps.

11.6 National Roads: Emergency Maintenance and Slope Management

Separate arrangements are made for emergency maintenance, under a different budget. Before the rains, the RAD writes to the DPWTs, asking them to identify sections of road where problems are expected. Bids are then invited, and contracts awarded, for contractors to provide a site presence and rapid emergency response on specified lengths of roads. If an emergency occurs, usually a landslide, then the contractor must clear it immediately and the actual quantities of debris shifted are estimated and agreed by the DPWT's and contractor's site engineers; they may use photographs and video records to help in this process. If there are really major problems, then there is flexibility for the DPWT to bring in contractors from neighbouring sections to help. If the expenditure is likely to exceed the budget, then the DPWT can consult with the MPWT, and an application made to the Prime Minister's Office (PMO) for it to be declared a National Disaster, which would cause special funds to be released.

Emergency maintenance activity categories mainly cover the resolution of external damage to the road. They are as follows.

- Removing of landslides, defined as immediate attention to open the road and clear the roadway, while being aware of the possibility of additional landslides.
- Emergency culvert repair, defined as replacing and backfilling damaged culverts as soon as possible.
- Emergency bridge repair, defined as attending to damaged bridges as soon as possible. A diversion should be considered but might be a problem due to the local surroundings.
- Erosion damage repair, defined as often resulting from the connection of heavy rain and flowing water. These are to be attended to and drainage provision improved to reduce the risk of further damage.

- Repair of collapsed road embankment, defined as finding the cause for the collapse and refilling with graded material.
- Blasting, defined as drilling and the use of dynamite as an option to use when rocks are of a size that cannot be removed easily.

At present the MPWT has no specialists in geotechnical engineering or other aspects of slope investigation and stabilisation, although a number of individuals have an encouraging interest in the topic. Expertise in river bank protection comprises a few individuals in the Department of Waterways. Neither do the provincial DPWTs nor the body of consultants and contractors have much recognised expertise in these areas.

In the majority of cases for slope instability above the road, the normal practice is that the slope is allowed to fail and the main effort is focussed on clearing the landslide debris as quickly as possible, perhaps with some minor slope trimming. After the emergency has passed, the appropriate DPWT Maintenance Engineer carries out an inspection and makes a decision as to whether any remedial structure is required. If it is, it most commonly consists of a breast wall in masonry or reinforced concrete.

Slope instability below the road usually manifests itself by the presence of cracks adjacent to or within the road surface. Although the road surface may be repaired, in general no other proactive work is carried out until the slope fails. After failure, which may include part of the road, an inspection is carried out by the DPWT and a decision made concerning the need and type of remedial work, which is likely to include the construction of a masonry or reinforced concrete retaining wall. Where the failure has been caused by river bank erosion the remedial works may comprise rip-rap, gabions walls, groynes or other suitable measures.

The practice of using performance-based maintenance contracts was introduced from financial year 2007-08, and now covers approximately 2,800 km of the 7,000 km national road network. The decision-making process for response to slope instability under this system is understood to consist of the procedures shown in the flow chart in Figure 11.1.

11.7 Provincial, District and Rural Roads

A set of Road Maintenance Procedures for Local Roads was produced by the LRD/LSRSP-2 in September 2002 (MCTPC, 2002). This document describes how the responsibility for all road maintenance lies with the MPWT, and how it is devolved down through the Department of Roads to the Roads Administration Division for National Roads, and to the Local Roads Division for other roads; and how responsibilities are further devolved by these two divisions to the respective sections of the Provincial DPWTs. The RAD and LRD must ensure that the central-provincial dialogue occurs in a productive manner. The maintenance of District and Rural (Village) Roads is further delegated from the DPWT to the Offices (OPWT) in the districts; and the OPWT must implement the maintenance works, and organise Village Maintenance Committees (VMC) where appropriate. VMCs are seen in the MCTPC (2002) document as the LRD's favoured body for maintenance arrangements on smaller local roads (Rural or Village Roads and some District Roads).

Basic Access Roads are effectively a sub-division of Rural (or Village or Community) Roads. These are supported by the Basic Access Component of the Lao-Swedish Road Sector Project-3 (LSRSP-3) as a means to reduce poverty in villages with no existing vehicular access. They are the most basic level of earth access track for tractors, and 2- and 3-wheeled vehicles, and are not currently built to formal standards. Many will probably be upgraded to District Roads in the future.

Figure 11.1. Flow chart of PBMC procedures for routine and emergency maintenance

Preparation and contracting

Routine maintenance	**Emergency maintenance**
The DPWT Engineer will estimate the cost of carrying out maintenance over a 3-year period according to the following headings. 131 Clearing of ditches by hand tools. 132 Clearing of ditches by machine. 133 Clearing of culverts. 134 Repair of culverts. 135 Repair of erosion damage. 136 Repair of retaining wall. 137 Repair of ditch linings.	The DPWT Engineer will estimate the cost of carrying out maintenance over a 3-year period according to the following headings; this requires an estimate of the possible extent of landslides and other repairs. 311 Removal of landslides. 312 Emergency culvert repair. 313 Emergency bridge repair. 314 Erosion damage repair. 315 Repair of collapsed road embankment 316 Blasting.

For both routine works and the repair of anticipated emergency problems, the DPWT Engineer will estimate the cost of rehabilitation and improvement works over a 3-year period according to the following headings.

435 Erosion protection by gabions.
436 Erosion protection by rocks.
437 Erosion protection by vegetation.

Having derived quantities under the various MACs and applied the MPWT's recommended unit rates, the DPWT will seek MPWT approval and invite a number of contractors (minimum three) to bid for the PBM contract.

Once the bids are received they are subjected to the normal scrutiny by a bid evaluation committee, the necessary MPWT approvals sought and the contractor instructed to carry out the work.

Quarterly payments are based on measured quantities, which means that the PBM contracts are effectively re-measurement contracts.

Implementation supervision and monitoring

Routine maintenance	**Emergency maintenance**
A joint inspection is carried out [at what frequency?]	Following an unusual event, the contractor must attempt to open the road and call for a joint inspection.
Agreed maintenance work must commence within 12 hours of the joint inspection.	If the landslide is of such magnitude that the contractor fails to open the road within 12 hours, he must obtain outside assistance to clear the debris as quickly as possible.
If the work is not carried out within certain periods, penalty clauses apply.	If the landslide is large and occurs under exceptional climatic circumstances, then the DPWT and MPWT can apply to the Prime Minister's Office (PMO) to have the event declared as a National Disaster.
	The DPWT, MPWT and the contractor agree on the scope of work, and quantities and costs.
	The DPWT and MPWT apply to the PMO.
	The PMO then consults with the Department of Meteorology and Hydrology for an opinion.
	If this accords, then special emergency funds are made available (additional to the PBMC amounts) and the contractor is instructed to carry out the work as an extension to the PBM contract.
	If the work is too great for a single contractor to handle, then other contractors may also be appointed.

11.8 The Provincial Road Maintenance Management System

The maintenance of Provincial, District and Rural (Village) roads is organised through the Provincial Road Maintenance Management System (PRoMMS), defined by MCTPC (2004a). The DPWT undertakes an annual condition survey and puts the resulting data into the program; this shows the current maintainable network and a long-list of works. It is submitted to the central LRD, along with a list of priorities; these priorities are generated automatically by PRoMMS, on the basis of the "class lists" of seriousness of the different factors (see tables below). The LRD checks the submissions and allocates the available national budget to a short-list for all 17 provinces. The short-lists are then sent back to the provinces for revision and detailed planning; these are then approved by the LRD. The provinces approve and implement the works, which is a new routine introduced from January 2007. Hence the responsibility for the physical works has been decentralised, but not that for fiscal decisions. This is being discussed, however, and the government has expressed an interest in making villages into implementation units. The financial year runs from October to September, but it was only in 2006 that approval for interventions has been given in October; in previous years it has usually been delayed until March or April. The 2005-06 annual local roads maintenance budget was 130 billion Kip.

Selected details of the physical parameters used in PRoMMS, as far as they relate to roadside slopes, are described below. A number of economic and on-road technical categories are omitted.

The general inspection includes the following topics.

- *Topographic zone:* What kind of topography is surrounding the road (flat, rolling or mountainous).
- *Accessibility:* To what extent the road is accessible per year, depending on the section surveyed (choose from list).

Accessibility (road closed by landslides, washout, flooding etc)

Class code	Class name	Description	Class factor
1	Accessible	Road open 12 months a year	1
2	Good_A	Road closed < one week per year	2
3	Fair_A	Road closed > 1 week but < 1 month per year	3
4	Low_A	Road closed > 1 month but < 3 months per year	4
5	Very low_A	Road closed > 3 months but < 6 months per year	5
6	Inadequate_A	Road closed > 6 months per year	6

- *Access Constraint Type:* Constraint type limiting the road accessibility (choose from list).

Access constraint type

Class code	Class name	Description	Class factor
1	No	None	1
2	BC	Bridge collapse	2
3	RC	Road collapse	3
4	CC	Culvert collapse	4
5	FC	Flooding of road	5
6	LS	Landslides	6
7	SR	Soft road	7
8	OT	Other	8

- *Surface condition:* Condition of road camber, road surface and surface material (choose from list).

Surface condition

Class code	Class name	Description	Class factor
1	Good	Only routine maintenance	1
2	Fair	Only routine maintenance; traffic group 1-2	2
3	Poor	Periodic maintenance needed	3
4	Bad	Emergency maintenance needed	4

- *Shoulder condition:* Condition of shoulder shape and surface, applies only to paved roads (choose from list).

Shoulder condition (applies only to paved roads)

Class code	Class name	Description	Class factor
1	Good	Well shaped and water can run off into drains	1
2	Fair	Some erosion, vegetation growth and grass cover	2
3	Poor	Serious erosion, heavy grass and vegetation cover	3
4	Bad	Collapsed or non-existent	4

- *Drainage condition:* Condition of ditches and culverts (choose from list).

Drainage condition

Class code	Class name	Description	Class factor
1	Good	Well drained, only routine maintenance	1
2	Fair	Minor drainage problems, periodic maintenance considered	2
3	Poor	Major drainage problems, periodic maintenance needed	3
4	Bad	No drainage, emergency maintenance needed	4

- *Roughness Index:* Estimated road roughness measured in IRI, applicable only to paved roads.
- *Remarks:* This is one of the few places where the user has flexibility to enter any details or wider remarks that might be needed.

There is a listing for structures, but this refers only to stream and river crossing structures.

PRoMMS lists the following routine maintenance activities:

- Filling of potholes;
- Reshape carriageway by hand tools;
- Temporary draining of road surface;
- Clearing of ditches by hand tools;
- Clearing of culverts;
- Repair of erosion damage;
- Bridge bush clearing;
- Bush cutting;
- Removing of landslides;
- Inspection and removal of small obstacles;
- Removal of large obstacles from the road.

These are given standard allocations of the scope of work and intervention frequency, to allow detailed planning and budgeting.

Equipment-based re-shaping is an allowable item under PRoMMS. This covers heavy grading and ditch clearing.

Periodic maintenance activities are categorised and costed under the following heads:

- Ditch clearing;
- Repair of culverts;
- Bush cutting;
- Reshaping the road;
- Re-gravelling;
- Construction of culverts.

An emergency maintenance fund exists for unexpected high cost problems on local roads, but the criteria for its use are not very clear.

11.9 Provincial Roads: Emergency Maintenance and Slope Management

The procedures for the response to emergencies on Provincial Roads are rather different from those for National Roads. In general, the following process is in place at the Provincial DPWT level.

- An engineer or small group of engineers from the DPWT visits the site of the emergency. This may be during a routine check, but if there is a road blockage it may be in response to a specific notification of a problem.
- The DPWT staff inspect the site and decide on a strategy to resolve the problem.
- If a contractor is present, he may be requested to take action. If not, local people may be asked to open the road. Sometimes it is a combination of the two, with a contractor asked to pay the local people until the necessary funds can be released from the government. Sometimes groups of road users (e.g. truck operators) are asked to assist with road opening.
- The DPWT staff make provision through a contract for any repair work to be carried out. Usually 60 to 70% of the work is carried out using provincial funds accessed through the Provincial Governor. Normally the remainder has to be met through a contribution of local people's labour.

Within this system, it is not clear how the local people benefit from their contribution to the opening of the road; if they are not primary road users, the incentive appears to be lacking.

11.10 Maintenance through Village Maintenance Committees

The MCTPC (2002) document outlines a financing arrangement where the VMC undertakes to keep a section of local road at a specified standard using local volunteer labour supported by a subsidy. The level of the subsidy depends on what funding can be made available, and is normally paid just for more complex work, such as for re-profiling the camber, but not for simpler activities such as cleaning drains. VMCs would be bound by signed agreements to maintain roads to an agreed set of simple performance criteria, such as:

- "Culverts are cleared and working properly;
- No blockage of the ditches, minimum ditch depth 15 cm;
- No water standing in the ditches;
- No water pools on the road surface; potholes are permitted but water shall be allowed to run off through 'surface drains' carried out by hand;
- The road surface shall permit a driving speed of 35 km/h; and
- The road area up to a distance of 1.5 m from the road formation edge shall be cleared from bushes at least once per year."

The authority of the VMC to close the road to vehicles exceeding the road design criteria is also mentioned in this document.

In a review of rural road maintenance, the ASIST-ILO (2004) considered that village organisations could not be expected to have capacity to maintain District and rural roads at the time, since the responsibility had been devolved without the accompanying allocations of adequate funding. "In examining maintenance options, all District and Rural roads are at present lumped together to be maintained by the voluntary contribution based VMC model with the CRM [Community Road Model] model proposed for improvement. The most important conclusion of this paper, from which all recommendations and implications follow, is that this treatment for all District and Rural roads is not an adequate strategy for this road network." However, the review records a positive finding with regard to rural employment, and this was certainly seen as an important part of the way forward. "Labour-based methods are now accepted for routine maintenance on all categories of roads in Lao PDR. Their suitability for periodic maintenance and improvement has also been demonstrated in

Lao PDR and elsewhere. Labour-based methods are expected to be cheaper and would also contribute to the employment generation and poverty alleviation objectives."

11.11 Comments on road maintenance issues

Our assessment so far suggests that the MPWT's procedures are essentially sound, but the following technical weaknesses exist in the system.

- DPWT staff are qualified highway engineers with no special training on slope dynamics and management.
- There are very few options in the guidelines to assist the DPWT engineers in their diagnosis of the problem and design of a cure.
- There are no slope stability specialists and few river engineers in the MPWT or the private sector on whom to call for advice.
- There are no apparent geotechnical or hazard based procedures in place for prioritisation

The overall institutional structure leads to a potential conflict. The MPWT oversees road maintenance centrally, using its ministerial authority to issue directives and organise appropriate plans and budgets. However, maintenance is administered through the DPWTs. As Provincial units, these come under the control of the Provincial Governors, who have the same level of authority as State Ministers. Staff in the DPWTs could conceivably find that priorities as ordered by the Provincial Governor's Office are different from central priorities as directed by the MPWT. In addition, as both the Ministry and the Provinces cover many remits other than just roads, there are frequently competing priorities on the time and interests of officials. This could become a particular problem at times of crisis, such as when a bad landslide causes a serious road blockage; but on the other hand it means that demands for emergency funds can come from several channels, strengthening the call.

Maintenance funds tend to end up covering more than what would normally be described as "maintaining an existing asset". This is particularly the case for slope-related problems. The PRoMMS system does not have any way of categorising road-related interventions other than through one of the maintenance categories. This means that items that really require special funding as post-construction works, are lumped into the maintenance budget. Because funds are limited, this means that an attempt is then made to resolve problems at an unrealistically low cost, so that the problem recurs in the next year or so. There is no system for choosing between different responses (regular or emergency maintenance funds), and knowledge in the DPWTs is too limited to decide whether an item is appropriate for maintenance or should be funded through separate investment. In any case, it is easier for DPWTs to gain access to maintenance funds than to investment funds.

Some of the lower categories of roads have evolved from pedestrian paths through incremental upgrading. As a result they have not benefited from proper engineering design in the alignment or slope and drainage works, and so tend to be flawed from a number of perspectives. There is a general lack of understanding among DPWT staff as to how to design slopes and respond to different materials.

Both RMS and PRoMMS, and the wider road management systems that they support, are very restricted in their coverage of off-road factors, and really only provide a response when the road has been affected. For example, a problem only features in even the non-emergency system when a landslide has occurred or a drainage system has failed. There is no provision for pre-emptive action or the assessment of factors that might lead to problems in the near future.

Since the main road inspections are undertaken as part of the annual RMS and PRoMMS input and planning exercises, it may be appropriate to boost these systems by adding items such as the following.

- A checklist of slope and drainage factors to be examined on a section-by-section basis during the annual road inspection.
- Categories to cover slope protection for both routine and periodic maintenance.
- Guidelines on vegetation management to avoid road disruption (such as from large trees falling on to the road).
- Guidelines on the setting of priorities and allocating of budgets based on the seriousness of those factors.

It might also be useful to consider the possibility of allocating part of the road management budget for pre-emptive action: for example, if a slope failure was inevitable and could be treated before it blocked the road, this might be preferable to waiting until the road is blocked and an emergency is created. However, this would probably need a rather different and more complex prioritisation system.

It is also clear that a set of manuals is needed to guide the various levels of staff in their off-road maintenance work. These will need enough background information to educate the users about the need for their work, as well as practical guidance to help them implement it.

PART E: ADDITIONAL MATERIAL

12. INVENTORY OF SLOPE INSTABILITY

The document presents information collected by the SEACAP 21 team as a means of gaining an overall assessment of the magnitude of slope instability affecting the national road network. Sampling was done by drive-over inspections of selected sections of road. The purpose of the exercise was not to develop a rigorous, comprehensive database. Instead, it was to gain an overall impression of the nature of slope hazards affecting roads, their relative size and impacts, and the relative risk they pose to road stability and the operation of the road network. An assessment was also made of any mitigation measures employed, and the residual risks remaining with these works in place.

The risk computation is given in the table below. In each case an assessment was made of the original risk posed by each hazard to the section of road involved, prior to mitigation (if any). A separate assessment was then made of the residual risk remaining through the likely performance of mitigation works, and the observed or anticipated effect on Probability (P). In some instances it was necessary to assess the potential risk of a given hazard based on residual geological and geomorphological conditions.

It must be stressed that the assessments given below are based on rapid observations and judgement. Important ground conditions and construction details may have been omitted.

Risk computation

Risk components	Assigned Relative Values			
	0	**1**	**2**	**3**
Magnitude of hazard (M)		Small (shallow and extending over up to 500m^2)	Moderate	Large (deep and extending over area of 5000m^2 or more)
Probability of hazard occurring during 20 year period (P)	Not expected to happen	Possible	Expected to happen	Definite
Value of road elements at risk (Va)		Existing slope works and side drain	Existing slope works, side drain, and up to 50% of carriageway width (one lane)	Entire carriageway and adjacent structures
Vulnerability of elements to the hazard, should it occur (Vu)	No effect	Deformation or blockage	Partial loss	Total loss
Risk = M x P x Va x Vu				

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 1E: The section of road examined is the road realignment along the south-western shoreline of the reservoir full supply level (FSL) for Nam Theun 2. The realignment took place between 1 and 2 years prior to the field visit. Earthworks are therefore recent and slopes and drainage systems are still in the process of adjusting to the new topographic condition. Chainages are from the southern end of the road realignment. The list of slide locations given below is not comprehensive, though it is anticipated that the main slide areas have been recorded. The inspection was undertaken on 11 February 2008. it should be noted that the contractor indicated that he intended to carry out further slope remedial works along this section of road, and therefore the observations below concerning total mitigation are incomplete.								
Road 1E	3+600	105°07'38" 17°43'45"	Sandstone WGIII-VI	Above Road: Slide along adverse bedding orientation in cut slope	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Cut slope has been laid back to an angle approaching dip of strata, though no other mitigation, other than clearance, has been undertaken.	NA	Above Road: M = 1 P = 2 Va = 2 Vu = 1 R = 4
Road 1E	5+300	105°07'09" 17°44'17"	Sandstone with silt/clay horizons WGIV-VI	Above Road: A slide took place in this cut slope and was probably associated with perched water in the silt/clay horizons within the sandstone sequence. It is likely that the original failure blocked the box cut.	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: Landslide material largely removed, but remaining debris has been benched.	Tension cracks developing in benched slope.	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12
Road 1E	9+500	105°05'26" 17°45'43"	Mudstone/ sandstone WG III-VI	Above Road: Cut slope failure, possibly within mudstone layer(s) within sedimentary sequence, and probably in association with perched water. Cut slope angle slightly steeper than dip of bedding.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: Landslide material largely removed, and presumably cut slope laid back.	Tension cracks continuing to develop in steeper, upper section of slope.	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8
Road 1E	14+600	105°03'35" 17°03'35'	Assumed sandstone mudstone WG II-III	Above Road: Failure in rock within benched cut and probably along adverse bedding	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Cut recently benched back, no other measures taken, though measures under consideration include, concrete screeding to prevent water ingress, bolting and toe support.	NA	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 1E	16+100	105°03'06" 17°47'24"	Sandstone mudstone WG II-III	Above Road: Rock slide in cut slope. 100m of road affected. Assume original failure blocked road.	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: Cut slope angle reduced to being slightly greater than angle of dip of strata. No other mitigation undertaken, though rock bolting is under consideration by the contractor.	Tension cracks continue to develop.	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 3: is located between Huay Xai and Na Tuey. Road upgrade construction completion was substantially complete at the time of the field inspection (16 and 17 February 2008). and the road was due to be handed over to the MPWT in March 2008. Construction contracts were let under three different financing and construction packages: Thai in the west, Chinese in the east and Lao (ADB-financed) in the centre. Deep cuttings characterise much of the Road. In the western and central sections they are benched and are laid back at shallow angles. In the east, cut angle appear to be generally steeper. Due to the ongoing construction activity on each of the three packages at the time of the field visit, chainage referencing was inconsistent along the alignment. Driving from west to east, from Huay Xai, chainages were found to increase in an easterly direction, but this then became superseded by a different set of chainages apparently originating from the eastern end. This inconsistency in chainage location reference at the time of the visit should be borne in mind when considering the locations described below. Chainages are reconciled as commencing at Na Teuy. The grid references provided should therefore be used as the definitive locator. It should also be noted that the observations given below are based on a rapid drive-through assessment of very recently formed cut slopes, and it may have been too early to have formed any representative assessment of medium to long term earthworks performance. Furthermore, observations were, in the main, made from road level with the help of a pair of binoculars to view distance tops of cutting. Clearly there is a limit to what can be identified in this way. The observations below exclude spoil dump instability and erosion problems; these were numerous and quite extensive in places at the time of the field visit.								
Road 3	2+150	101°37'46" 21°03'20"	Not known	Below Road: Road failed to ¾ width over a distance of 25m due to failed spoil/fill slope below. Seepage below is a possible contributor.	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: None, road bench reinstated (?). No other mitigation apparent.	NA	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54
Road 3	2+850	101°37'31" 21°03'23"	Not known WG VI?	Above Road: Small slump in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, clearance only (?)	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 3	9+050	101°34'43" 21°02'53"	Not known WG VI?	Above Road: Small slump in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, clearance only (?)	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 3	9+850	101°34'19" 21°02'46"	Not known	Below Road: Failure of ¾ of road width due to slide in embankment/spoil slope below, and probably continuing into natural ground. Toe erosion in stream was possible original trigger of movement.	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: Road reconstructed, no apparent other mitigation	NA	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 3	10+300 (approx)	101°34'12" 21°02'36"	Not known	Below Road: Road constructed on fill slopes along ridge line. It is apparent that these fill slopes have previously failed	Below Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36	Road edge reconstructed on mortared rip rap	Only partially successful. Standard of rip rap wall construction is poor and foundation appears to be on failing ground	Below Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36
Road 3	19+500	101°30'50" 20°59'48"	Not known	Below Road: Site of apparent road failure due to landslide (?) to river (?) below.	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: Road reconstructed on fill slope with concrete herringbone surface erosion protection structure on fill slope. Upslope drainage diverted to small culvert.	Partially successful. Appears that bulk of drainage seeps through embankment, cracking to reconstructed road surface.	Below Road: M = 2 P = 2 Va = 3 Vu = 3 R = 36
Road 3	22+200	101°29'51" 20°59'03"	Slaty phyllite	Above Road: Potential rock falls along steep foliation Below Road: Assume old slide area on river bend.	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3 Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27	Above Road: None Below Road: 4-5m high mortared masonry edge wall.	Appears successful to date, though RC wall has no weep holes	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3 Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27
Road 3	22+400	101°29'43" 20°58'59"	Not known	Below Road: Assumed previous road failure at this location. Slope failure may have been triggered by river scour below	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: 4m high RC road edge wall, apparent diversion of culvert	Appears successful to date, though RC wall has no weep holes	Below Road: M = 2 P = 1 Va = 3 Vu = 3 R = 18
Road 3	22+600	101°29'26" 20°58'56"	Slaty phyllite WG Adverse jointing	Above Road: Steep cut allows high angle wedges to daylight	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 3	45+200	101°20'11" 20°52'48"	Not known	Above Road: Small slump into side drain/adjacent road section. NB adjacent village huts at potential risk	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: 1.5m high mortared masonry wall constructed	Appears successful	Above Road: M = 1 P = 1 Va = 1 Vu = 1 R = 1
Road 3	45+900	101°19'53" 20°52'35"	Phyllite/ meta siltstone WGV (tecton-ically highly disturbed)	Above Road: Shallow failure and ravelling in benched cut slope (cut too steep for materials) Below Road: Cracks developing in road pavement indicative of embankment failure	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3 Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3 Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12
Road 3	46+100	100°19'44" 20°52'31"	Not known WG V?	Above Road: Small debris slide and flow in cut slope, probably originally into road. Below Road: Apparent failure of embankment slope with flow lobes to terrace below. Much seepage	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6 Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24	Above Road: 1.5m high masonry wall Below Road: No apparent measures taken, though patches to cracked to pavement.	Above Road: Wall apparently successful, though potential remains for falls and small slides in upper steep cut Below Road: Embankment edge still appears to be failing	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2 Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24
Road 3	64+500 (approx)	101°13'31" 20°46'38"	Not known WG IV?	Above Road: Failing rock mass forming cut slope. Original failure probably partially blocked road	Above Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36	Above Road: None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36
Road 3	100+800	101°02'52" 20°34'50"	Not known	Below Road: Failure of road edge on meander bend of river, though road located on slope above flood plain terrace, therefore river scour was not responsible	Below Road M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: Timber piles used as toe restraint against landslide heave on fp terrace below, slope reconstructed in concrete	Appears successful, though timber piles unlikely to provide much resisting force	Below Road: M = 2 P = 1 Va = 3 Vu = 3 R = 18

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 3	101+000	101°02'50" 20°34'44"	Not known	Above Road: Mudslide (mostly evacuated), blocked side drain only	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: None, probably clearance only.	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 3	122+700	100°55'58" 20°29'43"	Not known	Below Road: Embankment failure	Below Road M = 2 P = 3 Va = 2 Vu = 2 R = 24	Below Road: Construction of gabion wall on embankment slope and concrete screed to surrounding embankment slope	Poor wall construction, ravelling continuing	Below Road M = 2 P = 2 Va = 2 Vu = 2 R = 12
Road 3	139+600	100°50'53" 20°24'20"	Siltstone WG V	Above Road: Planar slope failure in cut slope plus erosion and flow into side drain	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 3	140+650	100°50'12" 20°24'02"	Phyllite/ Meta-siltstone WG IV-VI	Above Road: Debris slide in residual soil above 'rock head' in cut slope	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 3	152+300	100°45'14" 20°21'39"	Phyllite ? WG V	Above Road: Failure of upper 3 benches of cut	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	None, clearance only.	NA	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 3	153+000	100°44'50" 20°21'32"	Slaty phyllite WG III?	Above Road: Tectonically disturbed rock mass in cut undergoing deep creep into road side drain	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 3	156+700	100°43'12" 20°21'15"	Meta-siltstone with shaley horizons WG II-V	Above Road: Tectonically disturbed rock mass with shallow and localised sliding and ravelling.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 3	159+100	100°42'21" 20°21'42"	Phyllite/ Schist	Above Road: Localised failure from upper bench of cut. Flowed over cut and onto road.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 3	164+400	100°39'47" 20°21'32"	Meta-siltstone WG V	Above Road: Shallow failure in lower bench of cutting.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 3	167+600	100°38'12" 20°21'19"	Phyllite/ Meta-siltstone WG III-IV	Above Road: Incipient deep seated toppling along high angle joints or faults	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8	None	NA	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8
Road 3	169+250	100°37'46" 20°21'50"	Mudstone WG IV	Above Road: Deep box cut, local plane failures on adverse bedding, possible deeper seated rock creep along high angle wedge structures	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8	None	NA	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8
Road 3	187+120	100°31'20" 20°19'06"	Mudstone WG IV	Above Road: Adverse jointing in box cut. Benched cut. Apparent kinematic feasibility in bench risers, not in overall slope. Hence failures currently confined to individual benches	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 4 Pakvait to Sayaburi (total length approx 60km): This road was visited on 18 February 2008. Chainages from Pakvait. The road is not sealed and so therefore any settlements to the road formation are not readily apparent upon a quick drive-through. Edge failures should, however, be anticipated, due to steep slopes below the road pavement in many areas.								

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 4	19+500	102°04'32" 19°38'16"	Siltstone? WG VI	Above Road: Slump in cut slope	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 8: Ban Sok Kam (Road 13S junction) to Vietnam Border. Recent (probably completed 2006) slope stabilisation, flood protection and road reinstatement works have been constructed at a number of locations within the eastern 10km or so of this road. Neither the design nor as-built drawings for these works were available at the site of the field inspection (13 February 2008) and so the observations made below are based on visual observation and inference. Given the recent construction of these works, it is perhaps too early to judge performance. Chainages are from Ban Sok Kam.								
Road 8	43+100	104°32'41" 18°12'38"	Phyllite (?) WG IV-VI	Above Road: Erosion, shallow sliding and rock falls into side drain and adjacent carriageway	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 8	45+800 (approx)	104°34'01" 18°12'02"	Not known	Above Road: Small debris slide, side drain blocked	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None, clearance only.	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	50+750	104°36'02" 18°11'54"	Mudstone WGIV (?)	Above Road: Large slope failure from weathered zone towards top of cut, some adverse jointing. Original failure probably partially blocked road for distance of 40m	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 8	58+500	104°37'26" 18°13'02"	Not known	Above Road: Shallow debris slide in cut	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None, clearance only.	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	60+800	104°40'02" 18°14'03"	Mudstone WG IV-VI	Above Road: Shallow cut slope failure, 10-15m	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 8	61+500 (approx)	104°40'13" 18°14'13"	Mudstone (?) WG III-IV?	Above Road: Shallow cut slope failure	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 8	61+500 (approx)	104°40'13" 18°14'13"	Mudstone (?) WG III-IV?	Above Road: Shallow cut slope failure	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None, clearance only.	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 8	63+200	104°40'59" 18°14'45"	Phyllite WGIV-V	Above Road: Shallow cut slope failure with erosion	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: Wattle fence at base of cut slope to trap debris	Fence broken/not performing as intended	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	77+100	104°48'05" 18°13'23"	Phyllite WGIV-V	Above Road: Shallow cut slope failure with erosion	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: Wattle fence at base of cut slope to trap debris	Appears successful in controlling small debris volumes	Above Road: M = 1 P = 2 Va = 1 Vu = 1 R = 2
Road 8	110+700	105°02'44" 18°16'28"	Phyllite WGVI	Above Road: Minor slump and erosion	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	112+500	105°03'19" 18°17'07"	Schist/ Phyllite WGIII	Above Road: Shallow cut slope failure, 30-40m of road affected. Failure into side drain only, though original landslide may have part-blocked the road	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None, clearance only.	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	118+000	105°05'39" 18°18'31"	Granite (?)	Below Road: Slope failure below road, possibly to river below	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24	Below Road: Gabion wall and mattress/RE slope protection constructed on slope below road.	Appears intact and functioning	Below Road: M = 2 P = 2 Va = 2 Vu = 2 R = 16

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 8	118+100	105°05'39" 18°18'31"	Granite (?)	Below Road: Bend in river, failure of slope below road, possibly originally triggered by toe erosion.	Below Road: M = 2 P = 3 Va = 3 Vu = 2 R = 36	Below Road: Combined gabion toe wall, gabion mattress/RE protection and edge wall below road.	Structures and protection work appear to be currently intact	Below Road: M = 2 P = 2 Va = 3 Vu = 3 R = 24
Road 8	119+300	105°06'07" 18°18'50"	Granite (?)	Below Road: Bend in river, river scour	Below Road: M = 3 P = 3 Va = 3 Vu = 3 R = 81	Below Road: Gabion toe wall without concrete toe protection, gabion mattress/RE protection to fill slope above.	Gabion toe wall subsided due to under scour of foundation.	Below Road: M = 3 P = 2 Va = 3 Vu = 3 R = 54
Road 8	119+700	105°06'12" 18°19'01"	Granite (?) WGV	River meander bend, toe erosion by river. Shallow sliding and erosion in soil above the road.	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6 Below Road: M = 3 P = 3 Va = 3 Vu = 3 R = 81	Concrete scour protection structure, gabion toe wall and gabion mattress/RE protection to fill slope beneath the road. No action taken above road	Below road retaining and protection works appear to be functioning. Only minor erosion taking place on slope above.	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6 Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27
Road 8	124+800	105°07'45" 18°20'56"	Granite WG II-III	Above Road: Possible original wedge failure along adverse joints in cut slope.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: 4m gabion retaining wall.	Localised ground movements continue behind wall but structure appears intact	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 8	125+100	105°07'54" 18°21'04"	Granite, variable WG, above road WG V	Probable previous complete loss of road caused by failure of slope on meander bend. Toe erosion likely trigger	Above Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24 Below Road: M = 3 P = 3 Va = 3 Vu = 3 R = 81	Road presumably reconstructed at this location. Concrete toe protection at river level, 4-5m gabion toe wall above and sloping gabion apron/RE to road level above. Above road 4m gabion wall.	Evidence of flood level to top of gabion wall below road (base of sloping apron). Gabion locally broken open/infill removed by flooding but predominantly intact. Above road slope failures continue in weathered granite with sand and silt fans over top of wall caused by seepage	Above Road: M = 2 P = 2 Va = 2 Vu = 2 R = 16 Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27
Road 8	125+650	105°07'58" 18°21'19"	Granite WG iv-V	Above Road: Shallow (?) movements in cut slope	Above Road M = 1 P = 3 Va = 2 Vu = 1 R = 6	5m gabion wall	Appears successful, possibly over-designed for the scale of movement currently noted.	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2
Road 8	126+500 (approx)	105°08'08" 18°21'41"	Granite, variable WG	Original landslide probably triggered by toe erosion, leading to formation loss. Failure extended above road.	Below Road: M = 3 P = 3 Va = 3 Vu = 3 R = 81 Above Road: M = 3 P = 3 Va = 2 Vu = 1 R = 18	7-8m high gabion toe wall at river level below road with gabion mattress/RE protected fill slope to road. Road reconstructed and slope above supported by 4- 5m gabion wall over total length approx 100m.	Minor road surface displacements noted. Active movements including fresh slide scars in slope above road. Deposited (?) boulders (1-1.5m dia) at toe of gabion wall alongside river offer protection, but presumably are mobile during large floods.	Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27 Above Road: M = 3 P = 1 Va = 2 Vu = 1 R = 6
Road 8	126+700 (approx)	105°08'12" 18°21'48"	Assumed granite, variable WG	Above Road: Large area of slope failure above road.	Above Road: M = 3 P = 3 Va = 2 Vu = 1 R = 18	Above Road: 4m gabion wall supporting slope above road. Subsoil drains beneath roadside drain.	Drains functioning, though cracking and heave to road inside shoulder suggests movement continues	Above Road: M = 3 P = 2 Va = 2 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 8	126+830	105°08'13" 18°21'53"	Granite WG V and debris	Above Road: Probable debris slide, up to 3m deep in cut slope	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: 3-4m gabion cut slope retaining wall, constructed from rounded river boulders	Appears successful	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 8	127+400	105°08'24" 18°22'07"	Granite WG II-III	Below road scour potential from river Above road, ravelling, minor erosion in cut	Below road: M = 3 P = 3 Va = 3 Vu = 3 R = 81 Above road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Below road: 8m or 9m high gabion road fill RW with concrete protection to base. Above road: None	Below road: Appears stable, gabion structure partly founded on rock Above road: Limited residual effects	Below road: M = 3 P = 1 Va = 3 Vu = 3 R = 27 Above road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	128+300	105°08'45" 18°22'17"	Granite WG III	River scour on river bend, ravelling and shallow failure in jointed rock in cut slope above.	Below Road: M = 3 P = 3 Va = 3 Vu = 3 R = 81 Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Below road: Approx 6m high gabion wall supporting fill to road level Above Road: None	Below road: Appears stable, though toe protection might not be adequate Above road: Limited residual effects	Below Road: M = 3 P = 1 Va = 3 Vu = 3 R = 27 Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 8	128+600	105°08'57" 18°22'16"	Granite WG ii - III	Large deep-seated failure on bend of river, subjected to river scour.	M = 3 P = 3 Va = 3 Vu = 3 R = 81	Above road: 5m gabion RW, horizontal drains Below road: RC river scour protection, gabion toe wall and gabion protection/RE to fill slope	Appears successful, though slope movements are continuing behind gabion wall above road	M = 3 P = 1 Va = 3 V u = 3 R = 27
Road 8	128+800	105°09'00" 18°22'16"	Granite WG II	Above Road: Deep seated rockslide in cut slope. Approx 40m road length, extends approx 80m upslope	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12	Above Road: None, debris clearance only. Only other option would be large RW	OK, probable continued movement of debris into road	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 12: Thakhek to Ban Na Phao on Lao/Vietnam border (total length 146km). Road inspected on 7 April 2008. Last 90km completed in 2004 and handed over in 2005. Chainages from junction with Road 13S.								
Road 12	136+900	105°44'06" 17°37'16"	Colluvium above WG II	Above Road: 40m high x 30m wide up to 10m deep failure in colluvium above road	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18
Road 12	138+400	105°44'25" 17°37'43"	Colluvium above WG III to IV	Above Road: 20m high x 100m wide up to 5m deep failure in colluvium 4-10m above road	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18
Road 12	139+000	105°44'36" 17°37'51"	Colluvium	Above Road: 10m high x 70m wide failure above road	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: None, debris clearance only	Above Road: Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 12	139+800	105°44'49" 17°38'06"	Colluvium above WG IV-V	Above Road: 20m high x 70m wide x 7m deep failure in colluvium 10m above road	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 12	141+000	105°45'08" 17°38'30"	Colluvium above WG IV shale	Above Road: Up to 15m high x 100m wide x 5m deep failure in colluvium 3m above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 12	141+500	105°45'13" 17°38'39"	Colluvium	Above Road: 20m high x 55m wide x 5m deep failure in colluvium above road	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 12	142+600	105°45'32" 17°39'04"	Colluvium	Above Road: 20m high x 40m wide x 5m deep above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 12	143+300	105°45'37" 17°39'19"	Colluvium above WG II to III shale and Limestone	Above Road: 25m high x 25m wide x 3m deep failure 4m above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 12	143+600	105°45'39" 17°39'29"	Colluvium above WG III to IV shale	Above Road: 15m high by 15m wide up to 7m deep failure in colluvium 5m above road	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N: Na Teuy to Chinese Border. This road is posted as Road 13N.This section of road was inspected on 17 February 2008. Chainages from Na Teuy.								
Road 13N	0+100	101°38'30" 21°03'43"	Terrace Gravels over rock (type unknown) WG V	Above Road: Probable large cut slope failure	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: Slope benched. 1m masonry wall at up-chainage end	Appears successful, though erosion could become an issue on unvegetated slope	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 13N	6+900	101°38'13" 21°05'50"	Phyllite WG IV-V	Above Road: Benched cut undergoing erosion due to undermining and outflanking of concrete bench drain system. Below Road: Signs of road edge failing due to ground movement on slope below to river.	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6 Below Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6 Below Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 13N	19+000	101°38'13" 21°05'53"	Phyllite WG V-VI	Above Road: Debris slides in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: 2m high mortared masonry wall	Appears successful	Above Road: M = 1 P = 1 Va = 1 Vu = 1 R = 1

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Na Teuy to Oudomxay (total length approx 79km): This section of road does not appear to have a Road No but, by implication, it might be anticipated to be part of Road 13N. The road is apparently several decades old, and cut slopes are therefore mature and have been undisturbed for a considerable period of time. Vegetation is therefore well-established. This section of road was visited on 17 February 2008. Chainages from Na Teuy.								
Na Teuy to Oudomxay	19+100 (approx)	101°42'37'' 20°56'55''	Not known	Below Road: Edge of road lost for 15m due to failure in spoil/fill material (?) below	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	None	NA	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12
Na Teuy to Oudomxay	43+800	101°49'43'' 20°51'02''	Not known	Above Road: Cut slope failure	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: 2.5m high mortared masonry wall	Appears successful	Above Road: M = 1 P = 1 Va = 1 Vu = 1 R = 1
Na Teuy to Oudomxay	75+000	101°57'58'' 20°42'35''	Phyllite WG IV-VI Adverse jointing	Above Road: Cut slope failure	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 13N Oudomxay to Patmong (total length approx 82km): The road is apparently several decades old, and cut slopes are therefore mature and have been undisturbed for a considerable period of time. Vegetation is therefore well-established. This section of road was visited on 18 February 2008. Chainages from Oudomxay.								
Road 13N	15+600	102°01'18'' 20°36'33''	Phyllite (?)	Below Road: Slope failure below road to river below. Extends over 40m with ½ road width failed over distance of 10-15m	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: None seen, except road bench reinstatement	NA	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54
Road 13N	16+800	102°01'50'' 20°26'42''	NA	Below Road: Collapse of road edge due to apparent seepage erosion of embankment fill	NA	None	NA	NA
Road 13N	24+100	102°04'28'' 20°35'34''	Phyllite WG V-VI	Above Road: Shallow slide in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	29+750	102°06'12" 20°34'44"	Not known	Above Road: Shallow sliding and ravelling in cut slope above existing masonry wall. Apparent runoff in wet season main cause.	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: 1m high masonry wall	Insufficient to deal with extent of problem. Slide daylights above wall, and extends further upslope.	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 13N	30+600	102°06'35" 20°34'38"	Meta Siltstone WG IV-VI	Above Road: Shallow slide in cut	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	None, Slide scar revegetated naturally	NA	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 13N	33+150	102°07'57" 20o34'33"	Not known	Below Road: Masonry road edge wall collapsed due to undermining caused by erosion in river below	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	None	NA	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12
Road 13N	52+300	102°13'48" 20°33'41"	Meta Siltstone/ Phyllite WG IV-V	Above Road: Active slides and erosion in soil/weathered rock appears to cause partial blockage to road over a distance of 80m	Above Road: M = 3 P = 3 Va = 2 Vu = 1 R = 18	None, clearance		Above Road: M = 3 P = 3 Va = 2 Vu = 1 R = 18
Road 13N	53+850	102°14'25" 20°33'53"	Siltstone WG V-VI	Above Road: Small debris slide in cut slope, culvert inlet blocked and spoil dumped into stream channel downstream. Mortared masonry wall destroyed	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: Masonry breast wall	Wall destroyed by continuing failure	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	55+580	102°15'12" 20°34'13"	Siltstone? WG IV? Adverse jointing	Above Road: Shallow and localised rockslide along adverse joints in cut	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None, clearance only	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	61+000	102°17'18" 20°34'34"	Not known WG VI?	Above Road: Debris slide into side drain and road edge	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None, clearance only	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	62+900	102°17'34" 20°34'15"	Not known	Below Road: Washout of road edge due to road runoff	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	Below Road: Reinstatement by construction of masonry edge wall	Design/ construction unlikely to prove effective long-term	Below Road: M = 1 P = 2 Va = 2 Vu = 2 R = 8
Road 13N	72+700	102°20'44" 20°34'22"	Not known	Above Road: Old debris slide in cut, extends 50m or so upslope, now completely revegetated Below Road: Failure of road shoulder due to sliding/erosion to river below	Above Road: M = 1 P = 1 Va = 1 Vu = 1 R = 1 Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	None	NA	Above Road: M = 1 P = 1 Va = 1 Vu = 1 R = 1 Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12
Road 13N	80+450	102°23'43" 20°34'36"	Not known	Below Road: Road shoulder failure due to sliding/erosion to river below	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12	None	NA	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12
Road 13N Patmong to Luang Prabang (total length approx 109km): The road is apparently several decades old, and cut slopes are therefore mature and have been undisturbed for a considerable period of time. Vegetation is therefore well-established. This section of road was visited on 18 February 2008. Chainages from Patmong.								
Road 13N	30+100	102°20'49" 20°22'00"	Limestone WGVI	Above Road: Erosion and slumping in benched cut caused by lack of drainage control	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	43+050	102°25'01" 20°19'21"	Limestone WG VI	Above Road: Small debris slide in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	68+100	102°18'56" 20°10'14"	Siltstone?	Below Road: Large slope failure, possibly caused by failing spoil area. Road on embankment with culvert (1m dia – undersized for size of catchment above road). Road requires regular re-surfacing. Masonry road edge wall continuing to crack	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54	Below Road: Masonry road edge wall	Movement appears to be taking place beneath wall foundation	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54
Road 13N Luang Prabang to Km 238.2 (total length inspected 142 km): This section of road was inspected on 19 February 2008. Chainages from Vientiane.								
Road 13N	238+200	102°24'00" 19°20'49"	Unknown WG II-VI	Above Road: Retrogressing shallow landsliding and erosion in cut slope and slope above. Electricity pylon at risk from retreating back scar has since been removed.	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: Bio-engineering: including planting and masonry slope drains.	Partially successful, seepages taking place on slope, causing ongoing movement and erosion.	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12
Road 13N	239+400	102°24'40" 19°20'54"	Phyllite?	Below Road: Active failure of spoil(?) with slip scarp developed approx 1m from road shoulder. Pylons likely effected. Above Road: Recent slide in weathered rock forming benched cut slope.	Below Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36 Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident other than debris clearance, though road may have been realigned through this section in the past to avoid instability below.	NA	Below Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36 Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	242+600	102°25'27" 19°21'49"	Slaty phyllite	Below Road: Deep erosion and rock fall area below road. Road has been realigned in the past to avoid the receding back scar cliff. Approx 50m of road affected.	Road Below: M = 2 P = 3 Va = 2 Vu = 3 R = 36	Below Road: Phase 2 SEACAP 21 site Trimming and shotcreting of slope below road	Works in progress during site visit	Below Road: M = 2 P = 1 Va = 2 Vu = 3 R = 12
Road 13N	247+550	102°25'57" 19°23'16"	Unknown	Above Road: Shallow slide in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	247+750	102°25'52" 19°23'18"	Unknown	Below Road: Slope failure with back scar 2m from road shoulder. Above Road: Area of previous erosion and shallow sliding affecting road over 50m length.	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24 Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	2m high gabion toe/containment wall constructed. Slope re-establishing vegetation. No evident mitigation below road	Gabion wall probably not functioning as intended due to vegetation regrowth	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24 Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12
Road 13N	254+000	102°25'37" 19°25'23"	Meta-siltstone? WG III-IV	Below Road: Road edge failure with scour beneath culvert giving rise to failure of adjacent slopes and possibly road bench. Failed masonry edge wall	Below Road: M = 2 P = 3 Va = 2 Vu = 3 R = 36	Below Road: Phase 2 SEACAP 21 site Reconstruction/extension of masonry edge wall and channel protection	Ongoing at time of site visit	Below Road: M = 2 P = 1 Va = 2 Vu = 3 R = 12
Road 13N	257+850	102°25'12" 19°26'31"	Phyllite?	Above Road: Ravelling and shallow erosion. Recently constructed drain wall pushed over.	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	None evident, other than clearance	NA	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 13N	258+500	102°24'53" 19°26'33"	Phyllite?	Below Road: Erosion and shallow sliding on jointed rock Above Road: Erosion and shallow debris sliding	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Masonry toe/containment wall constructed in cut slope	Partially effective	Below Road: M = 1 P = 3 Va = 2 Vu = 2 R = 12 Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8
Road 13N	259+900	102°25'07" 19°26'48"	Phyllite?	Above Road: Debris slide/rock slide above road. Cut benches and slope above have failed.	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: 1.5m masonry containment wall constructed.	Wall has little if no effect on stability of main slope and limited containment potential.	Above Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	260+200-300	102°25'11'' 19°26'50''	Meta Siltstone? WGIII-IV Limestone pinnacle	Deep-seated landslide above and through road. Approx 120m or road affected.	M = 3 P = 3 Va = 3 Vu = 3 R = 81	Phase 2 SEACAP21 site Previously, approx 1m masonry toe wall constructed in cut slope. SEACAP21 works, include improvements to culvert outlet and slope monitoring	Toe wall cracked, and pushed forward due to slope failure daylighting at or beneath road surface	M = 3 P = 3 Va = 3 Vu = 3 R = 81
Road 13N	260+500	102°25'12'' 19°27'02''	Phyllite	Above Road: Failed cut slope benches above road along adverse jointing.	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: 2m gabion containment wall	Slope regained/regaining stability. Containment wall largely empty.	Above Road: M = 2 P = 2 Va = 1 Vu = 1 R = 4
Road 13N	262+900	102°25'20'' 19°27'57''	Phyllite	Below Road: Deep slope failure below road with back scar 1m from shoulder. 40m road length affected Above Road: Active debris slide with fresh striated shear surface towards top of slope. 60m length of road affected. Probably originally blocked road. It is possible that these two failures form parts of the same landslide, with the road now reinstated.	Below Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12 Above Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24	1-1.5m high masonry toe wall constructed in base of cut slope.	Active movement in cut slope taking place. Active retrogression of back scar (?) below road	Below Road: M = 2 P = 2 Va = 3 Vu = 1 R = 12 Above Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24
Road 13N	272+900	102°24'56'' 19°30'08''	Phyllite?	Above Road: Area of shallow debris sliding and erosion in cut slope. Possibly originally blocked road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: 1-2m high masonry toe/containment wall	Slope appears to be regaining stability	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 13N	272+950	102°24'56'' 19°30'09''	Phyllite WG V-VI	Above Road: Localised failure from upper portion of cut in WGVI	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	273+100	102°24’53’’ 19°30’13’’	Limestone WG NA	Above Road: Old debris slide in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	288+400	102°20’19’’ 19°33’03’’	Phyllite?	Above Road: Old debris slide in cut slope	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	289+050	102°20’18’’ 19°33’22’’	Phyllite? With limestone boulders	Failure in cut slope over road length of 50m. Likely to be associated with an possible original deeper seated failure that extended beneath road level, i.e. failure of entire slope.	Below Road: M = 2 P = 2 Va = 3 Vu = 3 R = 36 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Below Road: Not known, non observed Above Road: 1m high masonry toe wall. Slope above road revegetating and appears stable.	Below Road: No apparent distress to road Above Road: Slope above road revegetating and appears stable.	Below Road: M = 2 P = 1 Va = 3 Vu = 3 R = 18 Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 13N	297+350	102°17’29’’ 19°33’47	Phyllite?	Above Road: Shallow cut slope failure in weathered, jointed rock.	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None evident	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	299+300	102o16’40’’ 19°33’54’’	Phyllite WG V-VI Jointing adverse to stability	Below Road: Apparent slope failure/erosion originally caused partial or total road failure. Above Road (offset): Cut slope failure in weathered phyllite. Bare and potentially unstable back scar with steep lope above.	Below Road: M = 2 P = 3 Va = 3 Vu = 3 R = 54 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Below Road: Construction of RC road edge wall. Above Road: None, clearance only	Below Road: Wall construction appears to have led to successful road reinstatement Below Road: NA	Below Road: M = 2 P = 0 Va = 3 Vu = 3 R = 0 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	311+600	102°10'07" 19°04'54"	Phyllite WG IV-V Jointing adverse to stability	Above Road: Cut slope failure, probably originally partially blocked road. Some of slipped mass and back scar remains potentially unstable.	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Probably debris clearance only.	NA	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 13N	315+100	102°13'20" 19°34'44"	Phyllite?	Above Road: Cut slope failure, probably blocked road when it failed. Steep bare back scar, partly vegetated slip debris. Failure potential from back scar.	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Probably debris clearance only.	NA	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 13N	316+600	102°18'00' 19°06'56"						
Road 13N	317+900	102°12'24" 19°36'20"	Slaty phyllite WG III-IV	Landslide has caused loss of original road, probably constructed on fill embankment. 75m length of road affected.	M = 3 P = 3 Va = 3 Vu = 3 R = 81	Failed road level probably reinstated by additional filling. Phase 2 SEACAP 21 site Minor drainage improvements works not implemented at time of field visit. Slope monitoring under SEACAP21	Not known. In the long term the road formation is likely to continue to move.	M = 3 P = 3 Va = 3 Vu = 3 R = 81
Road 13N	323+800	102°11'19" 19°36'49"	Phyllite?	Above Road: Old cut slope failure, now mostly revegetated. Back scar at top of cut remains bare	Above Road: M = 2 P = 3 Va = 1 Vu = 2 R = 12	Above Road: None, though presumably original failure required clearance	NA, slope appears to have stabilised due to natural vegetation regrowth	Above Road: M = 2 P = 1 Va = 1 Vu = 2 R = 4
Road 13N	326+900	102°11'36" 19°37'42"	Phyllite	Below Road: Deformation/failure to road surface behind failed masonry edge wall over road length of 30m	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24	Below Road: None evident, it is assumed the edge wall was constructed prior to the road surface failure	NA	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24
Road 13N	329+100	102°11'39" 19°38'15"	Unknown, assume phyllite	Below Road: Apparent slow failure of entire slope below above river meander bend. Ground movement currently effects road side berm, edge retaining wall and probably pylon. 60m of roadside affected	Below Road: M = 3 P = 3 Va = 2 Vu = 2 R = 36	None evident	NA	Below Road: M = 3 P = 3 Va = 2 Vu = 2 R = 36

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	332+700	102°12'18" 19°39'08"	Phyllite WG V-VI	Above Road: Cut slope failure and failure of slope above	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: Phase 2 SEACAP 21 site earthworks, structural support and planting scheduled, but not implemented at time of site visit	Not known	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 13N	335+900	102°11'28" 19°39'39"	Phyllite WG V? Highly folded	Below Road: Road deflection/ deformation over 60m length	Below Rod: M = 2 P = 3 Va = 3 Vu = 2 R = 36	None evident	NA	Below Road: M = 2 P = 3 Va = 3 Vu = 2 R = 36
Road 13N	336+400	102°11'23" 190°39'46"	Phyllite WG V Folded and closely jointed	Below Road: Slope failure to river below caused deformation to road pavement over 35m length	Below Road: M = 2 P = 3 Va = 3 Vu = 2 R = 36	Below Road: Phase 2 SEACAP 21 site Road has been resurfaced by DPWT and slope monitored under SEACAP21	Surfacing appears adequate, long term movement of slope anticipated as mitigation not undertaken	Below Road: M = 2 P = 3 Va = 3 Vu = 2 R = 36
Road 13N	337+700		Not known, assumed phyllite	Below Road: Cracking to road edge due to failure of spoil wedge on slope below. Pylon probably affected Above Road: Shallow debris sliding, probably completely/partially blocked road	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Phase 1 SEACAP 21 site Below Road: Planting on spoil slope and cut off drain alongside outside road edge Above Road: Planting to cut slope	Below Road: Cracking continuing to spoil slope adjacent to road shoulder and drain cracked. Above Road: Majority of planting appears to have died due to dry soil	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24 Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 13N	339+900	102°12'0" 19°40'36"	Phyllite WG IV-V	Above Road: Cut slope failure and erosion, in part caused by seepage	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Phase 2 SEACAP 21 site. Drainage, earthworks, structural support and planting scheduled, but not implemented at time of site visit	Not known	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2
Road 13N	355+600 (approx)	102°11'38" 19°44'22"	Not known, assumed phyllite	Below Road: Deformation to outside carriageway for 50m. Slope failure below.	Below Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Below Road: Gabion road edge wall.	Assumed that failure surface passes beneath gabion wall foundation	Below Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 13N	357+100	102°11'25" 19°44'38"	Not known, assumed phyllite	Below Road: Road shoulder failed for approx 40m due to slope failure in spoil/fill below. Possible older failure extending above road, i.e failure below might be reactivation of pre-existing slide	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24	None	NA	Below Road: M = 2 P = 3 Va = 2 Vu = 2 R = 24
Road 13N	359+800 (approx)	102°11'19" 19°45'14"	Phyllite WG IV-V	Above Road: Rockslide in cut, probably half-blocked road.	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	None, clearance only	NA	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 13N	363+500	102°10'42" 19°46'50"	Slaty phyllite WG IV-V	Above Road: Debris slide in cut slope	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: JICA experimental bio-engineering site. Benches slope, drainage, wire netting, wattle fences, planting, gabion toe wall.	Mostly successful	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 13N	373+500	102°11'18" 19°50'47"	Siltstone? WGVI	Above Road: Soil fall into side drain	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 13N	375+500	102°10'30" 19°51'09"	Siltstone? WG IV-VI	Above Road: Debris slide in cut slope	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: EU experimental bio-engineering site. Mortared masonry catch wall, slope benching and planting	Partially successful	Above Road: M = 2 P = 2 Va = 2 Vu = 1 R = 8
Road 13N	380+100	102°07'55" 19°51'23"	Not known WG VI?	Above Road: Old small debris slide in cut slope, now mostly vegetated	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	None	NA	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 18b: **Attapeu to Lao/Vietnam border**. (total length approx 120km). Road inspected on 8 April 2008. Road completed in 2006 and handed over in 2007. Chainages from Attapeu.								
Road 18b	49+000	107°11'45" 14°50'10"	WG-IV	Above Road: 30m high x 10m and 30m wide surface ravelling	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 18b	49+200		WG-IV	Above Road: 40m high a 100m wide surface ravelling	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	49+700		WG II-V	Above Road: 40m high a 100m wide surface ravelling	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6
Road 18b	50+300	107°12'20" 14°49'54"	WG III-IV	Above Road: 2 x 10m high x 40m wide x max 2m deep failure 30m above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	67+800		WG IV-V	Above Road: Deep erosion gullies in 15m high slope above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Gabion containing wall 3m high	Appears intact and functioning	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2
Road 18b	71+200	107°21'20" 14°49'57"	Granite WG V-VI	Above Road: Deep erosion gullies in 10m high slope above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Gabion containing wall 3m high x 20m long	Appears intact and functioning	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2
Road 18b	71+300		Granite WG V-VI	Above Road: Deep erosion gullies in 15m high slope above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: Gabion containing wall 4m high x 70m long	Appears intact and functioning	Above Road: M = 1 P = 1 Va = 2 Vu = 1 R = 2

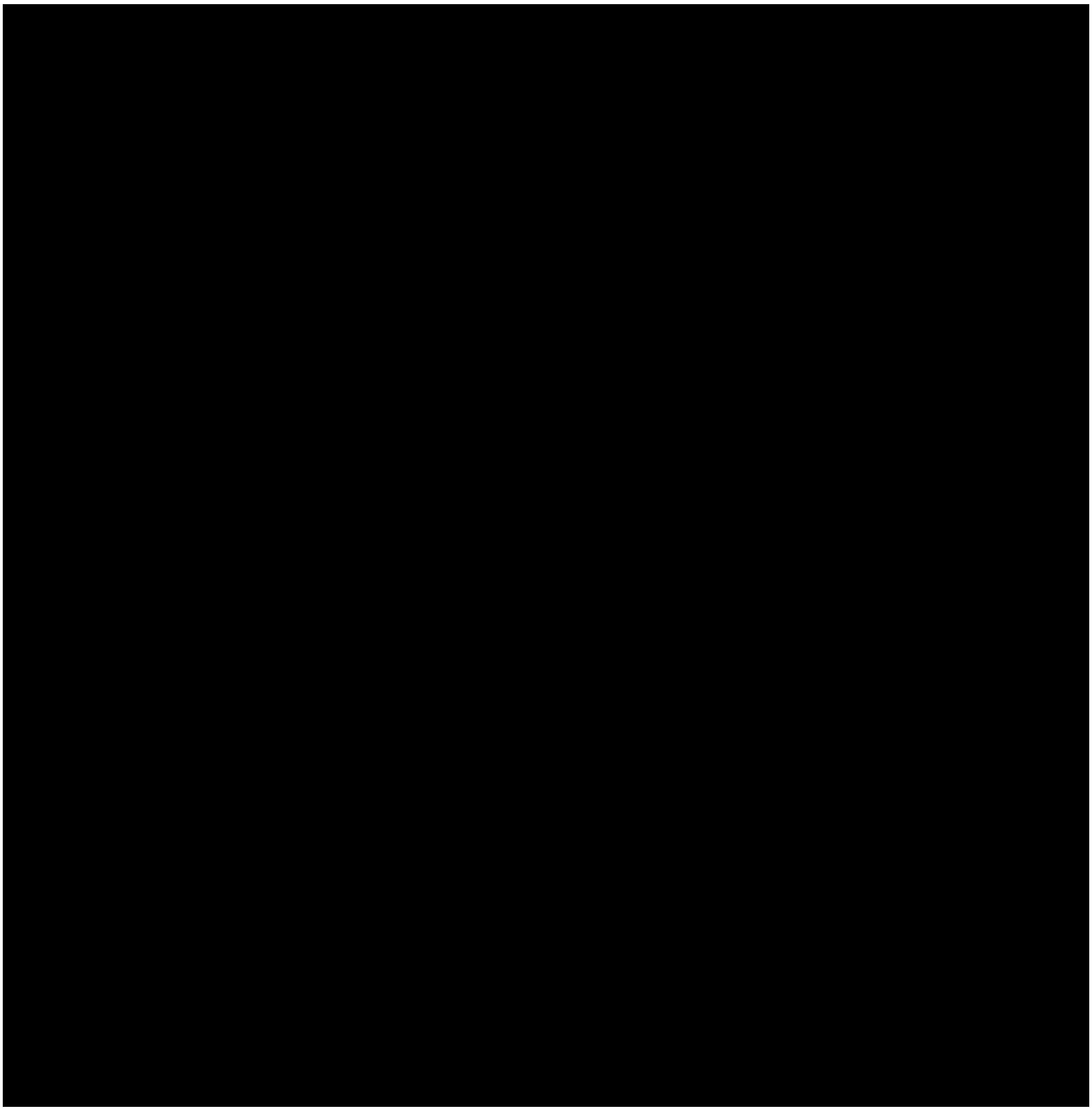
Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 18b	72+200	107°21'27" 14°49'37"	Granite WG II-V	Above Road: 30m high x 10m wide x 2m deep rock slide above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 18b	75+700	107°22'31" 14°48'51"	WG III-V	Above Road: 40m high x 30m wide x 3m deep erosion above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	76+200			Above Road: Erosion gulley above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 18b	76+400		WG III-IV	Above Road: 2x 10m high x 5m wide x 3m deep erosion above road	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 2 Va = 1 Vu = 1 R = 2
Road 18b	77+500		WG III-IV	Above Road: 3 x 5m high x 10m wide x up to 2m deep erosion above road	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 18b	78+200			Above Road: 30m high x 20m wide x 10m deep erosion gulley above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: Gabion containing wall 4m high x 50m long	Appears intact and functioning	Above Road: M = 2 P = 1 Va = 2 Vu = 1 R = 4
Road 18b	81+000			Above Road: 40m high x 50m wide x 3m deep erosion above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 18b	81+100	107°24'13" 14°48'30"	WG II-IV	Above Road: 40m high x 50m wide x up to 3m deep erosion above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	81+800		WG III-V	Above Road: 50m high x 80m wide x up to 5m deep failure/erosion above road	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18
Road 18b	82+100			Above Road: Localised failures in high cut slopes above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 18b	91+700	107°26'42" 14°46'50"	WG II-V	Above Road: 60m high x 100m wide a 2m deep mainly erosion above road	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27
Road 18b	93+700	107°27'07" 14°46'19"	WG II-V	Above Road: 20m high x 70m wide x 2m deep erosion and gulleying above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	96+000	107°27'37" 14°45'34"	WG II-V	Above Road: 120m high x 150m wide x up to 5m deep failure above road that occurred in 2006	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27
Road 18b	97+200		WG III-IV	Above Road: 25m high x 100m wide x up to 2m deep erosion above road	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 1 Vu = 1 R = 6

Road	Km	Grid Ref (E/N)	Geology	Hazard Type	Risk (without mitigation) R = M x P x Va x Vu	Measures Taken	Degree of Success/ Residual Effects	Risk (with mitigation, if undertaken) R = M x P x Va x Vu
Road 18b	105+500	107°30'58" 14°42'37"	WG III-VI	Above Road: 15m high x 120m wide erosion up to 5m deep above road	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 2 P = 3 Va = 2 Vu = 1 R = 12
Road 18b	108+500		WG III-V	Above Road: 20m high x 20m wide x up to 4m erosion above road	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 2 Vu = 1 R = 6
Road 18b	108+800		WG IV-V	Above Road: 20m high x 20m wide x up to 2m surface erosion above road	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 1 P = 3 Va = 1 Vu = 1 R = 3
Road 18b	109+700	107°32'37" 14°41'55"	WG II-V	Above Road: 90m high x 50m wide x 3m deep rock and soil slide above road	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18	Above Road: None, debris clearance only	Will continue to fail in wet season	Above Road: M = 2 P = 3 Va = 3 Vu = 1 R = 18
Road 18b	110+300	107°32'48" 14°42'05"	WG III-V	Above Road: 100m high x 60m wide up to 10m deep erosion gullying above road	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27	Above Road: None, debris clearance only	Will continue to erode in wet season	Above Road: M = 3 P = 3 Va = 3 Vu = 1 R = 27

13. UNIT COSTS FOR ENGINEERING WORKS

[redacted]



14. ENGINEERING RESPONSE TO SLOPE INSTABILITY

The SEACAP 21 project that is conducting slope stabilisation trials on two National Roads will produce the following key engineering guidelines in September 2008:

- Technical specifications for slope stabilisation and protection; and
- A slope management manual for design guidance.

It would therefore be premature to produce drafts of these documents only a few months before they are finalised. However, the Consultant is required to describe appropriate engineering response mechanisms as part of this study. The procedure described below is a standard way of assessing the response to a slope failure. It describes the way in which landslides should be assessed in order to determine the seriousness of a failure. Note, however, that this is only a basic outline of the full procedures that will be contained in the SEACAP 21 slope management manual.

Procedure for the mapping of large and complex landslides

Procedural steps		**Action**
Stage 1	Initial observations of the geomorphology. Look at the general locality and situation of the site: • make a note of the exact location so that you can direct others to the site if necessary; • see if it is in a part of the landscape where instability would be expected; • see if the joint orientation of the rocks, outcropping on the hillside around the site, indicate that the cause of the failure may be due to rock structure, either as planes of weakness or movement of water along fractures; • look at other sites in the area: they may have a similar geomorphic situation and a similar life progression.	**Observe**
Stage 2	Sketch the site from the road or other good observation point	
(a)	Draw the main features: • concentrate on getting the general proportions correct; • estimate the length from top to bottom: record this on the drawing; • estimate the width across the base: record this; • sometimes the landslide may be very complex, and some additional sub-drawings may help.	**Draw**
(b)	Look for the landslide zones: • scar; • transport; • debris. Note that you cannot yet see whether there is a zone of cracking above the scar. You do not have to record these zones on the drawing, but the completed drawing should be sufficiently well illustrated and labelled to let another person recognise which zones are present and where they are.	**Draw**
(c)	Examine the material forming the original hill slope: • debris; • soft rock; • hard rock; • alternating hard and soft rocks. All of these could be present on one landslide. The drawing should show where they are. You will have to check your classes during the site walkover (Stage 3b).	**Describe and draw**
(d)	Sketch a slope profile of the site from top to bottom. Angles do not have to be precise, but should indicate relative steepness. It can be augmented with more detail (e.g. with slope measurements) as you walk up the slide. Note that slopes >35° can be unstable unless composed of solid rock.	**Draw**
(e)	Sketch the surface water drainage: • streams; • any springs that may be visible from where you are standing.	**Draw**
(f)	Sketch areas of rock outcrop.	**Draw**
(g)	Landmarks: note any obvious landmarks on the site, such as prominent trees. This will help you to keep your bearings as you walk over and around the site.	**Draw**

Procedural steps		Action
Stage 3	Walkover survey	
(a)	Walk up the centre of the slide to the crown (head of scar). Measure the angles of major slope units. If the slope is too steep or dangerous, walk around the edge, looking into the scar.	**Measure**
(b)	Rock: visit each rock outcrop. Measure any relevant rock planes or observe how the planes relate to the slope and failure planes. Make sure that the rocks observed are true outcrops (attached to solid rock beneath) and not simply large boulders partly buried on the slope. Check the weathering grade: • hard rock is from weathering grades 1 to 4 and often rings when struck with a hammer); • soft rock is in weathering grade 5 or greater, and gives a dull thud when struck with a hammer). Note the: • uniformity or layering (bedding) of the rock units; • degree of weathering (hardness and discoloration of minerals) of the rocks; • degree of fracturing/jointing, especially any open fractures/joints; • signs of water movement along fractures.	**Measure and describe**
(c)	Debris and slope: indicate the area of the slide that is occupied by debris: • location and extent of landslide debris; • composition of debris; • wetness of debris; • depth of debris / depth of failure plane; • location, orientation and size of any cracks in the debris or on the slope; • any back-tilted slope, where water may collect (if this is present, it indicates a deep-seated circular failure – a shear failure); • tilted trees: these can indicate subsiding ground; • disrupted engineering structures, e.g. masonry surface drains; • points of ground water seepage.	**Describe and draw**
(d)	Margins and top. Look for the following. • Cracks in the ground: cracks are most frequent above the head of a slide, but they often occur also around the sides. The presence of cracks shows that the ground is under tension and that it will probably fail, and soon. Note the location, dimensions and orientation of the cracks. This information tells you where, and in which direction, the ground is under tension. The area of cracking tells you the area over which failure is taking place; • Streams, springs, irrigation channels or drainage structures, especially masonry drainage ditches. These features may be sending water into the slide. They may either have caused it in the first place, or they may be contributing to further failure. Irrigation channels and masonry drainage ditches should be inspected closely for any signs of cracking and leakage; • Irregular topography, not due to rock outcrops. This may indicate the presence of an old landslide, in which case you will have to survey the whole of this, too. Continue walking up the slope above the landslide until there is no further evidence of instability. This may mean walking at least fifty metres higher than the landslide scar, and much further if necessary.	**Draw**
(e)	Base of the slide: describe the features and ground conditions at the base. Possibilities are as follows. • Intact road. Instability is from above only. The road may be buried but the road itself is not disrupted by the slide plane. Note: if the road is disturbed, the road cannot be at the base and the slope condition at the base must come under one of the three categories below. • Stable, undisturbed hill slope. • Unstable hill slope. Cracked ground, landslide or topography that collects water. • Stream, with a possible risk of bank erosion and undercutting of slope.	**Describe**

<table>
<tr><th colspan="2">Procedural steps</th><th>Action</th></tr>
<tr><td>Stage 4</td><td>General assessment</td><td></td></tr>
<tr><td>(a)</td><td>Causes and mechanisms of instability. Based on your observations, assess whether any part of the failure is due to the following causes. Mark them on your plan of the site.
Surface water
• Erosion, or soaking of surface to cause shallow sliding.
• Effects of water infiltrating from surface. Causes shallow failures.
Ground water
• Ground water causes increased pore water pressure at depth.
• Failure plane is often deeper than in surface water failure.
Weathering
• Rock shear strength is reduced by weathering. Rock strength is reduced as constituent minerals are broken down into weathering products and clay minerals. Physical bonds between rock constituents are weakened or broken. The rock can fail along weakened fracture planes or through its body (mass).
Undercutting
• Slope is undercut by a flowing stream or by the opening up of a road cutting.
• Incision (downcutting) or lateral scour by streams is a major cause of slope failure. The initial failure can work rapidly up slope.
Addition of weight
• Weight added usually by landslide debris from above or by the dumping of spoil, or the construction of a road fill.</td><td>Describe</td></tr>
<tr><td>(b)</td><td>History and life progression of slide. Assess the likely evolution of the slide from its current condition into the future. Possibilities are as follows.
• Stable slope formed, or will stabilise naturally
• Single failure to stable rock plane or stable slope configuration. This is a relatively rare situation.
• Further movement is expected, by a less serious mechanism. ‘Less serious mechanism’ means a movement at a depth shallower than that of the original failure. This means that the instability is going through post-slide adjustment.
• Repeated movement expected, by the initial mechanism or another equally serious.
• Further movement is expected, by a more serious mechanism. ‘More serious mechanism’ means a movement at a greater depth than that involved in the original failure, or a mass movement involving a different cause or mechanism.</td><td>Describe</td></tr>
<tr><td>(c)</td><td>Severity of instability
Fill in the Check List for Assessing Severity of Slope Instability (see below).
This does not quantify the severity (it is still impossible to do so in a way which permits meaningful comparisons) but allows you to assess the severity rapidly. On the check list, the criteria in each category get progressively larger, more difficult and harder to rectify. Therefore in assessing severity, you should look at how far down each list you have ticked each of the twelve categories.</td><td>Check list</td></tr>
</table>

Procedural steps		**Action**
Stage 5 Determination of site treatment		
You should now have as much information as you are able to obtain from a straightforward site investigation without specialist advice and equipment.		**Refer to diagnostic table below**
Question	**Functional implication**	**Action if the answer is "yes"**
Is the site subject to a deep-seated (several metres depth and usually failing through rock) shear or rotational failure?	Major reinforcing, anchoring or physical support required.	If the failure plane can be identified, use retaining walls to support the toe. Alternatively, it may be possible to remove weight from higher up the slope by debris removal/heavy trimming.
Is the slope very long (greater than about 30 metres), steep and in danger of a mass failure?	Reinforcing or physical support is required. Armouring is also required.	If suitable foundations are available, use retaining walls to break the slope into smaller, more stable lengths.
Is the foot of the slope undermined, threatening the whole slope above?	Strong physical support is required.	Consider the necessity of building revetment, toe or prop walls.
Is there a distinct overhang or are there large boulders poorly supported by a soft, eroding band?	Localised physical support or anchoring are required.	Consider prop walls or dentition work to support the overhang.
Does the slope have a rough surface; or is it covered in loose debris; or is it a fractured rocky slope; or does it have any very steep or overhanging sections, however small?	Armouring is required, but only after the slope has been altered to stop it shedding loose material.	Trim the slope as far as possible to attain a smooth, clean surface with a straight profile in cross-section.
Is there water seepage, a spring or groundwater on the site, or a danger of mass slumping after heavy rain?	Deep drainage is required.	Consider the advisability of a surface or sub-surface drainage system, depending on site conditions.
Is the slope made up of poorly drained material, with a high clay content?	Techniques used on this sort of material must be designed to drain rather than accumulate moisture.	There is a danger of shallow slumping. Investigate the need for a surface or sub-surface drainage system, depending on site conditions.
Is the site a major gully, subject to occasional erosive torrents of water?	Major drainage is already present; heavy armouring is required.	Use masonry check dams to reduce the scouring effect.
Stage 6 Implementation of site treatment		
It should now be possible to move to the detailed survey of the site, so that you can assess the exact position and quantities of the structures that you require. These can then be designed on the basis of the national standards, and the works tendered and implemented in the usual ways. It is recommended that all significant failures are examined by an appropriately qualified and experienced engineering geologist before stabilisation measures are scheduled and designed.		**Refer to standard engineering design drawings**

Check list for assessing severity of slope instability

Within each section of this check list, the conditions are described in order of increasing severity. A site that can be described by the first category in each section is relatively mild and straightforward to stabilise. A site that is described by the last category in each section is a very severe problem, often requiring large-scale civil engineering works to repair.

Road: .... **Chainage:** .... **Observer:** .... **Date:** ....

1 LOCATION OF SLIDE
Off road alignment but within MPWT responsibility
Above road - any distance
Below road - any distance
Between roads, *i.e.* above one road and below another
Through road (slide is above and below road)

2 TYPE OF SLOPE AFFECTED
Road cutting but not hill slope
Hill slope but not road cutting
Road cutting plus hill slope
Embankment, fill or spoil slope

3 SLOPE CONDITIONS ABOVE SLIDE (above road, if road is at top of slide)
Crest of ridge, or gentle slope (less than 35°)
Stable, undisturbed hill slope
Unstable hill slope. Cracked ground, another landslide or topography that collects water
Cut-off drain or take-out drain

4 SLOPE CONDITIONS BELOW SLIDE (or below road, if road is at base)
Stable, undisturbed hill slope
Intact road at base of slide (road may be buried, but if it is disturbed, road is **not** at base)
Unstable hill slope. Cracks, landslide or topography collecting water
Stream

5 GENERAL TYPE OF FAILURE
Erosion, rilling or gullying up to 2 m deep
Gully more than 2 m deep
Mass movement (slide, flow or fall)

6 MATERIAL FORMING ORIGINAL (FAILED) SLOPE
Debris, colluvium or alluvium
Soft rock (weathering grade 5 or equivalent)
Hard rock (weathering grades 1 - 4)
Alternating hard and soft rocks

7 FAILURE MECHANISM
Erosion (rill, gully or pipe)
Plane failure in rock (slide, fall)
Collapse (fall with disintegration)
Flow or shear failure (slump or slide)
Undermining

8 CAUSE OF FAILURE
Surface water. Erosion, or soaking of surface: shallow slide/flow
Ground water, causing increased pore water pressure at depth
Addition of spoil or landslide debris
Weathering
Undercutting of slope by stream or road cutting

9 DEPTH OF FAILURE

Less than			25	mm	Erosion
	25	-	100	mm	}
	100	-	250	mm	} Slide, slump,
	250	-	1000	mm	} flow or fall
More than			1000	mm	}

10 LENGTH OF FAILURE (top to bottom)

Up to	15			m
	15	-	75	m
	75	-	150	m
More than			150	m

11 HISTORY OF SLIDE
Not moved within the last 5 years
Moved within the last 5 years but not this year
Moved this year for the first time
Moves every year by initial mechanism - diminishing
Moves every year by initial mechanism - constant or getting worse

12 LIFE PROGRESSION OF SLIDE
Stable slope formed, or will stabilise naturally
Further movement expected, by less serious mechanism (post-slide adjustment)
Repeated movement expected, by initial mechanism or another equally serious

NB the above checklist is designed principally with bio-engineering measures in mind. Large and deep seated landslides will require review by a suitably qualified and experienced engineering geologist, river bank erosion will require review by a suitably qualified and experienced river engineer.

15 LIST OF RAINFALL STATIONS AND THEIR AVAILABLE DATA

No	Province	District	Station Name	Start Year	Available Data	Missing Data
I	Vientiane Capital					
1		Meuang Sikhottabong	Vientiane Cap	1951	1951-2006	
2		Meuang Saythany	Tha Ngone	1965	1965-2006	
3		Meuangng Saythany	Veunkham	1990	1990-2006	
4		Meuang Pakngum	Nasone	1966	1966-1976;1979;1982;1991-2006	1977-1978;1980-1981;1983-1990
5		Meuang Saythany	Naphok	1997	1997-2006	
II	Phongsaly					
1		Meuang Phongsaly	Phongsaly	1988	1988-2006	
III	Bokeo					
1		Meuang Huayxay	Meuang Huayxay	1996	1996-2006	
IV	Luangnamtha					
1		Meuang Luangnamtha	Luangnamtha	1993	1993-2006	
V	Oudomxai					
1		Meuang Xai	Oudomxai	1990	1990-2006	
VI	Luangprabang					
1		Meuang LuangPrabang	LuangPrabang	1950	1950-2006	
2		Meuang LuangPrabang	Senkhalok	1971	1971-1975;1988-2006	
3		Meuang Xiengngeun	Xiengngeune	1992	1992-2006	
4		Meuang Pakseng	Pakseng	1992	1992-1998;2000-2005	
5		Meuang Ngoy	Meuang Ngoy	1992	1992-1993;1995-2006	
6		Meuang Nane	Meuang Nane	1993	1993-2006	
7		Meuang Phonxai	Meuang Phonxai	1990	1990-2006	
8		Meuang Nam Bak	Nam Bak	1987	1987-2006	
9		Meuang Viengkham	Ban Xe	1991	1991-2004	
11		Meuang Phoukhoun	Phoukhoun	1996	1996-2006	
VII	Xiengkhouang					
1		Meuang Pek	Thonghaihinh	1982	1982-2006	
2		Meuang Kham	Meuang Kham	1999	1999-2006	
VIII	Houaphanh					
1		Meuang Xamneua	Xamneua	1998	1998-2006	

No	Province	District	Station Name	Start Year	Available Data	Missing Data
2		Meuang Viengsay	Viengsay	1984	1984-1987;1989-2006	
IX	Xayabouly					
1		Meuang Xayabouly	Xayabouly	1971	1971-2006	
X	Vientiane					
1		Meuang Sanakham	Sanakham	1993	1993;1995-2006	
2		Meuang Kasy	Meuang Kasy	1969	1969-1976;1988-2006	
3		Meuang Vangvieng	Phatang	1994	1994-2002;2004-2006	
4		Meuang Vangvieng	Vangvieng	1969	1969-1970;1973-1985;1987-2006	
5		Meuang Hinheup	Hinheup	1968	1968-1976;1982;1987-2006	
6		Meuang Phonhong	Nalongkhoun	1971	1971-2006	
7		Meuang Thoulakom	Pakkhanhoung	1965	1965-1968;1970-1977;1990-2006	
8		Meuang Thoulakom	Napheng	1971	1971-2006	
9		Meuang Phoun	Naluang	1987	1987-2006	
10			Thalat	1980	1980;1982;1985;1987-1989;1995-2006	
XI	Borikhamxai					
1		Meuang Thaphabat	Pakthouay	1972	1972-1974;1991-2006	
2		Meuang Paksane	Paksane	1965	1965-1980;1983-2006	
3		Meuang Borikhan	Meuang Mai	1978	1978-1980;1985;1988-2006	
4		Meuang Borikhan	Meuang Kao	1978	1978-1979;1988-2006	
5		Meuang Khamkeut	Napai	1988	1988-2006	
6		Meuang Khamkeut	Kengkouang	1991	1991-2006	
7		Meuang Pakcading	Phonesy	1985	1985-1987;1990-1994;1999-2006	
XII	Thakhek					
1		Meuang Thakhek	Thakhek	1987	1987-2006	
2		Meuang Mahaxay	Mahaxay	1991	1991-2006	
3		Meuang Nakai	Signo	1991	1991-2006	
XIII	Savannakhet					
1		Meuang Savannakhet	Savannakhet	1971	1971-2006	
2		Meuang Outhoumphone	Seno	1951	1951-1956;1958-2006	
3		Meuang Phalane	Phalane	1993	1993-1994;1996-1998;2000-2006	
4		Meuang Phine	Meuang Phine	1988	1988-2006	

No	Province	District	Station Name	Start Year	Available Data	Missing Data
5		Meuang Atsaphone	Nakoutchan	1993	1993-2006	
6		Meuang Champhone	Laosoulinha	1993	1993-2001	
7		Meuang Champhone	Kengkok	1966	1966;1988-2006	
8		Meuang Sonbouly	Tangway			
9		Meuang Songkhone	Lahanam	1993	1993-2006	
10		Meuang Songkhone	Xebangnouane	1988	1988-2006	
11		Meuang Thapangthong	Thapangthong	1990	1990-2006	
12		Meuang Paksong	Songkhone	1988	1988-2000;2003;2004;2006	
XIV	Saravanh					
1		Meuang Saravanh	Saravanh	1981	1981-1984;1987-2006	
2		Meuang Khongsedone	Kongsedone	1964	1964-1972;1979;1983;1988-2006	
3		Meuang Lamam	Laongam	1991	1991-2006	
XV	Champasack					
1		Meuang Pakse	Pakse	1970	1970-2006	
2		Meuang Sanasomboun	Selabam	1988	1988-2006	
3		Meuang Batieng	Batieng	1990	1990-2006	
4		Meuang Paksong	Paksong	1992	1992-2006	
5		Meuang Paksong	Nikhom 34	1990	1990-2006	
6		Muong Paksong	Nonghine	1990	1990-2006	
7		Meuang Paksong	Phonthong	1990	1990-2006	
8		Meuang Champasack	Champasack	1979	1979-2006	
9		Meuang Pathoumphone	Pathoumphone	1979	1979-1984;1986-1987;1990-2006	
10		Meuang Soukhoumma	Soukhoumma	1981	1981-2006	
11		Meuang Mounlapamok	Mounlapamok	1965	1965-1969;1979-1987;1989-2001;2003-2006	
XVI	Sekong					
1		Meuang Xekong	Xekong	1992	1992-2006	
XVII	Attapeu					
1		Meuang Samakhyxay	Attapeu	1988	1988-2006	

Source: Department of Meteorology

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