LAO PEOPLE'S DEMOCRATIC REPUBLIC
PEACE INDEPENDENCE DEMOCRACY UNITY PROSPERITY

MPWT - SEACAP 21 - DFID

SLOPE STABILISATION TRIALS ON ROUTE 13N KASI – PHOU KHOUN – LUANG PRABANG AND ROUTE 7 PHOU KHOUN – LUANG PRABANG/XIENG KHUANG BORDER

END OF PROJECT REPORT

SUBMITTED BY

Scott Wilson

in association with

ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ
LAO CONSULTING GROUP

November 2008

SEACAP 21 Slope Stabilisation Trials

END OF PROJECT REPORT

CONTENTS

LIST OF ABBREVIATIONS

DCP	Dynamic Cone Penetration test
DFID	Department for International Development
DOR	Department of Roads
DPWT	Department of Public Works and Transport
LCG	Lao Consulting Group
LHS	Left Hand Side (of road, looking up-chainage)
LRD	Local Roads Division
MPWT	Ministry of Public Works and Transport
MOU	Memorandum of Understanding
OPWT	Office of Public Works and Transport
PBMC	Performance Based Maintenance Contract
PRoMMS	Provincial Road Maintenance Management System
PTD	Planning and Technical Division
RAD	Road Administration Division
RMS	Road Management System
RHS	Right Hand Side (of road, looking up-chainage)
SEACAP	South East Asia Community Access Project
SPT	Standard Penetration Test
TOR	Terms of Reference
WB	World Bank

SUMMARY

This is the End of Project Report for the slope stabilisation trials carried out on roads 13N and 7 in the hilly areas of northern Lao PDR. SEACAP 21/001 comprised four overlapping modules:

Module 1: Project Planning and Initiation
Module 2: Representative Data Capture
Module 3: Data Interpretation
Module 4: Information Dissemination and Training

Regular progress reports, plus separate reports on all of the modules, give considerable detail of the activities undertaken and results generated by the project. This report summarises the whole of the original project. It does not cover additional work under SEACAP 21/002 (Feasibility Study for a National Programme to Manage Slope Stability) or SEACAP 21/003 (Mainstreaming Slope Stability Management into the National University of Lao courses and the MPWT), since those are, or will be comprehensively reported elsewhere.

In Module 1, data were collected to inform the project, appropriate sites were selected and assessed in detail, and a series of slope stabilisation trials were designed. The trials were undertaken in two phases. In the first year (2007), three landslides were addressed that had mainly shallow failures and required slope protection that could be achieved predominantly using bio-engineering works. In the second year (2008), thirteen further sites were addressed that had significant mass movements and primarily required geotechnical engineering structures to achieve stabilisation. Many of these were first subjected to ground investigations as part of Module 1.

Module 2 involved the supervision of the trials, and their monitoring to collect the data required to assess performance. Construction was undertaken by contractors selected by the Ministry of Public Works and Transport, under funding from the World Bank through the Road Maintenance Project. There were some shortcomings in terms of poor work quality and late implementation, but in general these were overcome. Investigations of community-level resource use and decision-making were also conducted as part of this module.

In Module 3, the information collected in the course of the first two modules was assessed and interpretations made of the results achieved. The short duration of the project meant that it was not possible to derive fully comprehensive data, but the appraisal makes allowance for this and clearly defines the limits of knowledge on slope instability and the environmental factors that cause it. It also highlights the ways in which road sector management addresses slope instability.

Module 4 covered information dissemination and training. This was run concurrently with the other work, and consisted of the implementation of a strategy to disseminate knowledge and information on a range of slope stability issues, as and when it was appropriate to do so. This was achieved through a number of separate events, both formal in workshops and informal in the field, and published articles and documents.

This report also lists the outcomes of the research, and summarises the knowledge that was generated to enhance the management of roadside slopes. The project has clearly made a significant contribution to the understanding of slope instability in the Lao PDR, and the remedial options that may be used to resolve it. It is now possible to provide detailed guidance on the stabilisation and protection of slopes in the hilly parts of Laos, and the project has done this through its most comprehensive outputs: a slope manual and a site handbook. However, there are still gaps in this knowledge, and the final part of the report gives consideration to further research that would generate the data necessary to fill these gaps. Some of these are strategic, in that they would be intended to minimise the occurrence of instability on roadside slopes, and others are technical, intended to address a range of specific gaps in knowledge.

GENERAL OVERVIEW

There are three sub-projects within SEACAP 21, namely:

- SEACAP 21/001 'Local resource solution to problematic rural road access in Lao PDR, Slope Stabilisation Trials on Route 13 North and Route 7 in Lao PDR'.
- SEACAP 21/002 'Feasibility Study for a National Programme to manage slope stability'.
- SEACAP 21/003 'Mainstreaming Slope Stability Management into the National University of Lao courses and the MPWT'.

This report is only concerned with SEACAP 21/001 which commenced in October 2006 and was completed in September 2008.

SEACAP 21/001 comprised four overlapping modules:

Module 1: Project Planning and Initiation
Module 2: Representative Data Capture
Module 3: Data Interpretation
Module 4: Information Dissemination and Training

In accordance with the Terms of Reference (TOR), 'the consultant shall submit an End of Project Report that takes on board all the results of the research as well as the outcome of the information dissemination activities of Module 4. This End of Project Report will also contain a draft Terms of Reference for Phase 2 of this research'. Accordingly, this report will only make brief mention of the Modules (for which comprehensive individual Module Reports have already been issued), but will discuss in more detail the outcome of the research and information dissemination activities. It will also discuss a draft TOR for follow-on research activities.

The original objective of the research, again to quote the TOR, 'is to extend the present methodologies for the construction of rural access roads used locally, and in SE Asia generally, to cover problems relating to land-slips on the mountainous roads in Lao PDR. These rural roads are often impassable during the rainy season due to land-slips over relatively long stretches. This study aims at identifying cost-effective community-based methods of improving all-year access to the rural poor through low-cost local resource-based engineering techniques to reduce/eliminate land-slips'.

From the outset it was clear that Road 13 North could not be described as a rural access road, since it forms part of the main national highway running the entire length of the country. Nonetheless, the landslip problems experienced on Road 13 North are identical to those affecting rural roads, and the low-cost local resource-based stabilising methods adopted by the project are applicable to both. In addition it soon became clear that the contractual framework for constructing the stabilisation works under the World Bank funded 'Road Maintenance Project 2' was not sufficiently adaptable to include community-based methods, nor were such methods appropriate to a national highway. These aspects are discussed later.

The TOR subdivide each Module into a series of key activities, and for ease of reference these are repeated in the next section with a commentary on the work actually carried out.

1. MODULE 1: PROJECT PLANNING AND INITIATION

No	Activity	2006			2007										
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	**Module 1 Planning and Initiation**														
1.1	Develop relationship with RAD														
1.2	Access primary information relevant to slope stability														
1.3	Access or derive ancillary data sets														
1.4	Input and collate existing data into database		(scheduled for Modules 2 and 3)												
1.5	Review sections identified for the trials														
1.6	Undertake planning of field programme														
1.7	Prepare detailed design														
1.8	Identify specifications and costings														
1.9	Assist RAD with bid documents														
1.10	Draft detailed data collection programme														
1.11	Draft information dissemination and training strategy			(mostly scheduled for Module 4)											
1.12	Submit detailed report on actions and outcomes														
1.13	Assist MPWT with assessment and award of contracts														

Figure 1: Module 1 Programme

Module 1 covered the period October 2006 to November 2007.

1.1 Develop a working arrangement with the Road Administration Division

Since there was a direct linkage between the Consultant's Team Leader and the Director of the Road Administration Division, a working relationship was quickly developed and maintained by regular meetings between RAD staff and the Consultant's staff.

1.2 Access primary information relevant to current slope stabilisation measures being undertaken

Although the Consultant was unsuccessful in locating the original road construction drawings and other related data, we were able to obtain information relevant to the JICA funded bio-engineering work carried out at km 363.6 on Road 13N, including some relevant reports as well as some historic data from the Luang Prabang DPWT on earlier slope stabilisation work carried out on Road 13N.

1.3 Access or derive ancillary data sets

Other ancillary data sets included climatic data – particularly historic and current rainfall data – although the most relevant rainfall records were only available from July 2006, as well as topographic and geological mapping and aerial photography, although all of relatively small scale. Bio-engineering data were collected from a number of sources including research institutes and environmental agencies

1.4 Input and collate existing data into a finalised database

The data acquired were not of a type that could be collated into a database. However, much of the data are in electronic format and were further analysed in Modules 2 and 3.

1.5 Review the sections identified for the trials

The general area of the trials was set by an MOU between MPWT and DFID as ‘along the National Road No 13N (Kasi - Phou Khoun - Luang Prabang) and National Road No 7 (Phou Khoun - Luang Prabang / Xieng Khouang border). In February 2006 the Consultant carried out a detailed inspection which revealed more than twenty sites in total which were worthy of attention. The slopes mainly fell into the following broad categories:

- Category A. Shallow failure/soil erosion on slopes (usually cut) above the road but not through the road bench.
- Category B. Shallow failure/slope erosion on loose fill slopes below the road, usually the result of slip clearance.
- Category C. Deep seated failure on slopes (usually cut) above the road but not through the road bench.
- Category D. Deep seated failure through or beneath the road bench and extending to the slopes below and sometimes above the road.

A ranking exercise was undertaken to establish which sites carried the highest risk if nothing was done. The table below summarises the main characteristics of each potential slope stability trial site, the right hand columns indicating the ten originally preferred sites, the final list, for further analysis and design.

Route	Chainage (km)	Elevation (m)	Failure Category	Risk Ranking	Final List?	Phase	
						1	2
13N	238.0	735	A & B	3*	Yes	Yes	
	242.6	958	D	3			**
	254.0	1290	D	3	Yes		Yes
	258.6	1395	A & B	5			
	260.3	1317	C/D?	3	Yes		Yes
	262.9	1172	A/C?	4			
	287.2	941	D	3			**
	311.4	1320	A & B	5			
	316.6	1072	A & B	4	Yes	Yes	
	317.9	984	D	3?			**
	326.4	598	D?	4			
	326.9	530	D?	4			
	332.7	444	C	4	Yes		Yes
	335.8	596	D	5			
	336.4	621	D	3	Yes		Yes
	337.5	663	B	5			
	337.7	672	A & B	4	Yes	Yes	
	338.9	745	A & B	4			
	339.9	790	C	4	Yes		Yes
	341.2	844	A	5			
7	3.3	1302	D	3	Yes		Yes
	6.1	1465	D	3	Yes		Yes

* Ranking increased due to threat to electricity pylon
** To be included in phase 2 only to outline design

Table 2: Main Characteristics of Potential Trial Sites

Inevitably the choice of sites for the final list had an element of subjectivity. In addition to the considerations of failure category, risk ranking and elevation, the slope stabilisation trials were required to address a variety of failure mechanisms. Although there were still three site locations with a Risk Ranking of 3 which were not originally selected for the final list, these were eventually included thus raising the number of sites in the trials from ten to thirteen.

1.6 Undertake detailed planning of the main field programme

Since bio-engineering works are ideally carried out close to the beginning of the rainy season, it was proposed that the slope stabilisation work should be subdivided into two phases:

- Phase 1 would concentrate on those slopes where the works were predominantly bio-engineering but with some minor structural work (e.g. toe revetments, slope and roadside drainage). The designs for these comprised the application of standard details and were therefore relatively straightforward. The implementation of these works was in the period of May to July 2007.
- Phase 2 would concentrate on those slopes where the works were predominantly structural (i.e. where the slope instability is more deep-seated) but where some bio-engineering measures were required for surface erosion protection. For these slopes the design process would take longer, some requiring small-scale ground investigation work and all requiring engineering geological mapping and analysis. The civil works for these were scheduled for the period November 2007 to March 2008, and the bio-engineering works scheduled for the period May to July 2008.

1.7 Prepare the detailed design

Phase 1 detailed design began in December 2007 as soon as the topographic survey work had been completed. Three sites were involved: km 238.0, km 316.6 and km 337.7. Phase 2 detailed design began in January 2008. Ten sites were involved: km 242.6. km 254.0, km 260.3, km 287.2, km 317.9, km 332.7, km 336.4 and km 339.9, all on Route 13N; and km 3.3 and km 6.1 on Route 7.

1.8 Identify specifications and costings

Although numerous specifications related to slope stabilisation works were available to the Consultant that they had used elsewhere in the past, it was decided to utilise, to the maximum extent practicable, specifications that had already been used in previous projects in Lao PDR, since these would be more likely to be familiar to local contractors. For historic unit rates for the civil works a number of relevant local sources were used, but for the bio-engineering works it was necessary to derive these from first principles with considerations of labour, materials and construction plant (if relevant) needed for each activity.

1.9 Assist RAD in preparing bid documents

Bid documents for phase 1 were prepared over the period November 2006 to January 2007. Following the necessary approvals from the World Bank and MPWT, the contract went out to bid on 21st March with the submission date eventually set at 25th April. A site visit and pre-bid meeting were held during the bid period and a total of five bids were received. Bid documents for phase 2 were prepared over the period February 2007 to July 2007. Again, following the necessary approvals from the World Bank and MPWT, the contract went out to bid on 30th August with the submission date set at 5th October. A site visit and pre-bid meeting were held during the bid period and a total of seven bids were received

1.10 Draft a detailed data collection programme

This was undertaken and the relevant data were presented as part of Modules 2 and 3.

1.11 Draft an information dissemination and training strategy

This was presented in the Module 4 Report.

1.12 Submit a report detailing project actions and outcomes

This activity was covered by the Progress Reports issued every two months.

1.13 Assist MPWT in assessment and award of works contracts

The bid assessments were carried out by the MPWT bid evaluation committee, although assistance was provided by the Consultant, as necessary, with the provision of the contract documents. In each case the contracts were awarded to the lowest bidders.

2 MODULE 2: REPRESENTATIVE DATA CAPTURE

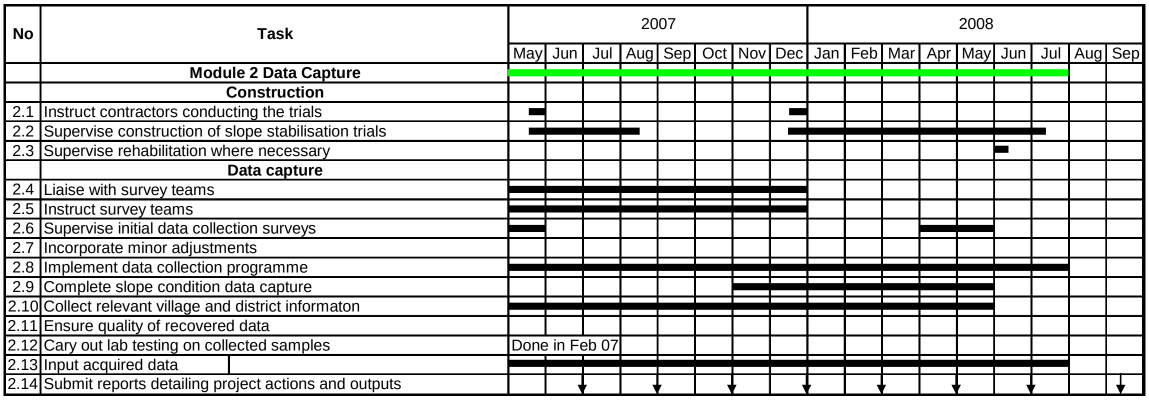

Figure 2: Module 2 Programme

2.1 Instruct the Contractors appointed by MPWT for conducting the trials

Phase 1 construction was awarded to Vone Thyling on 17th May 2007 with a required completion date of 14th August 2007; Phase 2 construction was awarded to Asean Civil Road Bridge and Irrigation Construction Co Ltd on 16th November 2007 with a required completion date of 13th May 2008.

2.2 Supervise the construction at the identified locations

Phase 1

The table following summarises the scope of work under Phase 1:

Location	Scope of work
km 238.0 Road 13N	*Cut slope on LHS*. Trim back scar and loose slope debris, re-profile and compact. Construct stone-lined slope drains. Construct gabion check dam. Shrub seeding in rock areas as required. Plant diagonal grass lines. *Fill slope on RHS*. Trim slope debris to a rounded profile. Smooth remaining debris and compact. Construct live check dams. Plant grass strips on slopes less than 35 deg and brush layers on slopes greater than 35 deg
km 316.6 Road 13N	*Cut slope on LHS*. Trim back scar and loose slope debris, re-profile and compact. Construct composite masonry revetment wall at toe and plant brush layers in backfill. Construct new side drain. Plant diagonal grass lines. *Fill slope on RHS.* Edge of debris bench to be trimmed and re-profiled. Plant truncheon hardwood cuttings throughout debris slope.
km 337.7 Road 13N	*Cut slope on LHS.* Trim back scar and loose debris. Fill and compact tension cracks. Plant diagonal grass slips. Sow shrub seeds. Form slope drainage channel. Construct masonry side drain. *Fill slope on RHS.* Construct earth bund along edge of road. Plant tree seedlings and grass slips on debris bench. Plant truncheon cuttings throughout bare debris slope.

Monthly construction progress reports were produced by the site supervision team in accordance with the requirements of the World Bank RMP2 programme.

Although the works were undertaken as planned, it became apparent that despite earlier demonstrations to show the contractor how to carry out the bio-engineering planting successfully, there was an unacceptably high failure rate of the planted grass slips. This was due to the workers improperly treating the slips, and a failure to water them in periods of dry weather. As a result of this, the contractor was instructed to replant the failed areas at the commencement of the following wet season, in June 2008. This was done.

As a result of the unsatisfactory performance of the bio-engineering planting in general, the grass slip specifications were revised to provide a larger plant with two or three stems together with other revisions to the specifications to ensure greater robustness of the live check dams and truncheon cuttings.

Phase 2

The table below summarises the scope of work under Phase 2:

Location	Original scope of work	Revisions during construction
km 3.3 Road 7	*Fill slope on LHS*. Construct 75m x 6m high masonry retaining wall. Construct new masonry roadside drain. Construct gabion check dam. Plant grass slips.	*Fill slope on LHS*. Wall shape changed. Trimming and grass planting added above culvert inlet and outlet on each side of the road
km 6.1 Road 7	*Cut slope on LHS.* Plant truncheon cuttings and diagonal grass slips. *Fill slope on RHS*. Construct 40m x 6m high masonry retaining wall. Plant grass slips and brush layers. Plant live check dams in gulley.	*Cut slope on LHS.* Bio-engineering works deleted. *Fill slope on RHS*. Wall shape changed.
Km 242.6 Road 13N	*Cut/fill slope on LHS*. Trim edge of backscar and re-profile upper 5m. Construct 75mm thick spray concrete slope protection. Repair asphalt road surface.	*Cut/fill slope on LHS.* Cast in-situ concrete panels substituted for spray concrete. Hand-applied in the end Grass planting added for small bare soil slope.
Km 254.0 Road 13N	*Cut/fill slope on LHS.* Construct 50m x 6m high masonry retaining wall. Construct 3m wide gabion drainage channel in existing gulley. Partially replace existing 1m dia cross culvert. Plant grass slips and brush layers. Plant live check dams in gullies.	*Cut/fill slope on LHS*. Retaining wall length reduced to approx 35m and shape changed. Cross channel replacement deleted. Masonry substituted for gabion. Drainage channel wall width increased downslope.
Km 260.3 Road 13N	*Cut slope on LHS.* Reconstruct roadside drain and remove slip debris. *Fill slope on RHS.* Remove and replace existing cross culvert. Construct gabion apron and check dams.	*Cut slope on LHS*. Masonry retaining wall constructed. Grass planting and brush layers added above wall. *Fill slope on RHS*. Existing cross culvert cleared and retained.
Km 287.2 Road 13N	*Fill slope on LHS.* Construct 60m x 3m high masonry retaining wall. Plant bamboo at base of slope.	*Fill slope on LHS*. Wall shape changed. Bio-engineering reduced.
Km 317.9 Road 13N	*Cut slope on RHS.* Construct gabion cascade down slope. Construct masonry stilling basin and new masonry roadside drain.	
Km 332.7 Road 13N	*Cut slope on LHS.* Construct 50m x 4m high masonry retaining wall. Install subsoil slope drainage and masonry drop channel outlet. Plant grass slips. Sow shrub and tree seeds below wall. *Fill slope on RHS.* Trim spoil slope and remove debris from existing culvert and channel. Plant grass slips, brush layers and truncheon cuttings.	*Cut slope on LHS.* Wall shape changed. Bio-engineering works added to right of wall.
Km 336.4 Road 13N	*Cut slope on LHS*. Upgrade roadside drain to mortared masonry. *Fill slope on RHS.* Trimming and bio-engineering works.	

Location	Original scope of work	Revisions during construction
Km 339.9 Road 13N	*Cut slope on LHS*. Construct 40m x 3-4m high masonry retaining wall. Install subsoil slope drainage and masonry drop channel outlet. Trim backscar and remove spoil. Plant grass slips. Sow shrub and tree seeds below wall. *Fill slope on RHS*. Construct bund. Trim top of spoil slope. Plant grass slips and shrub and tree seedlings on bench. Plant brush layers on debris slope.	*Cut slope on LHS.* Wall shape changed.
Km 357.1 Road 13N	Not included in original scope of work	*Fill slope on LHS*. 6m high masonry wall constructed.

Most revisions to the scope of work arose from practical considerations of the conditions exposed during the course of construction and of the funds available. In one particular respect however, namely the change of retaining wall shape, this was dictated by the MPWT. Furthermore, two additional sites were added and some minor but important slope protection works above the road at km 6.1 on Road 7 were removed.

Although the specified completion date for Phase 2 works was set at 13th May 2008, the contractor over-ran the contract period and actually completed on 6th July, fortunately prior to the heaviest rains of the 2008 wet season. Outstanding works included the road pavement reinstatement at the rear of the fill slope retaining walls and this will be carried out at the beginning of the 2008 dry season in October but still within the contract defects liability period.

Concerns were repeatedly expressed by the Consultant to the contractor over the quality of construction of the masonry retaining walls. Although the retaining walls are essentially unreinforced gravity walls, from considerations of durability they should not contain voids. This arose from the contractor (probably deliberately) using insufficient water in his cement mortar mix which was then applied too sparingly, as well as the poor placement of individual stones. Both the contractor and the supervisory staff were cautioned to ensure that the mix was of a sufficient consistency to fill the voids between the masonry stones and to ensure that there was good mechanical interlock between stones.

In his initial work on site the contractor was seen to have dumped surplus excavated material downslope, despite provision for payment in the contract documents for removing and dumping the surplus spoil in safe locations. This was rectified and the contractor then adhered to the provisions in the contract.

2.3 Supervise any necessary rehabilitation works

As noted in 2.2 above, remedial planting was carried out by the Phase 1 contractor in June 2008 during the Phase 2 construction work. This was supervised by the site supervision team.

2.4 Liaison with survey teams appointed for data collection

Generally, data collection was carried out directly by SEACAP 21 team members and so liaison simply comprised internal discussions within the team. In respect of the site investigation and ground movement monitoring, these were carried out as subcontracts under the direct supervision of the project Consultants.

Initial data capture for this project comprised the following elements:

- Rainfall records
- GPS data

- Topographical mapping
- Aerial photography
- Geological mapping
- Soil mapping/land use
- Bio-engineering data

The project Inception Report proposed that the data collection programme would include:

- Regular inspections and assessments of the stabilised slopes within the project area
- Regular inspections and assessments of the remaining 'unstabilised' or untreated slopes within the project area
- Inspection and assessment of areas with similar topography and rainfall in other parts of Lao PDR, with respect to slope instability and the remedial measures adopted.

During the course of Modules 2 and 3, inspections and assessments of the project area were carried out on a regular basis by the team members. Due to the relative paucity of rainfall in the 2007 wet season, no meaningful conclusions could be drawn – other than the need for greater care with the timing of planting work. For the 2008 wet season however, it was apparent that the study area experienced significant rainfall, reportedly well above the annual average.

As a consequence, a number of new landslides were triggered along Road 13N, and other existing landslides enlarged. In September a total of 64 significant new landslides were recorded over 150 km. In order to be counted each landslide had to be at least 5m by 5m in dimension. There were numerous features that were smaller than this, but these were considered to represent such a low level of hazard as to be inconsequential. Of the 64 recorded, 53 or 82% were located in cut slopes and natural slopes above the road and the remainder were located below the road. In total, the density of recorded new landslides amounted to an average of 1 landslide every 2.2 kilometres.

By comparison, the landslide inventory undertaken by the Consultant in February 2008 identified 38 landslides over the same 150 km length in February 2008. The data suggest that the 2008 wet season has been responsible for the creation of a significantly more than average number of landslides. This is consistent with the observations made of slope movements and related activity at some of the SEACAP 21 trial sites during the 2008 wet season.

Further data capture and investigation included:

- Ground investigation data for selected project sites
- Dynamic probe data for selected project sites
- Ground movement monitoring for selected project sites
- A landslide inventory of slope failures and remedies of areas with similar topography and rainfall. This inventory also overlapped with the requirements of SEACAP21/002 'Feasibility Study for a National Programme to Manage Slope Stability'.
- Community management of roadside slopes

2.5 Instruct survey teams on objectives, methodology and procedures

As noted in 2.4, the only external data collection was carried out by subcontract in which the objectives, methodology and procedures were specified and discussed in advance.

2.6 Supervise initial data collection surveys in selected provinces

Data collection in other selected provinces was confined to rainfall records and landslide inventory, as described in 2.4. The work was carried out by SEACAP 21 team members

2.7 Incorporate adjustments in procedures

Since no training programme in data collection was necessary, no adjustments in procedures were needed or incorporated.

2.8 Implement data collection programme in liaison with RAD

Specifically, the landslide inventory data collection was carried out in liaison with RAD who requested that National Roads 12 and 18b be reviewed, albeit under SEACAP 21/002.

2.9 Complete principal slope condition data

As noted in 2.4, a landslide inventory was carried out to satisfy both the requirements of SEACAP21/001 as well as SEACAP21/002.

2.10 Collect relevant village and district information

The ToR suggest that this information might include maintenance activity, flood data and local climate. Maintenance activity is discussed in 3.2.6 and is not repeated here. During the course of the project it was ascertained that there were no flood data or local climate records at this level that would be relevant to the project.

2.11 Ensure quality of data by cross checks

Apart from the landslide inventory, no other cross checking was considered appropriate.

2.12 Carry out laboratory testing and document results

Laboratory testing was carried out as part of the ground investigation work on selected Phase 2 sites and the results fully documented in a Geotechnical Work Report issued in March 2007 and summarised in the Module 2 and 3 Report.

2.13 Input acquired data into a database

Acquired data comes in many forms, e.g. small scale hard copy aerial photography and topographical maps, soft copy rainfall records and landslide inventory. Hard copy data have been filed and all soft copy data burnt onto CDs. These will be handed over to RAD upon project completion (i.e. following SEACAP 21/003).

2.14 Submit reports detailing project actions and outcomes

The bi-monthly progress reports have detailed project actions and outcomes throughout the project.

3. MODULE 3: DATA INTERPRETATION

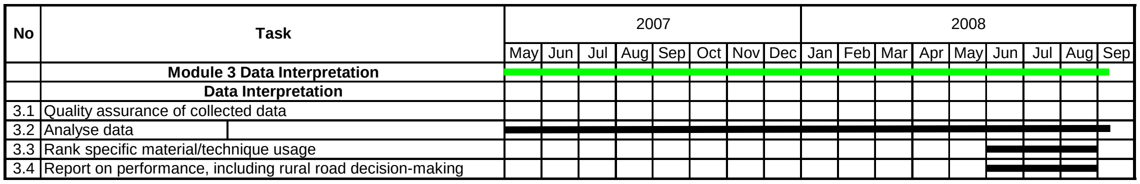

Figure 3: Module 3 Programme

3.1 Quality assure collected data

Although every effort was made to quality assure collected data, where this data came from a local source (e.g. publications and records) it was very rarely possible to carry out an independent check on its veracity. Consequently, most of the data acquired has had to be taken at face value.

3.2 Analyse data

In this section of the report, the following data and research are summarised and analysed:

- Ground investigation data for selected project sites
- Dynamic probe data for selected project sites
- Ground movement monitoring for selected project sites
- Landslide inventory of slope failures and remedies of areas with similar topography and rainfall
- Rainfall
- Community management of roadside slopes

3.2.1 Ground Investigation Data

In February 2007 a ground investigation comprising rotary augured boreholes and trial pits was carried out at nine of the Phase 2 sites, the results of which were formally reported in early March 2007. A total of seven boreholes were drilled, primarily to gain information on ground conditions beneath proposed retaining walls. Three of the boreholes were also completed with inclinometers/slip indicators that were intended to be able to indicate the depth of landsliding at these sites during the 2007 wet season.

Trial pits were predominantly carried out by mechanical excavator although hand dug pits were carried out at several sites, such as Km 6.1 on Road 7, due to access restrictions. The trial pits allowed a relatively economical and rapid assessment of ground conditions to be made and it was intended that at locations such as Km 260.3 on Road 13 they would also be able to delineate the extent of ground movement more accurately.

In addition to the fieldwork, limited laboratory geotechnical testing was also carried out on some of the soil samples to determine basic soil characteristics such as particle size distribution and Atterberg limits.

In general the results of the ground investigation were both useful and disappointing. Standard Penetration Tests (SPTs) carried out in the boreholes or shallow trial pits allowed the retaining wall designs to proceed on a rational basis for km 3.3 and 6.1 on Road 7, and km 254.0, 287.2, 332.7 and 336.9 on Road 13N. However, it was hoped that the investigation would reveal the depth of sliding at km 260.3, km 317.9 and km 336.4, but this was not the case. Furthermore, in 2007 none of the slip indicators gave any meaningful data, possibly as a result of the relatively dry 2007 wet season which was insufficient to induce further ground movement at these locations. However, during the course of the 2008 wet season, ground movements were observed both on the surface and in the slip indicator at km 317.9 (see section 3.2.3 below).

The value of a ground investigation is that it will usually allow the engineer to design with greater confidence, particularly in respect of retaining wall foundation depths. As a consequence the design will be economical and less subject to change during construction. Where construction contracts values are essentially fixed and very difficult to revise upwards during construction, this is an important factor. Ground investigation data are only relevant to the locations where the work was carried out, and have no meaningful implications for sites elsewhere within Laos, except where similar ground conditions might be inferred, using the reference condition approach, for example.

3.2.2 Dynamic Cone Penetrometer Data

In order to assess the actual ground conditions within the proposed base of retaining wall excavations, the site supervisory staff were instructed to carry out Dynamic Cone Penetrometer (DCP) tests. In general between 3 and 6 tests were conducted within each retaining wall excavation.

DCP data is only relevant to the locations where the work was carried out, and has no meaningful implications for sites elsewhere within Laos.

3.2.3 Ground Movement Monitoring Data

Ground movement monitoring was carried out as a subcontract at two sites (km 260.3 and km 317.9) over the 2007 wet season. The scale of both failures was such that the cost of any appropriate remedial measures would be far in excess of the amount budgeted for stabilisation, with each failure encompassing the entire road bench. Since it was considered that further instability was unlikely to be catastrophic, but more likely to result in gradual movement of the entire road bench, it was decided to get some idea of the response of both sites to rainfall. In this manner at least the magnitude of movement could be assessed.

Temporary benchmarks and monitoring points were established in pre-determined locations at each site. Monthly surveys were carried out over the period May to October 2007 to a required accuracy of 1mm. The results indicated movements generally downslope of up to 200mm but with the majority indicating less than 20mm and often less than 10mm. Disappointingly, the benchmarks themselves appeared to move up to 20mm at km 260.3, most probably indicating the true accuracy of the survey work.

In addition to the survey work, the slip indicators installed during the ground investigation were also checked at the same time. These indicated that no movement was apparent within the depths they had been installed.

Visual observations backed up the conclusion that the actual slope movements during the 2007 wet season were probably insignificant, and most likely due to the absence of any significant and prolonged periods of rain.

However, this situation was not repeated for the 2008 wet season, when higher rainfall gave rise to increased observed and monitored ground movements. At km 317.9 the slip indicator record suggested shear at a depth of 2.4m below ground level. This corresponded to the visual observation of the active movement on the slope surface. The surface monument monitoring indicated that ground movements at one location below the road had resulted in an elevation change of 1.6m and a lateral (down slope movement) of 4.5m. However, the other surface monuments in the area showed considerable less movement, for example of the order of 90mm or less. The larger recorded ground movement (1.6m) is therefore considered to be spurious.

3.2.4 Landslide inventory of slope failures and remedies

This work was commenced under SEACAP 21/001 and completed under SEACAP 21/002, and has been reported in Part E of the Background Paper, SEACAP 21/002 Feasibility Study for a National Programme to Manage Slope Stability (Sept 2008). Data collection was carried out by international members of the SEACAP 21 team prior to the onset of the 2008 wet season.

The inventory covered a little over 1,500 kilometres of the Lao PDR national road network. The network is slightly more than 7,000 kilometres in length, of which approximately half is judged to be in steep hilly or mountainous terrain. The inventory therefore covered about 50% of the national road network located through steep hilly or mountainous areas where landslide and earthworks failures are likely to pose the greatest hazards. In total over 150 landslides were recorded in the inventory, and a hazard and risk classification was assigned to each.

The majority of the landslides recorded appeared to have been caused by the effects of higher wet season groundwater and perched water levels in soils and weathered rock masses exposed in steep roadside cuts. Slope failures were often observed to originate from the upper portions of cut slopes where colluvium or the weaker, more weathered material, predominates in the weathering profile. Ground movements affecting the carriageway or outside edge of road from below appeared to be associated with localise shallow failures in fill slopes and construction spoil or more extensive areas of deeper failure of the natural hillside, in some instances associated with river scour. It should be noted that ground movements taking place on slopes below the road are often less easily identified than those above, and some of these may therefore be missing from the inventory.

3.2.5 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

A network of daily (24 hour) rain gauge stations exists covering the entire country. Many of these stations have more than 15 years of recording. 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.

In the absence of detailed studies it is difficult to obtain a sound overview of the situation. Existing rainfall maps show higher rainfall in the central and southern provinces bordering Vietnam and possibly the north west. 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.

The picture is generally supported by looking at the data supplied from two weather stations in northern Laos for monthly rainfall in mm over the period 1996 to 2005. 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.

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. Wet season 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.

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 rain gauge 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.

3.2.6 Community Management of Roadside Slopes

The project's research trials have been undertaken on national highways managed by central government. Ways were sought to involve communities in this work, but it was found to be impractical for a number of reasons. Not least among these were the difficulties in identifying suitable community structures with which to work, the inexperience of the MPWT in contracting and managing works through communities, and the difficulties of applying World Bank procurement rules to community groups. As a result, the research on this aspect remained theoretical.

There has certainly been some success in the introduction of community management in the Lao road sector. This has been mainly at the "basic access" level, where Village Management Committees are made responsible for short road sections serving specific villages. However, while this can be made to work close to settlements, the sparse rural population in Laos means that communities of sufficient size are not always available close enough to particular sections of road, particularly in the steeper mountainous areas. In addition, it is clear that a wage-based arrangement is essential for the engagement of workers for activities on all but the very lowest category of public road, where a clear vested interest exists for a community to open a basic track for access. Demands for voluntary labour contributions can be ethically unsound and contrary to good development. Rural communities do not necessarily want paid work, especially at times when they are busy with agricultural work. It is partly for these good reasons that governmental agencies rely on contractors to produce workers.

3.3 Recommend ranking of specific material/technique usage

Under SEACAP 21 a number of techniques have been tested and some empirical data has been derived on their performance. These can therefore be recommended in certain situations. However, it is not possible to decide how to stabilise mountain slopes on the basis of techniques alone. The use of a technique can only be determined when the problem is understood and an overall treatment programme has been devised. The difficulty is that slope instability problems cannot be simplified: the variables are numerous and most slopes show an interaction of several different factors.

Ultimately the only successful approach to slope stabilisation is through the diagnosis of instability, so that the problems are understood; and then to identify a course of treatment that will resolve the problems. Diagnosis is highly judgemental without recourse to expensive ground investigation data. A recommended method of diagnosis based on site observation is given in section 14 of the Background paper to the Feasibility Study for a National Programme to Manage Slope Stability (SEACAP21/002).

Recommended treatment tables are given in the Modules 2 and 3 Report. These provide the main response options to individual slope instability problems once they have been identified and understood.

3.4 Report on rural road decision-making process and long term monitoring

These issues were investigated under this project, but much of the material was then adapted and built on in the SEACAP 21/002 'Feasibility Study for a National Programme to Manage Slope Stability'. A detailed assessment is given in the Background Paper to the Feasibility Study, and the paragraphs below are modified from the Final Report.

Road management in Laos is divided between National Roads, under the Road Administration Division, and Provincial, District and Rural Roads, under the Local Road Division. Responsibility for implementation of management activities is decentralised to the Provincial DPWTs, with the central divisions retaining the remit for planning and monitoring. Budgetary control is kept at the centre, with approval from the MPWT required for the letting of contracts by the DPWTs. All works, including emergency maintenance, are implemented through contracts. Routine maintenance activities are labour-based on all categories of roads, but community involvement occurs only in the lowest category of Rural (or Village, Community or Basic Access) Roads.

Routine maintenance is carried out by the DPWTs, following well-established procedures based on a series of maintenance activity codes. The introduction of Performance-Based Maintenance Contracts (PBMCs) on nearly a third of the National Roads network in the last year or so has altered the programming timeframe because they require a three-year plan. However, these are still administered through the DPWTs.

Emergency maintenance (which covers slope repairs) is usually linked to routine maintenance, in that an annual budget estimate is also made and funds allocated from the Road Maintenance Fund in the same way. If the rains are particularly bad and emergency items cost too much, then a greater proportion is drawn from central government funds, through the Ministry of Finance. Where PBMCs are in place, they also cover emergency maintenance.

Periodic maintenance is planned annually through the Road Management System (RMS) for National Roads and the Provincial Road Maintenance Management System (PRoMMS) for Local Roads. These both follow a computer-based, menu-driven format, which channels decisions of maintenance interventions into a relatively narrow set of options. They are particularly restricted for off-road problems. While these systems are effective, they tend to dominate the decision-making process at road section level. Priorities are set through the computerised systems, but the level of expenditure is determined by a five-year rolling budget. Limited resources for maintenance overall mean that the centralised decisions on allocations between the Provinces are often not ideal.

In effect, all slope management comes under the emergency maintenance category, and this demonstrates the approach that is used. Proactive slope stabilisation works are rare, beyond a range of standard retaining walls and drainage systems for the higher standard roads. Most works are of a reactive nature, and the DPWT staff react as quickly as possible once a slope failure occurs; hence the advanced planning for an expected emergency budget and inclusion in the PBMCs. If a road is blocked, the first priority is to get it open and this is the stated purpose of the first emergency maintenance activity code (no. 311). There is considerable flexibility in the way that emergency funds can be used on both National and Provincial Roads, and the assistance of the Provincial Governor's Office, contractors and local people may be sought. In extreme cases, special additional central funds may be released through a process of declaring a big landslide as a National Disaster.

4. MODULE 4: INFORMATION DISSEMINATION AND TRAINING

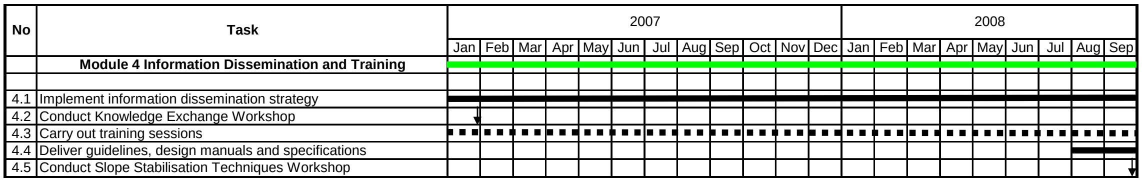

Figure 4: Module 4 Programme

4.1 Information dissemination strategy

4.1.1 Strategy objective

The spreading of knowledge is a key aim of SEACAP 21. As stated by the terms of reference, “the research purpose of the project is to determine and disseminate best-practice appropriate road technologies, and to support sustainable ownership mechanisms for the construction and maintenance of rural roads”. The project’s objective is “to extend the present methodologies for the construction of rural access roads used locally, and in SE Asia generally, to cover problems related to land-slips on the mountainous roads in Lao PDR”. There is a requirement to produce specifications, guidelines, manuals etc to “influence activities for change in indicators of standard practice”.

The project was set up mainly to undertake a series of trials and disseminate the results. The scope of training was therefore highly limited, and could not, for example, extend to the provision of full trainers’ manuals, handouts and other lecture materials, or any substantial training course. From the beginning the production of a substantial technical manual was anticipated, and to use this as the basis for the final dissemination event (i.e. the slope stabilisation workshop).

4.1.3 Decision-making analysis to target project knowledge outputs

In the broad context, the material disseminated by SEACAP 21 must fit within the framework of the new Rural Transport Infrastructure Policy. This was being scrutinised by a committee in the MCTPC, but unfortunately was not released during the life of the project.

The practical management of roads, including maintenance, is administered through a Department of Public Works and Transport (DPWT) in each of the seventeen Provinces. Within the DPWT there are two Offices, to cover National and Provincial roads respectively. Responsibilities for District and Rural Roads are delegated to Offices of Public Works and Transport (OPWTs) in each District. It is the engineers in these tiers of the organisation, as well as among the consultants and contractors whose services they procure, that are the target groups for SEACAP 21’s knowledge outputs.

The project’s knowledge outputs should be linked as far as possible to the existing systems for managing the different categories of roads, since it is these processes that SEACAP 21 seeks to enhance. The paragraphs below therefore summarise the context of the decision-making undertaken by the people who form the target audience just described, in relation to roadside slope management.

At present the scope of road management only extends to roadside slopes when they fail (i.e. through emergency maintenance). The objective of the project’s material is to provide the MPWT with the tools it needs to include an element of preventative slope management in its maintenance strategy, thereby reducing the occurrence of failures that require emergency maintenance. However, because many failures will not be detectable in advance, the tools must also cover the appropriate action to be taken in emergencies.

Maintenance of National roads is organised through the Road Management System (RMS). 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 Public Works and Transportation Institute (PTI) and the Planning and Technical Division (PTD) of the central MPWT. Data collection is done in February and March, and entered into the system in April and May. However, 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. The way that DPWTs undertake the assessment in response to this appears to vary from province to province, and to be somewhat ad hoc. Once replies are received from the DPWTs, 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.

The maintenance of Provincial, District and Rural (Village) roads is organised through the Provincial Road Maintenance Management System (PRoMMS). 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 "class lists" of seriousness of the different factors. 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 implement the works. Under this system, slope problems really enter only as a sub-set of "access constraints", but this small category in the program hides the potential complexity of resolution, which is where the SEACAP 21 project's manual can contribute. Assessment of a failing slope would also allow the DPWT to determine whether it qualifies for special treatment under the separate emergency maintenance fund that exists for Provincial and District roads.

An initiative of the Local Roads Division, supported by the Lao-Swedish Road Sector Project 3, is the development with the National University of Laos, of a rural road engineering curriculum. This is based on a combination of Lao and international best experience. Material derived from this project must either fit into the framework of the curriculum or must act as a complementary reference to it. 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. In general, these 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. 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. Unfortunately this valuable piece of work therefore 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.

4.1.4 On-the-job training

Training of counterpart staff

Counterpart Lao staff were trained on-the-job by the international consultants. This was carried out through semi-formal training sessions, as well as informally through coaching and mentoring in routine activities. Most of the individuals involved in this are from the local consultant partner company, LCG. However, a counterpart officer assigned to the project from MPWT was also a key recipient of this training.

During the construction of the Phase 2 trials, arrangements were made for DPWT staff to be attached to the site supervision team, thereby broadening the training on-the-job.

This training covered all of the practical aspects of the project as far as innovative techniques being introduced, from site assessment, through design and implementation to post-construction monitoring.

Training of contractors

There were two main areas of training for contractors. One was in formal pre-bid meetings, where bidders for slope stabilisation works contracts were given a detailed explanation of the type of activities required by the project. The other was for the winning contractors, through on-the-job training by the site supervision team. This latter category followed the same semi-formal and informal procedures as used for the training of counterpart staff (see above), though obviously only covering the innovative techniques of implementation. In this respect the on-the-job training used a cascading arrangement, since the training of contractors' personnel was carried out by the Lao counterpart staff.

4.1.5 Knowledge Exchange Workshop

This is covered in section 4.2 below.

4.1.6 Slope Stabilisation Workshop

This is covered in section 4.5 below.

4.2 Knowledge Exchange Workshop

The task here was to conduct a Knowledge Exchange Workshop at an early stage in the project to bring together the key stakeholders.

A Knowledge Exchange Workshop was held in the MPWT Conference Room 1 on the morning of 30th January 2007 and attended by approximately 70 participants.

Given that the purpose of the workshop was to describe the project and exchange views on the problems of slope stabilisation and remediation in Lao PDR, it was a success and provided a very useful forerunner for the workshops to be held later in the project. The discussion provoked several pertinent topics to be aired and provided a good opportunity for the team members to arrange further follow-up meetings.

4.3 Training Sessions

This task was defined as ensuring that training sessions are conducted throughout all Modules. In the project Inception Report, it was stated that "For Module 4, the TOR require that 'training sessions are conducted throughout all Modules for transferring knowledge at all hierarchical levels in the provinces'. Although we will endeavour to achieve this, we suggest that the main formal training emphasis be placed towards the end of the project when we have something to show and training manuals have been prepared. There will be, of course, a significant element of on-the-job training for the local consultant and Ministry personnel working with the international staff throughout the duration of the project."

That, broadly, is how the training elements of the project have evolved. What was not foreseen at that time was the opportunities that would arise for broader dissemination outside the MPWT network. The paragraphs below record the main dissemination events through the two years of the project, in addition to the Knowledge Exchange Workshop (see section 4.2) and the Slope Maintenance Workshop (see section 4.5).

Seminar at Luang Prabang DPWT

A formal seminar was held at the Luang Prabang DPWT in December 2006, by both local and international staff of the project. Powerpoint presentations were made of the project's work, and in particular of the Phase 1 trials. The low cost approach was explained and particular emphasis given to the use of bio-engineering by the project. Following the presentations, the event moved to field sites on Road 13 North, where the role of vegetation was explained. It finished with a short hands-on session to demonstrate the practical aspects of key bio-engineering works. Around twenty DPWT staff attended, and the event was held mainly in Lao, with the international specialist's contributions translated.

Contractors' Pre-bid Meetings

Pre-bid meetings were held for contractors in February 2007 (for Phase 1) and October 2007 (for Phase 2). Special presentations were made by the project specialists in Lao, to explain the nature of the works that were being tendered. These were done in such a way as to share practical information, since it was obvious that in each event only one contractor would actually undertake the work, so that it was logical to make use of the time to transfer knowledge to the others.

Article in *Ground Engineering*

An article written by one of the project's international specialists, Dr. Gareth Hearn, was published in the April 2007 edition of *Ground Engineering*. This described the work that was being undertaken and helped to bring international recognition to the Lao road sector, in a journal that is widely circulated among sectoral professionals.

Presentation in Kathmandu, Nepal

The opportunity was taken on 20th December 2007 of one of the project's specialists visiting Kathmandu, to make a presentation on the project's activities and early findings. This was made at a seminar arranged by the Department of Roads, and attended by around 30 members of staff from that organisation and the local roads equivalent, the Department of Local Infrastructure Development and Agricultural Roads, other transport sector representatives and donor personnel. This helped to show to a regional neighbour how Laos is building up its capabilities in off-road maintenance.

National University of Laos Students' Visit

In February 2008, the project organised a study tour to a selection of its Phase 1 and Phase 2 sites for some 70 staff and students of the Department of Civil Engineering of the National University of Laos. A newspaper report of this event is given in Annex C. The project specialists described the works on site in both Lao and English, and generated discussions on the reasons for, and effectiveness of, the methods used. Feedback from the students' post-trip evaluation suggested that they felt it to have been very valuable to them.

Feasibility Study Workshops

The project's specialists were also involved in the SEACAP 21-002 Feasibility Study for a National Programme to Manage Slope Stability. There were two seminars, in April and May 2008 respectively, at which this was discussed. Because of the obvious overlap with the main SEACAP 21 project, the opportunity was taken to give examples of work and findings from the project's trials. This increased the exposure of the project among the MPWT's Provincial staff, as DPWT personnel from Attapeu, Khammouan and Luang Prabang, as well as others, were present on both occasions.

Phnom Penh Conference

The project's specialists assisted in the preparation of a paper entitled "Managing Slope Instability in using Civil and Bio-engineering approaches in the Lao PDR". This was delivered by Mr Chanh Bouphalivanh, Director of the MPWT's Road Administration Division, at a Regional Workshop organised by the Institute of Technology of Cambodia on 18th and 19th August 2008. The theme of the workshop was "Natural Resources and Materials for Sustainable Development of ASEAN". A copy of the paper is given in Annex D.

SEACAP Practitioners' Meeting

A regional annual SEACAP Practitioners' Meeting was held in Hanoi in August 2007. A presentation on the scope of work then being undertaken by SEACAP 21 was presented by the Team Leader. The next annual meeting was held in Vientiane in November 2008, with an attendance of about 120 professionals. Two site visits to the SEACAP 21 trials were arranged, one for foreign delegates and the other for Lao attendees.

4.4 Technical Guidelines

The defined task here was to deliver a series of guidelines, design manuals and specifications evaluated in the earlier Modules. As the project evolved, it became clear that there were three main channels for the useful material that the project could generate that would assist the MPWT in the future. These are covered under the three sub-sections below.

4.4.1 Slope Maintenance Site Handbook

A key project output is the Slope Maintenance Site Handbook. This has been written in English but translated into Lao. While it incorporates best practice from other countries, it was written entirely for the Lao setting. It is structured around the MPWT's Maintenance Activity Codes, which are the administrative basis for all on-road and roadside maintenance, rehabilitation and improvement works. The intention is that, by following this structure, it allows site staff to relate their work to the budget codes under which the expenditure is allocated, thus making direct links between practical tasks and the completion of official accounting formats.

The Site Handbook is in A5 format and restricted to 33 pages (per language). Its target audience is the technician level staff of the DPWTs, who are qualified to diploma level and are responsible for overseeing works implementation on site. It is amply illustrated with clear photographs, all from the Lao road sector, and the language and technical messages kept as simple and practical as possible. The English version will be published only as an electronic file, but the Lao/English version will be printed.

4.4.2 Slope Maintenance Manual

The Slope Maintenance Manual covers the subject matter in much greater depth than the Site Handbook. It is intended to be used by engineers with a reasonable degree of experience and at least a moderate understanding of slope processes. It has not been an easy document to produce, since the subject matter is extremely broad and it is difficult to draw the limits. We have avoided writing a complete text book on slope maintenance issues, but this has had to be achieved at the risk of it being taken out of context and criticised as being incomplete. The intention is to cover the subject in sufficient detail that it provides a practical reference work for the managing engineers, while not covering every eventuality. It is clear that particularly large and complex failures will always require specialist analysis, just as large bridges need specialist design, and would be outsourced by the MPWT for the foreseeable future. The manual therefore attempts to provide the guidance needed for MPWT staff in addressing the great majority of slope problems found in the road network.

The manual is structured around four main thematic sections, which together form an iterative approach to the subject. These are as follows.

- The nature, extent and causes of slope instability in the Lao road sector.
- How to assess the problems, diagnose the processes and identify a solution strategy.
- The approach to the design of the main geotechnical and bio-engineering structures that can be used in the majority of situations.
- The construction of the remedial measures.

In these respects the manual is complemented by the Site Handbook, which covers the practical aspects of slope and wall maintenance. This complements the Site Handbook in telling the engineer what he needs to know when making the decisions that underlie the implementation of the different stages (i.e. assessment, design and construction) that make up the process of maintenance in practice.

The manual runs to approximately 100 pages and uses a standard A4 report format so that it can be easily reproduced. It is being published in an electronic English-language version, and in both electronic and printed formats in the Lao translation.

4.4.3 Technical Specifications for Slope Maintenance

The project has produced a complete set of technical specifications for slope stabilisation and protection works. These are based on international best practice, but were drafted to comply with other MPWT specifications, particularly those used by the World Bank-supported RMP-2, through which the actual trials contracts were financed. They were used in Phase 1 and modified in the light of experience, for Phase 2. There have been subsequent minor modifications to incorporate the lessons learnt.

Works contracts on projects part-financed by the World Bank are in English as the primary and legal language. However, it was felt that because the bio-engineering activities proposed under SEACAP 21 were completely new to the contractors, it would be helpful to have at least those specifications translated into Lao. This was therefore done for both the Phase 1 and Phase 2 bidding exercises. MPWT later requested that all of the project's specifications be translated, so that they form a better resource for future works contracting. This is thought to be the first time that a road sector project has produced a comprehensive set of technical specifications in Lao.

The actual subject matter covered by the specifications cover all aspects of site preparation, construction and drainage of slopes, and protection works, mainly through bio-engineering. A strength of this set of specifications is that it has been tested through two complete cycles of site trials, and so it can be assumed that, while not perfect, they are sufficiently robust for regular use by the DPWTs.

4.5 Slope Maintenance Workshop

The remit was to conduct a Slope Stabilisation Workshop in Vientiane at the end of the project. This took place at the MPWT conference centre on 26 September 2008, renamed slightly to take into account the institutional position of slope stabilisation and protection works under the MPWT's road management systems.

The intention was to design the workshop on a structure broadly similar to the Slope Maintenance Manual, so that it provided the participants with an iterative process. Having described the geographical setting for slope instability and explained the dynamics and causal factors, it covers the specialists' recommended approaches to scientific site assessment and problem diagnosis. This makes possible a logical prioritisation procedure for situations where there are too many slope problems to be covered adequately by the available resources. Once all this essential background decision making has been completed, the engineer can move on to design and construction. Maintenance then forms the over-arching theme, especially within the institutional establishment of MPWT, since it includes slope monitoring and response mechanisms, hence feeding back into the start of the process. The detailed presentations are provided on the internet via the SEACAP-INFO website, at:

http://seacap-info.org/?mod=home&act=pdesc&pid=22.

The workshop drew heavily on the experience gained from the SEACAP 21 trials throughout the technical sessions. All of the very numerous illustrations were from Laos, and mainly from these trials. To draw together the main lessons learnt, a special session was included to dwell on a number of key factors that were considered important by the specialists to bring into the debate since they should be used to help inform future directions in the MPWT's slope maintenance strategy. Finally, drawing on the experience of previous workshops, a significant time was allowed for discussion at the end, to ensure that it was possible to clarify uncertain matters and share the ideas that had been presented or brought by the participants.

5. RESULTS OF RESEARCH AND OUTCOME OF INFORMATION DISSEMINATION ACTIVITIES

5.1 Results of research

Detailed results of the research conducted under SEACAP 21/001 are documented within the individual Module Reports. However, the paragraphs below summarise the main findings.

Principles

- SEACAP 21 undertook trials of possible cost-effective options rather than demonstrations of best practice. This has sometimes been difficult to explain to people who expect to see examples of reliably stabilised slopes without consideration of the costs involved.
- Use of low cost techniques has allowed the exploration of the critical limits of slope engineering using limited financial resources. The fact that a number of partial failures occurred means that a better understanding of where the limits of low cost methods lie in some of the environments and with some of the materials that have been dealt with. If the project had gone for "safer" methods and undertaken the works using more robust, higher cost structures, it would never have known how far above the critical limits they lay.

Geotechnical engineering

- Simple geotechnical structures (retaining walls of gabion, mortared masonry and composite crib structures) are adequate for the majority of failures found in association with the national road network. These are relatively low in cost and serve the needs of most locations.
- There is virtually no tradition of construction in the Lao PDR that uses stone and mortar. Partly as a consequence of this, the contractors' workforces lacked the skills needed to build good structures, and the supervising staff lacked the confidence to be forceful regarding the achievement of good quality.
- There are no low cost solutions to the deep-seated failures that have led to displacement of the road benches in a number of locations. In these situations, ground investigations are essential and remedial structures may need to be large and founded quite deeply to ensure that they are below the failure plane.
- Retaining structures often need to be enhanced with drainage systems to remove either or both of surface and ground water from the slope. A number of straightforward options were tested and found to be appropriate.
- The lack of specialist skills suggests that it is important that the Lao road sector improves its capacity in site investigation and the design of slope stabilisation structures before starting to experiment with more complex systems such as reinforced earth and rock bolting.
- The dumping of loose debris on fill slopes below the road arising from landslides above the road or from structural excavation has to be condemned. It is important to ensure that such material is placed in pre-determined safe locations and that the contractor is paid to carry out this work as a separate bill item in the Bill of Quantities.

Bio-engineering

- Revegetation of slopes cut in original ground can be achieved using planted grass lines, with locally available species. A number of widely available species appear to perform well.
- The tradition of shifting cultivation with its cycles of slashing, cultivating and "fallow" (i.e. allowing the forest to restore itself) means that there are numerous species adapted to growing on bare ground. There are others that can re-establish a forest cover through a dense jungle of grasses, herbs and shrubs.
- Vetiver does not grow well on cut slopes in original ground. Other species do. Among them, broom grass (*Thysanolaena*) is particularly effective in central Laos.
- Harsh, stony sites do not revegetate quickly with sizeable plants, even in this humid tropical environment that is obviously favourable for plant growth. A "greening up" may occur through

the rapid germination of shallow-rooting herbaceous plants, but this does not have adequate strength to resist erosion in intense rainfall.

- Engineering staff seem generally to misunderstand the difference between revegetation works designed in engineering principles to add to the strength of the soil, and revegetation purely to demonstrate an ability to turn a bare slope green. This leads to a tendency to allow contractors simply to use seeds of fast-growing legumes throughout the sites.
- There are many appropriate species for the use of “Alpine” bio-engineering techniques such as brush layers, palisades and live check dams.
- Most of the species used for bio-engineering, including grasses, shrubs and trees, have recognised economic uses, which means that there can be associated livelihoods benefits for farmers.
- There are too many poorly understood variables to be certain as to the likely responses of plants in different sites, and of sites with certain characteristics in different locations. Two years of intermittent observations is inadequate for a comprehensive picture to be built up. Much longer trials are required. However, these could now be shaped by the experience gained in SEACAP 21.

Contracting and works management

- Construction contractors do not have the right skills and understanding for bio-engineering works. They expect to undertake them at any time, irrespective of the weather, and to treat plants as if they are as strong and robust as rocks. They will not sub-contract them to competent agricultural organisations but if they do sub-contract, they tend to use local farmers’ groups without providing any training or supervision.
- The lowest bidding contractors, in both Phases, ended up over-stretched on the works. Programming was very poor and quality control almost non-existent.
- It is impossible to complete slope stabilisation works to a fixed budget, since site conditions are always different from what can be predicted before site works start. It is essential to have a contingency sum in the Bill of Quantities to ensure that structures can be finished properly.
- Standard MPWT-WB procedures make it very difficult for site staff to re-assign more than token quantities between bill items. More flexibility is required in order to be able respond to conditions as they are found on the site.

5.2 Outcome of information dissemination activities

Detailed outcomes of the information dissemination activities conducted under SEACAP 21/001 are documented within the individual Module Reports. However, following concerns that such activities would not necessarily provide a sustainable result, SEACAP 21/003 has been introduced to strengthen these activities. Consequently it is necessary to take SEACAP 21/003 into account when discussing the overall outcomes.

Within MPWT, the stage has been reached where a number of MPWT and DPWT staff are aware of the research activities conducted under SEACAP 21/001. These might number in excess of 100 individuals. However, most of these will only have a superficial knowledge of the work carried out, mainly through the Workshops conducted in Vientiane, but only a very few, possibly numbering less than 5 individuals, have a greater depth of knowledge of the work. Partly this may be due to the widespread poor understanding of technical English within the Ministry and Departments, and partly due to the local lack of specialist skills.

It is anticipated that the production of the Slope Maintenance Site Handbook, the Slope Maintenance Manual and the Slope Maintenance Specifications in Lao will considerably help to disseminate the knowledge gained during the course of SEACAP 21/001. It is expected that the agreed numbers (60 copies of the Handbook and 20 copies of the Manual) will prove to be insufficient.

The outcomes of the ongoing SEACAP21/003 should also have a significant impact on the outcomes of the information dissemination activities. This includes the following work.

Training aspects

- Review and assess the relevant undergraduate engineering core curriculum at the National University of Laos for inclusion of the outputs of SEACAP21.
- Amend the existing courses accordingly.
- Draft outlines for: undergraduate thesis studies; graduate thesis studies; and new courses that are needed.
- Include interested students and faculty in the field trials.

Field trials (in co-operation with the MPWT and selected provinces)

- Undertake field trial approaches, guidelines, design manuals and specifications to preliminary design status.
- Select six sites representing a range of typical slope stability problems for these trials along NR 13 and 7.
- Carry out in-service training for the MPWT and provincial counterparts as well as participating students and faculty staff from the NUoL during the survey and design activities.

6. DRAFT TERMS OF REFERENCE FOR PHASE 2 RESEARCH

SEACAP21/001 has conducted valuable initial research into slope stabilisation options for the Lao PDR's road network. However, it is clear that it is only a start into what is inevitably a very large topic. Considerable further research is needed, and this must be done over a period of some years to ensure that the findings are properly replicable and not merely anecdotal from a small number of trials.

The Feasibility Study for a National Programme to Manage Slope Stability (SEACAP21/002) produced a comprehensive strategy for a way forward that includes training, capacity development and further research. That now needs to be taken forward and the Ministry of Public Works and Transport should commit an appropriate level of funding to this issue to develop the strategy on those lines.

In the context of uncertainty as to the exact means by which further research into slope stabilisation might take place, it is not considered to be appropriate to provide detailed terms of reference here. The sections below therefore suggest broad areas for a research strategy, and a number of key issues that would benefit from further research.

6.1 Research into hill road construction and maintenance strategies

The following main topic areas have been identified as worth pursuing through further research, to ensure that the Lao road network is better safeguarded. To a large extent, these are preventative measures intended to reduce the incidence of failures.

- Better alignment design. Increased study of the terrain in the design and fixing of the alignment of a mountain or riparian road can often lead to the selection of a more stable route. 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 away from rivers, 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.
- Cut/fill balance. Earthwork quantities can be minimised by ensuring that there is a cut/fill balance, either within the slope cross-section or within a short horizontal distance along the route. This means that the volume of cut is minimised and that most of the spoil produced is utilised within a very short haul distance as fill.
- 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. Its success also depends on the availability of resources during operation and maintenance, to ensure a fully functioning drainage system.

- Improvements to PBMC systems. Performance Based Maintenance Contracting has been started very recently in the Lao PDR and so the implications are not yet fully clear. Observations made in the course of SEACAP21 have shown that the contracts do not really deal properly with the work required in emergency situations, particularly with respect to major landslides above the road and almost any slide below the road. The PBMC arrangements need to be reviewed to ensure that the contracts are sufficiently flexible to ensure that the response in an emergency not only re-opens the road quickly and safely, but does this in a way that minimises the risk of further damage to the slopes (for example, spoil is disposed of only in approved safe locations, not on to any slope below the road). Furthermore, the responsibility for undertaking slope stabilisation works needs to be clarified, particularly for below road failures.
- Pro-active slope stability measures (mostly retaining structures), designed to achieve an acceptable slope factor of safety where this is not possible through 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.
- Pro-active river engineering works designed to correct the channel migration which will sooner or later trigger bank erosion. Typically this will include the use of groynes or stub groynes to deflect flow away flow the bank and encourage deposition at the toe of the bank; also to clear deposition on the opposite bank. Also use of toe walls and mattresses that will protect against undercutting by scour.
- 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.

6.2 Research into key technical issues

Most important in future practical research into slope stabilisation measures in Laos is the need to move beyond the National roads and into the lower tiers of the road network. This is important because SEACAP21 focussed only on the major roads where the most pressing economic need was identified by the MPWT. However, access in hilly rural areas is constrained in many cases by slope instability around provincial, district and village roads. Although SEACAP21 has started the process of identifying appropriate solutions, practical research is now needed to demonstrate how it might be achieved in practice. In this respect, there must be great reliance on the use of low cost systems, appropriate to low traffic roads. Promising findings from SEACAP21's trials will help to determine the strategy for applied research on these roads.

Examples of important technical issues that require further research or training are as follows.

- Improved construction quality of retaining walls. Research needs to investigate the optimum ways of developing the skills needed in Laos to build high quality walls. Examples are the importance of reducing voids and increasing interlock in structures of mortared masonry and gabion, and the use of the correct consistency of mortar. While the importance of these factors is understood in theory, ways have not yet been found of achieving it in practice.

- Improved understanding of the relative merits of the various types of walls and revetments and the need to adjust a design drawing to the actual conditions found on site. In the latter case a 35m long x 6m depth retaining wall might actually need to be 36.8m long with a depth varying from 3m to 7m.
- Timing of bio-engineering works. There are complexities in the rainfall patterns that are not fully understood. Rainfall data are not sufficiently comprehensive for hilly areas to give an accurate picture of variability. As a result, further research is needed as to the best timing for implementation of bio-engineering site works.
- Plant selection for bio-engineering. Nutrient levels and fluxes are not well understood on marginal hill soils in Laos. For this reason, more research is required to understand properly how different plants perform in difficult conditions.