The Republic of Uganda

Uganda National Roads Authority

Ministry of Works, Housing and Communications (MoWHC)

Consultancy Services for Feasibility Study, Detailed Engineering Design and Construction Supervision of Matugga - Semuto - Kapeeka Road Using Innovative Technologies

Contract: NDF / HW / S001

Pilot Demonstration Project (PDP)

Action Research Plan for Stage III (ARP-III)

April 2012

COWI

in association with

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1 Executive Summary

The Pilot Demonstration Project

The Matugga-Semuto-Kapeeka Pilot Demonstration Project (PDP) aimed to demonstrate the appropriateness of adopting in Uganda various techniques in relation to the construction of low traffic volume bitumen sealed roads in a more economical way, through the incorporation of construction trials in the Contract for the road upgrading. The results of this research are to be used to assist in the development of Design Manuals, Specifications and Guidelines for Sealed Low Traffic Volume Roads in Uganda.

Action Research Plan for Stage III

This Action Research Plan for Stage III of the Project (ARP-III) takes into account the findings of research activities during the construction Stage and fully develops and describes research activities required in the Post Construction Stage.

A new consultancy is to be awarded for carrying out and reporting performance monitoring of the PDP road for a period of up to 6 years after construction (Stage III of the project). The information obtained during this post construction monitoring period will be used by the appointed consultant to provide scientifically acceptable evidence to support the introduction in Uganda of innovative technologies for the construction of sealed low traffic volume roads though the publication of Design Manuals, Construction Guidelines and Specifications.

ARP-III describes how the road is to be monitored for up to a period of six years and further defines the framework for the development of the “Guidelines for Low Volume Traffic Roads”. ARP-III identifies the Scope of Works for Stage III of the project and includes cost estimates for carrying out the monitoring and for development and dissemination of the guidelines/ specifications.

Monitoring and Research during the Construction Period

Construction Trials

The Construction Contract included the building of 16 pavement research trial sections each of which was 350m long and comprised various types of subbase and base course materials with various different forms of bituminous surfacing. Also, two 350 m long sections of the Works were built in accordance with the design of the “main works” but are being specially monitored as “control reference sections”. Table 2-2 presents the “as built” road design and trial section matrix. The total length of the pavement trial sections is 7+050m (including the “reference sections”). The Project’s Third Research Report (RR-3) describes the pavement trials and reports on the testing which forms the “baseline” data collected during and immediately after completion of construction work concerning the characteristics and properties of the new road and its pavement trial sections

The Fourth Research Report (RR-4) documents the swamp construction trials using traditional and innovative methodologies carried out between km 16+500 to 17+000 and the results of investigations and monitoring during the construction phase.

The Fifth Research Report (RR-5) documents the culvert construction trials using U-PVC spiral wound pipes and the results of performance monitoring during the construction phase.

Database of Materials and Pavement Test Results

An accurate and detailed record of the engineering characteristics of the existing subgrade and the properties of the various road construction materials used was collected during the construction stage, because the performance of the various pavement constructions needs to be compared from one location to another during the post construction monitoring and evaluation.

A Construction and Research Database (CARD) has been created using Microsoft Access to store both the construction materials records and the baseline study information, so that this data is readily available and accessible for analysis and interpretation when required at any time during the 6 year study period (refer Project Third Research Report –RR-3). It is the intention that this database is up-dated when any additional investigation data is generated during the post construction monitoring phase of the project.

Baseline Pavement Testing

The Third Research Report (RR-3) describes and reports the pavement testing which was undertaken at the completion of the road construction and which will form the “baseline” data for accurately evaluating the engineering properties of the various road pavement sections at the start of their service life.

The tests performed during the Baseline Study are divided into non-destructive tests and destructive tests. The non-destructive tests performed include tests relating to traffic safety and traffic comfort such as skid resistance, surface texture, rutting and roughness measurement. The pavement strength tests carried out were also mainly non-destructive tests and included visual inspection, Benkelman Beam deflection testing, Falling Weight Deflectometer tests and Dynamic Cone Penetration (DCP) tests. Core drilling was the only destructive investigation carried out

RR-3 reports to how the baseline testing was carried out and analysed, so that similar procedures can be adopted in the future (allowing direct comparison for pavement performance evaluation).

Traffic Monitoring during Construction

An update of the traffic count surveys which were made during the design studies in 2004 was implemented at the end of the construction phase (December 2010). The traffic growth data obtained will be essential to help evaluate the performance of the different parts of the “main works” and trial sections one against another and so that the actual traffic conditions can be compared with the predicted traffic conditions at the design stage, which were the basis for the pavement layer thickness design.

The 2010 traffic survey has shown that the project road has generated much higher levels of traffic than was forecast during the design studies. The implementation of regular traffic surveys at least once a year during the monitoring period will be required to monitor this unexpected traffic growth.

The higher than expected traffic growth is good for the PDP pavement trial monitoring, because a much higher proportion of the design traffic loading will be experienced during the six year monitoring period than was originally expected (i.e. accelerated traffic loading will be experienced).

Climate Monitoring during Construction

The project area is located in a wet and humid region with a mean annual rainfall generally in the range of 1,100 to 1,200 mm. The rain mainly falls during two wet seasons in March - May and in September – November. Average annul temperature along the project road is 22deg C (minimum 13 deg C and maximum 36 deg C). The Climate is fairly typical of that found over much of Uganda.

Rainfall was monitored during the construction of the road and the site rainfall records are contained in the Third Research Report (RR-3). This Report also contains rainfall records for two permanent weather stations located close to the project road at Namulonge and Kawanda for the period 1970 to 2008.

Monitoring and Research after the Construction Period

Post Construction Pavement Monitoring

The post construction pavement monitoring will involve the same pavement evaluation methods and analysis procedures as carried out during the construction phase for the "baseline" data collection and described in RR-3.

Details of the scope of the pavement investigations, including frequency of testing during the 6 year monitoring period, are contained in Section 3 of this report and are summarised in Table 3-1 and Table 3-2.

Post Construction Traffic Monitoring and Evaluation of Economic Indicators

The main variable that may have significant impact on the in-service performance of the project road is changes in traffic conditions, specifically changes in the volume and composition of the vehicles using the road.

It is therefore required to implement classified traffic counts every 12 months, recording traffic in each direction at the locations selected for the baseline and design stage traffic surveys (refer RR-3). Axle load surveys using portable weigh bridge shall be undertaken simultaneously with the classified traffic counts.

The scope of the traffic surveys is to be extended to include the collection of information on Vehicle Operating Costs (VOCs), passenger fares and freight commodity rates by commodity and travel times.

Post Construction Climate Monitoring

It is considered that the meteorological records from Kawanda and Namulonge weather stations will provide sufficient information for monitoring the climatic conditions along the project road during the six year post construction monitoring period.

Preparation of Guidelines, Design Manuals and Specifications

Section 4 considers the preparation and expected content of the Low Traffic Volume Sealed Road Guidelines, Manuals and Specifications for Uganda. The document preparation aspects of Stage III will involve;

- Additional document research into current low traffic volume (LTV) road building practice in the region and similar environments (worldwide). In particular, the relevance of the new design manual and revised specifications for LVR recently developed by the Ethiopian Roads

Authority with assistance from the UK Department for International Development's Africa Community Access Programme (AFCAP).

- Analysis of results from the PDP trials and investigations;
- Utilisation of the PDP findings and other Uganda specific road construction data to justify the development and publication of new construction standards or the adoption of standards and specifications similar to those already developed for low volume traffic roads in similar environments.

The consultant concludes that as a result of the relatively limited scope of the research carried out during the PDP it would be unrealistic to expect the studies to provide conclusive evidence for radically different sealed low volume construction specifications. However, it is expected that the PDP research will provide the necessary justification for either adopting existing specifications from counties with similar construction environments or more likely somewhat modified/developed construction specifications and guidelines appropriate to the Uganda situation.

Equipment for Monitoring and Research

Apart from the Falling Weight Deflectometer (FWD) equipment most of the testing equipment required for the monitoring of the PDP road is expected to be available for hire within Uganda. Section 5 reviews equipment requirements.

Programme, Staffing and Budget for Stage III

Figure 6-1 and Figure 6-2 summarise the programme, staffing and reporting requirements for Stage III.

Appendix 1 contains a Bill of Quantities for Stage III Consultancy Services bid submissions.

Appendix 2 contains the Supervision Consultant's Estimate of the budget for Stage III, based on the Scope of Works outlined in this Action Research Plan for Stage III.

Conclusions

The baseline testing has shown that the various pavement constructions are well built and strong enough to accommodate the expected increase in traffic growth. This uniformity of high quality construction is important because any pavement deterioration due to poor workmanship would affect the proper evaluation of the success of introducing the less restrictive construction materials specifications and new types of lower cost construction.

The trial Special Specifications for the "main works" allowed the use of a large range of locally available lower quality natural clayey gravel deposits and clayey sands that were "modified" by adding just sufficient lime or cement to improve them to a standard which provided engineering properties acceptable for a low traffic volume sealed road. The uniformly high strength properties of the "main works" pavements as tested in the baseline studies goes a long way along the path of justifying the adoption of the project Special Specifications on other low volume traffic roads. Time will tell during the post construction pavement monitoring period whether full confidence in the Special Specifications is supported by "in service" performance.

It is concluded that the construction stage of this research process has been very successful particularly in demonstrating the possibilities of using lower quality locally available materials in some alternative forms of layer construction and bituminous surfacing that lend themselves to low technology and labour based

construction procedures (i.e. emulsion treated sandy base construction and Otta Seal surfacing).

Recommendations

The PDP trial sections are small scale, there is therefore a need to follow up this research by making relatively large scale construction trials as soon as possible, so that more detailed and varied data can be obtained. The success of the short trials in this project should serve as the basis and justification for the implementation of the full scale construction trials on other low traffic volume road upgrading projects.

The PDP trials were constructed using modern mechanised plant but some of the construction procedures demonstrated on this project lend themselves to simple labour based construction methods. It is recommended that additional trials be implemented adopting these labour based techniques particularly with respect to the alternative types of low cost bituminous surfacing.

The consultant has observed some high quality gravel roads in parts of Uganda, which could certainly be economically upgraded using low cost and labour intensive surfacing techniques. Periodic and routine maintenance activities on gravel roads are expensive commitments when they carry significant traffic volumes in wet tropical climates. The introduction of low cost sealing procedures in this situation needs very serious consideration and the implementation of carefully selected large scale field trials is recommended.

The construction phase of the PDP pavement research has been successful. The importance of building on this success during Stage III cannot be over stressed. The performance of the various trial constructions must be carefully monitored during the six year post construction period.

A suitable Consultant with international experience in relation to the design and construction of low traffic volume sealed roads needs to be appointed to evaluate the findings of the PDP and also to undertake a “state of the art” review of current best practice and research findings with respect to the economical construction of lightly trafficked sealed roads.

The appointed Consultant will develop Uganda’s "Guidelines for Low Traffic Volume Roads", which are expected to comprise various documents including Design Guidelines/ Manual(s), Construction Guidelines and less restrictive materials Specifications which promote the use of locally available “appropriate quality” natural clayey gravels and clayey sand construction materials and innovative technologies.

2 Introduction

2.1 Project Background

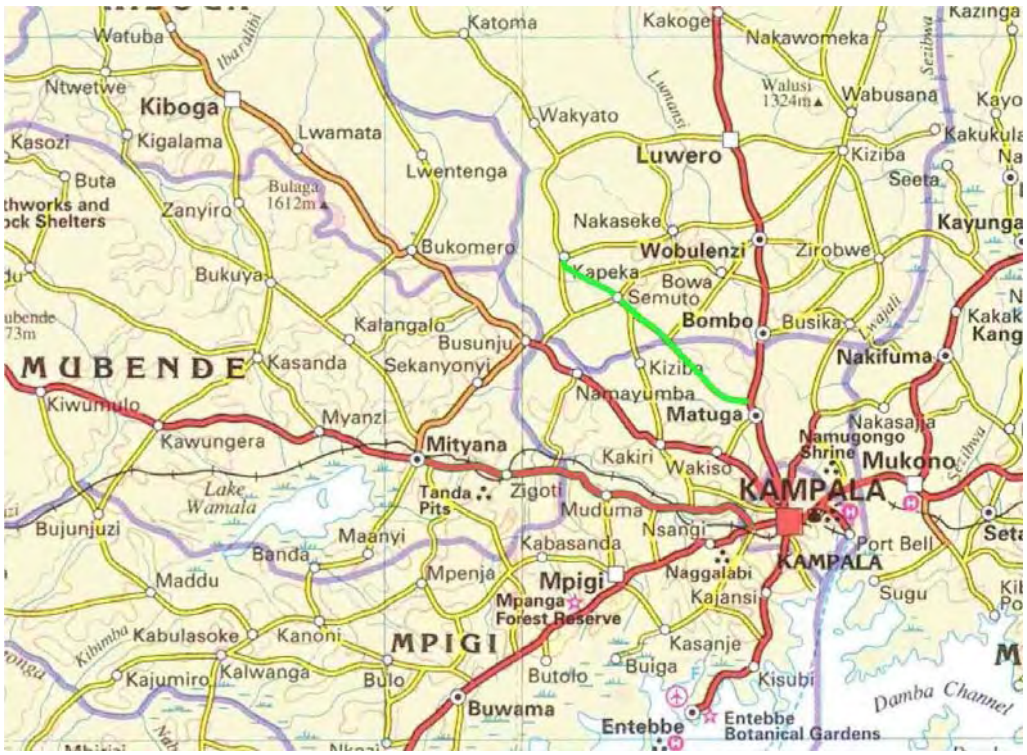
Road Development Programme Phase 2

The Government of Uganda received a credit from the Nordic Development Fund (NDF) toward the cost of the Road Development Programme Phase 2 (RDPP 2), and part of the proceeds of this credit was used to fund payments under the contract for Implementation of a Pilot Project for the Demonstration of Innovative Technologies for the Construction of Low Traffic Volume Roads on Matugga - Semuto - Kapeeka Road, Contract No.: NDF/HW/S001.

Location

The project road starts in Matugga at the Kampala - Bombo - Luwero - Gulu Road, about 18 km north of the Kalelwe Roundabout at Makerere University. The road passes through Semuto town at around km 29 - 30 and ends at the roundabout in Kapeeka town at km 41.1.

Figure 2-1 Location Map. (Project Road Shown in green)



Terrain

The project road passes mainly through rolling terrain with flat sections over about 7 km at swamp crossings. At about km 26.7, there is a 300m long mountainous section where the road crosses a ridge.

Drainage

From a hydrological point of view the project road is conveniently located, in that no major rivers have to be crossed. However, there are some swamp crossings with relatively big catchment areas as shown below:

Table 2-1 Catchment Areas for Major Swamp crossings

Location	Catchment Area	Name of Swamp
Km 0.82 - 1.31	16.50 km^2	Tugavune Swamp
Km 6.00 - 6.35	32.30 km^2	Munyika Swamp
Km 16.50 - 17.35	62.40 km^2	Danze Swamp
Km 20.30 - 20.60	55.90 km^2	Mayanjawenkalwe Swamp
Km 36.90 - 37.35	21.20 km^2	Nalugaga Swamp

There were a total of 88 existing cross drainage structures along the road. All the existing culverts were replaced by pipe or box culverts because of the following reasons: poor condition; insufficient discharge capacity; located too low, particularly in swamps.

Climate

The project area is located in a wet and humid region with a mean annual rainfall generally in the range of 1100 to 1200 mm. It rains primarily during two wet seasons, with heavy rains in March - May and the "short rains" in September - November with more than 100 mm/month, separated by dry seasons of about 50 – 80 mm/month.

Geology

Geologically the project road is dominated by gneisses or granites belonging to the Pre Cambrian (ancient) Basement Complex. At places there are intrusions from younger Pre Cambrain rocks belonging to the Buganda-Toro System and consisting of sandstone, slate, phyllites and schist (approximately km 0-5 and km 35-38) or gneisses or quartzites (approximately km 27-29 and 30-31).

Bedrock is typically blanketed with several metres of residual soil except in the valley bottoms and swamp areas where alluvial sands, silts and clays exist. The residual soils are typically silty sandy clay red lateritic deposits containing a variable quartz gravel content (derived primarily from vein quartz within the basement complex). Nodular laterite deposits have a scattered occurrence throughout the area.

Existing Road

The road was a Class C gravel road and should therefore have been an all weather passable road. However, there are 7 swamp crossings with lengths varying from around 300 m to 1 km and totalling about 4.1 km. These swamps and other low-lying wetland sections were liable to some flooding during very heavy rain storms.

Design Traffic Loads

The design traffic loads were light and were as follows:

Matugga to Kirolo (km 0 to 15) - 1.5 to 3.0 Mill. ESA;

Kirolo to Semuto (km 15 to 29) – 0.7 to 1.5 Mill. ESA

Semuto to Kapeeka (km 29 to 41) – 0.3 to 0.7 Mill ESA

Pilot Demonstration Project

The Matugga-Semuto-Kapeeka road upgrading project was selected as a suitable Pilot Demonstration Project for researching ways of constructing low traffic volume bitumen sealed roads in a more economical way, taking into account local conditions, the properties of locally available pavement construction materials and by testing more appropriate materials specifications for lower trafficked sealed roads.

Road Upgrading

The original road upgrading design involved construction of a 5.6m carriageway with gravel shoulders (1m wide in rural areas and 2nm wide in villages). During project implementation sealed shoulders were introduced and

the design changed to a 6m wide carriageway with 0.8 m sealed shoulders in rural areas and 1.8 m wide sealed shoulders in village areas.

The main part of the road has been upgraded by constructing a natural gravel subbase (lime improved between km 0 to km 30), cement treated road base and double bituminous surface dressing utilising natural local materials from within or close to the project area.

Construction Trials

The Project comprised a number of trial constructions to demonstrate innovative and appropriate construction technologies for low traffic volume roads. These included:

Pavement construction trials (refer Table 2-2);

Culvert construction trials;

Swamp construction trials

2.2 Background to the Research Activities

The three main research goals of this Pilot Demonstration Project (PDP) are as follows:

- Pioneer the development of innovative construction technologies for the construction of Sealed Low Volume Traffic Roads in Uganda.
- Through research (before, during and after construction) establish on a scientifically acceptable level a basis for the development of Design Manuals, Specifications and Guidelines for Sealed Low Volume Traffic Roads.
- Demonstrate the cost-effectiveness of the innovative technologies and their potential contribution to sustainable rural road infrastructure development in Uganda.

2.3 Background to Research Planning and Reporting

The various research objectives, activities and phases of research that are expected to be pursued during the Pilot Demonstration Project (PDP) have been outlined in the Pilot Project Concept Report (Overby & Refsdal 2000 [1]) and in the Consultant's Terms of Reference.

Proper advance planning is always a key issue in research projects such as the PDP. To consolidate the general framework for the research aspects of the project a General Action Research Plan (GARP) was produced soon after the implementation of the project in February 2004.

Both the Project Concept Report and GARP required individual Action Research Plans (ARP) and Research Reports (RR) to be formulated at the beginning of each of the three Phases of the project as follows:

- **ARP-I** outlined planning relating to the R&D activities during the Design stage (Phase I).
- **RR-1** reported investigations and research carried out during the design stage (Phase I) of the project.
- **ARP-II** primarily addressed the planning of research activities during the project construction (Phase II), but also advanced the planning and methodologies for Post Construction research and document production (manuals, specifications and guidelines relating to low volume traffic road construction in Uganda).

- **RR-2** outlines the scope of the research activities to be carried out during the project construction (Phase II).
- **RR-3** reports the “baseline data” collected during and immediately after completion of construction work concerning the characteristics and properties of the new road and its pavement trial sections. RR-3 also reports baseline data concerning the existing road environment (climate, traffic, etc).
- **RR-4** specifically documents the swamp construction trials using traditional and innovative methodologies carried out between km 16+500 and km 17+000.
- **RR-5** documents the culvert construction trials using U-PVC spiral wound pipes.
- **Construction and Research Database (CARD).** A Microsoft Access database has been established to store and catalogue both the normal construction records and research data, so that this information is readily accessible for analysis and interpretation throughout the 6 year study period.
- **Project Completion Report** The PCR will include an “As Build Pavement and Materials Report” covering both the “main works” and the various “pavement trials”.
- **ARP-III** is to be submitted at the end of the Construction Phase and fully develops and describes research activities and outputs required in the Post Construction Phase.

2.3.1 Action Research Plan III (ARP-III)

ARP-III takes into account the findings of research activities during the construction phase and fully develops and describes research activities required in the Post Construction Phase.

In particular, ARP-III describes how the road is to be monitored for up to a period of six years and further defines the framework for the development of "Guidelines for Low Volume Traffic Roads", which are expected to comprise various documents including Design Guidelines/Manual(s), Construction Guidelines and Specifications.

ARP-III identifies the Scope of Works for Stage III of the project and includes cost estimates for carrying out the monitoring and for development of the guidelines, specifications and design manuals.

Table 2-2 "As Built" Pavement Design and Summary Trial Section Matrix

Reference Section Trial Section No.	Station (km)		Layer	Capping Layer			Subbase Course			Base Course							Surfacing								Innovative Pavement Design Method	
	Start	End	Length of trial Section (m)	Subgrade Class S2	Subgrade Class S3	Subgrade Class S4	Lime Improved Gravel (CMS)	Mechanically Improved Gravel (G30)	Natural Gravel (G25)	Cement Modified Sand	Cement Modified Gravel (CMB)	Pozzolan/Cement Modified Gravel	Bitumen Treated (ETB) Gravel	Crushed Rock (CRS)	Mechanically Modified Gravel (G80)	Lime Modified Gravel (CMB)	Pre- Coated Double Surface Dressing	Double Surface Dressing	Inverted Double Surface Dressing (10mm & 20mm)	Concrete Paving Blocks	Single Surface Dressing (14mm) & Sand Seal	Double Sand Seal	Single Otta Seal + Sand Seal	Double Otta Seal	Reduced pavement thicknesses	Reduced thicknesses incl. increased base course strength (Note 5)
Main Works	0.00	15.00	15000	225	125	0	175				200							◆								
Main Works	15.00	16.50	1500	260	125	0	150				175							◆								
Swamp Trials	16.50	17.00	500	260			150				175							◆								
Main Works	17.00	19.05	2050	260	125	0	150				175							◆								
Reference Section A	19.05	19.40	350		125		150				175							◆								
Trial Sec. 1	19.40	19.75	350		125		125				150							◆								
Trial Sec. 2	19.75	20.10	350		125		125				150							◆								
Trial Sec. 2 A	20.10	20.85	750	260			150				175						◆									
Trial Sec. 3	20.85	21.20	350		125			150			175							◆								
Trial Sec. 4	21.20	21.55	350		125				150		175							◆								
Trial Sec. 5	21.55	21.90	350		125		150			175								◆								
Trial Sec. 6	21.90	22.25	350		125		150				175								◆							
Trial Sec. 7	22.25	22.60	350		125				100		150									◆						
Trial Sec. 8	22.60	22.95	350		125		150				175										◆					
Trial Sec. 9	22.95	23.30	350		125		150				175											◆				
Trial Sec. 10	23.30	23.65	350		125		150				175												◆			
Trial Sec. 11	23.65	24.00	350		125		150				175													◆		
Trial Sec. 12	24.00	24.35	350		125		150					175						◆								
Trial Sec. 13	24.35	24.70	350		125		150						175					◆								
Trial Sec. 14	24.70	25.05	350		120		150							200				◆								
Trial Sec. 15	25.05	25.40	350		125		150								175			◆								
Trial Sec. 16	25.40	25.75	350		125		150									175		◆								
Reference Section B	25.75	26.10	350		125		150				175							◆								
Main Works	26.10	30.00	3900	260	125	0	150				175							◆								
Main Works	30.00	41.10	11100	260	125	0			150		150							◆								
Total Length (m)			41100																							

Note 5: Half of the Trial Section No 2 will be constructed with predefined cracking pattern

3 Monitoring and Research after the Construction Period

3.1 Introduction

3.1.1 Monitoring and Research during the Construction Phase

As a part of the construction supervision (Phase II of the project) pavement trial sections have been constructed using innovative technologies (refer Table 2-2).

The scope of the monitoring and research activities that were proposed to be carried out during construction phase has been reported in the Second Research Report (RR-2, December 2005) and in Section 3 of the Action Research Plan for Phase II of the project.

The Third Research Report (RR-3) documents the "baseline data" collected during and immediately after completion of construction work concerning the characteristics and properties of the new road and its pavement trial sections. RR-3 also reports baseline data concerning the existing road environment (climate, traffic, etc).

The Fourth Research Report (RR-4) specifically documents the swamp construction trials using traditional and innovative methodologies carried out between km 16+500 and 17+000 between 0ctober 2009 and February 2010. The report presents details of the site investigations, trial layouts, baseline performance monitoring results along with conclusions and recommendations.

The Fifth Research Report (RR-5) documents the culvert construction trials using U-PVC spiral wound pipes and makes recommendations for post construction monitoring of these trials.

A Construction and Research Database (CARD) using Microsoft Access has been established to store and catalogue both the normal construction records and research data, so that this information is readily accessible for analysis, up-dating and interpretation throughout the 6 year study period

Visual condition surveys of the road have been carried out during the Defects Liability period.

3.1.2 Monitoring and Research after the Construction Phase

It is proposed that a new consultancy will be awarded for carrying out and reporting performance monitoring of the PDP road for a period of up to 6 years after construction (Stage III of the project). The information obtained during this post construction monitoring period will be used by the consultant to provide scientifically acceptable evidence to support the introduction in Uganda of innovative technologies for the construction of sealed low traffic volume

roads though the publication of Design Manuals, Construction Guidelines and Specifications.

This section of ARP-III outlines the proposed scope of the post construction monitoring and research activities that are to be carried out during Stage III of the project and Section 4 reviews the proposed preparation and content of the Guidelines and Specifications for Low Traffic Volume (LTV) Sealed Roads.

This part of ARP III will be included in the Consultancy bidding documents for Stage III after this research plan has been reviewed and agreed with UNRA and other stakeholders

3.2 Long Term Monitoring Activities

The major objective of the post construction monitoring is to record the actual in-service performance of the different innovative and traditional pavement constructions over a considerable period of time. In addition, any changes in the "road environment" that may have had an influence on the in-service performance of the road will be recorded. Long term performance will be evaluated in relation to the "baseline data" collected during the construction period (as reported in RR-3, RR-4, the Construction and Research Database, and the Project Completion Report).

Long term monitoring activities will comprise three types of data collection as follows:

- Monitoring of Economic Performance Indicators
- Monitoring of Climatic Conditions
- Monitoring of the Physical Performance of the road constructions in-service.

3.2.1 Monitoring of Economic Performance Indicators

i) Traffic Conditions

The main variable that may have significant impact on the in-service performance of the project road is changes in traffic conditions, specifically changes in the volume and composition of the vehicles using the road.

It is recommended that classified traffic counts be carried out every 12 months, recording traffic in each direction at the locations selected for the baseline and design stage traffic surveys (refer RR-3).

The counts should be carried out for a 7 day period, during which on one weekday and one weekend the counts shall be for 24 hours, while on the other 5 days the counts shall be made from 6am to 10pm. Counts should be avoided at times when travel activity is abnormal for short periods due to public holidays, public functions etc.

Axle load surveys using portable weigh bridge shall be undertaken simultaneously with the classified traffic counts for two days of at least 12 hours. The weigh bridges shall be calibrated prior to and after the survey. The survey shall include all heavy vehicles i.e. vehicles with un-laden weight of 3 tonnes or more such that representative ESA factor can be determined for each type.

ii) Monitoring of other Economic Performance Indicators

The scope of the traffic surveys should be extended to include collection of information on Vehicle Operating Costs (VOCs), passenger fares and freight commodity rates by commodity and travel times.

3.2.2 Monitoring of Climatic Conditions

Rainfall was monitored during the construction of the road initially at Ssanga and Semuto and later at Semuto and Kapeeka. All site rainfall records are contained in RR-3, in addition RR-3 contains rainfall records for two permanent weather stations located close to the project road at Namulonge and Kawanda for the period 1970 to 2008.

It is considered that the meteorological records from Kawanda and Namulonge weather stations will provide sufficient information for monitoring the climatic conditions along the project road during the six year post construction monitoring period.

3.2.3 Monitoring of In-Service Pavement Performance

It is proposed that the pavement testing regime described in the Third Research Report (RR-3, November 2011 for monitoring and research during the construction period be extended throughout the six year post construction monitoring period. This testing regime includes:

- Measurement of pavement distress as recorded in the form of rutting, cracking, ravelling, bleeding, potholes etc.
- Measurement of the road roughness (in terms of IRI) using vehicle mounted Bump Integrator (using the equipment and procedures adopted during the construction phase baseline monitoring and reported in RR-3). Alternatively a road profiling apparatus may be used.
- Measurement of pavement deflection parameters using a Benkelman Beam (following the procedure adopted during the construction phase and reported in RR-3).
- Measurement of development in the structural integrity of the road bases. This may be done by carrying out measurements with Falling Weight Deflectometer (FWD) and perform back-calculation of E-moduli of the base course materials (using the procedures adopted for the baseline studies and reported in RR-3).
- Measurement of bitumen ageing properties of surfacing materials.

The proposed method and frequency of post construction pavement investigations and monitoring for the "main works" is summarised on Table 3-1, whilst Table 3-2 summarises the proposed testing regime for the trial sections.

Table 3-1 Long Term Pavement Monitoring Programme for "Main Works"

Layer Construction		Minimum Pavement Testing & Monitoring	Recommended Minimum Test Frequency (Starting 6 months after the end of the Defects Liability Period)
"Main Works" km 0 to 15, 15 to 19 & 26 to 29.4		**"" Long Term Monitoring"**	
Surfacing :	DBST - 20&10 mm sealing aggregate	- Visual survey (including straight edge survey) carried out using the ASTM D6433 methodology;	Every 6 months
Road base: 175/200mm	CMB Type I - Cement Modified Base (CBR >160%)	- Bump integrator roughness survey at 100m intervals or road profiling survey;	Every 12 months
Subbase: 175/150mm	CMS - Lime Modified Subbase (CBR >60%)	- Benkelman Beam survey, both lanes at 100m intervals if uniform strength;	Every 12 months
Capping Layer	G15 - Natural gravel (CBR >15%)	-Additional DCP testing where B Beam indicates possible change in baseline pavement strength;	Every 12 months
"Main Works" km 29.4 to 40.1		- Falling Weight Deflectometer (FWD) deflection testing at 100m intervals if uniform strength.	Every 24 months
Surfacing :	DBST - 20&10 mm sealing aggregate	- Nuclear Density Testing at strength anomalies;	Every 12 months
Road base: 175/200mm	CMB Type II - Cement Modified Base (CBR >160%)	- Test pit or boring at 4 selected sites previously investigated and at any sites showing signs of distress;	Every 12 months
Subbase: 175/150mm	Natural Gravel Subbase (CBR >25%)	- Surface textures tests at 5 km intervals;	Every 12 months
Capping Layer	G15 - Natural gravel (CBR >15%)	- Stabilised base coring at 5km intervals for Lab UCS testing	Every 12 months
Notes: 1. Next FWD testing recommended 24 months after the baseline testing, which will be in November 2012.			

Table 3-2 Long Term Pavement Monitoring Programme for Trial Sections

Minimum Pavement Testing & Monitoring	Recommended Minimum Test Frequency (Starting 6 months after the end of the Defects Liability Period)
- Visual survey (including straight edge survey) carried out using the ASTM D6433 methodology;	Every 6 months
- Benkelman Beam testing typically at 25m intervals if uniform strength.	Every 12 months
- Additional DCP testing where B Beam indicates possible change in 'baseline" pavement strength	Every 12 months
- Falling Weight Deflectometer (FWD) deflection testing at 20m intervals if uniform strength or road profiling survey	Every 24 months
- Continuous MERLIN roughness measurements and Bump Integrator (roughness) measurement at 100m intervals;	Every 12 months
- Nuclear Density Testing at strength anomalies	Every 12 months
- Test pit or boring at site of previous coring (say 1 per trial) and at other locations showing signs of distress	Every 12 months
- Surface textures tests at 100m intervals	Every 12 months
- Additional stabilised base coring for Lab UCS tests etc if deflection testing or visual surveys indicate any change in pavement strength.	Every 12 months
Notes: 1. FWD testing recommended initially at the start of the defects liability period and at two year intervals thereafter.	

3.3 Analysis and Utilisation of Monitoring Data

It is proposed that all project construction and research records be stored and catalogued in a project database (Construction and Research Database -CARD, refer RR-3). The CARD database is designed to serve as an analysis tool, which will collate, summarise and report monitoring data.

The main objective of this analysis will be to arrive at conclusions that provide justification for the introduction of suitable innovative technologies in the design and construction of low traffic volume (LTV) sealed roads, which can be incorporated in construction guidelines and specifications for this type of road (refer Section 4).

An outline of the scope and objectives of the analysis and utilisation of monitoring data is given in the following paragraphs.

3.3.1 Analysis of the Physical Performance of Road Sections

The Third Research Report (RR-3, November 2011) reviews how the pavement monitoring research data collected during the 'baseline studies" was interpreted and analysed. The same procedures are to be applied to test results obtained during the post construction phase.

The pavement test results and observed changes in pavement condition over time are to be referenced to the pavement construction materials used, layer

design, road geometry (i.e. gradients, radii, drainage, etc), traffic and climatic conditions.

3.3.2 Evaluation of Appropriate Construction Methods

In order to investigate the suitability of various methods of construction, in terms of the plant used and construction techniques applied, an evaluation will be made of pavement performance in relation to construction methods used and associated costs. Conclusions reached will be used to assist develop the LTV sealed road construction guidelines.

3.3.3 Economic Analysis

The construction cost information gained during the PDP project in relation to the various types of pavement construction used and geometric design will be reviewed along with the construction costs for similar types of road construction recently completed in Uganda. The aim will be to establish a basis for comparing the relative construction and maintenance costs associated with the various road construction options, including those involving innovative pavement construction technologies.

An important component of the evaluation will be a comparison in terms of "whole life costs" gained from records of the construction and subsequent maintenance costs.

It is expected that this will demonstrate the cost effectiveness of some innovative technologies and their potential contribution to sustainable rural road infrastructure development in Uganda

4 Preparation of Guidelines, Design Manuals and Specifications

4.1 Introduction

The Ultimate objective of the research undertaken as a part of the PDP is to develop and introduce ways of constructing sealed low traffic volume roads in a more cost effective way taking account of local conditions and as far as possible utilising low cost locally available natural road construction materials.

The PDP has approached this objective in three stages. The first stage has been a review of the "state of the art" with respect to methods and technologies used in low traffic volume road construction in Uganda and similar tropical and sub tropical developing countries.

The second stage involved the selection of a range of potentially low cost road construction techniques appropriate for the typical Uganda rural road situation and the building of a series of trial constructions for intensive monitoring during construction and in the long term.

Finally, the third stage will be to draw conclusions from the field trials that can assist in establishing guidelines and specifications for sealed low traffic volume road construction in Uganda.

It is expected that the document preparation aspects of Stage III will involve;

- Additional document research into current low traffic volume (LTV) road building practice in the region and similar environments (worldwide). In particular, the relevance of the new design manual and revised specifications for LVR recently developed by the Ethiopian Roads Authority with assistance from the UK Department for International Development's Africa Community Access Programme (AFCAP).
- Analysis of results from the PDP trials and investigations;
- Utilisation of the PDP findings and other Uganda specific road construction data to justify the development and publication of new construction standards or the adoption of standards and specifications similar to those already developed for low volume traffic roads in similar environments.

It is concluded that as a result of the relatively limited scope of the research carried out during the PDP it would be unrealistic to expect the studies to provide conclusive evidence for radically different sealed low volume construction specifications. However, it is expected that the PDP research will provide the necessary justification for either adopting existing specification from counties with similar construction environments or more likely somewhat

modified/developed construction specifications and guidelines appropriate to the Uganda situation.

4.1.1 Development of Manuals and Specifications

In the following Sub Sections provide an initial review of the various possible elements and contents of the proposed guidelines and specifications. This is intended as forming a basis for discussion with UNRA and other project stakeholders. In particular, the intended status of the new "Low Traffic Volume (LTV) Road Design Manuals" with respect to the existing MoWHC Road Design Manual and General Specifications needs to be established.

In addition, it will be necessary to take account of a set of existing manuals prepared by the District and Urban Roads (DUR) division of MoWHC. This set of manuals comprises the following:

Volume 1	**Planning Manual**
A	Functional District Road Classification System & Route Numbering
B	Annual District Road Inventory and Condition Survey (ADRICS)
C	Rehabilitation and Maintenance Planning System (RAMPS)
D	Preparation of Annual District Road Work Plans
Volume 2	**Contract Management Manual**
A1	Contract Documents for Rehabilitation, Periodic Maintenance & Minor Works
A2	Technical Specification
A3	Bill of Quantity (BoQ) and Unit Rates Analysis (URA)
B1	Contract Documents for Labour Based Routine Maintenance
B2	Technical Specification
B3	Bill of Quantity (BoQ) and Unit Rates Analysis (URA)
Volume 3	**Implementation and Monitoring Manuals**
A	Implementation and Monitoring of District Road Work Plan
B	Preparation of Quarterly Progress Reports
Volume 4	**Technical Manuals**
A	Standard Design Manual
B	Technical Manual
Volume 5	**District Administrative and Operational Guidelines**
A	Guidelines for Establishment of Road Committees
B	Environmental Guidelines for District Engineers
C	Gender Guidelines for District Engineers
D	Occupational Health and Safety in the Workplace
E	Road Safety
F	Policy Document for Road Maintenance
G	Accounting Manuals for District Road Works

A detailed review will be made of these DUR manuals and specifications in order to ensure that the Low Traffic Volume (LTV) Sealed Road Manuals and

Specifications are supplementary to the DUR documents and as far as possible are neither contradictory nor repetitious.

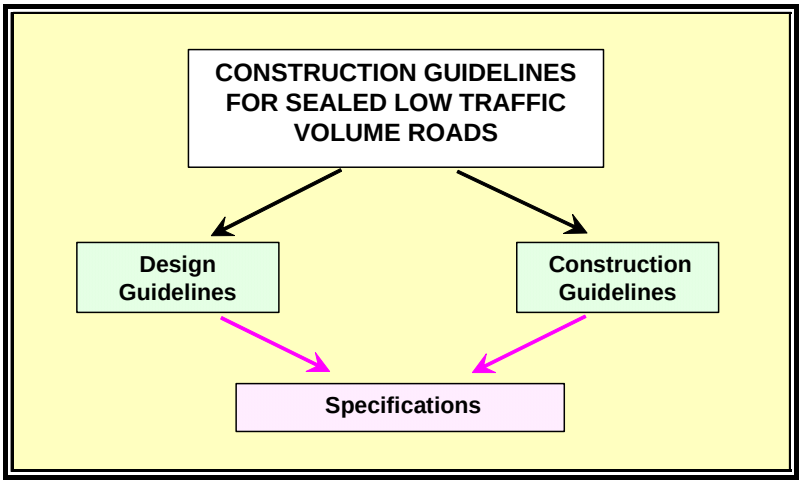
The emphasis of the DUR documents is towards planning, administration and management of rural roads. The emphasis of the LTV sealed road manuals will be directed towards the introduction of methods and procedures for the design and construction of LTV sealed roads in the most cost effective way, taking account of local conditions and as far as possible utilising low cost locally available natural road building materials.

It is essential that the client and stakeholders are intimately involved in defining the scope and presentation of the new publications, so that they are prepared in a suitable format for the intended recipient organisations (MoWHC, MOLG, DUR, Local Consultants, etc) and so that there is an appropriate feeling of "ownership" attached to the documents developed.

4.1.2 Format of Manuals and Specifications

It is anticipated that the following documents may be produced:

- Design Manual/Guidelines for Bitumen Sealed Low Traffic Volume (LTV) Roads.
- Construction Guidelines for Bitumen Sealed Low Traffic Volume (LTV) Roads
- Specifications for Bitumen Sealed Low Traffic Volume (LTV) Roads



The project Terms of Reference require that the documents only address sealed low volume road construction and do not extend to unsealed low volume roads. Hoever, it is expected that the Design Guideline will address the issue of when it is feasible and beneficial to upgrade from gravel road standard to bitumen sealed road standard.

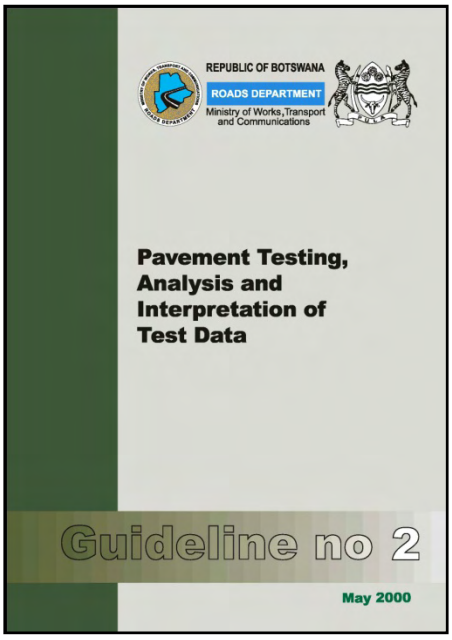
Whether separate design and construction guidelines are required (as opposed to a combined guideline document) would be subject to consultation/ clarification.

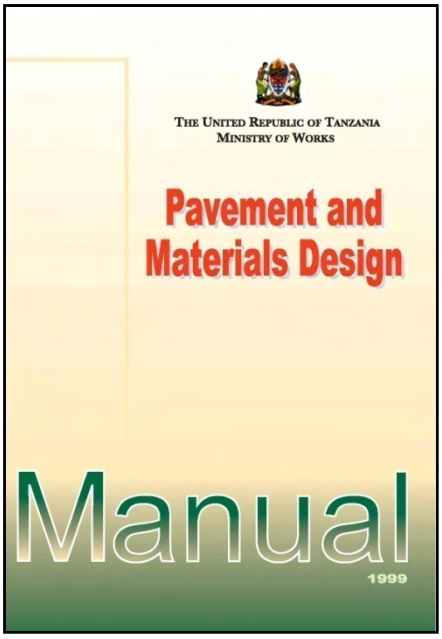
Format for the Guideline Documents

It is considered that a "bench mark" target standard for construction guidelines in terms of formatting and presentation has been established by recent documents produced in Tanzania and Botswana. Both these countries has had Institutional Co-operation Agreements jointly funded by their Governments and the Norwegian Agency for International Development (NORAD) that has resulted in the production of construction guidelines as part of a programme to develop technical standards for highway engineering. Excellent construction guidelines have been produced under these programmes and include:

- Pavement and Materials Design Manual -1999. The United Republic of Tanzania, Ministry of Works [2].
- The Design, Construction and Maintenance of Otta Seals. Guideline No 1 (June 1999). Republic of Botswana, Ministry of Works, Transport & Communications, Roads Department [3].
- Pavement Testing, Analysis and Interpretation of Test Data. Guideline No 2 (May 2000). Republic of Botswana, Ministry of Works, Transport & Communications, Roads Department [4].

Examples of "model" Construction Guidelines





It is considered that these Guidelines have a format which is well balanced in terms of their content comprising concise text supported by tables and frequent illustrations (figures and photographs). It is understood that these guidelines

have been well received and utilised in the engineering communities that were targeted. It is therefore recommended that the Uganda Low Volume Road Construction guidelines adopt a similar format.

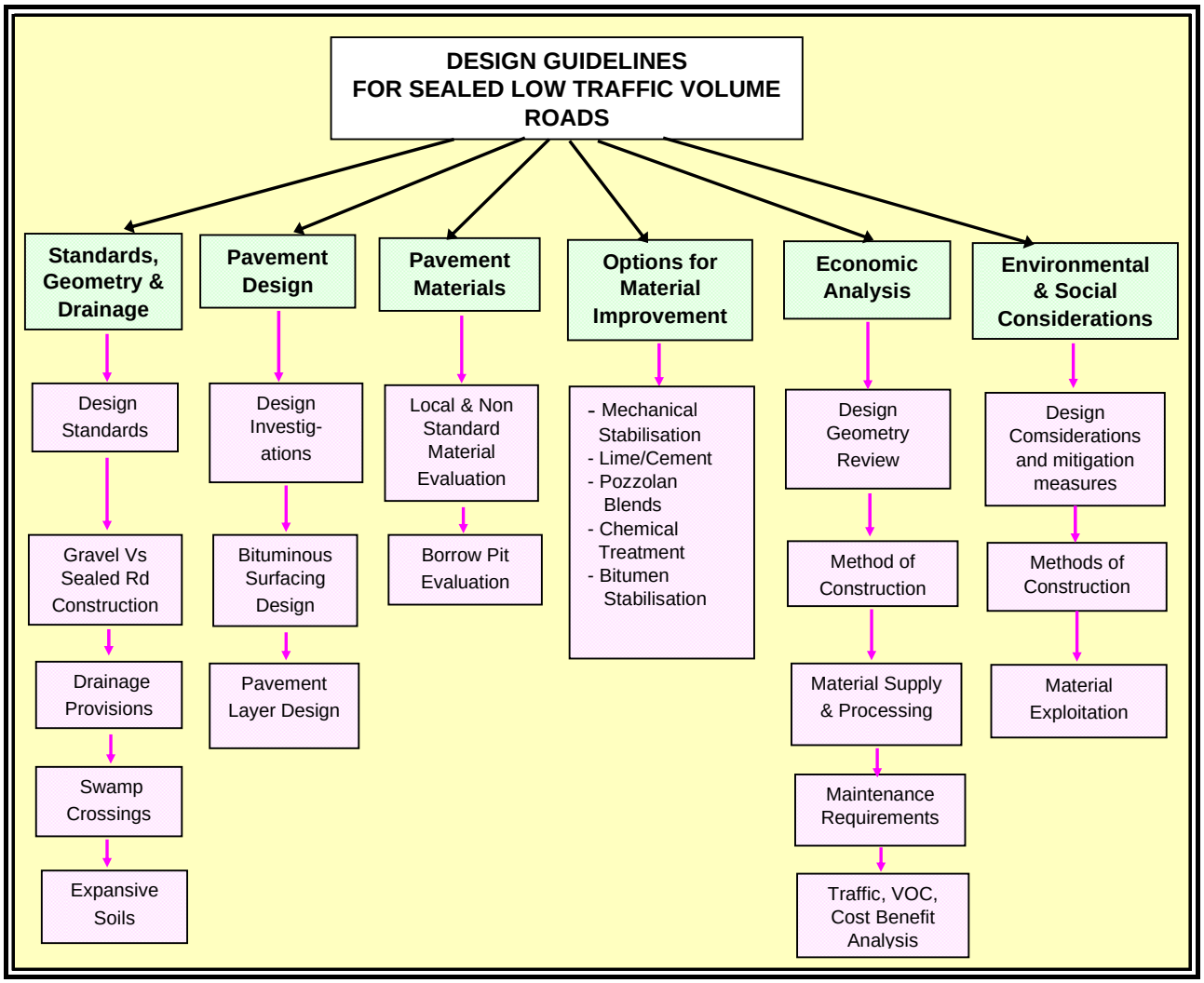
Format for the Sealed Low Traffic Volume (LTV) Road Specifications

It is anticipated that a "General Specifications for Sealed Low Volume Roads" would be a supplementary volume to the existing "General Specification for Road and Bridge Works" (2005). It would therefore adopt a similar format to the existing General Specification, but would only relate to Low Traffic Volume Road Construction.

4.2 Design Guidelines/Manuals

The expected framework for developing the Design Guidelines for Sealed Low Traffic Volume Roads is summarised in the flowchart below:

Figure 4-1 Framework for the Development of Design Guidelines



4.2.1 Construction Standards, Geometry and Drainage

i) Design Standards

The design guidelines will need to review the classification of various rural roads and consider the relationships between road function, predicted traffic loading (refer Section 4.4.1), terrain and their influence on cross section design, alignment design (vertical and horizontal) and economics.

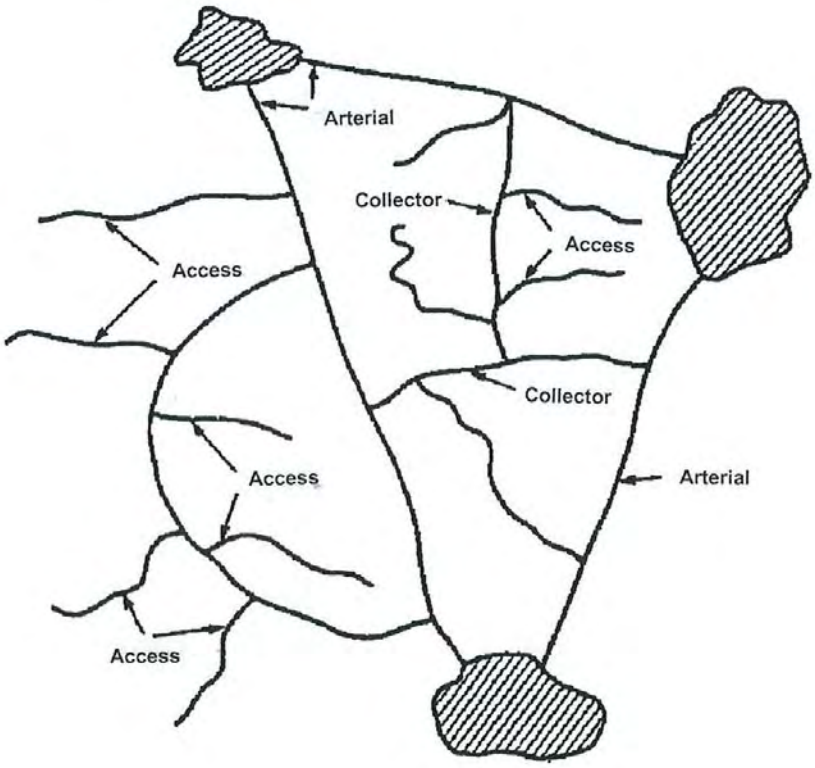
Existing Uganda rural road design standards should be reviewed (as contained in the Manuals of the District and Urban Roads division of MOTC - refer Section 4.1.2) and compared with recommendations in relevant publications such as TRL Overseas Road Note 6 "A Guide to Geometric Design" 1988 [5]. This publication is particularly relevant to rural roads in developing countries.

Table 4-1 Road Standards Recommended by ORN 6

Road Function	Design Class	Traffic Flow[1] (ADT)	Surface Type	Width (m)		Maximum Gradient (%)	Terrain / Design Speed (km/h)		
				Carriage-way	Shoulder		Mountainous	Rolling	Level
Arterial	A	5,000-15,000	Paved	6.5	2.5	8	85	100	120
	B	1,000-5,000	Paved	6.5	1.0	8	70	85	100
Collector	C	400-1,000	Paved	5.5	1.0	10	60	70	85
	D	100-400	Paved/ Unpaved	5.0	1.0[2]	10	50	60	70
Access	E	20-100	Paved/ Unpaved	3.0	1.5[2]	15	40	50	60
	F	<20	Paved/ Unpaved	2.5/3.0	Passing Places	15/20	N/A	N/A	N/A

Notes
1 The two way traffic flow is recommended to be not more than one Design Class step in excess of first year ADT.
2 For unpaved roads where the carraigeway is gravelled, the shoulders would not normally be gravelled; however, for Design Class D roads, consideration should be given to gravelling the shoulders if shoulder damage occurs.

Figure 4-2 Classification of Road Hierarchy and Function (ORN 6)



Changing or introducing new design standards for low traffic sealed roads will undoubtedly require policy decisions from the involved Government organisations. Therefore consultation will be an important element of the development of this part of the design guidelines.

Studies in Southern Africa (TRL 199[6]) and elsewhere investigating the performance of sealed low traffic volume roads have identified the special geometric design considerations associated with roads constructed with non standard natural gravel pavement materials. These need to be taken into account in the Uganda design guide.

In particular, the TRL studies concluded as follows: *"Sealed shoulders provide a structural and maintenance benefit and should be considered even on low volume roads if this enables local materials to be exploited and there is an overall whole-life benefit. A method is suggested for determining the optimum width for sealing shoulders but evidence from this study suggests a minimum width of one metre*". The importance of shoulder design is also recognised by the Tanzania Pavement and Materials Design Guide [2].

In the case of low volume roads there is justification for not imposing rigid regulations to road geometry, particularly in hilly terrain where excavation costs can be excessive locally in cut if the desirable full width construction cannot be varied to suit the site conditions. ORN 6 reviews opportunities to when relaxation of standards may be appropriate.

Ultimately designs should be justified economically and optimum choice will vary with both construction and road user costs. Construction costs will relate

mainly to terrain type and choice of pavement construction, whereas road user costs will be related to level and composition of traffic, journey time, vehicle operation and road accident costs (refer Section 4.2.5).

ii) Gravel versus Sealed Road Construction

It is recommended that the design guidelines address the issue of the evaluation of when a gravel surfaced road justifies upgrading to bitumen surfacing.

The importance of this issue is noted in the Project Concept Report [1], which notes that Uganda has a large network of unpaved roads, many of which are justified to be upgraded to a bituminous standard based on technical, economical and social grounds. Document review indicates that it can be cost effective to upgrade unpaved roads to a bituminous standard at traffic levels as low a 50 vehicles a day. Particularly when there are problems with supplying good unpaved road construction materials so maintenance costs are high and ride quality poor.

A limitation on upgrading gravel roads to sealed standard in the past has been the prohibitive cost associated with constructing them to normally accepted standards. Since the cost of the construction materials for a low traffic volume road can amount to more than 70% of the construction cost it is essential that designs are optimised and maximum use be made of any locally available and low cost construction materials.

iii) Drainage Provisions

As might be expected the TRL study of the performance of low volume sealed road in Southern Africa [6] concluded that drainage was a significant factor determining performance even in dry areas. At all location a minimum crown height of 0.75 m is recommended.

The following aspects of drainage design should be covered in the Uganda design guide:

- Drainage of the road surface (cross fall design)
- Drainage of the pavement layers
- Drainage of the subgrade

Once again road shoulders justify special consideration, as poor drainage beneath or through shoulders is a very common cause of poor performance in low volume roads. It is considered that Chapter 5 of ORN 31 [7] contains much which will need to be highlighted in the Uganda Low Volume road Design Manual.

iv) Swamp Crossings

There is no doubt that promotion of good practice in the construction of swamp crossings for low volume roads is required. In terms of most existing rural roads Uganda suffers from a legacy of poorly constructed swamp crossings. As a result of the use of poor construction techniques (including the use of "corduroy" mattresses formed from branches etc) the raising of existing crossings typically results in long term deformation and settlement problems. In some cases when road upgrading is required it is necessary to abandon

poorly constructed existing swamp crossings and construct completely new crossings.

Section on good engineering practice in swamp crossing construction is to be included in the proposed design guide, taking account of document research, Uganda case histories and information gained from the PDP trials.

v) Expansive Soils

Uganda does not suffer from the widespread occurrence of highly expansive soils, certainly not to the extent of its neighbours in Tanzania and Kenya. However, it is recommended that the Uganda design guide addresses this subject. It should indicate where such problem soils are likely to be encountered, how they should be investigated and what design options are appropriate for dealing with road construction involving these soils.

This subject is very well covered in a "state of the art" way in Chapter 6 of the Tanzania Pavement and Materials Design Manual (1999 [2]). The assessment of the expansiveness of soils is well covered in Gourley & Schieder (TRL 1993 [8]). The Uganda guide should draw on these references to indicate appropriate investigation and evaluation methods for expansive soils.

4.2.2 Pavement Design

i) Design Investigations

The design guidelines is to review the scope and method of performing pavement design investigations for low volume roads. This would include covering the following aspects:

- Classification of environmental influence (annual rainfall, temperature variation etc). Climatic zones may be defined for Uganda;
- Methodology for performing traffic surveys;
- Subgrade investigation and analysis of results for pavement design (use of DCP, etc);
- Testing and evaluation of existing pavements
- Construction materials investigation guidelines.

ii) Bituminous Surfacing Design

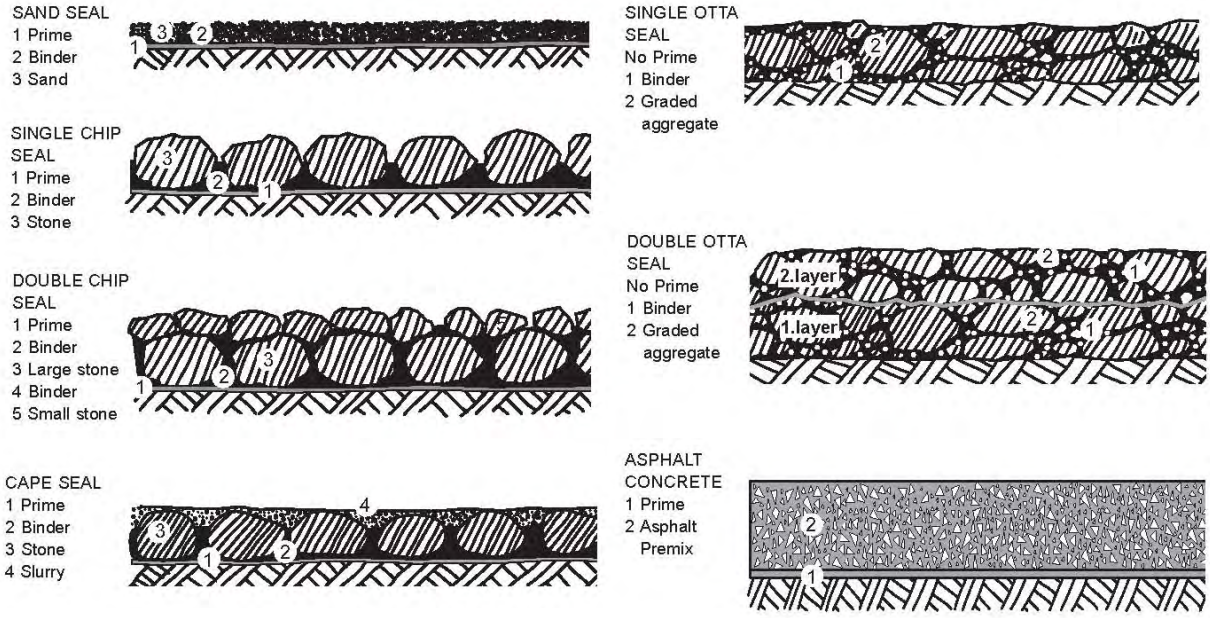
As stressed in the Project Concept Report [1], the judicious selection of bituminous surfacing can give considerable savings in the overall cost of low traffic volume road construction.

It is therefore important that the design guide reviews the suitability, "pros and cons" and relative costs of the various types of bituminous surfacing that may be appropriate in the low traffic volume environment. This aspect of the design guide will draw on available technical publications, construction records for projects in Uganda and analysis of research data and construction records from the PDP construction trials.

The low volume road design guide will include (but may not be limited to) review of the following:

- Sand Sealing
- Surface Dressing (single and double chip seals);
- Otta Sealing (single and double seals)
- Cape sealing

Figure 4-3 Schematic illustration of various types of bituminous surfacing



Extract from "The Design, Construction and Maintenance of Otta Seals", 1999 [3]

In the case of low traffic volume roads consideration of the use of a reduced standard of bituminous surfacing on the road shoulders may be appropriate. As a result, the surfacing requirements of road shoulders should be fully reviewed in the Uganda Design Guide.

iii) Pavement Layer Design

It is proposed that the Uganda Design Guide utilises recent developments and existing publications relating to low traffic volume pavement layer design to define design options that are most appropriate (technically and economically) for local conditions. In particular, the pavement layer design guide should provide the following:

a) Pavement Layer Design Charts utilising reduced strength base course layers (i.e CBR > 45 to 65% as opposed to CBR >80%).

The need for these design charts arises in situations where there are relatively good natural gravel deposits available, but they do not achieve CBR >.80% standard (i.e. they are not "standard" base course material quality).

Such design charts have been published by the UK TRL in "The Performance of Low Volume Sealed Roads: Results and Recommendations from Studies in Southern Africa" (1999[6] refer Figure 8.2 in the PDP Detailed Design Report). However, review of these charts is recommended in order to try to enable more flexibility in the utilisation of available materials (probably by introducing supplementary charts). Section 8.3.4 of the PDP Detailed Design Report has

reviewed some other relevant pavement layer design charts published in: Kenya Road Design Manual (1987 [9]); Botswana Road Design Manual (1983[10]); Centre Expéimental de Recherches et d'Etudes du Bâtiment des Travaux Publics (CEBTP, 1984 [11]; and Queensland Transport Pavement Design Manual (1990 [12]).

b) Pavement Layer Design Charts utilising "standard" strength base materials that are specifically prepared for very low traffic volume roads constructed with locally available pit materials.

The need for these design charts arises in situations where there are pit materials which provide CBR.>80 strength properties or alternatively existing pit materials are so poor that they required to be improved/ stabilised to obtain at least "standard" base course quality materials.

When "standard" strength base materials are to be used in low volume road construction there is a requirement to minimise the thickness of the base layer in order to conserve the high quality natural gravel resources or minimise costs associated with material improvement/ stabilisation. The Queensland Design Maunual [12] provides a key to this issue by utilising a constant minimum thickness of base (125 mm) supported on a variable thickness of "upper subbase" (CBR 30-40%) and "lower subbase" (CBR 25-35%) and by using available materials as selected subgrade (capping material CBR .15%) to minimise subbase thickness. This approach offers great scope for the economic use of a wide range of "as dug" materials in the road pavement and is considered to be an appropriate design methodology to develop in the Uganda Design Guide. It is expected that various elements of the PDP research (laboratory and field trials) will assist in developing such innovative pavement layer design charts.

4.2.3 Pavement Materials

Since the cost of pavement construction materials often makes up about 70% of the cost of low traffic volume road construction it is considered important that the Uganda Design Guide provides guidance with how to identify potential sources of locally available "low cost" pavement materials and evaluate their suitability for use.

Typically "low cost" pavement materials are derived from natural deposits that are easily excavated and can be processed with little or no crushing to produce a satisfactory road building material. Such deposits will not usually provide properties as good as "high cost" crushed stone aggregates. "Low cost pavement materials will usually have certain characteristics that are "non standard" (i.e. poor particle shape., low particle strength or relatively high plasticity fines) and therefore form a group often referred to as "marginal materials".

i) Local and Non Standard Materials Evaluation

The Uganda Design Guide shall include a section on the evaluation of available local and "non standard/marginal" materials and identifies potential applications for available materials in accordance with the adopted pavement design charts (also contained in the guide).

The main types of natural non standard/marginal materials that are to be found in Uganda and offer major potential for use in low cost sealed road construction include:

- Laterite Gravels;
- Quartz Gravels;
- Scoria/Cinder Gravels;
- Weathered Rock Deposits (i.e. Weathered Gneiss Gravel);
- Alluvial Sand and Gravels Deposits.

In order to effectively "prospect" or "search" for suitable deposits it is necessary to understand the geological origin of the materials. Appendix 2 presents an initial review of Uganda Material Types that offer potential for the supply of "low cost" pavement construction materials. Appendix 2 contains a marginal material classification system as reported in "Promoting the use of marginal materials in low cost road construction" (Cook, Gourley & Bishop, TRL 2002 [13] and summarises the characteristics and engineering properties of the marginal/ non standard natural materials that commonly occur in Uganda. It is suggested that such a review of available local materials resources be further developed for inclusion in the Uganda Design Guide along with the guidelines on how to assess the suitabilty of the materials for use in various pavement layers. The performance of the PDP trial sections constructed with non standard natural gravels will contribute to developing appropriate "acceptance criteria".

ii) Borrow Pit Evaluation

Guidelines are to be provided on the methodology for carrying out a systematic and comprehensive evaluation of potential borrow pit sites. Non standard pit materials often occur in relatively thin and impersistent layers that have variable characteristics. As a result, it is essential that the deposit is properly investigated and appropriate extraction plans prepared.

4.2.4 Options for Material Improvement

Many natural gravel deposits will not be suitable for use in the upper pavement layers without some kind of improvement. This might range from simple removal of oversize particles by a grizzly screen to cement stabilisation. The selected treatment will depend on the material characteristics and proposed use in the road pavement.

Guidelines on the selection of appropriate treatment are to be included in the design guide and will be influenced by the findings of the PDP pavement trials and document searches.

4.2.5 Economic Analysis

Economic analysis of "low cost" road construction options should generally be carried out in a similar manner to that of a standard road construction cost benefit analysis in order to identify the best engineering solution with an acceptable investment cost.

The factors that need to be assessed are well outlined in several publications including existing guidelines for economical evaluation and TRL ORN 5 "A guide to road project appraisal" (1988 [14]).

There are special considerations that are particularly relevant to low cost road investment analysis includeing: assessment of reduced maintenance and vehicle operating costs associated with upgrading from gravel to sealed road construction; special economic considerations appropriate for rural access roads; special consideration of construction material use and geometric design because material costs often amount to more than 70% of the construction cost.

Guidelines on the economic analysis of low volume sealed road construction are recommended to be included in the proposed Design Guide.

4.2.6 Environmental and Social Considerations

One of the objectives of the PDP is stated as the mitigation of environmental impact associated with the design and construction standards of sealed Low Volume Traffic Roads.

It is considered that environmental; and social considerations should be given considerable prominence (i.e. form a chapter) in the design guidelines for sealed low volume roads. However, the information shall be supplementary to that contained in the District and Urban Roads (DUR) Manuals (refer Section 4.1.2).

Low cost road construction has the potential to cause significant environmental damage unless sympathetic designs are prepared and particular attention is given to appropriate methods of construction (refer Table 4-2).

In particular, indiscriminate and careless exploitation of locally available natural gravel deposits can have significant negative impacts on the local environment and its inhabitants.

In Uganda low cost road construction relies heavily on winning construction materials from relatively thin and discontinuous near surface gravel deposits. These deposits often comprise laterite, residual quartz gravels and terrace alluvial gravels.

Easily extracted deposits close to existing unpaved roads are becoming exhausted along many road networks. This is now resulting in pressure to exploit marginal quality deposits in poor locations. The working of deposits less than 2m thick should be subject to an environmental impact review.

Care must be taken when developing borrow pits:
- Avoid locating next to the road;
- Take action to avoid soil erosion, and future land use degradation;
- Careful reinstatement is required as an area of the pit is worked out.

Working thin deposits involves a poor ratio between land take and resource size. This will become environmentally unacceptable in the following situations:

- Populated and cultivated areas, where pit development may result in permanent loss or down grading of productive land.
- Areas of natural beauty or habitats justifying a high level of conservation.
- Areas where topsoil is thin and cannot be salvaged to enable adequate pit reinstatement and prevention of soil erosion.

In such circumstances consideration must be given not only to initial economics of extraction, but also to long term economic and environmental consequences. Hauling material longer distances from pits with less adverse environmental impact needs to be considered.

Existing reference data dealing with the environmental; and social impacts of material exploitation for rural roads include:

- Environmental Reinstatement of Road Building Borrow its in Southern Africa UK Transport Research Laboratory1999 [15].
- "Guidelines on Materials and Borrow Pit Management for Low Cost Roads", Chapter 11, Roughton et al 2000 [16]

Other important environmental reference documents relevant for rural roads and produced by funding agencies include:

- "Roads and the Environment", A Handbook., World Bank Technical Paper No 376 1997 [17];
- Environmental Source Book Vol II Chapter 9 "Transportation", World Bank Technical Report No 154 [18];
- "Environmental Guidelines for Selected Infrastructure Projects", Asian Development Bank Office of the Environment 1993 [19];

- "Manual on Environmental Appraisal", Overseas Development Agency (now DFID) 1992 [20].

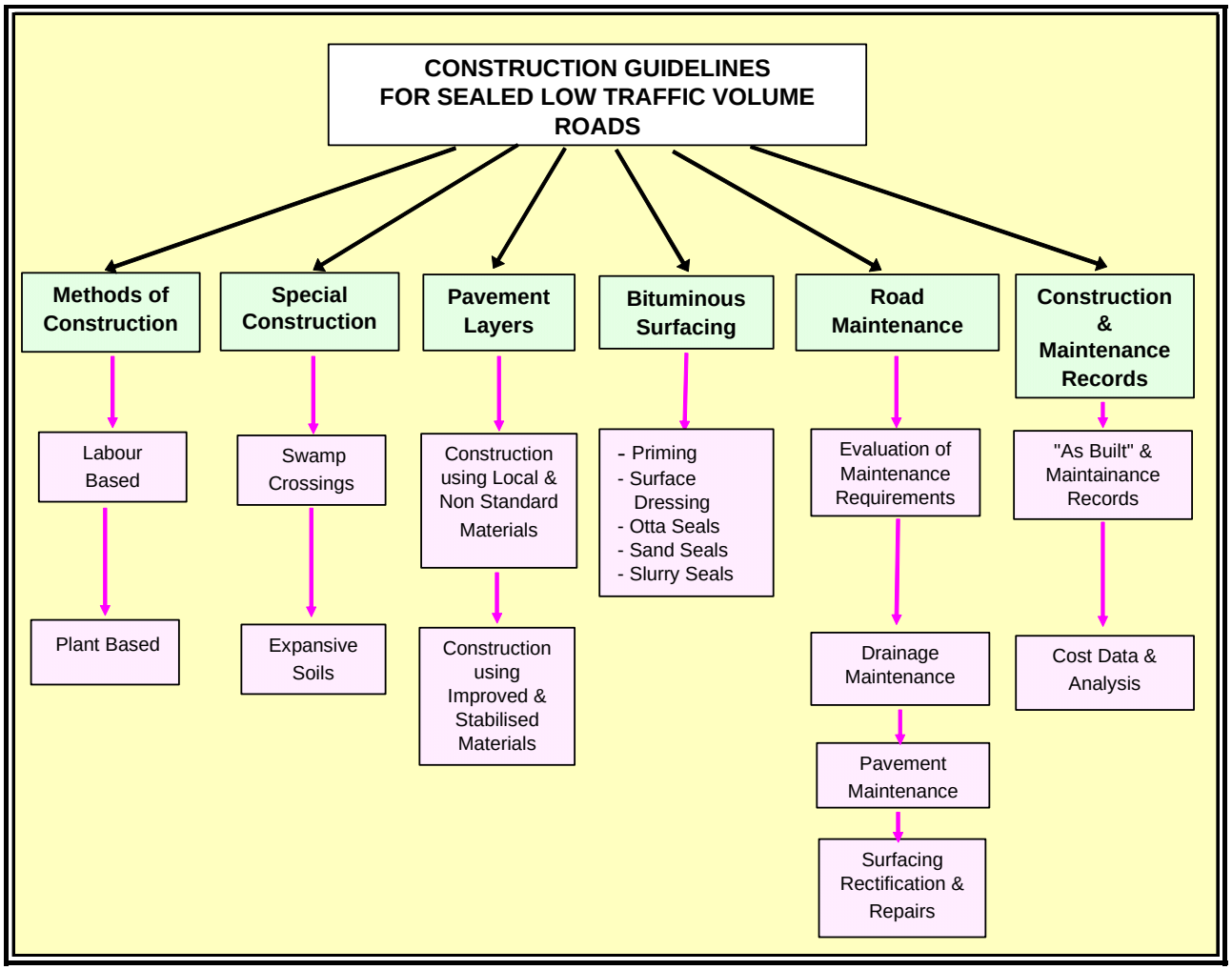
Table 4-2 Review of Potential Social and Environmental Impacts

SOCIAL & ENVIRONMETAL CONSIDERATIONS	DESIGN STAGE ACTIVITIES	MITIGATION MEASURES
Review Environmental Impacts of Design Standard Selected (i.e Gravel Surface Vs Bitumen Sealed Surface)	Consider both direct economic and social influences when selecting the design standards. Adverse impacts may be asoociate with dust, roughness, poor drainage (malaria hazard), unsafe geometric standards etc	Take proper account in the design to reduce adverse environmental and social impacts.
Preservation of areas and landuse of particular value	* Field survey of the road alignment to identify key areas & landuses * Locate other key features (eg sites of cultural and tourism importance), potential borrow areas etc	* Review road design to reduce impacts on key areas
Prevention of soil erosion, sedimentation, slope instability and disturbance of any vegetation	* Identification and investigation of potential unstable slopes. Review of * appropriate stabilisation techniques. * Careful design review of cross drainage structures with emphasis on avoiding concentration of flow and associated soil erosion and sedimentation hazards	* Ensure that slopes of embankments and cuttings are protected against soil erosion hazards (ie by design of culvert outfall cascades, drainage check dams, etc). * Design appropriate measures to stabilise potential landslides
Location and rehabilitation of construction material borrow pits, quarries, spoil tips and contractors camps	* Locate borrow pits, quarries and contractors camp with regard to environmental impact. * Review resource requirements and restoration of material sources * Review likely quantities of spoil material and approve appropriate sites for material disposal	* Contractor to provide a management plan for borrow pits and quarries to be agreed between the Engineer and Contractor in advance. When necessary the management plan will include a full reinstatement plan.
Avoidance or reduction of visual intrusion	* Identification of any areas where there might be severe or unacceptable visual impact (e.g. to local populations, tourism) * Assess visual intrusion of borrow pits and quarries	* Recommend measures to mitigate visual impacts by the most practical and cost effective means * Develop quarries so as to reduce visual intrusion.
Pollution, health and safety hazards (including water pollution, dust, noise, fuel and bitumen spillage, etc)	* Review potential pollution and health hazards associated with the construction process and with the establishment and operation of the Contractor's camps, workshops and quarries. * Supervise/monitor rock blasting procedures.	* Encourage/design construction practices which reduce pollution, health and safety hazards.
Road Safety	* Review safety measures incorporated into the road design.	* Implement appropriate road safety features in the design
Land take and Compensation	* Review procedures for land acquisition and compensation.	* Oversee payment of compensation when necessary
Impacts of construction on local communities	* Review impacts of road construction on "village/town environment" with regard to noise, dust, traffic management and employment of local people.	* Review provision in the design for speed restricting devices and road signs in villages and review need for other features such as covered drains, off road parking and bus bay facilities. Review use of Labour Intensive construction methods when appropriate and provisions for welfare of local workers and communities (HIV/AIDS and Gender issues).
Tourism	* Review potential positive and negative impacts with respect to tourism	* Implement design measures to promote tourism (ie identify locations for viewpoints, with off road parking, at locations of scenic beauty).

4.3 Construction Guidelines

The expected framework for developing the Construction Guidelines for Sealed Low Traffic Volume Roads is summarised in the flowchart below:

Figure 4-4 Framework for the Development of Construction Guidelines



4.3.1 Methods of Construction

i) Labour Based Construction

One of the stated objectives of the PDP is encourage where appropriate the application of "Labour Based Technology" in construction of low volume sealed roads.

Labour intensive methods may be appropriate with respect to material resource development and processing, some types of pavement and drainage constructions and in bituminous sealing operations. The International Labour Organisation (ILO) and other road research organisations like the UK Transport Research Laboratory have published numerous documents to assist in both deciding when labour based methods are appropriate and how to specify and implement labour based construction. It is recommended that the proposed construction guidelines draw on this wealth of information to clearly outline when and

how labour based technology should be utilised in low volume sealed road construction in Uganda. The guidelines developed will supplement the District and Urban Roads (DUR) division Contract Management Manual volume 2 (refer Section 4.1.2).

ii) Plant Based Construction

At present plant based construction methods are usually adopted for low volume sealed road construction in Uganda, except perhaps in the case of minor access and feeder road construction. It may be useful if the proposed construction guide reviews the appropriate types of plant which may be most efficiently used for different operations (i.e. material processing, material treatment and material placement). An evaluation of the comparative costs of plant and labour based construction methods in rural Uganda are to be included in the guide.

4.3.2 Special Construction

i) Swamp Crossing Construction

One aspect of the PDP has been to research appropriate methods of designing (refer Section 4.2.1) and constructing swamp crossings. The Construction guide will identify and promote appropriate methods of swamp crossing construction and will take account of trials carried out during the project.

ii) Expansive Soils

To accompany the design guidelines relating to roads located on expansive soils (refer Section 4.2.1), the construction guide will describe appropriate construction methods and options for ground treatment.

4.3.3 Pavement Layer Construction

i) Construction using Local and "Non Standard" Materials

a) Material Processing

Common defects associated with excavated local and "non standard" construction materials include the presence of "oversize" particles and too much or too little fine grained "binder" material. Various procedures and treatments can be used to improve the engineering characteristics of "as dug" materials. The selection of appropriate treatment will be strongly influenced by the severity of the problem and may be a balance of economic considerations in the case of low traffic volume road construction.

The construction guide will reviews options for dealing with oversize and procedures for blending deposits to achieve improved characteristics. Some relevant field research has beeen carried out as a part of the PDP pavement trials.

b) Material Placement

When using low cost non standard road materials in road construction consideration may need to be given to the identification of optimum methods of construction. In particular, the method of aggregate extraction, handling and compaction may influence the future performance of the pavement. The proposed construction guide should review special procedures that may need to be adopted with different local material types (i.e laterite gravels, scoria gravels, quartzitic gravels etc).

ii) Construction using Improved and Stabilised Materials

a) Material Treatment and Placement

The Design Guidelines will review the possible options for pavement material improvement (refer Section 4.2.4). To supplement this information the Construction Guidelines should present a "state of the art" review of construction techniques associated with pavement material improvement and stabilisation in relation to low traffic sealed road construction.

Experience obtained during the PDP field trials would be utilised when preparing these construction guidelines.

4.3.4 Bituminous Surfacing Construction

The Design Guide will review the various types of bituminous surfacing that may be appropriate for low traffic volume roads (refer Section 4.2.2). The Construction Guidelines should highlight the important construction aspects associated with these various types of low cost surfacing. PDP construction experience will contribute to these guidelines.

4.3.5 Road Maintenance

Roads designed to carry low volumes of traffic are inevitably weaker than those designed to carry heavy traffic. As a result, low traffic roads are often susceptible to rapid deterioration if timely and regular road maintenance activities are not implemented. This is particularly true when thin bituminous surfacings are placed on lower standard base course layers, in which case the lack of appropriate road maintenance may dramatically reduce the design life of the road.

i) Evaluation of Maintenance Requirements

The proposed construction guidelines will provide information on the evaluation of maintenance requirements for typical types of low volume road construction which would be supplementary to the District and Urban Roads division Planning Manual Volume 1 (refer Section 4.1.2).

ii) Drainage Maintenance

Relatively weak low volume roads are particularly prone to rapid deterioration when there are problems with road drainage, especially when non standard pavement materials with relatively high plasticity fines have been used in construction. As a result, drainage maintenance cannot be over promoted.

iii) Pavement Maintenance

The construction guidelines will outline appropriate methods of carrying out pavement maintenance. For example, correct procedures for repairing potholes in chemically improved pavement layers.

iv) Surfacing Repairs and Strengthening

Tthe construction guideline will indicate the expected in-service life of the various types of low cost bituminous surfacing and indicates the types of surface strengthening that may be appropriate to extend the life of the surfacing (i.e. interval between the application of additional sealing coats on sand seals, Otta seals and surface dressing constructions).

4.3.6 Construction and Maintenance Records

i) "As Built" and Maintenance Records

The construction guidelines should promote the preparation of accurate "as built" records for low volume sealed roads, as an important part of the ongoing development process to ensure economic and effective use of future road construction funds. Conclusions concerning pavement performance must relate back to the details of the original road construction, including characteristics and properties of pavement materials, thickness of layers and drainage provisions.

It is also important to stress the need and benefits of keeping accurate records of road maintenance carried out. The type and frequency of maintenance carried out on the pavement is a good indication of the possible causes of distress. Localised problems and associated maintenance activities are typically the result of poor pavement drainage or localised material or construction deficiencies, while large areas of heavy maintenance typically result from excessive traffic and/or design or construction deficiencies.

ii) Cost Data and Analysis

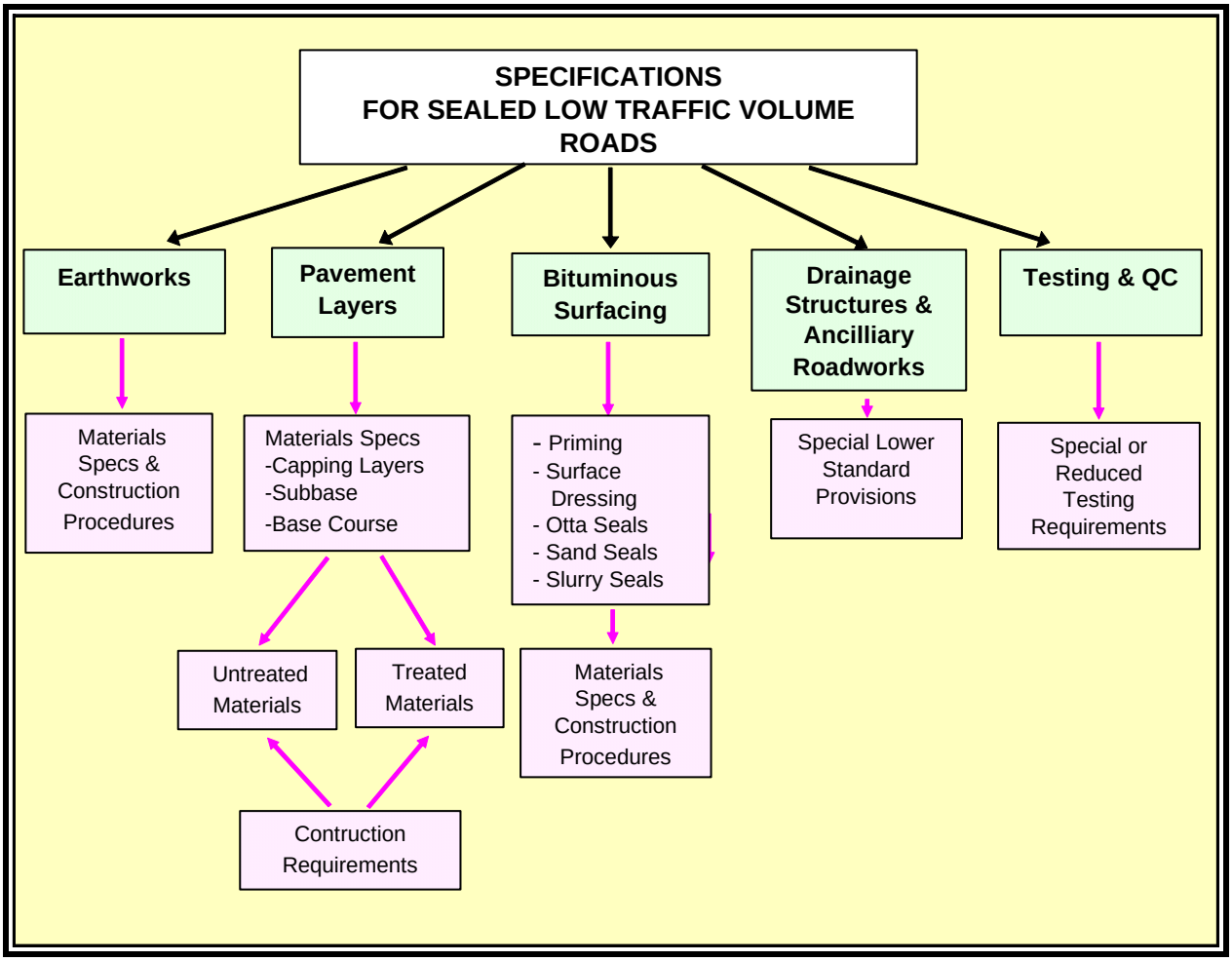
To compliment the construction records and maintenance histories it is important to document the relative costs of construction using different methods and materials, so that this information can be used to improve feasibility evaluation of similar future road construction projects.

4.4 Specifications

4.4.1 Introduction

The expected framework for developing the Specifications for Sealed Low Traffic Volume (LTV) Roads is summarised in the flowchart below:

Figure 4-5 Framework for the Development of Construction Specifications



The first task required in the preparation of specifications applicable exclusively for low volume sealed roads will be to agree with UNRA, MoWHC and other stackholders a classification system for low volume roads in terms of their traffic loading (either Average Annual Daily Traffic -AADT, or Million Equivalent Standard Axles -MESA) which will form the basis for defining appropriate specification limits and standards.

It is recommended that the upper limit for the use of the "low volume" classification should not exceed 3.0 MESA. It is further suggested that the categories of low volume traffic used in the pavement design charts contained in "Performance of low volume sealed roads: Results and recommendations from studies in Southern Africa" (TRL 1999 [6]) might form the basis for the classification system adopted in the Uganda

Specification. Table 4-3 presents this classification system and compares it with the design traffic classes contained in ORN 31 "A guide to the structural design of Bitumen surfaced roads in tropical and sub-tropical countries" (TRL 1003 [7]).

Table 4-3 Possible Low Traffic Volume Road Classification System

Low Traffic Volume (LTV) Classes (TRL 1999)	Design Traffic Loading (MESA)	Equivalent ORN 31 Traffic Class (TRL 1993)	PDP Traffic Classes Represented
LTV 1	<0.01	T1	
LTV 2	0.01 - 0.05	T1	
LTV 3	0.05 - 0.1	T1	
LTV 4	0.1 - 0.3	T1	Kambele to Kapeeka km 35.2 to 41.1
LTV 5	0.3 - 0.5	T2	Semuto to Kambele Km 29.0 to 35.2
LTV 6	0.5 - 1	T2/T3	Kalasa to Semuto km 22.5 to 29.0
LTV 7	1 - 3	T3/T4	Matugga to Kalasa km 0.0 to 22.5

The aim of the new Uganda LTV Road Specifications will be to significantly reduce the construction costs for roads carrying relatively light traffic loadings.

It has been recognised that the existing Uganda Specifications result in conservative or "over design" of certain aspects of low volume road construction. In particular, there is a need to identify "acceptance criteria" for the various elements of the construction that are appropriate for the various LTV design loadings.

Essentially this is a process of risk management leading to the development or adoption of appropriate (reduced) "acceptance criteria" and standards. The specifications must control the risk of premature road deterioration within acceptable limits that are defined primarily according to the road's load carrying requirement and road environment (climatic conditions, composition of traffic/overloading risk, etc).

It is expected that the research carried out during the PDP design investigations and construction phase will provide the necessary justification for adopting either existing specifications from countries with similar construction environments or more likely somewhat

modified/developed construction specifications and guidelines appropriate to the Uganda situation.

4.4.2 Earthworks Specifications

Material property and construction requirements for fill materials and pavement capping layers will be reviewed in the context of LTV road construction, but it is expected that there will be little justification or scope for major amendment of the existing General Specification requirements with respect to earthworks.

However, new or amended clauses will be prepared, as necessary, in relation to the construction of embankments over swampy ground, with the aim of ensuring that best construction practices are required in such situations.

In addition, new specification clauses will be prepared to control construction involving expansive soils and possibly other problem soils (i.e mica rich deposits).

4.4.3 Pavement Layer Specifications

It is expected that the design guidelines will contain pavement layer design charts for use with various design traffic loadings in the range <0.1 to 3 million ESA (refer Table 4-3). These guidelines will promote the use of low cost local and non standard construction materials where appropriate.

The Uganda LTV road Specifications will define the material "acceptance criteria" required at different LTV traffic loadings and will define required construction procedures (i.e. methods of compaction and levels of compaction etc).

In addition, the new specification will address in more detail technical aspects of natural gravel borrow pit investigation and exploitation, material selection and use.

i) Untreated (Non Standard/ Low Cost) Materials

It is proposed that acceptance criteria will be defined according to the "type" of natural gravel that may be utilised in pavement construction. For example, the property requirements for layers constructed with scoria gravels, laterites and alluvial gravels are likely to vary.

The Uganda LTV Specification limits will result from a "state of the art" document review and conclusions drawn from the PDP trial constructions.

The PDP Special Specification has introduced a new type of subbase material namely G25 (natural material with nominal CBR value of not less than 25%), this will almost certainly be adopted in the Uganda LTV Road Specification. In addition, new base material types may be introduced, such as G50 gravels (natural material with nominal CBR value of not less than 50%).

ii) Modified (Improved) and Stabilised Materials

The preparation of the PDP Special Specification has identified the need for various new classes of "modified" material for use in LTV road pavement construction, as listed below:

• CMB Type 1	Cement or lime modified base course material with minimum CBR strength of 160%
• CMB Type II	Cement or lime modified base course material with minimum CBR strength of 100%
• Pozzolan/Cement CMB Type II	Modified base course with minimum "target" CBR strength 100%
• CMS	Cement or lime modified subbase material with minimum CBR strength of 60%
• Liquid Soil Stabiliser CMS s	Modified subbase material with minimum "target" CBR strength of 60%

It is considered that the existing Uganda General Specification requirements for "stabilised" pavement materials may often result in unnecessarily high strength materials that require more stabilising agent than is necessary in the context of low traffic volume (LTV) road pavement construction.

Strongly cemented materials as classified in the existing General Specification (i.e. C1.0 and C0.7) are required to reach a stated level of rigidity that can be tested by unconfined compression strength (UCS) testing. PDP research and desk study research indicates that many locally available natural gravels in Uganda with relatively high plasticity fines cannot be "stabilised" in accordance with these UCS requirements, but can be "modified" to achieve acceptable plasticity and CBR characteristics for use in the pavement layers of LTV roads.

It is expected that the PDP field trials and literature searches will provide the necessary justification for introducing new types of "modified" pavement materials for use in LTV road construction in Uganda. These specifications will be carefully researched to ensure that material properties before and after modification are defined with the aim of allowing the economical use of a wide variety of locally available natural gravels in pavement construction without introducing an unacceptable risk of early pavement deterioration.

It is also proposed that new specification clauses will be drafted, as necessary, in relation to pavement construction with materials treated

with bituminous emulsions and synthetic soil stabilisers. A specification section on block paving construction and low cost concrete pavement construction may also be included in the LTV Road Specification.

4.4.4 Bituminous Surfacing

The LTV Road Specifications will need to address the methods and special requirements associated with the construction of low cost thin bituminous surface treatments. Such surfacing specifications will need to identify limits for the use of aggregates of lower strength than could be used on more heavily trafficked roads. The LTV Specifications are expected to include new clauses relating to surface dressing, sand sealing, Otta sealing, slurry sealing and construction of Cape seals.

The PDP Special Specifications have already identified the need for some new clauses to supplement the existing General Specifications. These new clauses relate to: priming; pre-coating of aggregate; planning for sealing work; safety and maintenance of surface sealing equipment.

New clauses covering the use of labour intensive methods for thin bituminous surfacing construction will also be included in the LTV Road Specifications.

4.4.5 Drainage Structures and Ancillary Structures

It appears that the Scope of Works for the PDP consultant does not include consideration of structures for LTV roads. This issue requires clarification with UNRA. The inclusion of revised specification provisions for drainage structures for low traffic volume roads would be beneficial for completeness of the specification document..

The Fifth Research Report (RR-5) documents the U-PVC pipe culvert construction trials and concludes that this technology is very promising in relation to the economical construction of low traffic volume sealed roads. So inclusion of this technology should be considered in the LTV Specifications.

4.4.6 Tollerances, Testing and Quality Control

In the context of low traffic volume roads there may be scope for considering the introduction of construction tolerances and testing requirements that are not as rigorous as those required for more heavily trafficked roads. Also, it may be acceptable to introduce some quick low cost methods of testing (such as DCP CBR testing) to supplement more expensive and time consuming tests (such as laboratory CBR testing) which may then be undertaken at lesser frequency.

However, caution is required in this respect because low cost natural gravel road building materials are likely to be more variable and more "marginal" in terms of their engineering properties than expensively processed quarried aggregates. Therefore care needs to be taken to ensure that appropriate quality control procedures are implemented during LTV road construction.

4.5 Review and Dissemination of Guidelines and Specifications

4.5.1 Technical Review of Guidelines and Specifications

i) Review during Document Development

It is recommended that the scope and content of the proposed guidelines and specifications are subject to review by a Technical Advisory Group (TAG) during development. It is expected that the Chairman and Co-ordinator of the TAG would be a senior staff member of UNRA or MoWHC and that TAG members would include representatives from both Government Agencies (stakeholder organisations) involved in road construction and organisations involved in research relating to road construction in Uganda.

ii) Review of Draft Documents

It is expected that document development will be "steered" and monitored primarily by Ugandan residents. However, it is recommended that the draft documents be circulated for comment to wider network of recognised authorities on low cost road construction for peer review. These internationally recognised specialist reviewers might include:

- Consultants to NDF such as C Overby or G Refsdal (who drafted the Pilot Project Concept Report and similar Road Construction Guidelines for Tanzania and Botswana);
- Senior Researcher in the UK Transport Research Laboratory (TRL) UK or DFID (i.e. Dr CS Gourley or PAK Greening).
- Senior Researcher from CSIR Republic of South Africa;
- Senior Researcher from the Australian Road Research Board (ARRB);
- Senior Specialist from ILO (International Labour Organisation) etc.

Ideally project funding for the monitoring and document production phase of the project will include a budget for funding technical review that will cover modest costs associated with document review and reviewers attendance at important project seminars.

4.5.2 Training and Presentations

After the construction phase, when performance monitoring is on-going and the guidelines and new specifications are being prepared, there will be a continuing need for presentations and seminars to maintain the involvement of the stakeholders and stimulate their interest in the documents content and their production.

A seminar to review the draft documents will be particularly important as a means of "fast tracking" the receipt of comments on the drafts.

4.5.3 Document Dissemination

The PDP project will only be totally successful if the proposed Low Traffic Volume (LTV) Sealed Road Construction Guidelines and Specifications are actively promoted and adopted by the stakeholder

organisations in Uganda. The documents can only be adopted if they are readily available.

It is not expected that the project will include a large budget for document dissemination. It is therefore expected that emphasis should relate to making soft copy (electronic) data available.

It is recommended that a project web site be established during Stage III, which will act as a future portal for downloading project guidelines and specifications when they become available.

In addition, it is expected that CDs containing the Guidelines, Specifications and supporting research data will be produced for distribution through MoWHC/UNRA.

5 Review of Equipment Required for Post Construction Monitoring and Research

5.1 Materials Laboratory Testing Equipment

It is expected that the Consultant appointed to carry out the post construction monitoring will use the facilities of an existing soils testing laboratory. Testing might, for example, be carried out at the MoWHC Central Materials Laboratory (CML) or at Makerere University.

Some specialist bitumen testing, for example, required to investigate the ageing characteristics of the bitumen in different types of surfacing, may have to be carried out at a specialist laboratory probably outside Uganda.

5.2 Pavement Field Testing Equipment

Pavement testing immediately after construction was carried out to establish the engineering characteristics of the various sections of the road built with different types of pavement material. The test procedures and equipment used have been described in the Third Research Report (RR-3).The field testing equipment that will be required is briefly reviewed in the following paragraphs.

5.2.1 Density Testing

During the post construction monitoring phase of the project it is anticipated that density testing may be carried out along any sections of road showing unexpected or unusual weakness or deterioration.

The standard method for determining the compacted density of pavement layers is the sand replacement test, which uses a simple cone apparatus to measure the density of material removed from a small hole (usually150mm diameter by about150mm deep) which has a of volume measured with sand. This test procedure is time consuming and somewhat damaging to the completed construction.

In order to enable a large number of non destructive density measurements to be performed quickly as a part of the monitoring and research studies it is expected that a nuclear density meter will be used.

It is expected that this equipment will be available for hire within Uganda from a commercial materials testing laboratory or from a road building contractor.

5.2.2 Measurement of Rutting

The measurement of rut depth will be carried out as a part of all visual inspections using a 2 m straight edge and measuring wedge.

5.2.3 Measurement of Roughness

The standard measure of road roughness is the International Roughness Index (IRI). During the "baseline studies the IRI of the project road was measured using a TRL Bump Integrator, calibrated against a MERLIN (a Machine for Evaluating Roughness using Low-cost INstrumentation - Cundel 1996[21]).

Ideally a similar method of measuring roughness will be used during post construction monitoring. However, the TRL bump integrator is no longer manufactured and more sophisticated methods of measuring road roughness have been developed. If a TRL bump integrator is not available then a road profiling apparatus should be used during post construction monitoring. It is understood that this equipment may be made available through UNRA.

5.2.4 Measurement of Skid Resistance

The skid resistance characteristics of the surfacing trials was measured using a skid resistance tester as described in Road Note 27 [22] during the baseline studies.

This equipment was hired from Makerere University and should therefore be available to the Stage III consultant.

5.2.5 DCP Testing

It is expected that post construction monitoring will include DCP testing along any sections of road showing unexpected or unusual weakness or deterioration

An 8kg DCP of the type described in Appendix C of TRL ORN 31 [7] will be used. It is expected that DCPs will be available for hire in Uganda but if not are relatively inexpensive items of test equipment (recommended source Dick King Laboratories, South Africa).

5.2.6 In Situ CBR Testing

The consultant appointed to carry out the post construction monitoring may wish to test the *in situ* CBR strength of certain road sections using an *in situ* CBR testing apparatus. This test equipment is similar to the lab equipment except that it can be vehicle mounted allowing the test to be performed in the field. The test procedure is described in BS 1377 part (1990).

It is understood that this equipment may be available for loan from the MoWHC Central Materials Laboratory or from a road building contractor in Uganda. However the test is much slower that a DCP test which is expected to be the preferred method of evaluation the *in situ* CBR profile of sections of the project road.

5.2.7 Plate Bearing Testing

Plate bearing test apparatus has not been included in the proposed post construction monitoring regime and this testing was not included in the baseline testing. However, if the equipment is available from the Central

Materials Laboratory, consideration may be given to using this test to obtain reliable information on the resilient modulus of pavement layers in certain trial sections.

5.2.8 Pavement Deflection Testing

i) Benkelman Beam Testing

During the baseline testing a pair of Benkelman beams (TRL type) were used to investigate the strength characteristics of the project road. The equipment and test procedure adopted is described in the Third Research Report (RR-3).

Benkelman beam testing is a low cost pavement evaluation method and it is proposed that this testing be carried out at yearly intervals during the post construction monitoring (refer Table 3-1 and Table 3-2).

It is expected that suitable Benkelman beams will be available for hire within Uganda during the post construction monitoring.

ii) Falling Weight Deflectometer (FWD) Testing

It is proposed that a Falling Weight Deflectometer (FWD) survey be carried out along the whole length of the road at 24 month intervals starting in November 2012 (2 years after the baseline study).

The baseline FWD survey was carried out and reported by a specialist firm based in Kenya (Gauff) . In November 2010 the cost of the FWD survey, analysis and reporting was Euro 7,920.

If possible FWD testing along the PDP road should be combined with any other FWD surveying that may be required by UNRA to minimise mobilisation costs (which may make up a significant % of the cost of the testing).

5.2.9 Pavement Test Pitting and Coring

It is expected that pavement test pitting and coring will be methods of investigation of section of road which are starting to show distress during the post construction monitoring and research.

It will be possible to hire pavement coring equipment from commercial laboratories or from road building contractors in Uganda.

A set of hand auger equipment may also be hired locally should this equipment be required to investigate subgrade soils.

5.3 Traffic Survey Equipment

It is proposed that traffic counts will be made manually and will therefore require no specialist equipment. However, it has been assumed that portable weigh bridges may be loaned from the MoWHC for the axle load surveys that are to be carried out during the post construction monitoring.

6 Programme, Staff and Budget for Stage III

6.1 Introduction

The terms of reference for the Supervision Consultant requires that an estimate be prepared of the costs that will be associated with the pavement monitoring and research activities that are proposed after construction.

The proposed scope of the PDP road monitoring during the six year monitoring period is presented in Section 3 of this report and the procedures and methods of testing and analysis are described in the Third Research Report (RR-3, November 2011). The proposed scope of works relating to the development and dissemination of the Low Traffic Volume Sealed Roads Guidelines, Manuals and Specifications is presented in Section 4 of this report.

The estimate of the costs of the Stage III activities are presented in Appendix 1.

6.2 Programme for Stage III

For programming and costing purposes Stage III post construction activities has been sub divided into two parts as follows:

i) Stage III A (November 2012 to End of 2014)

It is assumed that the Stage III consultant will be appointed and working by November 2012. In which case, the first part of Stage III will run from November 2012 to end of 2014.

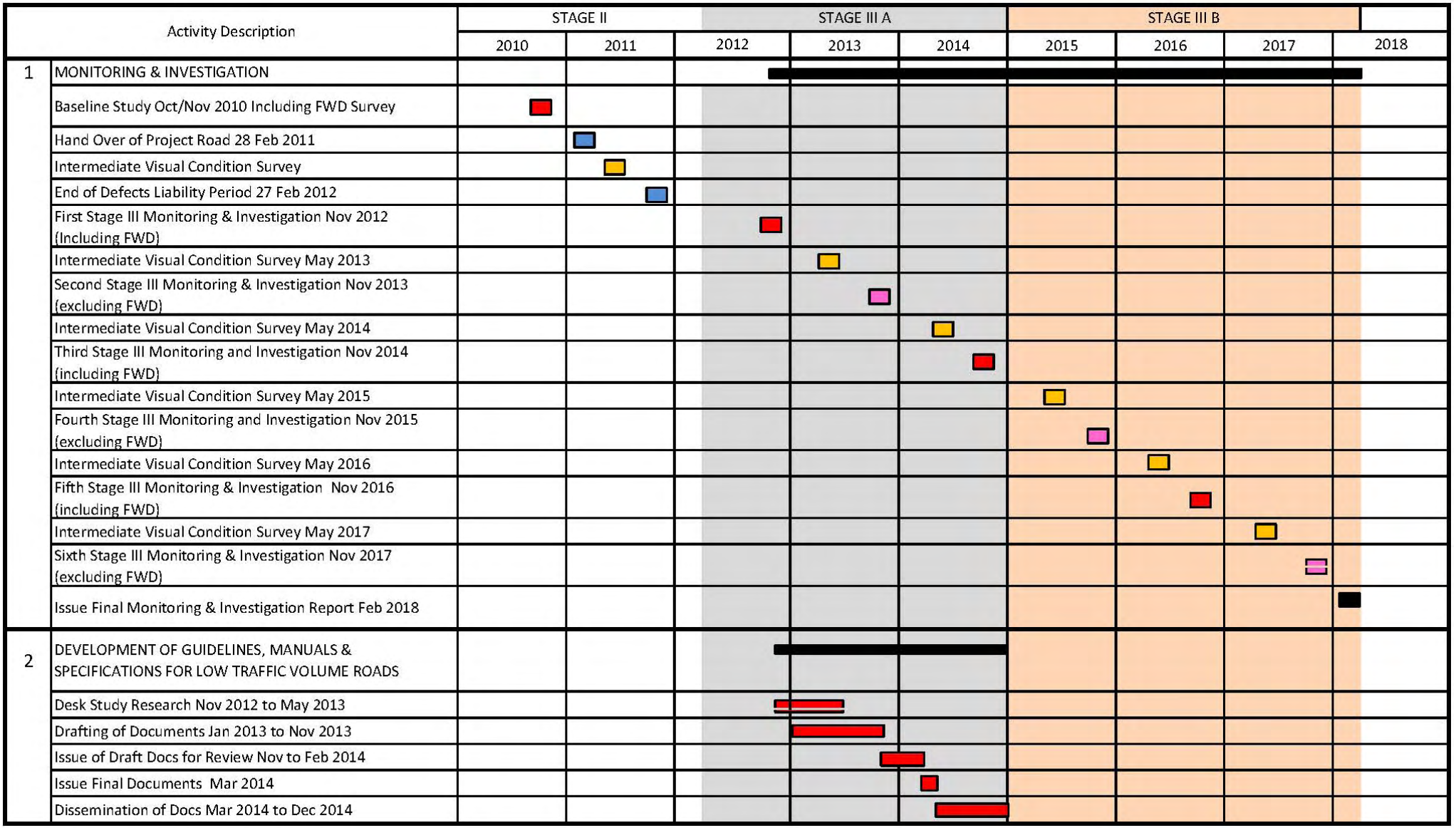
Initial monitoring and investigation of the PDP road during Stage III A will involve three detailed monitoring surveys at 12 month intervals starting in November 2012 with two intermediate visual condition surveys in accordance with the programme chart forming Figure 6-1.

In addition, it is proposed that by the end of Stage III A the Low Volume Traffic Sealed Road Guidelines, Manuals and Specifications will have been drafted, approved and adopted in accordance with the Figure 6-1 programme.

ii) Stage III B (January 2015 to Feb 2018)

Stage III B will only involve the final monitoring and investigation of the PDP road. It will comprise three detailed monitoring surveys at 12 monthly intervals and three intermediate visual condition surveys culminating in the issue of the Final Monitoring and Investigation Report in February 2018 (as shown on Figure 6-1).

Figure 6-1 Activity Programme for Stage III



6.3 Human Resource Input for Stage III

This sub section reviews the key personnel to be assigned to carry out the Stage III activities. Figure 6-2 shows the proposed staffing programme.

6.3.1 Project Manager (PM)

It is anticipated that the Project Manager (PM) will be a Ugandan Engineer with more than 10 years professional experience associated with the design and construction of road projects in Uganda. Relevant experience gained other countries in the region would be an advantage as would previous experience of road research and contract document preparation..

The PM will be responsible the day to day management and administration of the Stage III activities. The PM will oversee the organisation of the PDP road monitoring activities and supervise the field work and its reporting.

The PM will be involved with the desk study research and the development of the Low Volume Traffic Sealed Road Guidelines, Manuals and Specifications. He will be responsible for liaison with the Project Steering Committee (comprising representatives of UNRA, MOTC, Min of Local Government, etc) and will also work with the Technical Advisory Group (TAG) which will also include key stakeholders. The PM will be actively involved with promoting the dissemination of the project documents and with the organisation and implementation of project seminars and workshops.

6.3.2 Research Engineer (R Eng)

It is expected that the Research Engineer will have more than 15 years experience in the design and construction of road projects in various developing countries (preferably including Uganda) and will have had considerable previous involvement with research projects relevant to the current assignment. He will most likely hold a research/ post graduate degree.

The Research Engineer will be responsible for planning, implementing and monitoring all the research aspects of Stage III. He will ensure the quality of the research reporting.

The Research Engineer will bring his/her experience to bear during the development of the Low Volume Traffic Sealed Road Guidelines, Manuals and Specifications for Uganda. The Research Engineer will liaise closely with the Project Steering Committee and with the Technical Advisory Group (TAG). The Research Engineer will have a key involvement in promoting the dissemination of the project documents through the project seminars and workshops.

6.3.3 Research Assistant (RA)

The Research Assistant will be a graduate Engineer with at least 5 years relevant professional experience associated with road design and

construction in Uganda. The Research Assistance will assist with the analysis and reporting of the PDP monitoring and investigation activities.

The Research Assistant will also be intimately involved with the desk study research and development of the C.

6.3.4 Contract Document Specialist

The contract document specialist will be an Engineer with specialist knowledge and experience in relation to the development of design and contract documents for roads projects. He/she will have a short term input into the development and Quality Assurance of the Low Volume Traffic Sealed Road Guidelines, Manuals and Specifications for Uganda.

6.3.5 Field Engineer

The Field Engineer will be graduate with more than 5 years experience relating to the design investigations and construction of roads in Uganda. The Field Engineer will be responsible for the day to day organisation and supervision of the monitoring and investigation of the PDP Road throughout the 6 years monitoring period. He/she will ensure the quality of the field data collected and will assist with the analysis, evaluation and reporting of the field investigations.

6.4 Stage III Reporting

Figure 6-2 summarises the reporting programme and reporting requirements for both the PDP road monitoring and investigation and for the development of the Low Volume Traffic Sealed Road Guidelines, Manuals and Specifications for Uganda.

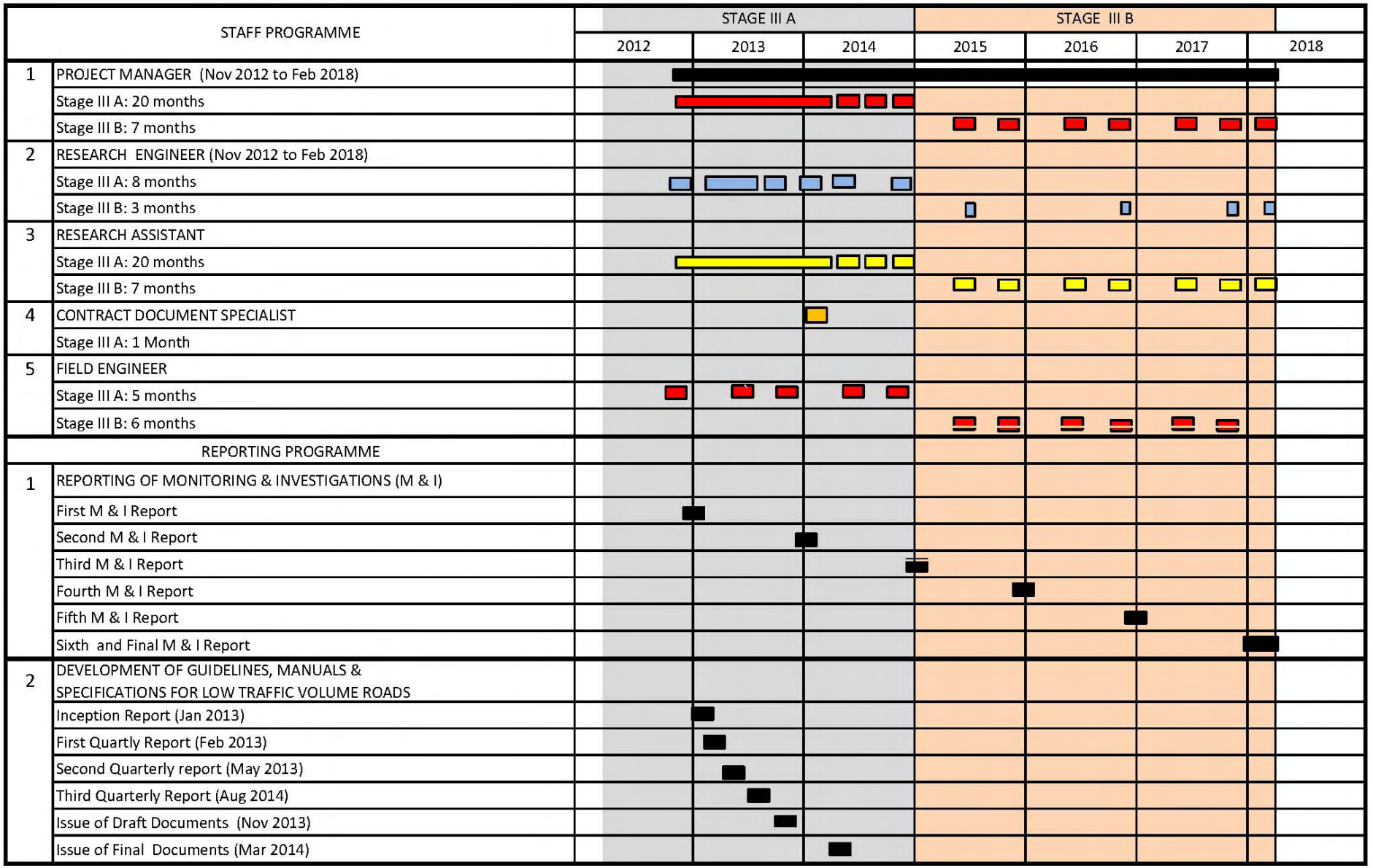
It is proposed that production and dissemination costs are minimised by producing very few hard copies of the project documents, which will be made readily available in soft copy either as a download from the project web site or as computer discs available from UNRA or the Project Consultant.

6.5 Budget for Stage III

Appendix 1 contains a Bill of Quantities for Stage III Consultancy Services bid submissions.

Appendix 2 contains the Supervision Consultant’s Estimate of the budget for Stage III, based on the Scope of Works outlined in this Action Research Plan for Stage III.

Figure 6-2 Staffing and Reporting Programme for Stage III



7 References

References Identified in the Report Text:

1. Overby, C. and Refsdal, G.: "Pilot Project Concept Report: Demonstration of Innovative Technologies in Road Construction for Low Volume Traffic Roads in Uganda." Road Development Programme Phase II (RDP II). March 2000.
2. United Republic of Tanzania, Ministry of Works, "Pavement and Materials Design Manual", 1999
3. Republic of Botswana, Ministry of Works, Transportation & Communications, Roads Department, "The Design, Construction and Maintenance of Otta Seals", Guideline No 1, June 1999.
4. Republic of Botswana, Ministry of Works, Transportation & Communications, Roads Department, "Pavement Testing, Analysis and Interpretation of Test Data", Guideline No 1, June 1999.
5. TRL Overseas Road Note 6 "A Guide to Geometric Design", Transport Research Laboratory, Crowthorne UK, 1988.
6. Gourley CS, Greening PAK. "Performance of Low Volume Sealed Roads; Results and Recommendations from Studies in Southern Africa. TRL Project Report PR/OSC/167/99 (Project Record No R6020), Transport Research Laboratory, Crowthorne UK, 1999.
7. TRL Overseas Road Note 31 (4^{th} Edition): "A Guide to the Structural design of Bitumen Surfaced Roads in Tropical and Sub-Tropical Countries." Transport Research Laboratory, Crowthorne UK, 1993.
8. Gourley CS & Schieder HD. "Assessment of the Expansiveness of Soils". Transport Research Laboratory (TRL) Project Report PR/osc/012/93, Crowthorne UK, 1993.
9. Kenya Ministry of Transport & Communications "Road Design Manual Part III" Materials and Pavement Design for New Roads. Roads Department MT&C, 1987.
10. Botswana Ministry of Works & Communications "Botswana Road Design Manual". Roads Department, 1982.
11. Centre Expéimental de Recherches et d'Etudes du Bâtiment des Travaux Publics (CEBTP)"Guide Practique de Dimensionement des Chaussées pour les Pays Tropicaux", 1984.
12. Queensland Transport, Pavement Design Manual, 1990.

13. Cook J, Gourley CS & Bishop EC "Promoting the Use of Marginal Materials in Low Cost Roads". Transport Research Laboratory (TRL), Crowthorne UK, Project Report PR/INT/205/2002, 2002.

14. TRL Overseas Road Note 5: "A Guide to Road Project Appraisal." Transport Research Laboratory, Crowthorne UK, 1988.

15. TRL "Environmental Reinstatement of Road Building Borrow Pits in Southern Africa" Transport Research Laboratory, Crowthorne UK, 1999.

16. Roughton International in association with Birmingham University and Nottingham University "Appropriate and Efficient Maintenance of Low Cost Rural Roads in Developing Countries; Guidelines on Materials and Borrow Pit Management for Low Cost Roads". DFID UK (2000).

17. World Bank Technical Paper No 376,"Roads and the Environment", A Handbook., 1997

18. World Bank Technical Report No 154 "Environmental Source Book" Vol II Chapter 9 "Transportation",

19. Asian Development Bank Office of the Environment", Environmental Guidelines for Selected Infrastructure Projects", 1993.

20. Overseas Development Agency (now DFID)"Manual on Environmental Appraisal", 1992

21. Cundill MA. The MERLIN road roughness machine: User guide. TRL report TRL 229 Transport Research Laboratory, Crowthorne UK (1996).

22. Road Research Laboratory Instructions for using the portable skid resistance tester. Road Note 27 Stationary Office London (1969).

Other References Consulted

Committee of State Road Authorities: Flexible pavement rehabilitation , investigation and design TRH 12 CSIR, Pretoria, South Africa (1997).

Committee of State Road Authorities: The measurement of deflection and curavature of road surfaces Draft TMH6, Technical Methods for Highways Pretoria, South Africa (1984).

Dehlen GL. Flexure of a road surface , its relation to fatigue cracking and factors determining its severity. HRB Bulletin (1962).

Greening, P.A.K.: "A guideline for low-volume sealed roads in the SADC region." First Road Transportation Technology Transfer Conference in Africa, Arusha, Tanzania, May 2001.

Gourley CS (1997). "Lightly Trafficked Sealed Roads In Southern Africa". UK Transport Research Laboratory PA3283/97

Gourley CS, Greening PAK & Brudefors U (1998) "A Structural Design Guide for Low Volume Feeder Roads in Zimbabawe". UK Transport Research Laboratory PA3395/98

Hide, H.S. Abaynayaka, S. W, Sayer, I. & Wyatt R.J. The Kenya road transport study; research on vehicle operating costs. Laboratory Report LR 672 Transport Research Laboratory, Crowthorne UK (1974).

Hodges JW, Rolt J & Jones TE. The Kenya road transport cost study: research on road deterioration. LR 673 Transport Research Laboratory, Crowthorne UK (1975).

Ministry of Works, Transport & Communication, Government of Uganda "Road Design Manual", November 1994.

Petts R, "Rational for the Compilation of International Guidelines for Low Cost Sustainable Road Surfacing". Low Cost Road Surfacing Project, LCS Working Paper No 1Intech Associates - DFID 2002

Robinson P, Oppy T and Giumarra G. " Pavement Materials in Road Building, Guidelines for Making Better Use of Local Materials. Australian Road Research Board (ARRB) Transport Research Ltd. (1999)

Roberts JD & Martin TC. Recommendations for monitoring pavement performance. Research Report ARR 293 ARRB Transport Research Ltd Victoria, Australia (1996).

TRL "Appropriate bituminous surfacings for labour-based construction". ILO Assist, Bulletin No. 13, Transport Research Laboratory, Crowthorne UK March 2002.

TRL Overseas Road Note 3"A Guide to Surface Dressing in Tropical and Sub-Tropical Countries", 2nd Edition, Transport Research Laboratory, Crowthorne UK (2000).

TRL Overseas Road Note 18 "A Guide to the Pavement Evaluation and Maintenance of bitumen surfaced roads in tropical and sub-tropical countries." Transport Research Laboratory, Crowthorne UK, 1999

Transport Research Laboratory "Manual for Labour-based Construction of Bituminous Surfacings on Low-Volume Roads" Project Reference R7470 2003.

Project Reports

Pilot Demonstration Project, Terms of Reference for Consultancy Services for the Feasibility Study, Detailed Engineering Design and Construction Supervision of Matugga-Semuto-Kapeeka Road

Overby, C. and Refsdal, G.: "Pilot Project Concept Report: Demonstration of Innovative Technologies in Road Construction for Low Volume Traffic Roads in Uganda." Road Development Programme Phase II (RDP II). March 2000.

Matugga - Semuto - Kapeeka Road. General Action Research Plan (GARP), February 2004.

Matugga - Semuto - Kapeeka Road. Action Research Plan I (ARP-I), February 2004.

Matugga - Semuto - Kapeeka Road - Interim Report May 2004

Matugga - Semuto - Kapeeka Road. First Research Report (RR-1) September 2004.

Matugga - Semuto - Kapeeka Road - Final Feasibility Report, December 2004.

Matugga - Semuto - Kapeeka Road - Final Environmental Impact Assessment Report, June 2005

Matugga - Semuto - Kapeeka Road - Final Detailed Design Report, December 2005.

Matugga - Semuto - Kapeeka Road. Second Research Report (RR-2), December 2005.

Matugga - Semuto - Kapeeka Road, Bidding Documents Volume 2 Section VI(C) Special Specifications, January 2006.

Matugga - Semuto - Kapeeka Road. Action Research Plan II (ARP-II), April 2006.

Matugga - Semuto - Kapeeka Road. Third Research Report (RR-3) Road Pavement Baseline Study, November 2011

Matugga - Semuto - Kapeeka Road. Fourth Research Report (RR-4) Swamp Construction Trials, November 2011.

Matugga – Semuto-Kapeeka Road Fifth Research Report (RR-5) U-PVC Pipe Culvert Construction Trials, November 2011.

Appendix 1

Bill of Quantities for Bid Submissions for Consultancy Services for Stage III

BILL OF QUANTITIES FOR STAGE III A (Nov 2012 to end Dec 2014)

		Unit	Quantity	Rate USD	Total
1	**STAFF SCHEDULE**				
	Project Manager	Month	20		
	Research Engineer	Month	8		
	Research Assistant	Month	20		
	Contract Document Specialist	Month	1		
	Field Engineer	Month	5		
	Sub Total				
2	**TRAVEL & SUBSISTENCE**				
	Research Engineer International Travel & Incidental Costs (baggage, taxis, etc)	Return Ticket	6		
	Research Engineer Accomodation & Subsistence	Month	8		
	Car Hire Research Engineer	Month	8		
	Car Hire Project Manager	Month	20		
	Car Hire Field Engineer	Month	5		
	Regional Flight to Meetings/Seminars Ethiopian Road Authority, TANROADS, etc. Incl Hotel Accom & incidentals	Return Tickets	4		
	Sub Total				
3	**MSK RD MONITORING & INVESTIGATION**				
	First Stage III Monitoring & Investigation (Including FWD Survey)	No	1		
	Intermedaite Visual Condition Survey	No	1		
	Second Stage III Monitoring & Investigation (excluding FWD Survey)	No	1		
	Intermedaite Visual Condition Survey	No	1		
	Third Stage III Monitoring & Investigation (Including FWD Survey)	No	1		
	Lab Testing	LS	1		
	Sub Total				
4	**REPORT PRODUCTION**				
	MSK Monitoring and Investigation Reports (PH III A) 3 No x 8 copies each	No	3		
	Inception & Quarterly Reports for LTV Road Guidelines & Specs 4 No x 8 copies each	No	4		
	Draft Guidelines, Manuals & Specifications for LTV Sealed Roads 8 Copies	No	1		
	Allow for Seminars, Workshops during and after doc production & fund document peer review by Technical Specialists	LS	1		
	Issue Final Guidelines, Maunals & Specs for LTV Sealed Roads (20 Copies)	No	1		
	Establish and Maintain Project Web Site/Portal Poduce CDs for dissemination	No	1		
	Purchase Reference documents (specifications,manuals, weather records, etc)	LS	1		
	Sub Total				
	GRAND TOTAL				

BILL OF QUANTITIES FOR STAGE III B (Jan 2015 to end Feb 2018)

		Unit	Quantity	Rate USD	Total
1	**STAFF SCHEDULE**				
	Project Manager	Month	7		
	Research Engineer	Month	3		
	Research Assistant	Month	7		
	Contract Document Specialist	Month	0		
	Field Engineer	Month	6		
	Sub Total				
2	**TRAVEL & SUBSISTENCE**				
	Research Engineer International Travel & Incidental Costs (baggage, taxis, etc)	Return Ticket	4		
	Research Engineer Accomodation & Subsistence	Month	3		
	Car Hire Research Engineer	Month	3		
	Car Hire Project Manager	Month	7		
	Car Hire Field Engineer	Month	6		
	Regional Flight to Meetings/Seminars Ethiopian Road Authority, TANROADS, etc. Incl Hotel Accom & incidentals	Return Tickets	0		
	Sub Total				
3	**MSK RD MONITORING & INVESTIGATION**				
	Intermedaite Visual Condition Survey	No	1		
	Fourth Stage III Monitoring & Investigation (excluding FWD Survey)	No	1		
	Intermedaite Visual Condition Survey	No	1		
	Fifth Stage III Monitoring & Investigation (Including FWD Survey)	No	1		
	Intermedaite Visual Condition Survey	No	1		
	Sixth Stage III Monitoring & Investigation (excluding FWD Survey)	No	1		
	Lab Testing	LS	1		
	Sub Total				
4	**REPORT PRODUCTION**				
	MSK Monitoring and Investigation Reports (Stage III B) 3 No x 8 copies each	No	3		
	Sub Total				
	GRAND TOTAL				

Appendix 2
Consultant's Estimate for Consultancy Services for Stage III

Appendix 2
Consultant's Estimate for Consultancy Services for Stage III

COST ESTIMATE FOR STAGE III A (Nov 2012 to end Dec 2014)

		Unit	Quantity	Rate USD	Total
1	**STAFF SCHEDULE**				
	Project Manager	Month	20	8,000	160,000
	Research Engineer	Month	8	20,000	160,000
	Research Assistant	Month	20	5,000	100,000
	Contract Document Specialist	Month	1	20,000	20,000
	Field Engineer	Month	5	5,000	25,000
	Sub Total				465,000
2	**TRAVEL & SUBSISTENCE**				
	Research Engineer International Travel & Incidental Costs (baggage, taxis, etc)	Return Ticket	6	2,000	12,000
	Research Engineer Accomodation & Subsistence	Month	8	3,600	28,800
	Car Hire Research Engineer	Month	8	2,000	16,000
	Car Hire Project Manager	Month	20	2,000	40,000
	Car Hire Field Engineer	Month	5	2,000	10,000
	Regional Flight to Meetings/Seminars Ethiopian Road Authority, TANROADS, etc. Incl Hotel Accom & incidentals	Return Tickets	4	1,000	4,000
	Sub Total				**110,800**
3	**MSK RD MONITORING & INVESTIGATION**				
	First Stage III Monitoring & Investigation (Including FWD Survey)	No	1	13,950	13,950
	Intermedaite Visual Condition Survey	No	1	400	400
	Second Stage III Monitoring & Investigation (excluding FWD Survey)	No	1	3,350	3,350
	Intermedaite Visual Condition Survey	No	1	400	400
	Third Stage III Monitoring & Investigation (Including FWD Survey)	No	1	13,950	13,950
	Lab Testing	LS	1	1,000	1,000
	Sub Total				**33,050**
4	**REPORT PRODUCTION**				
	MSK Monitoring and Investigation Reports (PH III A) 3 No x 8 copies each	No	3	300	900
	Inception & Quarterly Reports for LTV Road Guidelines & Specs 4 No x 8 copies each	No	4	300	1,200
	Draft Guidelines, Manuals & Specifications for LTV Sealed Roads 8 Copies	No	1	800	800
	Allow for Seminars, Workshops during and after doc production & fund document peer review by Technical Specialists	LS	1	3,000	3,000
	Issue Final Guidelines, Maunals & Specs for LTV Sealed Roads (20 Copies)	No	1	2,000	2,000
	Establish and Maintain Project Web Site/Portal Poduce CDs for dissemination	No	1	800	800
	Purchase Reference documents (specifications,manuals, weather records, etc)	LS	1	800	800
	Sub Total				**9,500**
	GRAND TOTAL				618,350

COST ESTIMATE FOR STAGE III B (Jan 2015 to end Feb 2018)

		Unit	Quantity	Rate USD	Total
1	**STAFF SCHEDULE**				
	Project Manager	Month	7	9,200	64,400
	Research Engineer	Month	3	23,000	69,000
	Research Assistant	Month	7	5,750	40,250
	Contract Document Specialist	Month	0	23,000	0
	Field Engineer	Month	6	5,750	34,500
	Sub Total				**208,150**
2	**TRAVEL & SUBSISTENCE**				
	Research Engineer International Travel & Incidental Costs (baggage, taxis, etc)	Return Ticket	4	2,300	9,200
	Research Engineer Accomodation & Subsistence	Month	3	4,140	12,420
	Car Hire Research Engineer	Month	3	2,300	6,900
	Car Hire Project Manager	Month	7	2,300	16,100
	Car Hire Field Engineer	Month	6	2,300	13,800
	Regional Flight to Meetings/Seminars Ethiopian Road Authority, TANROADS, etc. Incl Hotel Accom & incidentals	Return Tickets	0	1,015	0
	Sub Total				**58,420**
3	**MSK RD MONITORING & INVESTIGATION**				
	Intermedaite Visual Condition Survey	No	1	460	460
	Fourth Stage III Monitoring & Investigation (excluding FWD Survey)	No	1	3,853	3,853
	Intermedaite Visual Condition Survey	No	1	460	460
	Fifth Stage III Monitoring & Investigation (Including FWD Survey)	No	1	14,159	14,159
	Intermedaite Visual Condition Survey	No	1	460	460
	Sixth Stage III Monitoring & Investigation (excluding FWD Survey)	No	1	3,853	3,853
	Lab Testing	LS	1	2,000	2,000
	Sub Total				**25,244**
4	**REPORT PRODUCTION**				
	MSK Monitoring and Investigation Reports (Stage III B) 3 No x 8 copies each	No	3	345	1,035
	Sub Total				**1,035**
	GRAND TOTAL				292,849