ROYAL GOVERNMENT OF CAMBODIA

SOUTH EAST ASIA COMMUNITY ACCESS PROGRAMME

DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

August 2008

UNPUBLISHED PROJECT REPORT

UNPUBLISHED PROJECT REPORT

DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

SEACAP 19

TECHNICAL PAPER 7

PILOT ROAD MATERIALS DATABASE

By

Dr J R Cook (OtB Engineering)

Heng Kackada (KACE)

Prepared for: Project Record:	**SEACAP 019. Development of Local Resource Based Standards.**
Client:	**DfID; South East Asian Community Access Programme (SEACAP) for the Royal Government of Cambodia**

	Approvals
Task Manager **Dr J R Cook**	
Quality Reviewed,	

CONTENTS

Appendix B The Pilot Road Materials Database

Appendix C Concept Note for Expanding the Pilot Database

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
ADT	Average Daily Traffic
ASEAN	Association of Southeast Asian Nations
AusAID	Australian Agency for International Aid
CBR	California Bearing Ratio
CNCTP	Cambodia National Community of Transport Practitioners
CSIR	Council for Scientific and Industrial Research
DFID	Department for International Development
DTW	A Mechanical Engineering NGO
FFW	Food For Work
GMSARN	Greater Mekong Sub-region Academic & Research Network
GTZ	German Agency for Technical Co-operation
IFRTD	International Forum for Rural Transport Development
ILO	International Labour Organisation
IRAP	Integrated Rural Accessibility Planning
IRD	Integrated Rural Development
IRI	International Roughness Index
ITC	Institute of Technology Cambodia
KaR	Knowledge and Research
km	kilometre
kW	kilowatt
LBAT	Labour-Based Appropriate Technology
LCS	Low Cost Surfacing
m	metre
MPW&T	Ministry of Public Works and Transport (Cambodia)
MRD	Ministry of Rural Development (Cambodia)
NGOs	Non-Governmental Organisations
NPA	Norwegian People's Aid
NRDP	North-western Rural Development Project
ORN	Overseas Road Note
PDRD	Provincial Department of Rural Development
PIARC	World Road Association
PRDC	Provincial Rural Development Committee
PRIP	Provincial and Rural Infrastructure Programme
RGC	Royal Government of Cambodia

RIIP	Rural Infrastructure Improvement Project
RRGAP	The Rural Road Gravel Assessment Programme
RRSR	The Rural Road Surfacing Research
RRST	Rural Roads Surfacing Trials
SEACAP	South East Asia Community Access Programme
SEILA	Multilateral donors - Government Rural Infrastructure Development Programme
SIDA	Swedish International Development Agency
gTKP	Transport Knowledge Partnership
TRIP	Tertiary Roads Improvement Project
TRL	Transport Research Laboratory
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
WB	World Bank
WBM	Water Bound Macadam
WFP	World Food Programme

Executive Summary

SEACAP has included the development of a Pilot Road Materials Database (PRDM) within its current SEACAP 19 project in Cambodia. The main task objective was to establish a materials database methodology through the assembly of a pilot computer-based system, which would then be available for subsequent expansion to a National scale.

A key objective in sustainable road construction is to best match the available construction material to its function in the road and the effective use of natural resources enables a better and more sustainable development of rural infrastructure within limited budgets. This, together with the need for the management of scarce financial resources, means that widespread use of local materials is essential for Low Volume Rural Roads (LVRRs).

The ability of the materials to perform their particular function in the road is normally assessed by their compliance, or non-compliance, with construction material specifications. These specifications are applied to control the impacts of excavation, transportation, compaction and placing, and the in-service impacts of both the traffic and environment depending on the nature and position of the materials in the pavement structure. A full understanding of the capabilities of local materials is a necessary prerequisite to adopting and proposals for amended or relaxed specifications.

It follows from the above that prior knowledge of the location, quantity and quality of available materials would be of great advantage to national, provincial and district authorities in the planning and appropriate design of LVRRs. An accurate database of material resources would greatly facilitate the planning and more accurate costing of construction projects. Materials appropriate to the road tasks could be more easily selected or shortfalls identified. Material costs could be better forecasted.

A Pilot Materials Database relational structure has been set up, procedures developed for data capture and a representative suite of data has been collected and entered into this structure. The two provinces of Siem Reap and Kandal were selected as the principal trial areas containing a suitable selection of representative materials sources, from sub-grade soil borrow pits to hard rock quarries

The PRMD records the location and details of quarries, the types of material available and the products derived from these materials, along with details of samples taken for testing and the results of the tests. The PRMD is based on the Microsoft Access® database platform which has advantage of being simple to develop for and widely available as a desktop application. Since the PRMD is relatively small and limited to single user access, the choice of Access as a platform does not pose any problems

The structure allows the easy entry and reporting of materials information relevant to rural infrastructure engineers.

The options for the further expansion of the Pilot Road Materials Database (PRMD) are firstly into a National Road Materials Database (NRMD) on a province by province basis and then further development into wider a National Road Materials Information System (NRMIS) through the incorporation of research data and road materials information from existing roads and related road performance data

Further details of this potential expansion and development of the PRDM are included in an attached Concept Note.

SEACAP 19: TECHNICAL PAPER 7

PILOT ROAD MATERIALS DATABASE

1 Introduction

1.1 Task Objectives

There is an increasing awareness of the cost-effectiveness of including natural resource management as part of the planning for infrastructure development. To this end a National Road Materials Database (NRDM or a National Road Materials Information System NRMIS) can play a key role in the dissemination of information on local materials and indicate their most appropriate use. Hence the South East Asian Community Access Programme (SEACAP) has included the development of a Pilot Road Materials Database (PRDM) within its current SEACAP 19 project in Cambodia. Key elements of this Task have been defined as follows:

1. Review the IRAP (Integrated Rural Accessibility Planning) maps and resource inventories developed by the ILO/NRDP.
2. Prepare a materials database, which is GIS based.
3. Undertake a pilot a study in 3 districts in 2 provinces.
4. Prepare a project document for a staged roll out of the database

The Task objectives were seen as being based on establishing a database methodology through the assembly of a pilot computer-based system to store and manage information on naturally occurring Cambodian road construction materials. This would then be available for subsequent expansion to a National scale to provide readily accessible road engineering materials information early in project planning, in site investigations and in resource surveys.

This Task is a vital adjunct to other project tasks in SEACAP 19 as well as other regional SEACAP initiatives.

.

1.2 Task Framework

Four key elements were recognised as being crucial to the successful completion of the project task. These were:

Review A study had to be conducted of previous regional and international experience in development of materials databases together with the identification and collation of existing materials data in Cambodia, including the maps and resource inventories developed by the ILO/NRDP.

Database Structure A structure and associated methodology for assembling the proposed pilot database had to be developed. TRL already had basic materials data structures and collection procedures which were able to be further developed for the needs of this project.

Data Collection The database procedures should be trialled in pilot studies within 2 provinces by collecting quarry and material information and taking samples for subsequent laboratory testing. It was seen as crucial that the collected information should be reasonably representative of the data sets likely to be encountered in a full scale national database.

Reporting The database methodology should be fully reported to ensure an effective roll-out on a national scale at a later stage. Recommendations would be necessary on how this transition could be undertaken and on how this should be best achieved.

.

1.3 Document Structure

This document comprises a Main Text and three Appendices. Following the Introduction, the Main Text summarises the importance of local materials in the development of rural infrastructure and the advantages of being able to readily access information of the nature and quantities of available construction materials. Chapters 4 and 5 describe the development and current status of the SEACAP 19 Pilot Materials Database (PRMD), while Chapter 6 outlines the way forward through a staged expansion of the PRMD. A selected bibliography of useful papers and reports is included.

Appendix A provides a guideline of the data collection procedure as developed for the PRMD and Appendix B describes the associated database structure. Appendix C is a Concept Note on the expansion of the PRMD through a series of Modules.

2 Road Construction Materials

2.1 Appropriate Use of Materials

The performance of a road depends on a whole range of factors that cumulatively can be described as the "road environment" within which construction material is a key factor over which road practitioners have some limited control within the context of natural availability. This control is maximised when the road designer has access to all available materials resource information, thus allowing him match the most appropriate materials with the road task and its environment

A key objective in sustainable road construction is to best match the available construction material to its function in the road within its local environment. The effective use of natural resources enables a better and more sustainable development of rural infrastructure within limited budgets. Cost-effective road designs that incorporate appropriate materials allow more kilometres per unit cost of access to be built, rehabilitated and maintained. The benefits of utilising locally available materials arise from a reduction in haulage costs and less damage to existing pavements from extended haul as well enabling ongoing maintenance to be more locally centred. Benefits also stem from the better management of local resources that can steer new road construction towards the more environmentally aware use of natural resources.

The materials used in road construction and maintenance are an important and expensive resource that are not limitless and are largely non-renewable. This, together with the need for the management of scarce financial resources, means that widespread use of local materials is essential for Low Volume Rural Roads (LVRRs). Where reserves are limited or of marginal quality, as they are in certain rural areas of Cambodia, their relevant usage is a priority and it is important to use materials appropriate to their role neither in the road, that is, to ensure that they are neither sub-standard nor wastefully above the standards demanded by their engineering task.

Road construction materials requirements are generally focussed on the higher quality, and higher cost, needs of the pavement layers and for concrete structures. There are also, however, requirements for locally available sub-grade and earthwork materials. General road material requirements may be summarised as follows;

- Common fill
- Select fill
- Capping layer or imported sub-grade
- Filter and drainage aggregate
- Concrete aggregate
- Sub-base
- Base
- Surfacing aggregate

The ability of the materials to perform their particular function in the road is normally assessed by their compliance, or non-compliance, with construction material specifications. These specifications are applied to control the impacts of excavation, transportation, compaction and placing, and the in-service impacts of both the traffic and environment depending on the nature and position of the materials in the pavement structure.

There is growing acceptance of the concept that these specifications need to be flexible enough to accommodate the use of local materials whilst at the same ensuring that they are fit for purpose in terms of their task within the road pavement or surface.

By necessity general specifications must cover a very wide range of potential material types and natural environments and consequently they are likely to contain significant in-built factors of safety. By implication this means that proven specifications drawn-up for specific materials for specific environments need not be so conservative in approach and hence may allow the use of

previously non-conforming or marginal materials. In effect this means selecting materials on an "appropriateness-for-use" basis. A full understanding of the capabilities of local materials is a necessary prerequisite to adopting and proposals for amended or relaxed specifications.

2.2 LVRR Materials Resource Management

The planning, design, construction and maintenance of road projects in an effective and economic manner depends on reliable information being available to the engineer in an easily recognisable and accessible format, at an appropriate level of accuracy. Rural infrastructure projects present particular information problems because they can cover large areas in remote terrain, with very variable geology and soils

It follows from the above that prior knowledge of the location, quantity and quality of available materials would be of great advantage to national, provincial and district authorities in the planning and appropriate design of LVRRs.

There is a demonstrable need to move away from a narrow project-related, and frequently superficial, collection of materials information to a much wider strategic knowledge base of materials data. A database of local material sources and engineering characteristics provides rural road practitioners with a powerful tool in selecting road surfacing options appropriate to the local road environment, and hence a vital adjunct to the potential achievements of project tasks such as pavement upgrading and maintenance.

The relative quality and in-service performance of road materials are largely determined by six fundamental characteristics s as listed in Table1.

Table 1 Key Material Characteristics

	Material Characteristic	Description of the Material Property	Main Laboratory Tests Designed to Evaluate the Property
1	Particle Size Grading	The relative proportions of each size fraction from gravel to clay size. Implications for compactability and permeability	Sieve Analysis
2	Plasticity of Fine Fraction	The characteristics of the particles smaller than 0.425mm to behave as a plastic/ cohesive material at different moisture contents	Liquid Limit Test Plastic Limit Test Linear Shrinkage Test
3	Load bearing capacity of compacted material	The capacity of the compacted materials to support imposed loads under saturated conditions	4 day soaked California Bearing Ratio (CBR)
4	Volume Stability	Volumetric response of the compacted material to swell on soaking. Indicator of moisture susceptibility of fines.	Swell measurement during 4 day soaked CBR Test (CBR)
5	Particle Strength and Durability	The existing strength of individual particles and the ability of the particles to maintain this strength during the life of the road.	10 % Fines Aggregate Crushing Test (10% FACT) and wet/dry ratio Los Angeles Abrasion Test (LAA) Aggregate Impact Value Test (AIV) Magnesium or Sodium Sulphate Soundness Test
6	Particle Shape	The angularity and flakiness of the aggregate particles and their ability to interlock together	Visual description Flakiness Index Test Elongation Index Test

Specifications are designed to define limits or ranges of the above laboratory test results that will ensure satisfactory performance. In general, particularly with respect to highly trafficked or strategically important roads, a fairly large factor of safety is built in to the specification to cover their use over a large range of materials and environments. There is scope, therefore, in some cases, and this is particularly so for low volume sealed roads, to consider a reduction in specification standard when considering particular material types within defined environments.

The appropriate use of what may, in conventional terms, be categorised as "marginal materials" is an important issue and the availability of information relating to the use of these materials is an essential part of an assessment process if economic LVRR designs are to be adopted associated and risks are to be accurately assessed. It is often only through the documented evidence from construction experience and in-service performance, in a variety of road environments, that appropriate (empirical) specifications are actually developed

In road construction the location of natural materials has generally been regarded as specific task and incorporated into the costs for each project. In the case where there is a lack of reliable information and a degree of uncertainty regarding the location of acceptable materials, contractors usually quote a premium price. However if an accurate database of material resources was available it would greatly facilitate the planning and more accurate costing of construction projects. Materials appropriate to the road tasks could be more easily selected or shortfalls identified. Material costs could be better forecasted.

A systematic approach to the development and use of road construction sources enables a greater control to kept on any potentially detrimental environment impacts, both in terms of quarry or borrow pit excavation and their eventual reinstatement.

2.3 Sources of Road Construction Materials in Cambodia

There is a perceived lack of conventional road building materials in many areas of rural Cambodia and this is borne out by consideration of the Cambodian geological setting[1,2].

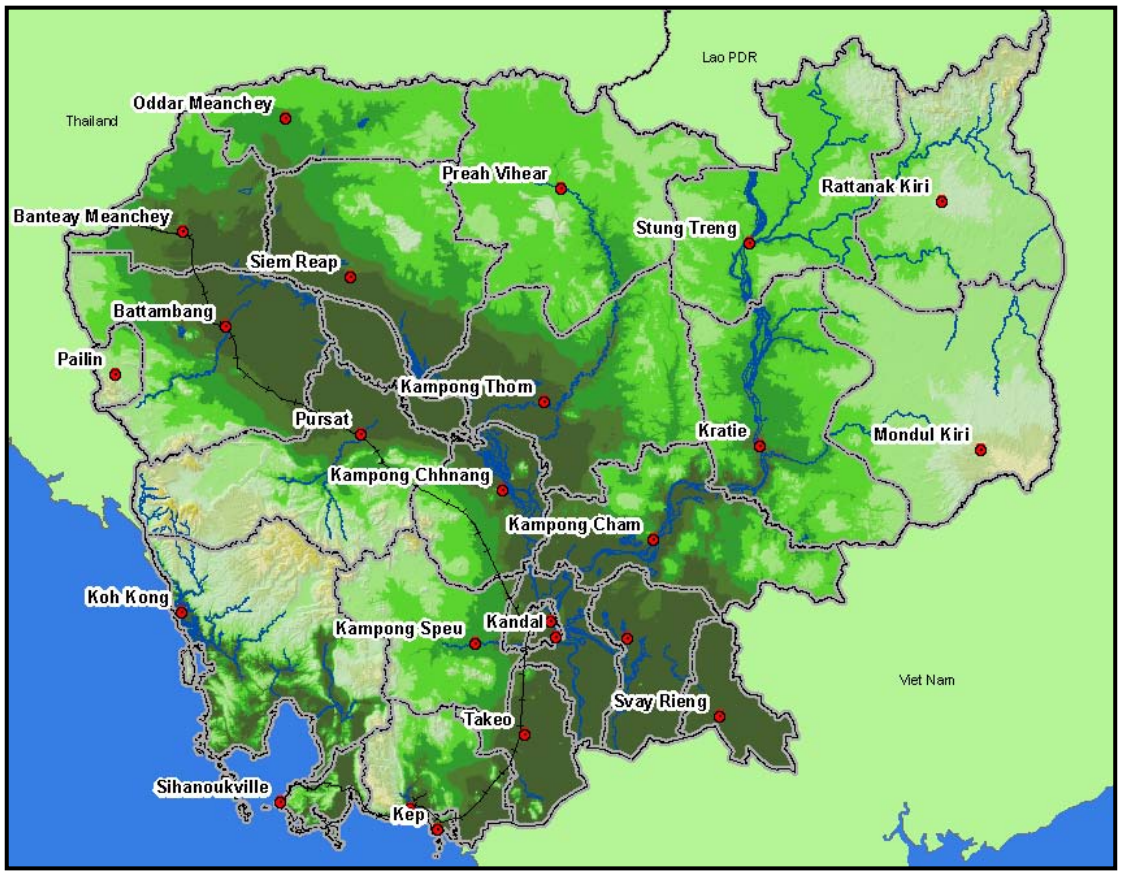
Large areas of Cambodia are dominated by Quaternary alluvium and lacustrine deposits of sand silt and clay. In general terms these Quaternary deposits underlie a large swathe of Cambodia running NW-SE from Odder Mancheay and Banteay Mancheay through to Svay Rieng and Takaev, Figure 1 Within this area only isolated rock outcrops occur. The weathering of some these rock areas as for example in Siem Reap is associated with useable laterite gravel deposits.

South east of this area a band of hilly terrain running through the provinces of Battambang,; Pursat; and Koh Kong; to Kompot is underlain by sedimentary and igneous rock with the latter in particular having potential as construction aggregate.

In the North East of Cambodia the hill to mountain provinces Rattanakiri and Mandal Kiri have substantial outcrops of potentially useable igneous, sedimentary and occasional metamorphic rock types, as have parts of the provinces of Krahcheh, Stung Teng and Siem Reap.

[1] 1: 1,000,000 geological map of S E Asia
[2] Atlas of Environmental maps of Cambodia

Figure 1 Topography of Provinces of Cambodia



3 Road Construction Materials Databases

3.1 Justification

Resources available for gathering relevant information on construction materials may be limited in Cambodia, where, in addition there may not be the wealth of historical data that is commonly available to engineers in other countries. The effective management of information gathering and collation procedures is therefore of critical importance. Compiling and maintaining an inventory of material sources and properties is one way of making already-gathered information available for cost-effective re-use.

There is now an awareness of the cost-effectiveness of assembling materials databases, for example, in Southern Africa (Gourley & Greening, 1999) and in Indonesia (Woodbridge & Cook, 1998).

A report by Beaven, Cook and Moestapha (1990) set out the potential for such a system on national level in Indonesia:

1. At a national planning level the information supplied by the database can be used to estimate the materials cost component of road building activities.
2. At a local planning level the information could be used in the preparation of feasibility studies.
3. Local engineers can use the system to identify suitable sources of material for construction and maintenance activities.
4. The availability of materials can be assessed at a regional level and used as justification for increasing capacity through the establishment of new quarries or processing plants.

To be fully effective a materials database for Cambodia needs to address the diverse requirements of all of potential users and stakeholders:

1. The data should available in a single location and in a compact standard format and at the same time be capable of dissemination down to province and district levels in more than one ministry.
2. The system should be simple to understand and provide information required by road engineers.
3. The database should be capable of manipulation to provide answers to specific enquiries.
4. The data sets should capable of being updated when necessary without difficulty and used in conjunction with other relevant data sets and GIS systems.

Storing this information on microcomputer database provides a rapid, reliable and effective method of sorting, retrieving and presenting relevant information. Computer technology is now an accepted tool to increase organisational capacity and the use of a computerised database offers several advantages. Data can be:

1. Accessed easily
2. Interrogated and edited so that data are added, modified or deleted, according to the needs of the user
3. Manipulated by sorting, querying, filtering, and indexing
4. Related to different databases with the same key fields (eg pit number or road number and chainage)
5. Used to produce reports which are designed and produced according to the users' or customers' specifications.

.

3.2 User and institutional issues

The identification of the end users, their needs and requirements forms an integral part of the database development process, together with the commitment available at local level to support the system is an important issue. Table 2 summarises practical end-user application.

Table 2 Summary of Materials Information Utilisation

Application	Description
Resource planning	Planning the utilisation of the available materials in the most cost-effective manner that is compliant with the engineering requirements of the project. Ensuring, for example, that high quality aggregate resources are not wasted as low-specification materials and that mass-haul diagrams are programmed effectively.
Processing requirements	Identifying what processing is required for various materials and ensuring that appropriate processing plant is selected
Stabilisation requirements	Identifying requirements for stabilisation- e.g. mechanical, chemical, bitumen etc. Drawing up testing and trial programmes that establish detailed design and construction procedures.
Materials design and control	Drawing up guidelines for materials testing programmes that ensures that consistent quality material is brought to site and is placed correctly. The exact nature of the tests to be used will be a function of information acquired at an early stage in the materials investigation process.
Design modifications	Material information may lead to design modifications; for example, in the fill-slope angles or in the detailed pavement design.
Construction techniques	Material information may be used to decide on construction methods; for example some fabric-sensitive fill materials will require special handling and placement techniques.

It is important to appreciate that a materials inventory is not just a computerised data storage system, but also involves issues of data management. Management procedures and the availability of suitably trained staff need to be in place to enable the system to be updated, managed, maintained and used properly.

Key to the success and development of the PRMD was to identify its objectives and to design a system capable of satisfying the needs of the relevant stakeholders. Table 3 summarises local stakeholder expectations based on the experienced gained with setting up other systems.

Table 3 Stakeholder Expectations

Stakeholders	Expectations
Local Communities	Better planning of local extractions for construction and maintenance, more effective safeguards on environmental damage, advance warning on potential overloading and deterioration of local roads.
Ministries (MRD, MPW&T)	Data available on the location, properties and costs of materials; more accurate cost planning; more effective use of diminishing resources, greater control on quality and cost of materials items within contracts.
Local Research Institutions (ITC)	Transfer of technology on the procedures for materials location and practical data management. Institutional strengthening.
SEACAP/gTKP	Development of methodologies for international adaptation.
Donors	Better information for the assessment of road schemes and more accurate cost estimates.

3.3 Data Management

No matter how the data is acquired, its effective storage, collation and overall management lie at the heart of an effective materials database. Reliable and relevant materials information forms the core of any practical database system. The solution to the problem of providing easily accessible materials information must take on board a number of basic questions, namely:

- What materials are available?
- What is their nature?
- Where are they located?

Table 4 lists key information sets and summarises their importance with respect to construction materials.

Economic factors should include information on costs of winning materials including extraction, processing and transport to site. To be fully effective, data on any long term, or whole-life, cost implications of using particular materials should also be accessed; this may include relative maintenance and repair costs, and also long term cost implications of using inappropriately high grade resources. Information on the relative costs of stabilisation options for utilisation of lower quality materials would, for example, be required to balance judgement with the technical assessment.

The increasing importance given to environmental impact means that information on factors such as loss of habitat and pollution, are very relevant to materials source development (Gourley et al 1999). This may be particularly applicable for some materials, for example the development and processing of technically hard quartz-rich rocks may incur risks due to production of silica dust. There is also the need to consider the environmental and economic implications of quarry or borrow pit restoration.

Table 4 Materials Information Sets

Information Set	Description of Potential Information Sets	Key Applications
Location	Location of materials sources by co-ordinates, by road chainage or by representation on maps.	Identification of resources; distances for material haulage; mass haul calculations.
Quantities of material	Amounts of potentially available material.	Reviewed in conjunction with volumes required and stockpiled quantities achievable and wastage. Requirements for further materials exploration or investigation
Geological nature	Classification: rock types, sand and gravel; duricrust etc. Morphology of the source. Amounts of weathering or overburden.	Material options identified for design. Potential problem identification. Overburden ratio calculations. Outline methods of extraction and processing.
Geotechnical character	Index or behaviour properties, either from tests on in situ, processed material or in service road performance.	Material quality identified. Appropriate methods of processing or use. Also, the identification of possible problems associated with these activities.
Project specifications	Engineering requirements will generally be readily available for sub-grade and pavement materials and probably also for fill and filter media.	Appropriate use of materials. Influence on design modifications required. Requirements for material processing or stabilisation. Possible impacts on construction plant selection and construction methodologies.
Economic factors	Costs of material processing; of haulage; and of any required modification.	Mass-haul cost calculations. Project costing.
Environmental impact factors	Impacts on the environment: pollution - dust, noise etc; Health – water borne disease; Loss of productive land etc.	Methods of source extraction, material processing and rehabilitation. Limits imposed by groundwater levels.

There were significant advantages to be gained by in ensuring that the design of the database was compatible with other projects within the overall SEACAP research strategy, such as the ENS studies in Cambodia and the RRGAP research in Vietnam.

4 Development of the Pilot Database

4.1 Preparation and Initial Design

An initial review was undertaken of previously assembled materials databases including the Indonesian Construction Materials Information System and the material information system developed as part of the SADC Guidelines project (both compiled by TRL) as well as the more basic materials database assembled as part of the SEILA and IRAP programmes in Cambodia.

Based on this experience the following key points were adopted:

- The database would comprise number of related tables of files
- Materials information would be quarry-based rather than road-performance based
- Information would be collected from a representative selection quarries
- Laboratory testing would be undertaken on representative samples
- There should a GIS capability within the database
- Links would be established with the existing IRAP materials information.

In the preparation phase previous research work on materials databases in the region was used to select and modify appropriate fields within the data tables. At the same time requests for information on the location of construction materials information were circulated to provincial departments of MRD and MPW&T within the identified target provinces of Siem Reap and Kandal. Useful information was received and this was incorporated into the fieldwork planning.

Initial field data collection forms were developed and trialled in sources close to Phnom Penh. Trial data sets were entered into the preliminary database and the final structure arrived by a process of review and modification.

A summary of data collection procedures together with relevant data forms is included as Appendix A

4.2 Fieldwork

The two provinces of Siem Reap and Kandal were selected as the principal trial areas containing a suitable selection of representative materials sources, from sub-grade soil borrow pits to hard rock quarries. The key geological and natural resource characteristics for the main trial provinces are as follows:

> **Sim Reap** Largely underlain by alluvial and lacustrine deposits of sand, silt and clay. Marginal quality sandstones occur in the centre of the province together with some isolated better quality igneous rock sources. There are some duricrust and latertite gravel sources of at least wearing course quality (used in the historical past to construct Angkor Wat). In the North East districts of Svay Leu and Chi Kreong there are significant hard rock occurrences of andesite, basalt and granite.
>
> **Kandal** Almost exclusively underlain by Younger Alluvium of sand silt and clay.

The selection of these two contrasting provinces had the added advantage of allowing for overlap and coordination with other Tasks within the project.

The data collection was preceded by a process of coordination and discussions with national provincial and district authorities from a number of ministries and organisations. This process essential both as regards identifying local material sources but also to obtain important ancillary information relevant to any resource development. Table 5 summarises information obtained.

Table 5, Information Sources

Organisation	Information Sought
Ministry of Rural Development	Existing borrow pits and quarries
Ministry of Public Works and Transport	Existing borrow pits and quarries
Ministry of Environment	Protected areas and national parks
Ministry of Culture and Art	Cultural Protected Areas
APSARA Authority	Cultural Protected Areas
Ministry of Mine and Industry	An inventory of construction material and mineral reserve areas
Ministry of Land Management Urbanisation Planning and Construction	Land use and urban planning
Ministry of Tourism	Eco-tourism protect areas
Landmine Authority	Update on landmine affected areas

A total of 71 quarries and borrow areas were surveyed as part of the PRMD, 22 were soil sources; 14 were sand; 24 were gravel and 11 were comprised of hard rock. Tables 5 summarises the extent of the fieldwork.

Plate 1 Typical Sand Borrow Pit

Plate 2 Typical Hard Rock Quarry

Table 5, PRMD Sources

Province	District	No. of Sources
Sim Reap	Angkor Thum	2
	Angkor Chum	3
	Banteay Srey	2
	Puok	11
	Chi Kreang	11
	Soutre Nikam	1
	Svay Leu	11
	Varin	15
Kandal	Kandal Steung	6
	Ksach Kandal	4
	Angkor Snuol	5
	Saang	2
	Ponhea Lueu	2
Kampot	Angkor Chey	2
Kampong Cham	Batheay	1

4.3 Laboratory Testing

A wide range of possible tests exists for the assessment of road construction materials (Cook et al 2001) In the light of the project time constraints this range of possible materials test was reviewed and a list of essential index and strength tests was agreed upon, Table 6.

Table 6 Range of Laboratory Testing

Test	No.	Test	No.
Soil			
Particle Size	77	Atterberg Limit	45
Linear shrinkage	43	Sand equivalent	15
Compaction	58	CBR	58
Rock			
Water Absorption	9	Specific Gravity	9
Bulk density	2	LAA	7

This testing programme was considered sufficient for the purposes of the PRMD and for most standard LVRR material requirements. It is however possible to expand on this list of tests and a

suggested list of additional tests is included within the Concept Note on PRMD expansion (Appendix C)

Material testing was undertaken at the following geotechnical laboratories

Institute of Technology Cambodia (ITC)

Ministry of Public Works and Transport (MPW&T)

Ministry of Water Resources and Meteorology (MWRM)

Plate 3 Linear Shrinkage Testing

Plate 4 CBR Strength Testing

5 The Status of the Pilot Database

5.1 Structure

The PRMD records the location and details of quarries, the types of material available and the products derived from these materials, along with details of samples taken for testing and the results of the tests. The PRMD is based on the Microsoft Access® database platform which has advantage of being simple to develop for and widely available as a desktop application. Since the PRMD is relatively small and limited to single user access, the choice of Access as a platform does not pose any problems.

The advantage of using a relational database such as Access® over a series of individual files to store the data is that data records (rows) from different tables can be defined as being interrelated in some fashion. A good database structure therefore is one which does not duplicate data unnecessarily and is organised so that no restrictions are placed on the amount of data that can be stored. Converting data into a database structure with minimal duplication is a process called normalisation.

The database is comprised of six main data tables and associated data entry forms, with numerous supporting lookup tables. The six main data tables are as follows:

- tbllocation – table containing data on the quarry's location, utilities, processing capabilities, accessibility and environment
- tblMaterial – table containing data on the available materials at the quarry sites
- tblProduct – table containing data on quarry products derived from the available materials
- tblsample – table containing data on materials samples taken for testing
- tblTestingResultSoil – table containing data from materials tests on soil samples
- tblTestingResultStone – table containing data from materials tests on rock/stone samples

A full description of the database tables and the fields within the six main tables can be found in Appendix B to this report.

The structure of the Materials Database is structured such that logical separations have been made of Quarry Location data, Materials data and Product Data. Many of the fields are coded using lookup tables which are an excellent way of keeping the database size to a minimum, whilst making it easy for the user to select items from pull down lists (combo boxes) when populating the database.

5.2 GIS Links

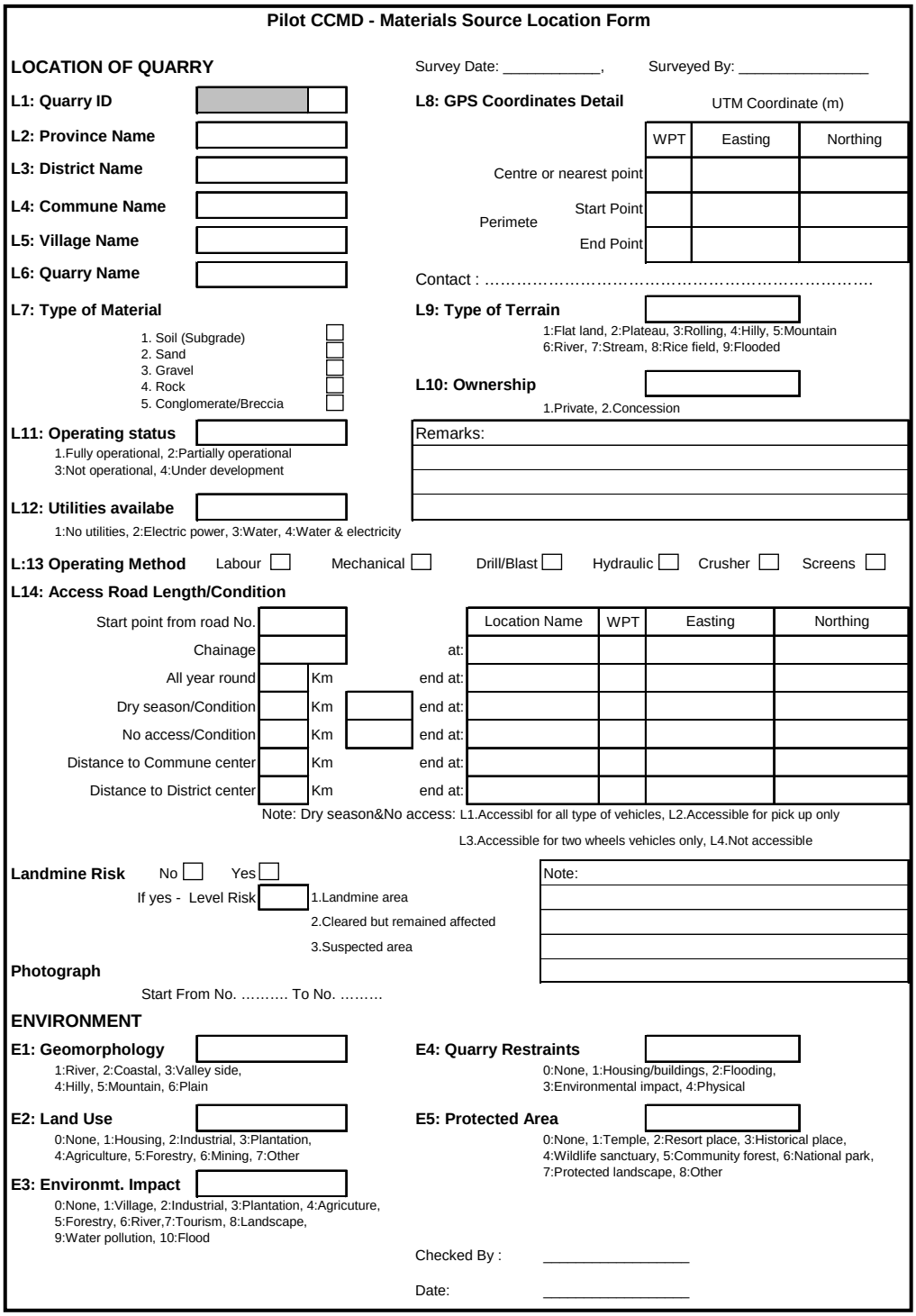
The database automatically creates and maintains a table (GISLINK) of geo-referenced information that can be manually linked to the ArcView® GIS package to provide mapping of the Quarry sites. To map the data correctly the correct co-ordinate system must also be loaded into ArcView. At present GIS functionality is limited to a mapping layer showing the location of each Quarry and the Material Types. Additional mapping layers not included in the database provide information on the provincial boundaries and the Cambodian road network.

This basic GIS functionality is all that is required at present, but could be extended easily in the future should additional mapping features be required.

5.3 Data Entry

Users of the Materials Database enter, edit and delete data through the database's forms. Good form design can reduces the risk of entering erroneous data or changing a data field's value inadvertently. Based on experience the PRMD forms have been designed for each data table so as to promote easy of use of the database through a main menu (the "switchboard") and at the same time protect it from inadvertent damage, Figure 2.

Figure 2 The Quarry Location Data Entry Form



Pilot CCMD - Materials Source Location Form

LOCATION OF QUARRY

Survey Date: _____, Surveyed By: _____

L1: Quarry ID

L2: Province Name

L3: District Name

L4: Commune Name

L5: Village Name

L6: Quarry Name

L8: GPS Coordinates Detail UTM Coordinate (m)

	WPT	Easting	Northing
Centre or nearest point			
Perimete Start Point			
Perimete End Point			

Contact : ……

L7: Type of Material

1. Soil (Subgrade)
2. Sand
3. Gravel
4. Rock
5. Conglomerate/Breccia

L9: Type of Terrain

1:Flat land, 2:Plateau, 3:Rolling, 4:Hilly, 5:Mountain
6:River, 7:Stream, 8:Rice field, 9:Flooded

L10: Ownership

1.Private, 2.Concession

L11: Operating status

1.Fully operational, 2:Partially operational
3:Not operational, 4:Under development

Remarks:

L12: Utilities availabe

1:No utilities, 2:Electric power, 3:Water, 4:Water & electricity

L:13 Operating Method Labour ☐ Mechanical ☐ Drill/Blast ☐ Hydraulic ☐ Crusher ☐ Screens ☐

L14: Access Road Length/Condition

				Location Name	WPT	Easting	Northing
Start point from road No.			at:				
Chainage			end at:				
All year round		Km	end at:				
Dry season/Condition		Km	end at:				
No access/Condition		Km	end at:				
Distance to Commune center		Km	end at:				
Distance to District center		Km	end at:				

Note: Dry season&No access: L1.Accessibl for all type of vehicles, L2.Accessible for pick up only
L3.Accessible for two wheels vehicles only, L4.Not accessible

Landmine Risk No ☐ Yes ☐

If yes - Level Risk

1.Landmine area
2.Cleared but remained affected
3.Suspected area

Note:

Photograph

Start From No. ……. To No. ……

ENVIRONMENT

E1: Geomorphology

1:River, 2:Coastal, 3:Valley side,
4:Hilly, 5:Mountain, 6:Plain

E2: Land Use

0:None, 1:Housing, 2:Industrial, 3:Plantation,
4:Agriculture, 5:Forestry, 6:Mining, 7:Other

E3: Environmt. Impact

0:None, 1:Village, 2:Industrial, 3:Plantation, 4:Agricuture,
5:Forestry, 6:River,7:Tourism, 8:Landscape,
9:Water pollution, 10:Flood

E4: Quarry Restraints

0:None, 1:Housing/buildings, 2:Flooding,
3:Environmental impact, 4:Physical

E5: Protected Area

0:None, 1:Temple, 2:Resort place, 3:Historical place,
4:Wildlife sanctuary, 5:Community forest, 6:National park,
7:Protected landscape, 8:Other

Checked By : _____

Date: _____

5.4 Data Reporting

The database currently includes five predefined reports for viewing the quarry location, material, product, sample and testing data. Adding additional reports to the database is relatively simple and the available reports will most likely grow over time as users of the database request new reports. In the longer term a dedicated reporting tools section (form) could be added to the database accessible through the switchboard (main menu). The dedicated reporting tools allow the user to select one of the default reports and allow them to customise it to a degree. For example a user may want a report on the quarry locations from a specific region or only the quarries that have a specified material type. The exact nature of the reporting and customisation can be developed over time in consultation with the users.

Information from the database can also be easily exported in spreadsheet format for easier analysis or transfer to district offices.

6 The Way Forward

6.1 Expansion Options

The options for the further expansion of the Pilot Road Materials Database (PRMD) are, firstly, into a National Road Materials Database (NRMD) on a province by province basis, and then further development into wider a National Road Materials Information System (NRMIS) through the incorporation of research data and road materials information from existing roads and related road performance data.

The key points regarded these options are outlined in Table 7 and are presented in more detail in Appendix C.

Table 7 The PRMD Expansion Options

Option	Description	Key Upgrade Issues
NRMD	A database of existing sources of road construction materials in Cambodia based on the existing structure and procedures in the SEACAP 19 PRMD	Expansion to cover all the province and districts of Cambodia Centrally based in either MRD or MPW&T Additional laboratory test procedures Increased reporting capacity Provincial management capability Upgrade of GIS capacity
NRMIS	The NRMD expanded to include information on road performance related to their constituent materials as well as any related research and development, including earthworks and slope protection. A more comprehensive reporting capability would include recommendations on use and modification for specific road tasks. (Figure 3)	Inclusion of performance data on all Cambodian roads Expansion of structure to include additional tables concerned with desk study data (maps, reports etc) Inclusion of all relevant road research information Inclusion of information from project reports on materials investigation and subsequent use Inclusion of road environment data Widening of GIS capability

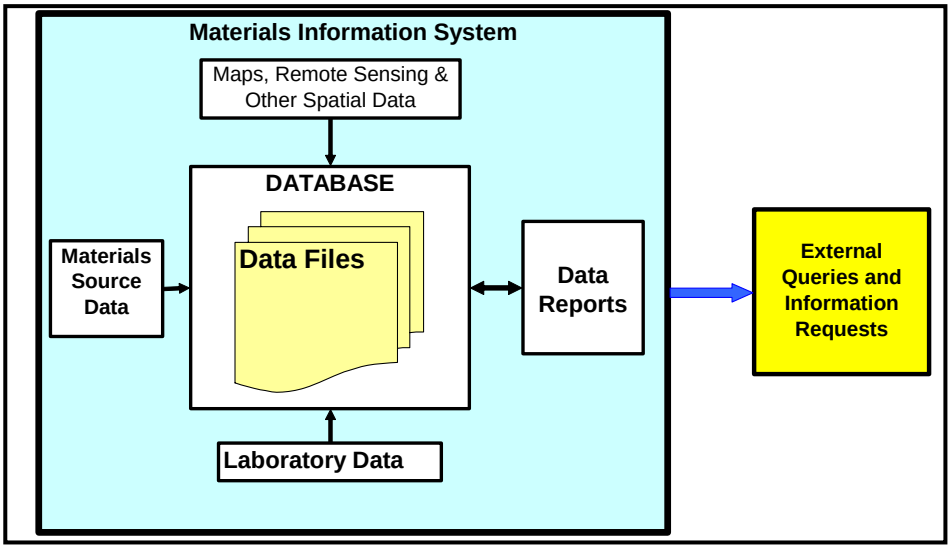
6.2 Structural Development

The expansion to NRDM would not require significant structural alteration, other than to allow for the possible sub-division into provincial level systems. Some upgrading of the GIS capacity could be considered.

Should the database increase in size beyond Access' 2GB maximum or the requirements change so that the constraints of Access® are no longer acceptable then migration to a more complex and

comprehensive system is advised e.g. MySQL. This scenario is not likely within the upgrade to NRMD, but may be an issue to a larger scale MRMIS.

Figure 3 General Structure of a Possible NRMIS



6.3 Sustainability

Before considering the expansion of the PRMD it is essential that serious and realistic consideration be given to its long term sustainability. Materials' databases are not "one-off" exercises: they require ongoing commitment to update, manage and disseminate their information.

Sustainability may be assessed under the following headings:

Political Will: The must be a clear commitment at Ministerial level to support the database.

Institutional Capacity: There must a recognised body; be it University, Ministry, or Research Institute, with the capacity to manage the database.

Financial Commitment: There has to be an established budget that is secured for number of years ahead that is adequate both for the expansion and the ongoing management of the database.

Technical Capability: There must be engineers, technicians and IT specialists who have the technical capacity to undertake the defined tasks in relation to the expansion of the database.

Table 8 assesses these risks associated with the above in terms of the two phases of development.

Table 8 PRDM Expansion Risks

Sustainability Issue	Phase 1- NRDM	Phase 2 - NRMIS
Political Will	Low risk (MPWT)	Medium to high risk
Institutional capacity	Low risk (ITC or MPWT)	Medium risk
Financial Risk	High risk	Very high risk
Technical; Capability	Low risk	Medium risk

It may be seen that Phase 1 requires only the long term financial commitment to be come a sustainable project, whilst the expansion to Phase 2 would require further discussion and institutional development at ministerial level.

7 Summary

A Pilot Materials Database relational structure has been set up and a representative suite of data has been collected and entered into this structure. The structure allows the easy entry and reporting of materials information relevant to rural infrastructure engineers.

The main PRMD itself is currently held on a portable hard disk at the Ministry of Rural Development with additional back-up copies being held by SEACAP and the project consultants.

The following is a summary of achievements on the previously identified four key issues (Section 1.2)

Review A review of previous materials databases has been undertaken and the lessons absorbed into the PRMD.

Database Structure A structure and associated methodology has been developed, as reported in Appendix B

Data Collection The database procedures have within 2 contrasting provinces. Reasonably representative of the data sets have been entered onto the PRMD.

Reporting The database methodology is presented in the accompanying Appendix A and recommendations on expansion presented in Appendix C.

ACKNOWLEDGEMENTS

This report was produced as part of the SEACAP 19 project contracted to TRL Ltd in principal association with KACE Ltd. The drafting of this report was undertaken by Dr Jasper Cook (OtB Engineering Ltd) in association with Heng Kackada (KACE). The report was reviewed by Trevor Bradbury (TRL Ltd).

The fieldwork was undertaken by Thai Kheang, Heng Kackada and Ross Sobunn from KACE and the database design was directed by Mao Hat (KACE).

Comment and support from members of the SEACAP 19 Steering Committee under the Chairmanship of H E Suos Kong is gratefully acknowledged.

Valuable assistance was supplied by other members of the SEACAP 19 Team. David Salter, the SEACAP Programme Manager, provided key facilitation, guidance and programme support.

SELECTED BIBLIOGRAPHY

ARRB 1995, Sealed Local Roads Manual.

ARRB 2000. Unsealed Roads Manual, Guideline to Good Practice. Giummarra G, editor.

Charman J.M. (ed), (1988). Laterite in Road Pavements.CIRIA Spec. Pub. No.47, London

Cook J R and Petts R, 2005. Rural Road Gravel Assessment Programme. SEACAP 4: Module 4 Report.

Cook J R, Gourley C & Elsworth N, Guidelines on the Selection and Use of Construction Materials in Developing Countries. DFID Knowledge and Research report, R6989. TRL Ltd, 2001.

Geol. Soc.,(1997). Tropical Residual Soils. A Geological Society Engineering Group. Working Party Revised Report. Geological Society Professional Handbooks. 184pp

Gourley C.S. & Greening P.A.K. (1999) Environmental damage from extraction of road building materials: Resulst and recommendations from studies in Southern Africa. TRL-DFID Report on Collaborative Research Programme on Highway Engineering Materials in the SADC Region. Volume 3. TRL Report PR/OSC/169/99.

Gourley C.S. & Greening P.A.K. (1999) Establishment of information systems for managing road construction material resources in Southern Africa. TRL-DFID Report on Collaborative Research Programme on Highway Engineering Materials in the SADC Region. Volume 4. TRL Report PR/OSC/170/99.

McNally G.H. (1998). Soil and rock construction materials. E & F N Spoon, London. 403pp

Millard R.S. (1990). Road building in the tropics. TRL State of the Art Review.

Roughton International (2000). Guidelines on borrow pit management for low cost roads. DFID Knowledge and Research Project Report (Ref. R6852).

Smith and Collis (eds), (1993). Aggregates: Sand, Gravel and Crushed Rock Aggregates for Construction (2nd Edition). Geological Society, UK.

Thagesen B, (ed) (1996). Highway and Traffic Engineering in Developing Countries. E & FN Spon.

Transport Research Laboratory (2005). Overseas Road Note 5, A Guide to Project Appraisal. TRL, Crowthorne.

TRL, Overseas Road Note 31 (4th Edition) A Guide to the Structural Design of Bitumen Surfaced Roads in Tropical and Sub-Tropical Countries, 1993.

Woodbridge M E, Cook, J R & Moestofa B. 1999 Development and Implementation of a Construction Material Information System. 7th Int Conf. on Low-Volume Roads, Louisiana, USA

DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

PILOT CONSTRUCTION MATERIALS DATABASE

APPENDIX A

A1: DATA COLLECTION PROCEDURES

A1 Introduction

The current procedures for the PRMD are based on the collection of information only from existing sources of road construction materials. The procedures are essentially a combination of visual assessment backed by limited in situ tests and from associated laboratory testing of representative samples. They do not include measures for collecting data from sub-surface investigations such as boreholes, trial pits or geophysics. Previous DfID research on these topics is included in Roughton, 2000 and , Cook et al 2001 . General descriptions are included in Smith et al 1993.

At some stage in the future development of a Cambodian NRMD this data collection could be expanded to include the following:

- Information from material investigations aimed at identifying new material resources or expanding existing quarries or borrow pits
- Materials data from road construction contracts
- Materials performance information from constructed roads.

The following sections describe the procedures developed for the Cambodian PRMD as outlined in the SEACAP 19 Task 7 main document.

A2 Fieldwork Preparation and Programming

A2.1 Planning

Adequate pre-planning is required for a materials source data gathering programme. Key elements are:

1. Liaison with relevant ministries central level, including MPWT, MRD, MMI
2. Obtain existing available information on materials source in the target area through desk study of contract reports and contact with local provincial and district authorities.
3. Draw up general fieldwork plan and notify local authorities.
4. Ensure adequate resources are available.
5. Ensure that any required field training is undertaken prior to start of main fieldwork.
6. Liaise with relevant authorities and NGOs on the situation regarding UXBs in the target survey areas.
7. Obtain key phone numbers.

A2.2 Fieldwork Resources

Materials data collection is best undertaken using one or more dedicated field teams. Each team would normally comprise

- Team Leader: experienced Materials Engineer or Engineering Geologist
- Assistant engineer or geologist
- Pick-up vehicle with driver

Team such as these would normally expect to visit, characterise and sample on average between 10 and 15 material sources per week, depending distances to be travelled

Teams should be supplied with a number of basic items to carry out their data collection survey; as follows:

Field forms and associated guidance tables
Note pad
GPS device
Measuring tapes (30m and 5m)
Digital camera
Geological hammer
Small bottle of 10% HCL
Mobile phone
Scale rule
Shovel and pick
Large and small sample bags
First aid kit

Optional items include:

Schmidt hammer
Rock-soil colour chart
Inclinometer

A3 Field Data Collection

The PRMD field procedures are based on the use of the principal standard data collection. On arrival at each site the following general procedure is recommended:

1. Note location of access road
2. Make contact with quarry/borrow pit owner of available
3. Obtain basic information on ownership etc
4. Obtain any information on product use, costs etc
5. Walk-over the site taking GPS reading at key areas
6. Complete Form I (Location, status and environment)
7. Make site sketch and take key photographs
8. Concentrate on materials and complete Form II
9. Complete Form III (products)
10. Take suitably sized samples from stockpiles or quarry (Table A1)
11. Mark sample bags clearly with unique numbers
12. Complete Form IV describing samples and suggesting suitable lab tests
13. Cross- check that all forms are complete and obtain any missing data

A4 Laboratory Testing

Samples should be assigned using a standard sheet (see Form V as an example) and then transferred to the designated laboratory. Laboratory tests should be undertake as per the agreed standard (normally ASTM-ASSHTO), Table A2.

Table A2 Standard Laboratory Tests

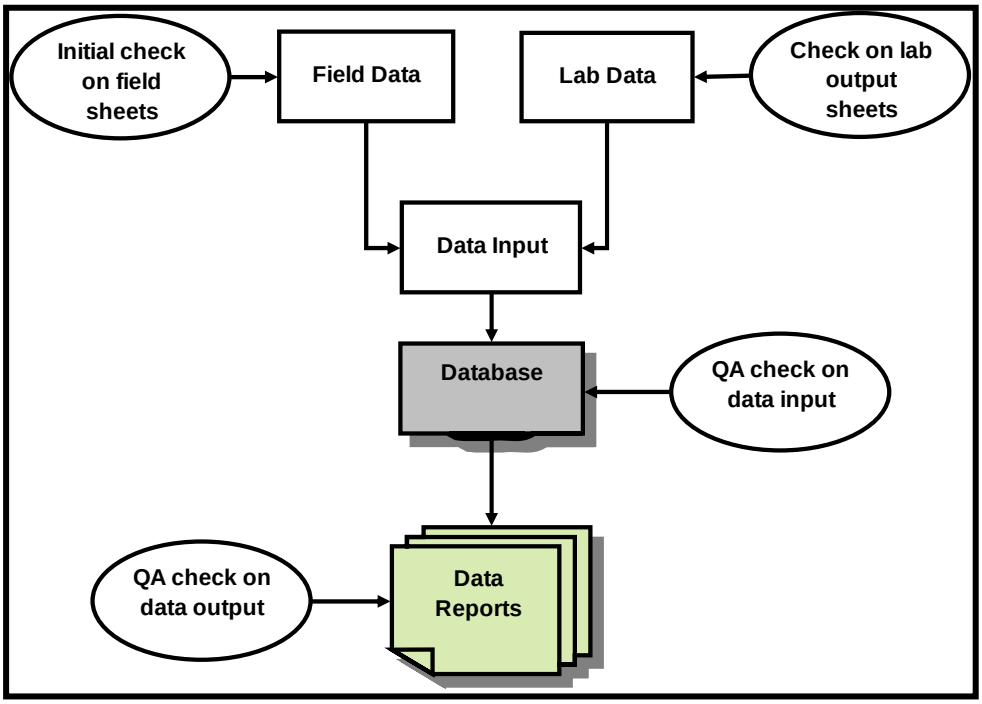
Standard Tests: Soil	**Standard Procedures**	
	BS	**ASTM**
Moisture Content	1377: 2:,3.1:	D2216
Liquid Limit (WL)	1377:2,:4.3-6	D4318
Plastic Limit (Wp)	1377:2,:5.3	D4318
Linear Shrinkage (Ls)	1377:2,:6.5	
Particle Size Distribution	1377:9:2.3-5	D422
Soil Particle Density	1377:2, 8.2	D854
Bulk Density	1377:2	C29 & C29M
Compaction	1377:4, 3.3-7	D698 & D1557
CBR	1377:4, 7	D1883
Vane Shear (Lab)	1377:7, 3	D4648
Standard Tests : Rock		
Water Absorption	812:109	C127 & C128
Aggregate Grading (Sieve)	812:103,1 812:103,1	C136 & C117
Flakiness Index (If)	812:105, 1	D4791
Elongation Index (Ie)	812:105, 2	D4791
Aggregate Particle Density	812:2	C127/128
Point Load Strength	[ISRM]	
Unconfined Compressive Strength	[ISRM]	D2938
10% Fines Aggregate Crushing Test	812: 111	
Aggregate Impact Value (AIV)	812: 112	
Sulphate Soundness	BS 812: 121	C88
Slake Durability	[ISRM]	D4644
Los Angeles Abrasion (LAA)		C131/535

Laboratory test results should be reported as per the relevant Standard, with key summary results being transferred to the database after Quality Assurance checking.

A5 Data Management

Management of recovered materials information should follow a clear path of collection, collation and dissemination, with in-built quality assurance checks at key stages, Figure A1. The final phase of dissemination can be facilitated by utilising standard report forms developed form the ACCESS database system.

Figure A1 Outline of Data Management Actions



DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

PILOT CONSTRUCTION MATERIALS DATABASE

APPENDIX A

A2: STANDARD FORMS

Data Collection Form I: Location, Status and Environment

FORM I: Pilot Road Materials Database

QUARRY LOCATION

Survey Date: _____, Surveyed By: _____

L1: Quarry ID

L2: Province Name

L3: District Name

L4: Commune Name

L5: Village Name

L6: Quarry Name

L8: GPS Coordinates Detail UTM Coordinate (m)

	WPT	Easting	Northing
Centre or nearest point			
Perimeter – Start Point			
Perimeter – End Point			

Contact : ……

L7: Type of Material

1. Soil (Subgrade) ☐
2. Sand ☐
3. Gravel ☐
4. Rock ☐
5. Conglomerate/Breccia ☐

L9: Type of Terrain

1:Flat land, 2:Plateau, 3:Rolling, 4:Hilly, 5:Mountain
6:River, 7:Stream, 8:Rice field, 9:Flooded

L10: Ownership

1.Private, 2.Concession

L11: Operating status

1.Fully operational, 2:Partially operational
3:Not operational, 4:Under development

Remarks:

L12: Utilities available

1:No utilities, 2:Electric power, 3:Water, 4:Water & electricity

L:13 Operating Method Labour ☐ Mechanical ☐ Drill/Blast ☐ Hydraulic ☐ Crusher ☐ Screens ☐

L14: Access Road Length/Condition

				Location Name	WPT	Easting	Northing
Start point from road No.			at:				
Chainage			end at:				
All year round		Km	end at:				
Dry season/Condition		Km	end at:				
No access/Condition		Km	end at:				
Distance to Commune center		Km	end at:				
Distance to District center		Km	end at:				

Note:Access Condition: L1.Accessible for all type of vehicles, L2.Accessible for pick up only
L3.Accessible for two wheels vehicles only, L4.Not accessible

Landmine Risk No ☐ Yes ☐

If yes - Level Risk ____ 1.Landmine area
2.Cleared but remained affected
3.Suspected area

Note:

Photograph

Start From No. ……. To No. ……

ENVIRONMENT

E1: Geomorphology

1:River, 2:Coastal, 3:Valley side,
4:Hilly, 5:Mountain, 6:Plain

E4: Quarry Restraints

0:None, 1:Housing/buildings, 2:Flooding,
3:Environmental impact, 4:Physical

E2: Land Use

0:None, 1:Housing, 2:Industrial, 3:Plantation,
4:Agriculture, 5:Forestry, 6:Mining, 7:Other

E5: Protected Area

0:None, 1:Temple, 2:Resort place, 3:Historical place,
4:Wildlife sanctuary, 5:Community forest, 6:National park,
7:Protected landscape, 8:Other

E3: Environment. Impact

0:None, 1:Village, 2:Industrial, 3:Plantation, 4:Agricuture,
5:Forestry, 6:River,7:Tourism, 8:Landscape,
9:Water pollution, 10:Flood

Checked By : _____

Date: _____

Data Collection Form II: Materials

Pilot Road Materials Database
Form II

QUARRY MATERIAL DATA

Quarry ID		**Material ID**	
Q1: Physical State		**Q2: Material Type**	
Soil		1.Soil(Subgrade), 2.Sand, 3.Gravel,	
1.Loose, 2.Massive, 3.Compact		4.Rock, 5.Conglomerate/Breccia	
Stone			
1.Weathering, 2.Massive		**Q4: Material Definition**	
		1.Alluvium, Terrace deposit, 2.Andesite, Granit, Diorite, Metamorphic	
Q3: Material Quality		3.Conglomerate, Breccia, 4.Limestone, santstone, shale	
1.None, 2.Poor, 3.Average, 4.Good			
		Q6: Overburden Type	
Q5: Reserve estimate, m^3		1.None, 2.Loose, 3.Mixed loose & hard, 4.Compact	
Q7: Overburden		**Q8: Material Use**	
Thickness	m	1. Surface dressing, 2. Asphalt aggregate, 3. Roadbase,	
Thickness	1: < 1m, 2: 1 - 2m, 3: 2 - 4m, 4: >4m	4. Subbase, 5. Concrete aggregate, 6. Fill, 7. Housing & others	
		8.Embankment, 9. Sub-grade, 10.Bedding	

Data Collection Form III: Quarry Products

Pilot Road materials Database Form III

QUARRY PRODUCT

Product ID		**P1: Type**	**P2: Size, Max & Min** (mm)		
	01	10x20		1	
	02	40x60		2	
	03	M30		3	
	04	M40		4	
	05	Seal 19mm		5	
	06	Seal 12mm		6	
	07			7	
	08			8	

P3: Production rate (m^3/day)		**P4: Price** (USD/m^3)	
	1		1
	2		2
	3		3
	4		4
	5		5
	6		6
	7		7
	8		8

Form IV: Sample Description and Test Assignment

Pilot Road Materials Database

Quarry Name: …… **Province Name:** ……

Material ID **Sample ID**

SAMPLE DESCRIPTION AND LABORATORY TESTS REQUIRED

1 Material Type

1.Soil(Subgrade),
2.Sand,
3.Gravel,
4.Rock,
5.Conglomerate/Breccia

2 Sample derivation

1. Test pit
2. Borehole
3. Surface
4. Side section
5. Hand
6.Stockpile

3 Sample Type

1.Bulk(>25kg), 2.Large disturbed(25kg)
3.Small disturbed, 4.Undisturbed,
5.Hand specimen

4 Laboratory Tests required

Water Absorption		Atterberg Limits	
Specific Gravity(bulk)		Compaction	
Specific Gravity(ssd)		Grading	
Specific Gravity(app)		Hydrometer	
Los Angles Abrasion		Soil Particle Density(Specific Gravity of Soils)	
10% Fines (dry)		CBR	
10% Fines (soaked)		Swell	
Impact Value (dry)		Moisture Content	
Impact Value (soaked)		Organic Content	
Elongation		Linear Shrinkage	
Flakiness		Particle Size Distribution	
Stripping		Vane Shear	
Sulphate Soundness		Binocular Microscopy	
Polished Stone Value			
Aggregate Particle Density			
Unconfined Compessive Strength			
Sand Equivalent Value			
Surface Condition			
Bulk Density			
Point Load Strength			
schmidt Hammer			
Slake Durability			
Aggregate Bitumen Adhesion			
Qualitative Visual Examination			
Quantitative Visual Examination			

Requested By: …….. Received By: ……

Date : …… Date : ……

REQUEST FOR LABORATORY TEST

TO:

Lab No.	Sample ID	Location ID	Loaction Name	Date Sampled	Material Type	Tests Required

Submitted By : Date :

Received By : Date & Time:

Remarks :

Form A1

DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

PILOT CONSTRUCTION MATERIALS DATABASE

APPENDIX B

THE DATABASE STRUCTURE

ABBREVIATIONS AND TERMINOLOGY

ArcView	GIS application
Combo Box	A control on a form that accepts text input or allows the user to select an item from a drop down list of possibilities
Command Button	A control on a form that resembles a push button.
Data Type	The type of a data item. E.g. Text, Number, Memo etc.
Field	Each record in a database consists of one or more fields; the fields of all records form the columns.
Field Size	The size of a field, i.e. the largest amount of data it can contain
Form	In the context of a database a form is the interface between the user and the data. Forms are used to create, edit and delete records within the database and typically feature controls such as command buttons, combo boxes and text boxes.
GIS	Geographic(al)/Geospatial Information System
GUI	Graphical User Interface
IRAP	Integrated Rural Accessibility Planning
MD	Materials Database
MoSCoW	System for analysing and prioritising software requirements (Must, Should, Could and Won't)
MySQL	Open Source Relational Database Management Software
Record	In the context of a relational database, a record—also called a row or tuple—represents a single, implicitly structured data item in a table.
Recordset	A recordset is a collection of a number of database records. Recordsets can be created and manipulated by computer programs.
Radio button	A GUI control used to select between two or more mutually exclusive options
Relational Database	A database in which data is stored in a number of interrelated tables.
Report	In the context of a database a report is a defined formatted output based on the available data or a defined subset of the available data.
SEA	South East Asia
SEACAP	South East Asia Community Access Programme
SQL	Structured Query Language
Table	The primary building blocks of a database. Data is organised into tables with each field forming a column and each row forming a record.
VBA	Visual Basic for Applications: programming language supplied with the Microsoft Office® software suite.

B1 Introduction

Figure B1 summarises the relationships between the main database tables and the supporting lookup tables. A description of every table within the database is given in Table B1. The majority of the tables are simple lookup tables that are used to represent the coding of the data in the six main tables. .

Tables B2 to B7 give the details of all the fields in the six main data tables within the database. These tables were generated from the 'documenter' tool within Access® and edited to reduce the amount of information presented. In many cases cells within the tables in sections 0 to 0 are blank. A blank cell indicates that property has not yet been assigned a value for the corresponding field.

A MoSCoW analysis has been undertaken on the structure and its tables. The MoSCoW method is used in software development to understand the importance placed by the customer on the delivery of each functional requirement. MoSCoW stands for:

M - MUST have this .Anything labelled as "MUST" has to be included in the project delivery in order for it to be a success.

S - SHOULD have this if at all possible. While not critical to the success of the project delivery, "SHOULD" items are nearly as important and should be included if at all possible.

C - COULD have this if it does not affect anything else. "COULD" items are less critical than "SHOULD" items and can be thought of as "nice to have".

W - WON'T have this time but WOULD like in the future. "WON'T" items are either the least-critical or lowest-payback items. As a result they are not planned into the current project iteration. "WON'T" items are either dropped or reconsidered in later project increments. However this doesn't make them any less important. Sometimes this is described simply as "Would like to have" in the future.

All requirements are important, but they are prioritised to deliver the greatest and most immediate benefits early. Developers will initially try to deliver all the M, S and C categories but the S and Cs will be the first to be dropped if the delivery timescale looks threatened.

The MoSCoW approach is usually adopted at the start of the development process. However the approach has merit as part of the review undertaken by TRL of the Materials Database as it captures the recommendations stemming from the database review and prioritise their importance in terms of the delivery of a workable system for the future.

Table B8 shows a MoSCoW analysis for the SEACAP19 Materials Database together with actions already implemented.

.

Figure B1 Database Table and Field Relationship

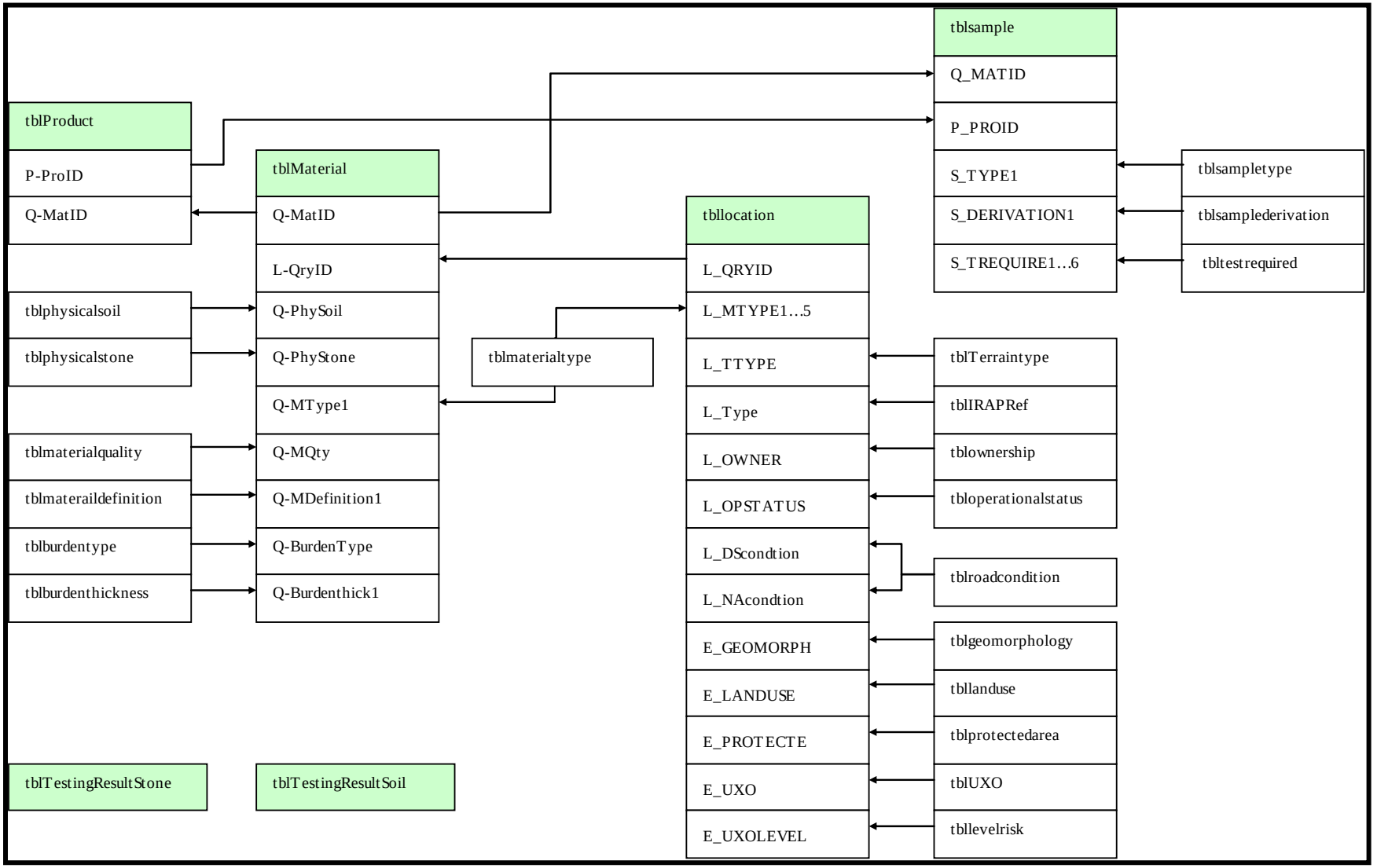


Table B 1 Database Tables

Table Name	Description
GISLINK	Subset of the data in tbllocation used for linking with GIS application. The GISLINK table is created through VBA form code when the frmlocation form is closed.
Switchboard Items	Table that defines the items on the switchboard and their behaviour. The switchboard is the form that opens when the database starts. It contains command buttons to: access the data entry forms, update the lookup tables and exit the database.
tblburdenthickness	Lookup table: overburden thickness options.
tblburdentype	Lookup table: type of overburden
tblgeomorphology	Lookup table: quarry geomorphology
tbllanduse	Lookup table: predominant surrounding land use at quarry sites
tbllevelrisk	Lookup table: risk level due to unexploded ordinance (land mines)
tbllocation	Table that contains all of the details about a quarry including where it is located within the country, the type of materials available, what utilities the quarry has, the condition and length of the access road and information on the surrounding environment
tbllocationImg	Table of explicit references to the location of the directories within the filesystem where the photographs of each quarry are stored
tblmateraildefinition	Lookup table: material classification by geological type
tblMaterial	Table containing details of the quarry materials including type, quality, an estimate of the reserves and suitability for use in different construction activities
tblmaterialquality	Lookup table: quality of the quarry material (None; Poor; Average; Good)
tblmaterialtype	Lookup table: type of material e.g. soil, rock, sand etc.
tbloperationalstatus	Lookup table: quarry's operational status, e.g. Partially operational
tblownership	Lookup table: quarry's ownership status (Private or Concession)
tblphysicalsoil	Lookup table: physical characteristics of soils e.g. loose; compact
tblphysicalstone	Lookup table: physical characteristics of stone material

Table Name	Description
tblProduct	Table of quarry products, types of product, production rates and maximum and minimum particle sizes and price in USD$ per cube
tblprotectedarea	Lookup table: protected status of area surrounding the quarry e.g. national park; tempe
tblroadcondition	Lookup table: condition of quarry access road
tblsample	Table of material sample data
tblsamplederivation	Lookup table: where the material sample was derived from e.g. test pit; stockpile
tblsampletype	Lookup table: type of sample taken e.g. bulk; undisturbed; hand specimen
tblterraintype	Lookup table: type of terrain where the quarry is sited
tblTestingResultSoil	Table of test results for tests carried out on soil samples
tblTestingResultStone	Table of test results for tests carried out on stone samples
tbltestrequired	Lookup table: list of other tests (additional to the standard suite) that can be carried out on material samples
tblUXO	Lookup table: Yes/No is there a risk of unexploded ordinance (land mines)

Table B2 Quarry Location (tbllocation) field details

Name	Type	Size	Caption:	Description:	RowSource:
L_QRYID	Double	8	Quarry ID	Quarry ID	
L_PVIN	Text	25	Province name	Province name	
L_DSTRICT	Text	25	District name	District name	
L_CMUNE	Text	25	Commune name	Commune name	
L_VLAGE	Text	25	Village name	Village name	
L_LNAME	Text	25	Quarry name	Quarry name	
L_DATE	Date/Time	8	Surveyed Date	Surveyed Date	
L_MTYPE1	Text	50	Type of materail 1	Type of materail 1	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
L_MTYPE2	Text	50	Type of materail 2	Type of materail 2	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
L_MTYPE3	Text	50	Type of materail 3	Type of materail 3	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
L_MTYPE4	Text	50	Type of materail 4	Type of materail 4	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
L_MTYPE5	Text	50	Type of materail 5	Type of materail 5	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
L_TTYPE	Text	50	Type of terrain	Type of terrain	SELECT tblTerraintype.CODE, tblTerraintype.NAME FROM tblTerraintype;
L_Type	Text	50	IRAP Type	IRAP Type	SELECT tblIRAPRef.Code, tblIRAPRef.IRAPType FROM tblIRAPRef;
L_Size	Text	50	IRAP Size (ha)	IRAP Size	
L_UAVAILAB1	Yes/No	1	1.No utilities	1.No utilities	
L_UAVAILAB2	Yes/No	1	2.Electric power	2.Electric power	
L_UAVAILAB3	Yes/No	1	3.Water	3.Water	
L_UAVAILAB4	Yes/No	1	4.Water and electricity	4.Water and electricity	
L_OWNER	Text	50	Ownership	Ownership	SELECT tblownership.CODE, tblownership.NAME FROM tblownership;
L_OPSTATUS	Text	50	Operational status	Operational status	SELECT tbloperationalstatus.CODE, tbloperationalstatus.NAME FROM tbloperationalstatus;

Name	Type	Size	Caption:	Description:	RowSource:
L_OPMETHOD1	Yes/No	1	Labour-based	Labour-based	
L_OPMETHOD2	Yes/No	1	Mechanical	Mechanical	
L_OPMETHOD3	Yes/No	1	Drill/Blast	Drill/Blast	
L_OPMETHOD4	Yes/No	1	Hydrolic	Hydrolic	
L_OPMETHOD5	Yes/No	1	Crusher	Crusher	
L_OPMETHOD6	Yes/No	1	Screens	Screens	
L_E1	Double	8	Easting	Easting centre	
L_N1	Double	8	Northing	Northing centre	
L_E2	Double	8	Easting	Easting strat point	
L_N2	Double	8	Northing	Northing start point	
L_E3	Double	8	Easting	Easting end point	
L_N3	Double	8	Northing	Northing end point	
L_SROADNO	Text	25	Start point from raod No.	Start point from raod No.	
L_CHANAIGE	Text	25	Chanaige	Chanaige	
L_CHNAME	Text	25	Location name	Chaniage location name	
L_CHE	Double	8	Easting	Easting	
L_CHN	Double	8	Northing	Northing	
L_LENGHTAY	Double	8	All year round	All year round length	
L_AYRNAME	Text	25	Location name	Location name	
L_AYRE	Double	8	Easting	Easting	
L_AYRN	Double	8	Northing	Northing	
L_LENGHTDS	Double	8	Dry season	Dry season length	
L_DScondtion	Text	50	Conditon	Condtion	SELECT tblroadcondition.Code, tblroadcondition.Condition FROM tblroadcondition;
L_DSNAME	Text	25	Location name	Location name	
L_DSE	Double	8	Easting	Easting	

Name	Type	Size	Caption:	Description:	RowSource:
L_DSN	Double	8	Northing	Northing	
L_LENGHTNA	Double	8	No access	No access length	
L_NAcondtion	Text	50	Condtion	Condtion	SELECT tblroadcondition.Code, tblroadcondition.Condition FROM tblroadcondition;
L_NANAME	Text	25	Location name	Location name	
L_NAE	Double	8	Easting	Easting	
L_NAN	Double	8	Northing	Northing	
L_LENGHTCC	Double	8	Distanct to commune centre	Distanct to commune centre	
L_CCNAME	Text	25	Location name	Location name	
L_CCE	Double	8	Easting	Easting	
L_CCN	Double	8	Northing	Northing	
L_LENGHTDC	Double	8	Distanct to district centre	Distanct to district centre	
L_DCNAME	Text	25	Location name	Location name	
L_DCE	Double	8	Easting	Easting	
L_DCN	Double	8	Northing	Northing	
E_GEOMORPH	Text	50	Geomorphology	Geomorphology	SELECT tblgeomorphology.CODE, tblgeomorphology.NAME FROM tblgeomorphology;
E_LANDUSE	Text	50	Land use	Land use	SELECT tbllanduse.CODE, tbllanduse.NAME FROM tbllanduse;
E_EI0	Yes/No	1	0.None	0.None	
E_EI1	Yes/No	1	1.Village	1.Village	
E_EI2	Yes/No	1	2.Industrial	2.Industrial	
E_EI3	Yes/No	1	3.Plantation	3.Plantation	
E_EI4	Yes/No	1	4.Agriculture	4.Agriculture	
E_EI5	Yes/No	1	5.Forestry	5.Forestry	
E_EI6	Yes/No	1	6.River	6.River	
E_EI7	Yes/No	1	7.Tourism	7.Tourism	
E_EI8	Yes/No	1	8.Landscape	8.Landscape	

Name	Type	Size	Caption:	Description:	RowSource:
E_EI9	Yes/No	1	9.Water pollution	9.Water pollution	
E_EI10	Yes/No	1	10.Flood	10.Flood	
E_QURRESTR0	Yes/No	1	0.None	0.None	
E_QURRESTR1	Yes/No	1	1.Housing/building	1.Housing/building	
E_QURRESTR2	Yes/No	1	2.Flooding	2.Flooding	
E_QURRESTR3	Yes/No	1	3.Environmental impact	3.Environmental impact	
E_QURRESTR4	Yes/No	1	4.Physical	4.Physical	
E_PROTECTE	Text	50	Protected area	Protected area	SELECT tblprotectedarea.NAME FROM tblprotectedarea;
E_UXO	Byte	1	Landmine risk	Landmine risk	SELECT tblUXO.CODE, tblUXO.NAME FROM tblUXO;
E_UXOLEVEL	Long Integer	4	If yes-level of risk	If yes-level of risk	SELECT tbllevelrisk.CODE, tbllevelrisk.NAME FROM tbllevelrisk;
O_SURVEYOR	Text	25	Surveyor team	Surveyor team	
O_ADDINFO	Memo	-	Additional information	Additional information	
O_MAP	Anchor	-	PDF map	PDF map	

Table B3 Materials Data (tblMaterial) field details

Name	Type	Size	Caption:	Description:	RowSource:
Q-MatID	Long Integer	4		Material ID	
L-QryID	Double	8		Quarry ID	SELECT tbllocation.L_QRYID FROM tbllocation;
Q-PhySoil	Text	255	Soil	Physical state of soil	SELECT tblphysicalsoil.CODE, tblphysicalsoil.NAME FROM tblphysicalsoil;
Q-PhyStone	Text	255	Stone	Physical state of stone	SELECT tblphysicalstone.CODE, tblphysicalstone.NAME FROM tblphysicalstone;
Q-MType1	Text	255	Type of Material	Type of Material	SELECT tblmaterialtype.CODE, tblmaterialtype.NAME FROM tblmaterialtype;
Q-MQty	Text	255	Quality of material	Quality of material	SELECT tblmaterialquality.CODE, tblmaterialquality.NAME FROM tblmaterialquality;
Q-MDefinition1	Text	255	Definition of material	Definition of material	SELECT tblmateraildefinition.CODE, tblmateraildefinition.NAME FROM tblmateraildefinition;
Q-ResEstimate	Text	255	Reserve estimate	Reserve estimate	
Q-BurdenType	Text	255	Type of overburden	Type of overburden	SELECT tblburdentype.CODE, tblburdentype.NAME FROM tblburdentype;
Q-Burdenthick1	Text	255	Terrace deposite thickness	Terrace deposite thickness	SELECT tblburdenthickness.CODE, tblburdenthickness.CODE FROM tblburdenthickness;
Q-Burdenthick2	Long Integer	4	Hill (highness)	Hill (highness)	
Q-Muse1	Yes/No	1	1.Surface dressing	1.Surface dressing	
Q-Muse2	Yes/No	1	2.Asphalt aggregate	2.Asphalt aggregate	
Q-Muse3	Yes/No	1	3.Roadbase	3.Roadbase	
Q-Muse4	Yes/No	1	4.Subbase	4.Subbase	
Q-Muse5	Yes/No	1	5.Concret aggregate	5.Concret aggregate	
Q-Muse6	Yes/No	1	6.Fill	6.Fill	
Q-Muse7	Yes/No	1	7.Housing and others	7.Housing and others	
Q-Muse8	Yes/No	1	8.Embankment	8.Embankment	
Q-Muse9	Yes/No	1	9.Sub-grade	9.Sub-grade	
Q-Muse10	Yes/No	1	10.Bedding	10.Bedding	

Table B4 Quarry Product Data (tblProduct) field details

Name	Type	Size	Caption:	Description:	RowSource:
P-ProID	Double	8	Product ID	Product ID	
Q-MatID	Long Integer	4	Material ID	Material ID	SELECT tblMaterial.[Q-MatID] FROM tblMaterial;
P-Type1	Text	25	Type of product	Type of Product	
P-PRate1	Long Integer	4	Production rate	Production rate	
P-SizeMax1	Text	25	Max (mm)	Size Max (mm)	
P-SizeMin1	Text	25	Min (mm)	Size Min (mm)	
P-Price1	Currency	8	Price (USD/m3)	Price (USD/m3)	

Table B5 Material Samples Data (tblsample) field details

Name	Type	Size	Caption:	Description:	RowSource:
Q_MATID	Long Integer	4	Material ID	Material ID	SELECT tblMaterial.[Q-MatID] FROM tblMaterial;
P_PROID	Double	8	Product ID	Product ID	SELECT tblProduct.[P-ProID] FROM tblProduct;
S_ID1	Text	13	Sample ID	Sample ID	
S_TYPE1	Text	50	Sample type	Sample type	SELECT tblsampletype.CODE, tblsampletype.NAME FROM tblsampletype;
S_DERIVATION1	Text	50	Sample derivation	Sample derivation	SELECT tblsamplederivation.CODE, tblsamplederivation.NAME FROM tblsamplederivation;
S-E1	Decimal	16	Easting	Easting	
S_N1	Decimal	16	Northing	Northing	
Sieve	Yes/No	1	Sieve	Sieve	
Hydrommeter	Yes/No	1	Hydrommeter	Hydrommeter	

Name	Type	Size	Caption:	Description:	RowSource:
LLPL	Yes/No	1	LL/PL	LLPL	
MC	Yes/No	1	MC	MC	
Compaction	Yes/No	1	Compaction	Compaction	
CBR	Yes/No	1	CBR	CBR	
LAAAiv	Yes/No	1	LA/AAiv	LAAAiv	
WA	Yes/No	1	WA	WA	
S_TREQUIRE1	Text	50	Other test required 1	S_TREQUIRE1	SELECT tbltestrequired.NAME FROM tbltestrequired;
S_TREQUIRE2	Text	50	Other test required 2	S_TREQUIRE2	SELECT tbltestrequired.NAME FROM tbltestrequired;
S_TREQUIRE3	Text	50	Other test required 3	S_TREQUIRE3	SELECT tbltestrequired.NAME FROM tbltestrequired;
S_TREQUIRE4	Text	50		S_TREQUIRE4	SELECT tbltestrequired.NAME FROM tbltestrequired;
S_TREQUIRE5	Text	50		S_TREQUIRE5	SELECT tbltestrequired.NAME FROM tbltestrequired;
S_TREQUIRE6	Text	50		S_TREQUIRE6	SELECT tbltestrequired.NAME FROM tbltestrequired;

Table B6 Soil Testing Results Data (tblTestingResultSoil) field details

Name	Type	Size	Caption:	Description:	RowSource:
ID	Long Integer	4			
ProductID	Text	50			
QuarryID	Text	50			
MaterialID	Text	50			
S1T1	Text	50	Soil Name (UCS)		
S1T2	Text	50	Coefficient of Unifomities (CU)		
S1T3	Text	50	Passing 0.75mm sieve, %		
S1T4	Text	50	Liquid Limit (LL), %		
S1T5	Text	50	Plastic Limit (PL), %		
S1T6	Text	50	Plasticity Index (PI=LL-PL), %		
S1T7	Text	50	Linerair Shinkage, %		
S1T8	Text	50	Hydrometer		
S1T9	Text	50	Particle Size Distribution		
S1T10	Text	50	Moisture Content, %		
S1T11	Text	50	Organic Content, %		
S1T12	Text	50	Sand Equivalent Value		
S1T13	Text	50	Soil Particle Density		
S1T14	Text	50	Compaction Type		
S1T15	Text	50	Maximum dry density Kg/cc		
S1T16	Text	50	Optimum moisture content, %		
S1T17	Text	50	CBR at Optimum moisture content, %		
S1T18	Text	50	CBR (at OMC) after 4 days soaking, %		
S1T19	Text	50	Swell, %		
S1T20	Text	50	Vane Shear		
S2T1	Text	50			

Table B7 Stone Testing Results (tblTestingResultStone) field details

Name	Type	Size	Caption:	Description:	RowSource:
ID	Long Integer	4			
ProductID	Text	50			
QuarryID	Text	50			
MaterialID	Text	50			
S1T21	Text	50	Sand Equivalent Value		
S1T22	Text	50	Frakiness, %		
S1T23	Text	50	Water Absorption, %		
S1T24	Text	50	Specific Gravity (dry), %		
S1T25	Text	50	Bulk Density		
S1T26	Text	50	Los Angeles Abrasion, %		
S1T27	Text	50	10% Fines Value (dry), kN		
S1T28	Text	50	10% Fines Value (soaked), kN		
S1T29	Text	50	Sulphate Soundness, %		
S1T30	Text	50	Polished Stone Value, %		
S1T31	Text	50	Unconfined Compressive Strength		
S1T32	Text	50	Point Load Strength		
S1T33	Text	50	Schmidt Hammer		
S1T34	Text	50	Aggregate Bitumen Adhesion		
S1T35	Text	50	Stripping, %		
S1T36	Text	50	Suface Condtion		

Table B8. MoSCoW analysis for materials database

Description	MoSCoW	Actioned
Prevent database from crashing when loading images	Must	Yes
Add controls to materials form for overburden type and thickness	Should	Yes
Change default behaviour of report selection radio buttons to 'Current Record'	Could	No
Change design of large forms, using sub-forms and/or tabbed pages so that information is displayed on a single screen (eliminate need for the user to scroll up and down)	Could	No
Review data types and field sizes, updating them to match the data to be stored	Should	Yes
Implement form hierarchy to aid navigation of records by only showing the user information relevant to the current quarry → material → product → sample → test	Should	No
Implement new reporting tool to allow the user to customise standard reports to their requirements.	Won't	No
Change code and data to ensure that all links to external files are relative and not explicit	Should	Yes
Improve data checking with input masks or checks within the database code	Could	No
Add an 'Apply' button to all data entry forms to force the user to apply changes to the data.	Won't	No
Implement lookup tables for Provinces, Districts, Communes and Villages	Could	No
Implement some form of access control to prohibit unauthorised changes to the data	Could	Yes
Fix logical inconsistencies in the database, e.g. selection of quarry utilities; types of material. Check database carefully for other examples	Should	Yes

DEVELOPMENT OF LOCAL RESOURCE BASED STANDARDS

PILOT CONSTRUCTION MATERIALS DATABASE

APPENDIX C

CONCEPT NOTE ON FURTHER DEVELOPMENT

Further Research Concept Note

C1 General Introduction

SEACAP 19 Technical Paper 7 has reviewed the needs for a Cambodian Road Material Database and summarised the work undertaken in developing a Pilot Road Materials Database (PRMD). This document presents the options for the further expansion of the Pilot Materials Database (PRMD) and summarises the related activities.

The options for PRMD expansion are firstly into a National Road Materials Database (NRMD) on a province by province basis and its further development into a wider National Road Materials Information System (NRMIS) through the incorporation of road materials information form existing roads and related road performance data.

The activities related to these two options are listed and discussed within a series of Task Groups that may be transformed, if required, into Term of Reference for future projects.

Technical Paper 7 assessed the risks for long-term database sustainability based on the currently perceived situation in the Cambodian transport sector, Table C1. Recognition of these sustainability risks is integrated into this Concept Note

Table C1 PRDM Expansion Risks

Sustainability Issue	Phase 1- NRDM	Phase 2 - NRMIS
Political Will	Low risk (MPWT)	Medium to high risk
Institutional capacity	Low risk (ITC or MPWT)	Medium risk
Financial Risk	High risk	Very high risk
Technical; Capability	Low risk	Medium risk

C1 Phase 1: Expansion to NRMD

This expansion involves the expansion to cover all currently known sources of road construction material within all 26 provinces of Cambodia. It is in essence a much larger version of the current PRMD utilising the same information collection and data management procedures. Some minor improvements to these procedures may be necessary to make them more user-friendly for use at provincial level. Some additional management capacity would also be required for this expansion.

It is suggested that the NRMD expansion could be done as rolling programme on a province-by-province basis. The exact sequence of provinces would be based on Ministerial requirements.

Work required for this expansion may be considered under four principal Modules as summarised in Figure C1 and key points highlighted in the following sections. Module 1 would be an essential pre-cursor to the finalisation of budget details for the other three modules.

Module 1: Programme Planning

1. Review current situation: - a review of the status of the existing database and the relevance of its information at the time of the programme expansion

2. Stakeholder discussion: Discuss their expectations and information requirements with key stakeholders
3. Coordination Committee Steering Committee: Experience on SEACAP projects has indicated usefulness of having an effective coordinating or steering committee. This will be particularly important in the case of the NRMD which will require the cooperation of at least three Ministries; MRD; MPWT and Mines-Geology.
4. Province Prioritisation: The expansion is likely to involve a rolling programme and identification of priority province will be an early and important issue.
5. Programme Assessment: An overall programme will be required based on the agreed expansion priority. This programme should clearly identify required resources.
6. Provincial Liaison: Effective liaison is essential with the provincial officials of all involved ministries.

Module 2: Set-up and Training

1. Assemble teams-equipment: The field data collection teams should be mobilised together will all required equipment (see Appendix A)
2. Training: All teams should be fully trained in the required a data collection and site procedures.
3. Identify laboratory resources: Reliable laboratory testing will be significant element within the NRMD expansion. Any proposed laboratory should be certified for all required test procedures.
4. Detailed planning; the fieldwork, laboratory testing and data collation should be integrated into a comprehensive programme.

Module 3: Provincial Data Collection

1. District level liaison: Effective liaison with district officials is necessary early requirement for the fieldwork programme.
2. Source data collection: Collection of materials source data based on the procedures used in the Pilot Study and described in Appendix A
3. Sampling: Collection of suitably representative samples
4. Laboratory testing assignment: Assignment of laboratory testing as per Table A2. Use standard laboratory assignment sheet.
5. QA on field data QA systems should developed to allow recovered data sets to be initially checked for gross errors and omissions followed by a correlation geotechnical check on the data as input into database
6. Laboratory test data: QA systems should developed to allow reported laboratory results to be initially checked for gross errors followed by a correlation geotechnical check on the data as input into database

Module 4: Database Management

1. Amendments to database: Some improvements to the existing database structure have been recommended and in addition the expansion to the NRMD will of necessity require some additional amendments
2. Data input: All field and laboratory test data must be input into the database.

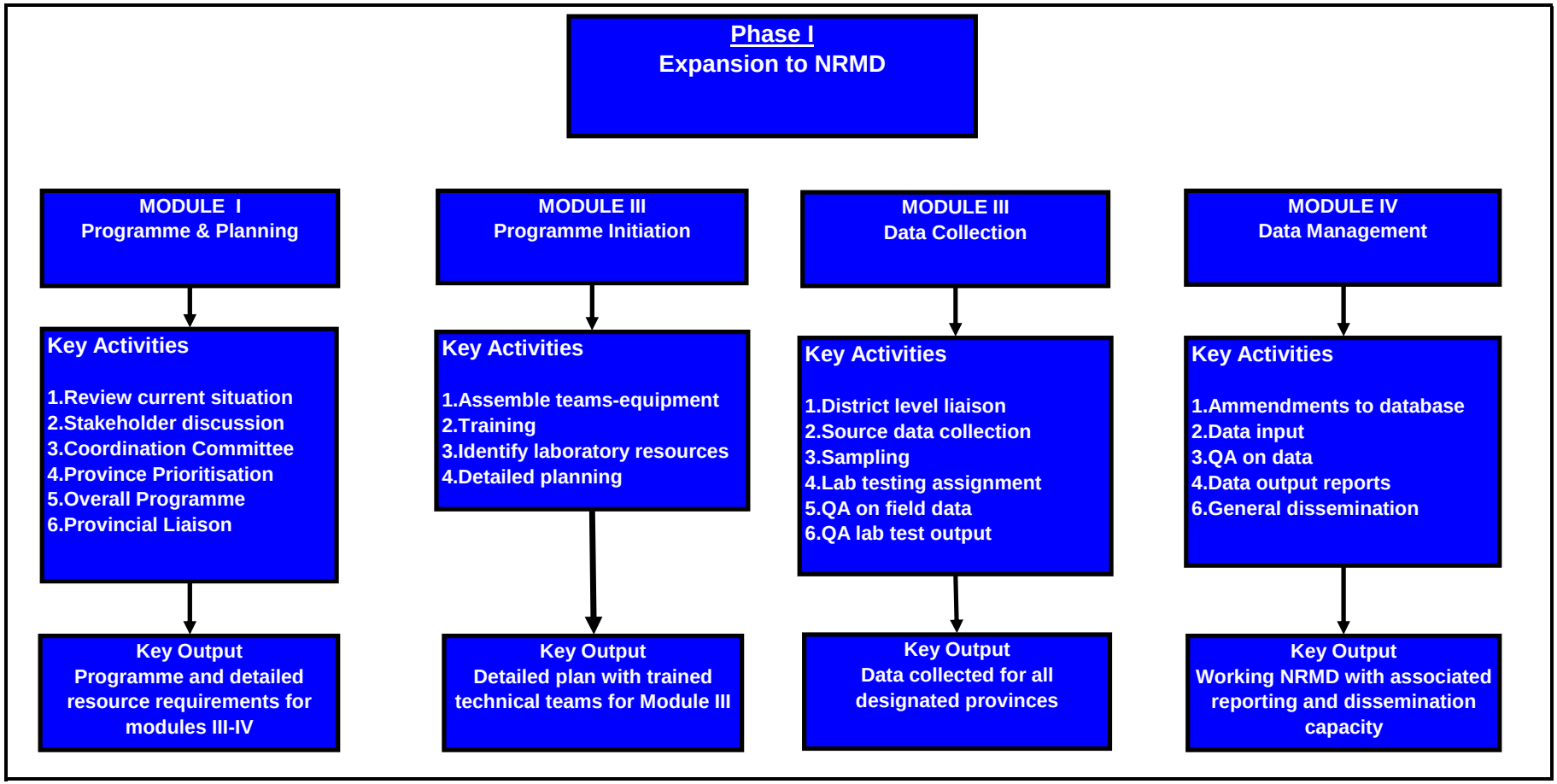
3. Data output reports; a series of standard output reports should be developed in cooperation with key stakeholders. These reports should be capable of presenting materials data either for practical use in infrastructure project planning or for research analysis.
4. General dissemination: An ongoing programme should be developed to disseminate materials information to potential users.

Key staffing requirements for these modules are summarised in Table C2. The detailed budget requirement would be a function of the scale of the project in terms of existing materials sources and provinces to be assessed. This would be a key output from Module 1.

Table C2 Key Resources

Module	Key Staff
1	Team Leader (Materials Specialist) Local consultant (Provincial and Ministry Liaison)
2	Team Leader (Materials Specialist and Trainer) Local consultant (Provincial and Ministry Liaison) Field Teams (each 1 Engineer and 1 technician)
3	Team Leader (Materials Specialist) Local consultant (Liaison and local management) Field Teams (each 1 Engineer and 1 technician) Geotechnical engineer (QA)
4	Team Leader (IT Specialist Local consultant (Provincial and Ministry Liaison) IT Engineer

Figure C1 NRMD Modules



C3 Phase 2: Expansion to NRMIS

The expansion from the NRMD to NRMIS is a major widening of the scope of the project and would be require significant increase technical and managerial resources. The scale of the programme is likely to become much clearer during the initial expansion from PRMD to NRMD and hence only an outline of the NRMIS programme is presented; the objective of which would be to produce a working system as summarised in Figure C2

The following Modules are likely to for the basis of the NRMIS set-up and ongoing management:

Module 1: Programme and Planning

Module 2: Procedures Upgrade

Module 3: Initial Information Retrieval

Module 4: NRMIS Management

Figure C2 Key Elements of a Proposed Cambodian NRMIS