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MAINSTREAMING SLOPE STABILITY MANAGEMENT INTO THE NATIONAL UNIVERSITY OF LAO COURSES AND THE MPWT

TERMINAL REPORT

SUBMITTED BY

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in association with

Lao Consulting Group and SD & XP Consultants

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SEACAP 21/003 – Mainstreaming Slope Stability Management

TERMINAL REPORT

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
ASIST-ILO	Advisory Support, Information Services and Training – International Labour Organisation
BAC	Basic Access Component
CMC	Community Road Maintenance Committee
CRM	Community Road Model
DCE	Department of Civil Engineering (of the NUoL)
DFID	Department for International Development
DPWT	Department of Public Works and Transport
ESCAP	Economic and Social Commission for Asia and the Pacific
LCG	Lao Consulting Group
LRD	Local Roads Division
LSRSP	Lao-Swedish Road Sector Project
MAF	Ministry of Agriculture and Forests
MCTPC	Ministry of Communication, Transport, Post and Construction, now MPWT
MPWT	Ministry of Public Works and Transport
NAFRI	National Agriculture and Forestry Research Institute
NUoL	National University of Laos
OPWT	Office of Public Works and Transport
PBMC	Performance-Based Maintenance Contract
PMO	Project Management Office
PRTP	Participatory Rural Transport Planning
PTI	Public Works and Transportation Institute (of MPWT)
RAD	Road Administration Division
RMP	Road Maintenance Project
SEACAP	South East Asia Community Access Programme
SIDA	Swedish International Development Agency
SPT	Standard Penetration Test
TOR	Terms of Reference
UNDP	United Nations Development Programme
URI	Urban Research Institute (now PTI)
VMC	Village Maintenance Committee
WG	Weathering Grade

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SUMMARY

Courses at the National University of Laos

A number of meetings were held with staff at the National University of Laos (NUoL), particularly those from the Faculty of Engineering and the Faculty of Forestry. It was generally agreed that the existing undergraduate course at the Department of Civil Engineering was already full, and that slope related themes came under several existing modules. The Department also runs a post-graduate course, a Master of Engineering programme entitled 'Infrastructure in Civil Engineering', as a collaborative effort with the Chulalongkorn University in Bangkok. Within this course there is an elective module on 'Geotechnical Design and Construction' which runs for three weeks with 15 hours of lectures a week. The course lecture notes indicate that the fundamentals of slope stability analysis and retaining wall design are covered in a reasonable degree of detail.

There is no Department of Geology at NUoL, although the Department of Civil Engineering runs a BSc course in Mining Engineering which covers rock mechanics and rock slope analysis. With respect to bio-engineering, the main BSc Forestry degree does cover soil erosion but to a very limited extent, although the course lecturers do have some understanding of the needs of bio-engineering.

Assessment of the various courses led to the conclusion that it would be preferable to concentrate on the post-graduate approach, due to the relative complexity of the work carried out under SEACAP 21. The two best options seem to be either a post-graduate elective course in slope engineering as part of the M Eng course or a special one-off course in slope engineering.

Slope Problems of the Ministry of Public Works and Transport

Six sites were selected along Road 13N for preliminary design of stabilisation works. The selection was biased towards the more complex or problematic locations. Topographic surveys and a ground investigation were carried out, from which preliminary designs were prepared.

Dissemination Activities

At NUoL, dissemination activities included one short presentation and one three-hour seminar on the work undertaken in SEACAP 21. In all, up to 90 students and lecturers were in attendance and both meetings were well received. Six undergraduates are preparing theses on three of the six sites and copies of all the relevant data were provided to them. Three on-site training visits were sponsored; one for selected students and lecturers from NUoL and two for the staff of the Ministry and Departments of Public Works and Transport. In all, staff from four of the most severely affected mountain province DPWTs were given an overview of the methods of site assessment and interpretation of the slope stability problems, along with detailed discussions on the findings and the proposed stabilisation and protection works.

A number of technical books and other publications dealing with slope stabilisation related matters were procured and presented to the Department of Civil Engineering library.

Technical papers are currently under preparation for anticipated publication in 'Ground Engineering' and the 2009 Regional Conference of the Road Engineering Association of Asia and Australasia.

Other matters

Printing and binding of the Slope Maintenance Manual and Slope Maintenance Site Handbook has been delayed due to a prolonged period of translation and approvals, but is fully expected to take place during February 2009.

1. COURSES AT THE NATIONAL UNIVERSITY OF LAOS

1.1 Assessment of courses

A number of meetings were held with staff of the National University of Laos, and in particular with officials from:

- the Department of Civil Engineering (DCE);
- the Department of Communication and Transport; and
- the Department of Forestry.

The last of these was included because of the possible interest of the foresters in the bio-engineering aspects being promoted by SEACAP 21.

The Faculty of Engineering comprises six departments (Civil Engineering, Mechanical Engineering, Electronic Engineering, Communications and Transport Engineering, and Water Resources Engineering). The normal lecturing day is from 8 am to 11 am (two subjects) and 12.30 pm to 3.30 pm (also two subjects). The academic years runs from September to the end of January (first semester) and March to July (second semester).

It was generally agreed that the existing undergraduate course at the DCE is already very full, and that slope stabilisation related themes come under several different modules (e.g. Soil Mechanics, Soil Mechanics Lab, Engineering Geology, Reinforced Concrete II, Road Construction and Maintenance). One new core module concerned Rural Transport, replacing Labour Based Road Construction Technology, and within that module there is a “Rural Engineering Materials and Techniques” set of lectures for which one lecture is entitled “Landslides and Erosion Protection Measures”. This course was set up in conjunction with the Local Roads Division of MPWT, and was appraised under SEACAP 21/002 (see Annex A).

The Rural Engineering Curriculum is part of the undergraduate core curriculum, and is taught by Lao lecturers in two modules for a total of 5 credits and 80 hours of teaching in the second and third years. It clearly provides a useful introduction to low cost road engineering in mountainous terrain, but it does not give adequate depth to slope stability issues to give rise to the expertise required in the road sector. In addition, it is more directed towards the lower categories of road classes, which come under the remit of the Local Roads Division, and not the national highways that are the concern of the Roads Administration Division and which have been the focus of SEACAP 21. For these reasons, it was concluded in the SEACAP 21/002 Feasibility Study that it would not in itself satisfy the skills gap in this technical area.

The DCE also runs a post-graduate course, a Master of Engineering programme entitled “Infrastructure in Civil Engineering”, through its Research and Post-Graduate Division. The main teaching language is Thai, using English lecture notes and written examinations in English. Within the Masters course there is an elective module on “Geotechnical Engineering Design and Construction” (GC2101). This is understood to run for a period of three weeks with 15 hours of lectures a week, followed by an exam. The lecturers come from the National University of Lao (NUoL) and the Department of Civil Engineering, Chulalangkorn University, Bangkok, although it is intended that the course will shortly be run entirely by NUoL. The course lecture notes prepared by the Thai lecturers include foundation design, settlement, pile foundations (including theory and analysis), plus a series of lectures entitled “Earth Structures – Retaining Walls and Stability of Slopes”. The Earth Structures lectures cover slope stability analyses using a number of different methods (e.g. simplified method of slices, Bishop-Taylor’s modified method of slices) and potential remedial measures including deep drainage and buttresses. Back analysis is covered in a very simple manner and so is the use of inclinometers. Retaining wall design (simple reinforced concrete gravity walls with stem and base considering only external forces) is also covered in some detail, including active and passive pressures, trial wedge, surcharge, factors of safety, and overall stability if located on a hillside.

In addition to these courses, there is a Master's course entitled "Environmental Engineering and Management [E²M]". This course is funded under Europe Aid through the Asia Link programme of the European Commission. It is managed by the University of Siegen in Germany, in collaboration with the AGH University of Science and Technology in Krakow, Poland, the Sirindhorn International Institute of Technology, Pathum Thani, Thailand, and the National University of Laos. The overall budget is around Euro 1 million. Students are required to have passed the IELTS English exam before enrolling on to the course. There are 150 credits and it is a full time, 5 days a week course, unlike the MSc for Infrastructure Engineering which is part-time (although over two years) and requires far fewer credits. The [E²M] course is structured in modules, with specialisations in electrical, environmental and mechanical engineering. Its focus is on water and the control of pollution, and the word "slope" does not feature anywhere in the course outline material and prospectus; erosion is mentioned only as a possible source of water course pollution.

There has also been an MSc in Mechanical Engineering sponsored by the Vietnamese government. It is understood that in this case the students were required to spend one year learning Vietnamese and then went to Vietnam to undertake the course.

There is no Department of Geology at NUoL. However, the DCE runs a Bachelor of Engineering in Mining Engineering. This was set up a few years ago and now has 60 students per year. The course covers rock mechanics, rock slope analysis and tunnel design, and the intention is to include soil mechanics to cover open-cast mining.

The Department of Forestry is part of the Faculty of Forestry. The main B.Sc. Forestry degree has three major options: Wood Industry; Forest Management; and Watershed Management and Land Use Planning. The watershed elements of the curriculum include some consideration of erosion protection, but this amounts to around only about one hour of the course. The construction of forest roads is also covered, but this appears to be restricted to the basic engineering required to open earth tracks in easy terrain. There have been some undergraduate theses on soil conservation. However, the Faculty's main focus is on forest management.

Despite this, NUoL's forestry staff do have some understanding of the needs of bio-engineering. Some have been involved in a project to stabilise sections of the bank of the Mekong using a local shrub. Obviously they also have an in-depth understanding of vegetation characteristics, as well as in plant propagation, planting and other practical matters.

1.2 Recommendations for additional course content

The assessment of the various courses led to the conclusion that it would be preferable to concentrate on a post-graduate approach rather than an undergraduate approach. This is largely due to the relative complexity of the work carried out under SEACAP 21, and the need for individuals to have the background knowledge to build on as they specialise in this topic. Although an interest in geotechnics would certainly be generated at the undergraduate level, it would not be possible to cover the subject matter adequately in the time available to give them a usable level of skill.

Beyond this there are various ways to provide assistance to courses. Without pre-empting the scope of work scheduled for SEACAP 21/004, the two best options would seem to be:

- either a post-graduate elective course in slope engineering as part of the M.Eng. course;
- or a special one-off post graduate course in slope engineering.

For the first of these, it might be possible simply to supply the lecture notes and let the existing lecturers run the course. For the second course, the preference would be to hold it either in February or August when the students are not studying. However, neither date is feasible for the SEACAP 21 specialists with respect to current 21/003 DFID funding.

Beyond students at NUoL, the other issue is the need for additional skills in slope engineering within the MPWT. This was assessed in 2008 under the SEACAP 21/002 Feasibility Study for a National Programme to Manage Slope Stability. That recommended that a comprehensive, multi-level training programme be devised and undertaken on the basis of the details given in Table 1.1, although the scale needed to be verified through the consolidation of the MPWT's training needs analysis during 2008, under the Organisational Capacity Development Plan.

Table 1.1. Recommended training courses (Table 9.3 in the Final Report of the SEACAP 21-02 Feasibility Study for a National Programme to Manage Slope Stability (September 2008)

Group	Type of course	Duration	Number to attend
Directors and Deputy Directors of RAD, LRD and the DPWTs.	Series of lectures and seminars	10 no. 1-hour-long lectures over the period of two weeks	30
Site staff: professional engineers in the DPWTs; consultants' site engineers.	Formal lecture room training with frequent site visits	4 weeks in two blocks; conduct regionally in 4 regional locations	60
Specialist staff: professional engineers in the central offices of the RAD and LRD; consultants' design engineers.	Formal lecture room training with frequent site visits	4 weeks in two blocks	40
	Specialist, in-depth overseas training (diploma or masters)	Typically a one-year course (1 year per person)	4
Academic specialists (lecturers and researchers).	Formal lecture room training with frequent site visits	5 weeks in two blocks	20
Contractors' supervisory staff (qualified engineers) and DPWT Technicians.	Split between classroom and site	1 week; conduct regionally in 4 locations; or run on-the-job	60
Contractors' construction technicians.	Practical site-based course.	1 week, on-the-job	40

The recommendation made here is therefore that technical components of a course should be devised in line with and as part of the SEACAP 21/002 recommendations. This would be usable by lecturers at the National University of Laos, either in an elective module on slope engineering, or to give a training to practising professionals, such as staff of the MPWT. The target groups are therefore:

- postgraduate students at the NUoL;
- road sector site staff: professional engineers in the DPWTs and consultants' site engineers; and
- road sector specialist staff: professional engineers in the central offices of the RAD and LRD, and consultants' design engineers.

The main topics to be covered in the course were listed in the SEACAP 21/002 Feasibility Study for a National Programme to Manage Slope Stability and, as regards slope stabilisation, were as follows.

- Roads in the mountain landscape (including alignment selection).
- Terrain evolution and slope dynamics; forms and processes of slope instability.
- Recognition and mapping of landslides and potentially unstable slope conditions.
- Details of landslide risk assessment and works prioritisation.
- Practicalities of alignment selection to ensure that slope problems are minimised.
- Practical approaches to site investigation.
- Diagnosing slope instability and determining solutions.
- Slope stabilisation and protection systems and how they work.
- Design of the various systems, including retaining wall design.
- Slope stabilisation, drainage and bio-engineering specifications.

More details on a course structure are given in Annex B, showing a rationalised and expanded development of this outline.

Again without pre-empting the scope of work due to be scheduled under SEACAP 21/004, the implementation of the training depends in part on how it is organised and funded. Because of the lack of these technical skills in Laos, it is recommended that a tiered approach be used, similar to the development of the Rural Engineering Curriculum. This involves the use of international specialists to develop the training material and instruct selected NUoL lecturers in its content and delivery. The language for most of the training should be Lao.

As a final note on the subject, the detailed technical skills covered by SEACAP 21 can only be dealt with in a relatively superficial manner in a short course. Ultimately, MPWT or a local consultant would benefit considerably from an individual(s) undergoing training overseas on an appropriate full-time one-year duration MSc course.

1.3 Suggested thesis topics

The terms of reference require that suitable future topics for possible undergraduate or postgraduate thesis topics be suggested. Options that might be able to draw on the various outputs of SEACAP 21 are as follows.

- The use of engineering geology in landslide recognition and mapping.
- Landslide hazard and risk assessment.
- The importance of site investigation in slope stabilisation.
- Methods of site investigation appropriate to slope stabilisation in Lao PDR.
- The relative merits of different low cost structures for slope stabilisation in Lao PDR.
- The significance of structural backfill in slope retaining structures.
- Drainage as the key to slope stabilisation and protection works.
- The use of vegetation in slope protection in Lao PDR.
- Optimum species for use in bio-engineering works in northern Laos.
- The relative merits of grass-based and hardwood cutting-based bio-engineering systems.
- Integration of bio-engineering measures with slope stabilisation structures on Road 13 North.
- The potential for widespread use of bio-engineering in the Lao PDR.
- Case studies of almost any landslide, using material covered by the SEACAP 21 *Slope Maintenance Manual*.

2. SLOPE PROBLEMS OF THE MINISTRY OF PUBLIC WORKS AND TRANSPORT

2.1 Identification of sites for study

As recorded in the Inception Report, six sites were selected for study from a longlist of thirteen identified possible landslide sites. These were:

- km 239.3;
- km 257.1;
- km 257.9;
- km 317.9;
- km 336.4; and
- km 341.2/8.

These were selected and approved on the basis that the MPWT wished the Consultant to undertake the preliminary design of the more complex or problematic sites found on Road 13 North.

A full account of the selection of these sites is given in the Inception Report, and so does not need to be repeated here.

2.2 Site assessments and preliminary designs

The topographical survey for all six sites was conducted in November 2008, followed by the ground investigation in November and December. These were undertaken with supervision by the international Geotechnical Engineer and the local Ground Investigation Supervisor. The output from this was a set of detailed site drawings, both plans and profiles, showing the engineering geology and geomorphological features of the sites. These were used as the basis for preliminary designs of low cost remedial works that followed the general pattern set previously by SEACAP 21/001. Details of the investigation work and subsequent preliminary designs are given in Annex C.

3. DISSEMINATION ACTIVITIES

3.1 Workshops

Due to a lack of time in which to organise the **Inception Workshop**, this did not take place. Although the Team Leader commenced his first input on 27th October, a week before the 2008 SEACAP Practitioners Meeting, it was imperative to commence the fieldwork on site and agree with MPWT which sites were to be included in 21/003 as quickly as possible, so that the remaining fieldwork (topographical survey and ground investigation) could be concluded well in advance of the international team's main input in January 2009. In addition, during that same period, initial discussions were held with NUoL about the scope of work the team hoped to achieve in January. Accordingly, although the Inception Workshop was abandoned, it was considered that detailed discussions had been made with all the main decision makers, who were aware of what was hoped to be achieved in January 2009.

The **Terminal Workshop** was planned for 22 January 2009 and materials prepared in both English and Lao (see outline programme in Annex D), but was postponed at the request of the MPWT so as not to interrupt the site programmes of the Provincial DPWTs. It is now planned to hold this in a few months time, assuming the proposed SEACAP 21/004 project component goes ahead.

3.2 Seminars at the National University of Laos

As part of the Faculty of Engineering Alumni Association annual meeting, a 15 minute seminar was held at NUoL on 19th December 2008. This was presented by Bounthavy Siliphone (the Construction Supervisor for Phases 1 and 2 work in 21/001) on the subject of 'Bio-engineering in Slope Stabilisation'. It was attended by about 50 people, mainly students and staff of the Department of Civil Engineering and the Department of Communications and Transport and elicited much interest.

This was later followed by a seminar entitled 'Workshop on Landslide Stabilisation' given at the same institution on 16th January 2009, attended by about 40 people. Three of the international specialists from the SEACAP 21 team each made dual-language technical presentations with simultaneous translation of the verbal addresses. This was followed by a number of questions and discussion, and such was the interest that the seminar ran to nearly double the 90 minute allotted time. Feedback from the seminar was very positive, and participants expressed a hope for further collaboration. A electronic copy of the presentation was handed over to the Head of Department.

At present there are six undergraduates preparing theses on some of the sites that are the subject of SEACAP 21/003 study: two students each on the sites at km 239.3, km 317.9 and km 336.4. The project's specialists provided them with additional materials to help their research, and offered to answer any questions they might have.

3.3 On-site training

A site training visit was made by 16 students and two lecturers from NuOL over the period 21st – 23rd November 2008 during the course of the initial ground investigation when the international Geotechnical Engineer and the local Ground Investigation Supervisor were on site. The students were shown the six new 21/003 sites and a selection of the earlier 21/001 Phases 1 and 2 sites. The stability problems were described together with the remedial measures undertaken or proposed.

It had also been planned to undertake a training visit to the sites by staff from MPWT/DPWTs in November to take advantage of the presence of the international Geotechnical Engineer on site. Although the MPWT was unable to organise this within the timeframe required, four engineers from DPWT Luang Prabang were able to make a one-day visit on 18th December when the replacement ground investigation contractor and the local Ground Investigation Supervisor were on site.

However, a later training visit was made to the six sites for which outline designs had been prepared under 21/003, and many of the trial sites tackled earlier by 21/001. The event lasted three days (19th to 21st January 2009) and involved the three international specialists, the local Ground Investigation Supervisor and the Construction Supervisor for 21/001 acting partly as translators, and two engineers from each of four mountain province DPWTs:

- Luang Prabang;
- Vientiane;
- Borikhamxai; and
- Attapeu.

At each site, the specialists described their approach to site assessment and their interpretation of the slope problems. In so doing, they were also verifying their initial ideas based on the assessments of engineering geology prepared in advance, and very rapid overviews made before the project. This process led to discussion on the findings and the proposed stabilisation and protection works. The participating engineers suggested a number of alternatives and modifications that were valid, leading to a genuine two-way exchange of information. By combining both “new” and “old” sites, it was possible to see both what typical slope problems look like, and how some of the available treatments appear in practice.

Copies of the Slope Maintenance Site Handbook (in English and Lao) were given to all the participants.

Feedback suggested that the participants had found the site discussions very useful, as they were entirely practical and relevant in nature. A suggestion was made that it would be useful for the specialists to visit the southern provinces, to look at problems alongside the engineers from Borikhamxai and Attapeu.

3.4 Provision of additional documents

Arising from discussions with the Head of the Civil Engineering Department at NUoL, it was clear that the donation of technical books on slope engineering to the department’s library would be very much appreciated. Accordingly the following documents were procured and presented to the NUoL.

- Atkinson, J: *The Mechanics of Soils and Foundations* (Spon, 2007). (2 copies)
- Blyth, FGH and de Freitas, M: *A Geology for Engineers* (Elsevier, 1987). (2 copies)
- TRL: Overseas Road Note 16: *Principles of Low Cost Road Engineering in Mountainous Regions* (1997). (2 copies)
- ICIMOD: *Landslide Hazard Mitigation in the Hindu Kush - Himalayas* (2001).
- Nepal Department of Roads: *Roadside Bio-engineering, Reference Manual* (1999). (2 copies)
- Nepal Department of Roads: *Roadside Bio-engineering, Site Handbook* (1999). (2 copies)
- Nepal Department of Roads: *Use of Bio-engineering* (1997). (2 copies)
- Nepal Department of Roads: *Vegetation Structures for Stabilising Highway Slopes* (1991). (2 copies)
- DFID: *Gaining Ground with Bio-engineering* (1998). (2 copies)
- Hong Kong Geotechnical Engineering Office: *Geotechnical manual for slopes* (1984)
- Hong Kong Geotechnical Engineering Office: *Geoguide 1 Guide to Retaining Wall Design* (1993)
- Hong Kong Geotechnical Engineering Office: *Geoguide 2 Guide to Site Investigation* (1987)

- Hong Kong Geotechnical Engineering Office: *Geoguide 3 Guide to Rock & Soil Descriptions* (1988)

In addition, two copies each of the Lao versions of SEACAP 21 *Slope Maintenance Manual* and *Slope Maintenance Site Handbook* will be handed over to NUoL as soon as they are available.

3.5 Dissemination of papers

Scientific papers

The GMSARN journal (Greater Mekong Sub-region Academic and Research Network) was investigated as a destination for a paper, but was not considered very appropriate since this journal is essentially geographical in nature and circulated around a range of academics too general in nature for the SEACAP 21 findings to have much impact. Since it is also understood that there is the intention to include a paper for GMSARN in SEACAP 21/004, papers are therefore being prepared for the following.

- Ground Engineering, a UK-based publication that is very international in coverage from the Institution of Civil Engineers.
- Conference (July 2009) of the Road Engineering Association of Asia and Australasia (REAAA).

In respect of the REAAA conference, although two abstracts were submitted, it is assumed that there will be a preference for the abstract on bioengineering and that this will be accepted. (Not known at the time this report was being prepared).

The abstract of the paper for the REAAA Conference is as follows. It covers the work of the main SEACAP 21 project trials, as well as the dissemination work undertaken as part of SEACAP 21-03. In addition, it is planned that the SEACAP 21 *Slope Maintenance Manual* and *Slope Maintenance Site Handbook* will be presented in a "Table Topic" session at the REAAA Conference.

Adapting affordable slope protection techniques to new environments

John Howell, Tim Hunt, Xayphone Chonephetsarath and Gareth Hearn

The most widespread and affordable techniques of slope protection involve the use of vegetation. In the form of bio-engineering this can be applied to extreme sites, such as landslide scars and debris tips. These sites are subject to major stresses, particularly in monsoonal and tropical environments with high seasonal variations in the water regimes. While the techniques are well known, in practice it is difficult to adapt them from one country to another. The reasons for this are mainly biological, as the identification and testing of the right plant species and techniques can take considerable time and refinement. There are also institutional issues that need to be resolved in adapting to the use of new materials. This paper records the authors' experience of introducing bio-engineering techniques for slope protection into new areas. While this can be done successfully, a number of pitfalls can occur, and expectations need to be kept at a realistic level. Ultimately, "affordable" approaches have less predictable outcomes and therefore carry higher levels of risk.

Materials for the SEACAP website

It is recommended that the following outputs of SEACAP 21 be added to the SEACAP website.

- The SEACAP 21 *Slope Maintenance Manual* in PDF form.
- The SEACAP 21 *Slope Maintenance Site Handbook* in PDF form.

4. OTHER MATTERS

4.1 Slope Maintenance Manual and Site Handbook

The printing and binding of the Site Handbook was being held back until comments/approval by MPWT of the Lao version of the Slope Maintenance Manual had been received, so that both documents could be printed and bound at the same time. Comments are now anticipated during the first week of February and following any necessary revisions, printing and binding will then go ahead It is fully expected that delivery to MPWT will take place during February 2009.

4.2 SEACAP 21/004

Section 1.2 and Annex B of this report were written without the any consideration of the Terms of Reference contained in SEACAP 21/004. They should be regarded as ‘blue sky’ proposals and not be regarded in any way as a critique of those Terms of Reference.

Annex A: Appraisal of the NUoL's Rural Engineering Curriculum

[This appraisal is taken from the Final Report (Background Paper) of the Feasibility Study for a National Programme to Manage Slope Stability: SEACAP 21-02, September 2008]

The Local Roads Division has recently developed a curriculum for rural road engineering with the National University of Lao PDR (NUOL)[1] (MPWT, 2008a). The aim is to ensure that the supply of engineering graduates is familiar with the approaches of low cost engineering, to fulfil the technical needs in the construction and maintenance of local roads. It is specifically hosted by the Department of Civil Engineering of the NUOL's Faculty of Engineering. There are three main courses, each divided into a number of modules.

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

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

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

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

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

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

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

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

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

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

[1] MPWT: Ministry of Public Works and Transport. 2008. *Rural Engineering Curricula*. National University of Lao PDR with Basic Access Component, Lao-Swedish Road Sector Project-3, Swedish International Development Cooperation Agency. Local Roads Division, Department of Roads, MPWT, Vientiane.

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

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

Annex B: Outline of Proposed Training in Slope Maintenance

Aims and objectives

The following aims and objectives would underlie this course.

The **aims** of the course are to introduce participants to:
- the causes and mechanisms of slope failure within the geological and geomorphological context of Lao PDR;
- landslide mapping and landslide repair prioritisation;
- engineering solutions to slope instability problems;
- the involvement of local communities in slope stabilisation and protection;
- designing of civil engineering and bio-engineering structures for the stabilisation and protection of slopes in Lao PDR;
- the implementation of civil and bio-engineering works.

The **objectives** are that, at the end of the course, the participants will have more confidence to:
- examine an unstable slope and identify the causes and components of instability;
- map landslides and establish repair priorities;
- establish the engineering functions required of remedial measures on specific sites;
- identify the role of local communities in slope management;
- design and evaluate civil engineering and bio-engineering structures, and integrate the two for slope protection;
- plan the implementation of civil engineering and bio-engineering works;
- manage and supervise the preparation of sites and the implementation of civil engineering and bio-engineering works;
- prepare bio-engineering works programmes and manage the implementation of these works.

Course outline

The course covers the following main topics
- Geology, geomorphology and hydrology of upland Laos
- Approaches to slope stabilisation
- Civil engineering systems for slope stabilisation: design and construction
- Slope programme, particularly using bio-engineering

Participant target groups

The course is to be developed for the following groups of people
- Postgraduate students at the National University of Laos
- Appropriate professional project staff of the MPWT
- Engineering site staff of the DPWTs
- Senior technical staff of the DPWTs
- Consultancy companies; design and supervision engineering staff
- Contractors' site engineers

Course topics (tentative list)

No.	Topic	Duration	Location
Component A: Geological Background to Slope Development			
1.	Minerals and the weathering of rocks	2 hours	Classroom
2.	Identification of common rocks	2 hours	Classroom/field
3.	Geological background of the Lao PDR	1 hour	Classroom
4.	Planes of weakness in rocks	3 hours	Classroom/field
5.	Field methods for measuring slopes	2 hours	Field
Component B: Geomorphology and Hydrology of Slopes			
6.	Slope and landform development	1 hour	Classroom
7.	Soils and materials	2 hours	Classroom/field
8.	Rainfall and moisture	2 hours	Classroom
9.	Movement of water in slopes	3 hours	Classroom/field
10.	Slope failure	3 hours	Classroom/field
11.	Role of land use and local communities	2 hours	Classroom/field
Component C: Approaches to Slope Stabilisation and Protection			
12.	Site assessment: inspection and investigation	6 hours	Classroom/field
13.	Site prioritisation	2 hours	Classroom/field
14.	Functions of civil engineering structures	3 hours	Classroom/field
Component D: Background to Bio-engineering			
15.	Engineering influences of plants	1 hour	Classroom
16.	Bio-engineering structures and their functions	3 hours	Classroom/field
17.	Plant types for bio-engineering	2 hours	Classroom/field
18.	Biological site characterisation and plant ecology	3 hours	Classroom/field
19.	Choice of bio-engineering technique	2 hours	Classroom/field
20.	Selection of species for bio-engineering	1 hour	Classroom
21.	Indigenous land rehabilitation and stabilisation	2 hours	Classroom/field
Component E: Design of Slope Stabilisation and Protection Measures			
22.	Design in practice (1): landslides above roads	3 hours	Classroom/field
23.	Design in practice (2): landslides below roads	3 hours	Classroom/field
24.	Design in practice (3): gullies and slope drainage	3 hours	Classroom/field
25.	Design in practice (4): surface protection systems	3 hours	Classroom/field
26.	Design in practice (5): eroding stream banks	3 hours	Classroom/field
Component F: Construction of Civil Engineering Systems			
27.	Introduction to MPWT's *Slope Maintenance Manual*	1 hour	Classroom
28.	Practical construction issues: safety and site management	2 hours	Classroom/field
29.	Construction of civil engineering systems: (1) retaining walls	3 hours	Field
30.	Construction of civil engineering systems: (2) drains	3 hours	Field
Component G: Construction of Bio-engineering Systems			
31.	Provision of bio-engineering plant materials	1 hours	Classroom
32.	Nurseries and their management	3 hours	Field
33.	Plant propagation	2 hours	Field
34.	Bio-engineering construction: (1) grass-based techniques	3 hours	Field
35.	Bio-engineering construction: (2) hardwood-based techniques	3 hours	Field
Component H: Implementation of Slope Works			
36.	Programming civil engineering and bio-engineering works	1 hour	Classroom
37.	MPWT's standard specifications	1 hour	Classroom
38.	Estimating and costing	3 hours	Classroom/field
39.	Introduction to MPWT's *Slope Maintenance Site Handbook*	1 hour	Classroom
40.	Slope maintenance activities	3 hours	Classroom/field
41.	Monitoring procedures	1 hour	Classroom

Annex C: Site Assessment and Preliminary Designs

Ground Investigation

The ground investigation commenced on 20th November 2008 under the supervision of the international Geotechnical Engineer and the local Ground Investigation Supervisor. On 23rd November, following the use of unsatisfactory borehole methods, it was decided to replace the ground investigation contractor. A second ground investigation contractor then completed the work during the period 17th to 19th December. A brief summary of the scope of work and the findings is given in the table below. The borehole and trial pit locations are marked on the drawings at the end of this Annex:

Site	Fieldwork	Findings
km 239.3	2 boreholes; BH1 to 9m depth, BH2 to 10.5m depth 2 trial pits; TP1 to 2.2m depth, TP2 to 3m depth	Possibly 3m fill overlying 4.5m to 6m landslip debris. Original ground perhaps at 7.5m to 9m depth. SPT blow counts vary from 5 to 14, average approx 8, but suspected to be unduly low due to boring methods. TP1 - 1.5m fill overlying WG VI Phyllite. TP2 – WG IV-VI Phyllite to 1.4m depth overlying highly weathered sandstone/siltstone
km 257.1	None	None
km 257.9	None	None
km 317.9	2 boreholes, BH1 and 2, both to 4m depth 2 trial pits, TP1 to 2.5m depth, TP2 to 4m depth	Possibly 4m fill/colluvium overlying weathered rock. SPT blow counts vary from 23 to 70 (at base of both boreholes). Both trial pits indicated 2m fill overlying colluvium.
km 336.4	2 boreholes; BH1 to 3.5m depth, BH2 to 6.5m depth 1 trial pit; TP1 to 2.4m depth	Possibly 3.5m to 6.5m fill/colluvium overlying weathered rock. SPT blow counts vary from 7 to 70 (at base of both holes). TP1 – 2m fill overlying Grade IV Phyllite.
km 341.2/8	None	None

In addition a number of laboratory tests were carried out on disturbed soil samples.

The results of the ground investigation were somewhat disappointing, with the boreholes being terminated without positive proof that weathered bedrock had been reached. This would have required rock coring, and no drill rig was then available to carry out this type of work.

Site Assessment

Engineering geological assessments of the six sites are given below. Reference is made to the drawings given at the end of this Annex.

<u>It is important to note that the drawings and recommendations for km 239.3 were prepared prior to the current major earthworks taking place in late January 2009 to realign the road further into the hillside. This work was being carried out for the Vientiane DPWT who is now aware of these recommendations to construct a retaining wall rather than realign the road. The recommendations still remain valid, and it is understood that the DPWT is reconsidering its options.</u>

km 239.3 (Drawing 108031/DWG/100)

This is a pre-existing landslide with a toe in the stream channel below and a current head at original road level. It is likely that the failure was originally precipitated or aggravated by the placement of fill on the slope as a result of original road construction and, more lately, spoil disposal.

The present failure occurred during the 2008 wet season and appears to have regressed from the lower slope headwards, ultimately removing all support to the road over a distance of 60m or more.

Field observations indicate that failure at the top of the slope above the stream channel is active, probably even in the dry season. From the limited ground investigations undertaken it appears that most of the slope comprises a thickness of gravely clay (fill material) and possible previous landslide debris overlying a silt/clay material, which is interpreted to be derived from in situ weathering of the underlying rock.

Consequently, the driving force for the ongoing ground movements is probably a combination of slope loading and pore pressures developed on the underlying silt/clay surface. It is unclear how active the stream erosion remains in the channel below.

The earlier engineering response to this landslide has been to realign the road progressively into the hillside. The recommended measures are to construct a mortared masonry retaining wall on the outside edge of the road, founded on intact material beneath the failure surface. The horizontal alignment for the road should be as ‘tight’ to the existing cut slope as possible. It is anticipated that the depth of this wall should be up to 6m below original (pre-current earthworks) ground level, to as little as 2m – 3m in the vicinity of the trial pit locations. Removal of soil and fill from the landslide head should lead to an overall improvement in the stability of the slope below. It is recommended that visual monitoring of the alignment is carried out immediately up (239+430) and down chainage (239+250) as the movements below the road extend into these areas as well. It will be important to ensure close geotechnical supervision during construction in order to derive final designs and founding depths.

km 257.1 (Drawing 108031/DWG/200)

This failure occurred during the 2008 wet season in the centre of Phou Khoun. The road edge was previously retained by a masonry wall, which has collapsed into the gully below. There is a culvert outlet at this location and it is anticipated that scour beneath this outlet originally led to loss of support to the wall and its eventual failure. There is also a water supply pipe that runs across the slope, and it is understood that leakage from this also contributed to the problem. Failure of the wall has led to exposure of the road edge over a distance of approximately 15m.

Weathered phyllite is exposed in the adjacent cut slope and there are indications that it is also exposed as outcrop on the slide scar beneath the road. It is anticipated that the majority of the steep scar below the road is composed of in situ weathered phyllite with residual soil and fill forming the upper section. The slope is approximately 2V:1H on average and is up to 7m at its greatest extent. Beneath this is a debris slope that has been covered by refuse. Due to access difficulties and safety issues, no inspections have been made directly of the materials exposed directly below the road.

Early considerations here were for a reinforced concrete cantilevered road retaining wall. Depending upon materials ultimately exposed this wall would require an exposed height of up to 7m, plus foundation, though it is likely that the required height could be significantly less than this. If this option is taken up then it will be necessary to carry out in situ testing of the ground for bearing capacity confirmation.

During the DPWT training visit to the site in January 2009, the option for constructing an upturned cantilevered structure was discussed, similar to that designed and supervised by the Luang Prabang DPWT at km 229.3. This would comprise a reinforced concrete slab constructed across half the road width (or more) over the affected section, keyed into the existing road cut by a reinforced concrete stub wall constructed along the centreline. On the outside edge of the road, a wall would be connected to the road slab and constructed in reinforced concrete to a variable depth beneath the road edge level, thus providing protection to the outside edge of the road for the majority of the exposed height. This is the preferred option. Beneath this the remaining scar should be protected from erosion and shallow failure by using hand-applied shotcrete, similar to that employed at km 242.6 under 21/001. The culvert outfall should also be protected against erosion through the construction of a nominally 20-25m long gabion cascade. The water supply pipe needs additional protection to ensure that a re-occurrence cannot happen.

km 257.9 (Drawing 108031/DWG/300)

This is a cut slope failure in weathered and closely jointed phyllite. The failure depth is shallow and the slope is steep (up to 1:1 in places). The lower part of the slope is covered in slide material from above, and appeared damp during the 21/003 site inspection. There is therefore likely to be a significant source of water which will aggravate instability. Above the cut slope there is a break in slope. Inspection of this slope revealed evidence for additional instability, possibly ultimately related to the cut slope failure below. Given the uncertainty, however, it is recommended that efforts are focussed on the cut slope only. It is recommended that this comprises a 3m high, 40m long composite masonry revetment. Debris clearing and trimming from the slope in general should take place prior to constructing this wall and bio-engineering applied to the final slope.

km 317.9 (Drawing 108031/DWG/400)

This is a large landslide that extends from the stream channel below the road to the hillside above. There is every indication that this landslide has been in existence for many years. The road had been realigned further into the hillside prior to the commencement of 21/001, but in recent years it is apparent that movements have continued and the road continues to fail. In 21/001 the extent of this movement was recognised and some surface improvement works and monitoring was carried out. The ground movements have continued and some of these works have been damaged as a result.

During 21/001 three boreholes were put down. These found landslide and fill material but were inconclusive in terms of identifying the failure plane. A makeshift inclinometer was installed in one of these holes and readings implied shallow movement at a depth of approximately 2.4m below ground level. This is interpreted to be movement on a shallow surface, above the main landslide movement.

During 21/003 further field observation have been made and it is confirmed that the slopes below and above the road are continuing to fail. Movements on the slopes above the stream channel below the road are particularly active.

The driving force for this movement is anticipated to be toe erosion (at least in terms of precipitating the original failure), slope steepness on the lower slope, weak material on the sliding surface (as yet unconfirmed) and groundwater, given the large catchment area above. The placement of fill and spoil on the slope may have aggravated the instability.

The recommendation at this site is to construct a gabion retaining wall to a depth of up to 5m. This should retain the road against shallow failure but cannot be founded beneath the ultimate failure surface that might be of the order of 10m based on field observations (ref drawing 108031/DWG/401). Consequently, the wall will provide some temporary support to the road but may ultimately fail. It will be important to ensure close geotechnical supervision during construction in order to derive final designs and founding depths.

km 336.4 (Drawing 108031/DWG/500)

The section of road between 336+295 and 336+330 has been undergoing deep seated movement since before SEACAP 21/001 began in October 2006. Boreholes were put down on the outside edge of the road but these were inconclusive in terms of failure depth and materials. The interpretation at the time of 21/001 was that the failure had been precipitated as a result of the steepness of slope, the extremely disturbed nature of the underlying rock (as exposed in the cut slope) and possibly, originally, toe erosion in the river below. The rock appears to be particularly weak and tectonically disturbed. The conclusion of 21/001 was that a solution at this location would be expensive and would probably comprise the extension of the existing culvert at 336+220 downstream to a point where it would have enabled a fill slope to be constructed above it, thus providing support to the slope above. Such a solution would need careful investigation and design were the funds to be available. The 21/001 works were only therefore aimed at carrying out monitoring and superficial slope improvement and drainage works.

During 21/003 fieldwork it has become apparent that the extent of slope instability has increased significantly. This increased instability comprises a slow failure of the entire cut slope between 336+230 and 336+330. It is apparent that this failure has daylighted in the toe of the cut slope because the side drain is pushed forward in many places. The road between 336+230 and 336+295 is not yet showing any signs of disturbance, which supports this interpretation. The hillsides above the road are also failing in association with the cut slope instability described above. The majority of this movement appears to be fresh, i.e. indicative of first-time movement, though there is evidence of weathered scarp slopes indicative of previous movement.

Given that the only permanent solution would be to realign the road away from the cut slope into the valley on the top of a substantial culverted fill slope, and in view of the significant cost of carrying out such works, the recommendation here is to accept that movements of the road will continue to occur and to make adequate provision for maintenance that might include regular reinstatement of the road surface and the roadside drain, as well as minor cut slope trimming.

km 341.2/8 (Drawing 108031/DWG/600)

This is a slope located between two sections of road joined by a hairpin bend. Shallow instability (probably 1-2m deep) has occurred over large parts of the slope over a road distance of approximately 50m. The instability has taken place predominantly in the upper slope and this has extended back to the edge of the side drain to the upper road in two main locations. The scars associated with these features are approximately 8m and 5m width respectively. If this process is allowed to continue then the edge of the road itself will itself fail. The debris from these failures has overtopped the revetment wall to the road below and material is in the side drain.

The side drain to the upper road section on the outside edge is surplus to drainage requirements and it is recommended that it is filled in. This would allow walls to be constructed in masonry to the edge of the road on the upper section. These walls should be constructed in masonry and founded on in situ rock beneath the fill that currently comprises the upper slope. Once this is done and the material has been trimmed, the resultant slope below the walls should be protected with hand-applied shotcrete down to the level of the steep break in slope below. This should be sufficient to protect the upper section of road. For the section below, it is recommended that all loose material be cleared and the slope protected with bio-engineering. If, in this process loose intact rock is exposed in places, then this can be protected with either hand-applied shotcrete or masonry revetment.

Preliminary Designs

Preliminary designs are presented on the drawings in Annex F and are summarised below.

Site	Drawing Nos	Main design and construction features
km 239.3	108031/DWG/101 108031/DWG/102	Construct 60m long mortared masonry wall as close to the base of the existing cut slope making due allowance for the road width. Wall likely to be founded up to 6m depth below pre-existing earthworks (roughly 834m elevation at km 239.5 using the established control points) but likely to reduce to 3m in places. It will be important to ensure that the base is founded on original ground beneath the failure plane that has an adequate bearing capacity. The wall dimensions should be those as given in the Slope Maintenance Manual, drawing SMM/DWG/001. On the valley side of the new wall the fill should be removed from site and disposed of at a safe stable location
km 257.1	108031/DWG/201 108031/DWG/202 108031/DWG/203	Construct the reinforced concrete structure shown on the drawings comprising a varying width road slab connected on one side to a vertical cut-off wall close to and parallel to the road centre line, and on the other side to a cantilevered retaining wall. This should be constructed in short bays, maximum 5m length, to reduce the possibility of slope failure during construction. The existing culvert should be extended through the wall and a stilling basin constructed at the current ground level. This should be connected to a masonry cascade constructed at the existing drainage course level and extended for at least 20-25m downslope to a stable discharge point. The existing slope beneath the cantilevered retaining wall should be protected with a hand-applied reinforced concrete surface layer extending to the cascade.
km 257.9	108031/DWG/301 108031/DWG/302	Clear existing debris within the failed area and trim back any back or side scarps to a smooth profile. Construct 3m high, 40m long composite

		masonry revetment at the toe of the slope. Plant three lines of brush layering immediately above the revetment. Elsewhere within the trimmed area plant grass slips at the spacing shown on the drawings. Reconstruct the roadside drain at the base of the revetment.
km 317.9	108031/DWG/401 108031/DWG/402	Construct 60m long gabion retaining wall as close to the base of the existing cut slopes making due allowance for the road width. Wall likely to be founded up to 6m depth but could be less than this towards each end. It is very likely that good ground conditions may not exist within the central section of the wall, but a greater depth of wall is not recommended unless it is certain that better stable conditions are no more than 1 - 2m lower. The wall dimensions should be as those given in the Slope Maintenance Manual, drawing SMM/DWG/002. On the valley side of the new wall the fill should be removed from site and disposed of at a safe stable location. It must be emphasised that the wall only provides a temporary solution, and that in the long term, wall movements can be expected to occur.
km 336.4	108031/DWG/501 108031/DWG/502	Remove all loose debris. Reinstate road surface and roadside drain.
Km 341.2 341.8	108031/DWG/601 108031/DWG/602	Construct mortared masonry retaining walls 8m and 5m long at the locations shown on the drawings. These must be located immediately adjacent to the existing road such that the crest of the wall is at the road edge. The walls must be founded in original ground (weathered rock) and are expected to be up to 3m depth. The existing failed areas in the slopes below should be cleared of loose debris and any back or side scarps trimmed back to a smooth profile. The surface should then be protected using both bio-engineering methods and hand-applied concrete in the areas shown on the drawings.

Annex D: Programme for the Terminal Workshop (Postponed)

SEACAP 21 SLOPE MAINTENANCE TERMINAL WORKSHOP

22nd January 2009

Time	**Topic**	**Led by**
1345 - 1400	Registration	
1400 – 1405	Welcome	Laokham Somphet
1405 – 1415	SEACAP 21/001	Tim Hunt
1415 – 1425	SEACAP 21/002	Gareth Hearn
1425 – 1435	SEACAP 21/003	Tim Hunt
1435 – 1500	Design & Construction Issues – Structures	Gareth Hearn, Tim Hunt
1500 – 1515	Coffee break	
1515 – 1545	Design & Construction Issues – Bio-engineering	John Howell
1545 - 1615	Slope Manual and Handbook	Gareth Hearn, Tim Hunt, John Howell
1615 – 1620	Training	Tim Hunt
1620 – 1640	Questions, answers and discussion	Laokham Somphet
1640 – 1645	Wrap-up comments and closure	Laokham Somphet

Annex E: Pictures

The pictures that follow illustrate some of the work carried out for SEACAP 21/003.

Landslide site at km 239.3

Landslide site at km 257.1

Landslide site at km 257.9

Landslide site at km 317.9

Landslide site at km 336.4

Landside site at km 341.2

Ground Investigation – SPT testing

Ground Investigation – trial pit logging

University students training visit

Luang Prabang DPWT training visit

4 DPWT Provinces training visit

4 DPWT Provinces training visit

NUoL presentation by Bounthavy Siliphone

NUoL presentation by Gareth Hearn

NUoL presentation by John Howell

Handover of technical books to NUoL

Annex F: Preliminary Design Drawings

The following drawings are presented in this Annex:

Drawing No	Title
108031/DWG/100	Road 13N – km 239.3 Site Assessment – Engineering Geology
108031/DWG/101	Road 13N – km 239.3 Cross Section at 239+350
108031/DWG/102	Road 13N – km 239.3 Recommended Remedial Works
108031/DWG/200	Road 13N – km 257.1 Site Assessment – Engineering Geology
108031/DWG/201	Road 13N – km 257.1 Cross Section at 257+125
108031/DWG/202	Road 13N – km 257.1 Recommended Remedial Works
108031/DWG/203	Road 13N – km 257.1 Cross Sections
108031/DWG/300	Road 13N – km 257.9 Site Assessment – Engineering Geology
108031/DWG/301	Road 13N – km 257.9 Cross Section at 257+910
108031/DWG/302	Road 13N – km 257.9 Recommended Remedial Works
108031/DWG/400	Road 13N – km 317.9 Site Assessment – Engineering Geology
108031/DWG/401	Road 13N – km 317.9 Cross Section at 317+977
108031/DWG/402	Road 13N – km 317.9 Recommended Remedial Works
108031/DWG/500	Road 13N – km 336.4 Site Assessment – Engineering Geology
108031/DWG/501	Road 13N – km 336.4 Cross Section at 336+310
108031/DWG/502	Road 13N – km 336.4 Recommended Remedial Works
108031/DWG/600	Road 13N – km 341.2 Site Assessment – Engineering Geology
108031/DWG/601	Road 13N – km 341.2 Cross Section at 341+297
108031/DWG/602	Road 13N – km 341.2 Recommended Remedial Works

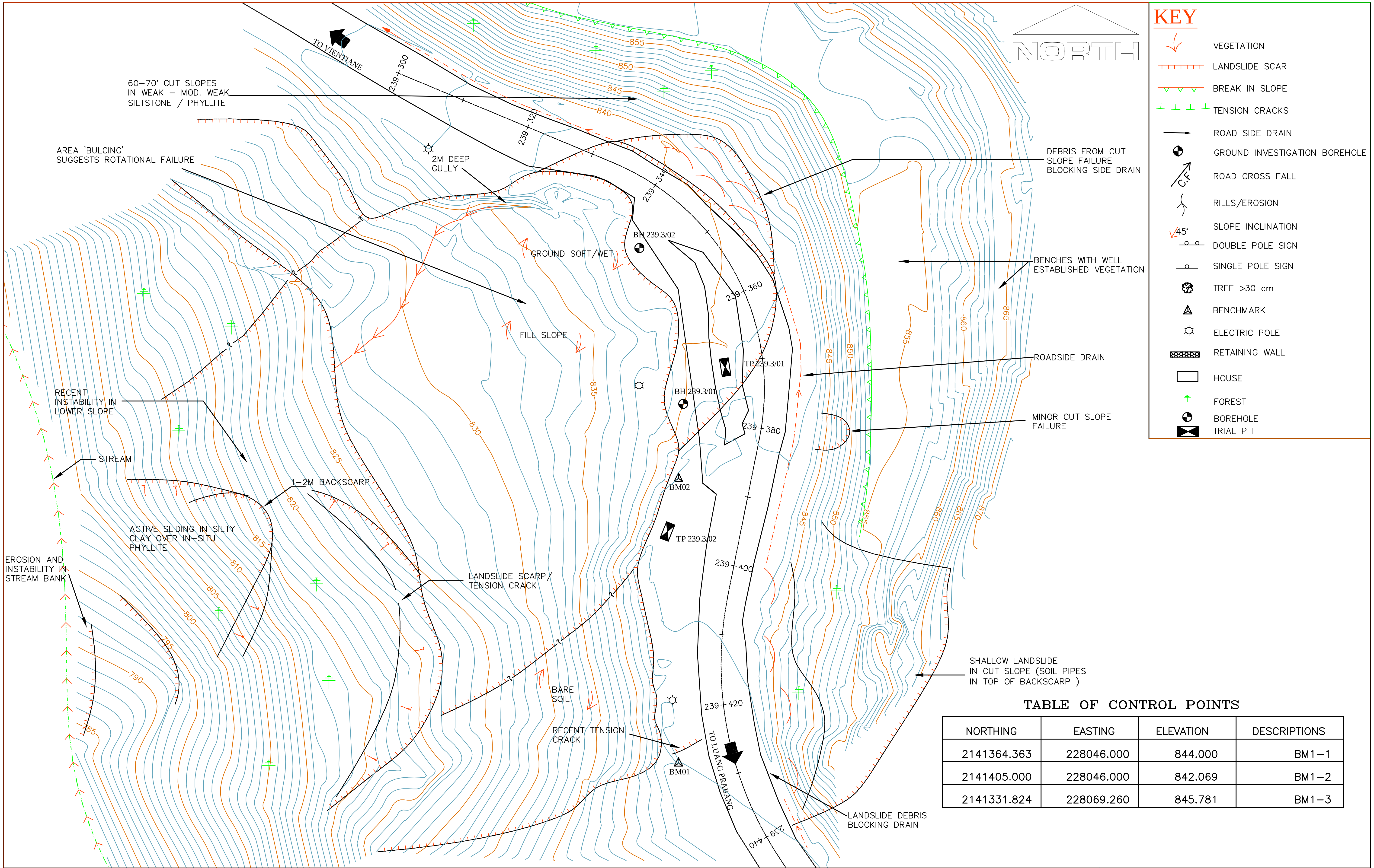


TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2141364.363	228046.000	844.000	BM1–1
2141405.000	228046.000	842.069	BM1–2
2141331.824	228069.260	845.781	BM1–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

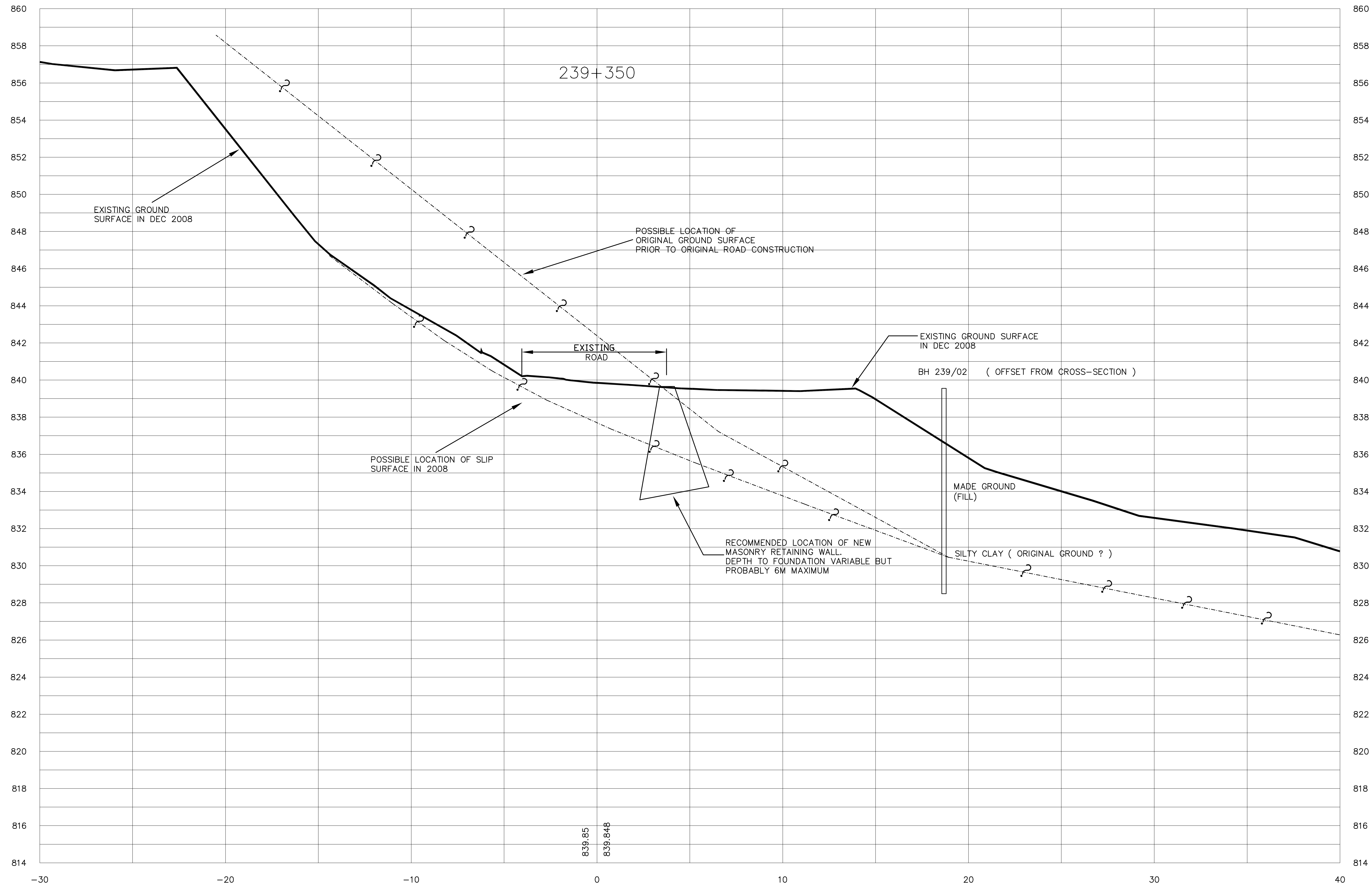
ROAD 13 N - KM 239.3
SITE ASSESSMENT - ENGINEERING GEOLOGY

108031/DWG/ 100

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date Dec 08

ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ LAO CONSULTING GROUP
SD & XP Consultants Group
Scott Wilson
www.scottwilson.com



Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 239+350
CROSS SECTION

108031/DWG/101

Scale at A3 : 1/200

Drw	App	Rev A
Chk	Date	Date Dec 08

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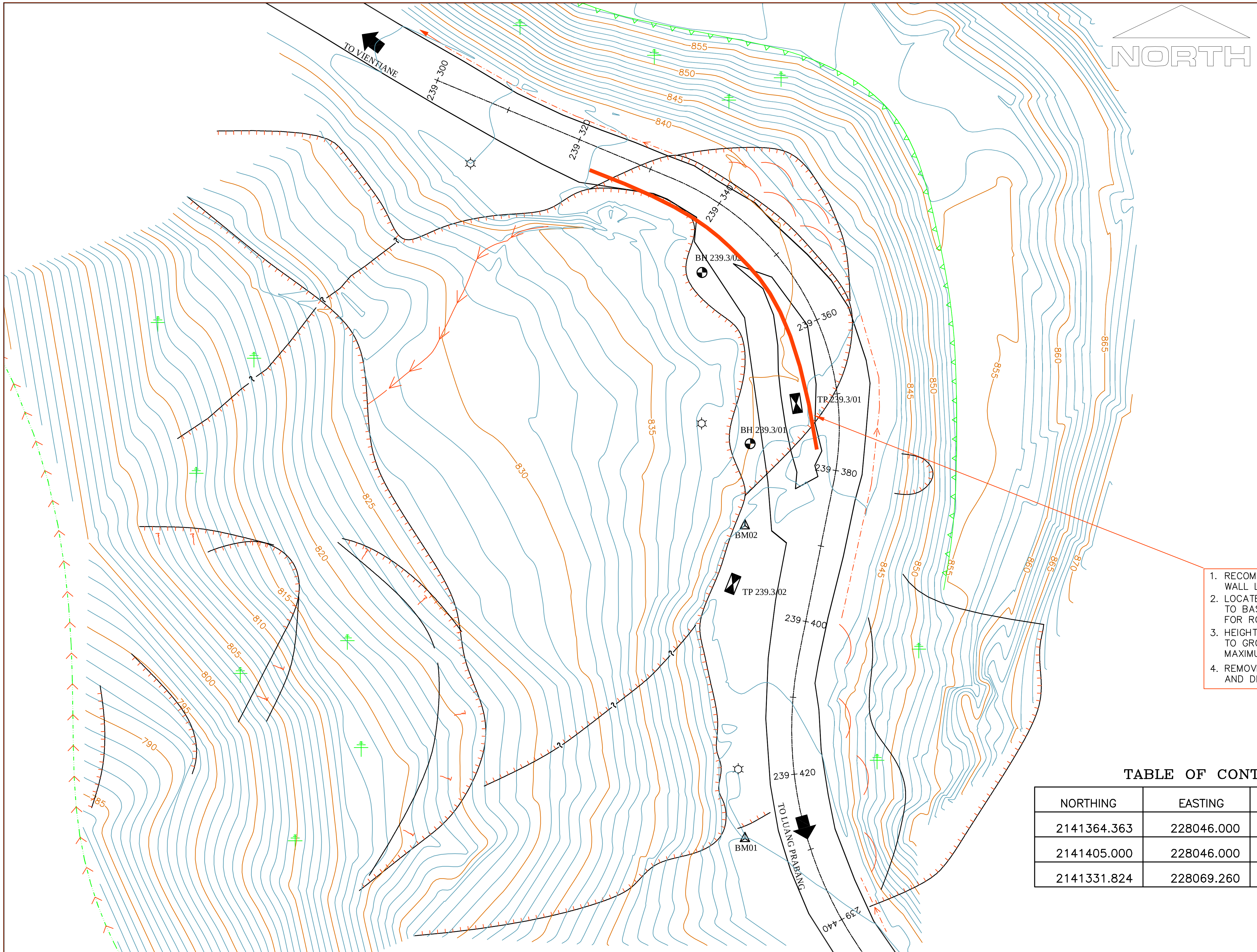

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- ROAD CROSS FALL
- RILLS/EROSION
- SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- HOUSE
- FOREST
- BOREHOLE
- TRIAL PIT

1. RECOMMENDED MASONRY RETAINING WALL LOCATION , 60M LONG.
2. LOCATE WALL AS CLOSE AS POSSIBLE TO BASE OF CUT SLOPE BUT ALLOWING FOR ROAD WIDTH
3. HEIGHT OF WALL WILL VARY ACCORDING TO GROUND CONDITION BUT PROBABLY MAXIMUM 6M
4. REMOVE FILL FROM VALLEY SIDE OF WALL AND DISPOSE AT SAFE STABLE LOCATION

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2141364.363	228046.000	844.000	BM1−1
2141405.000	228046.000	842.069	BM1−2
2141331.824	228069.260	845.781	BM1−3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 239.3
RECOMMENDED REMEDIAL WORKS

108031/DWG/ 102

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date Dec 08

ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ
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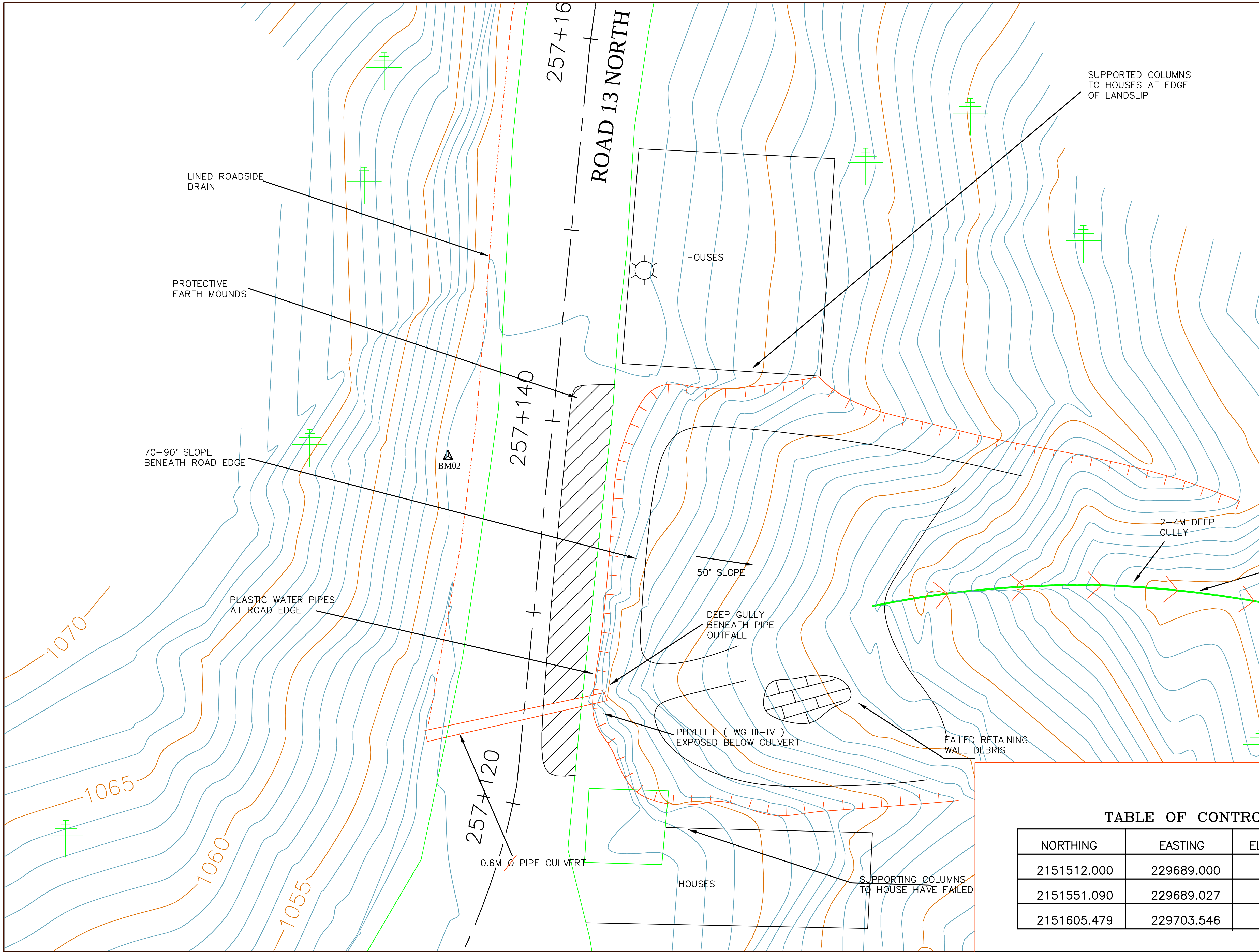

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- C.F. ROAD CROSS FALL
- RILLS/EROSION
- 45° SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- HOUSE
- FOREST

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151512.000	229689.000	1053.262	BM2–1
2151551.090	229689.027	1053.815	BM2–2
2151605.479	229703.546	1056.107	BM2–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 257.1
SITE ASSESSMENT - ENGINEERING GEOLOGY

108031/DWG/200

Scale at A3 : 1/200

Drw	App	Rev A
Chk	Date	Date

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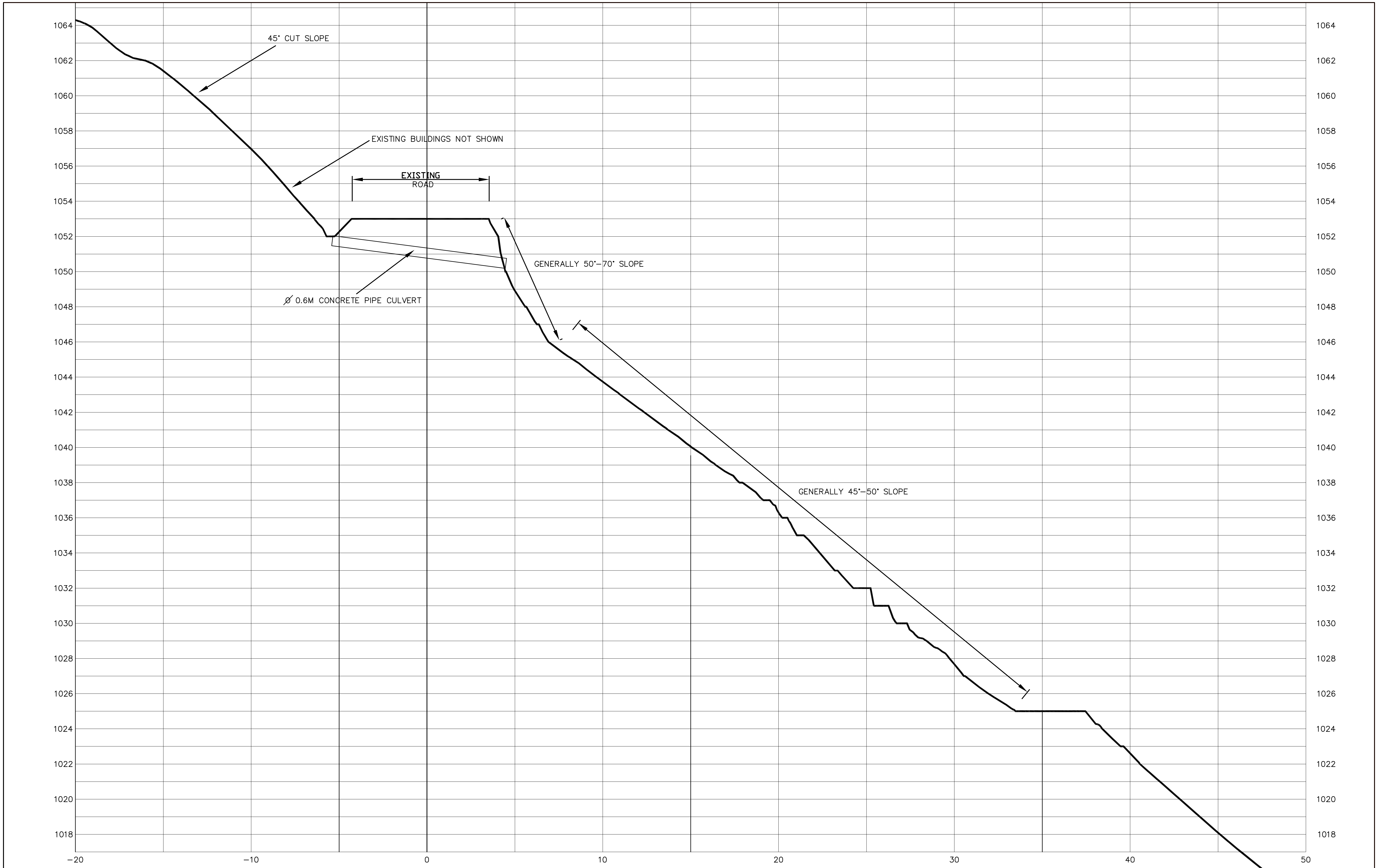

Project	Drawing Title	
MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	ROAD 13 N - KM 257+125 CROSS SECTION ALONG EXISTING CULVERT AND GULLY	108031/DWG/201 Scale at A3 : 1/200 Drw / App / Rev A Chk / Date / Date Jan 09

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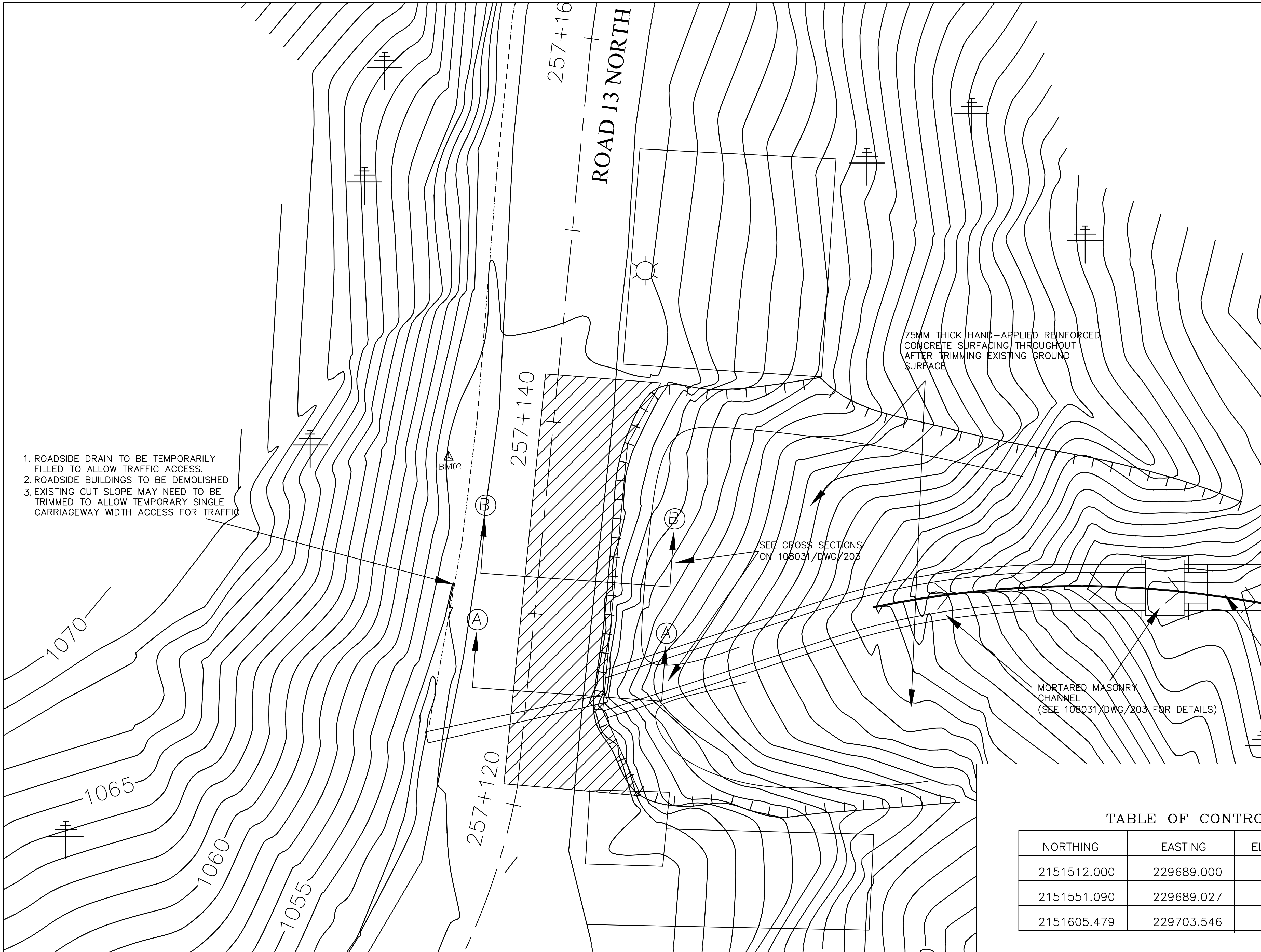

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- C.F. ROAD CROSS FALL
- RILLS/EROSION
- 45° SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- HOUSE
- FOREST

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151512.000	229689.000	1053.262	BM2−1
2151551.090	229689.027	1053.815	BM2−2
2151605.479	229703.546	1056.107	BM2−3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 257.1
RECOMMENDED REMEDIAL WORKS

108031/DWG/202

Scale at A3 : 1/200

Drw	App	Rev D
Chk	Date	Date Jan 09

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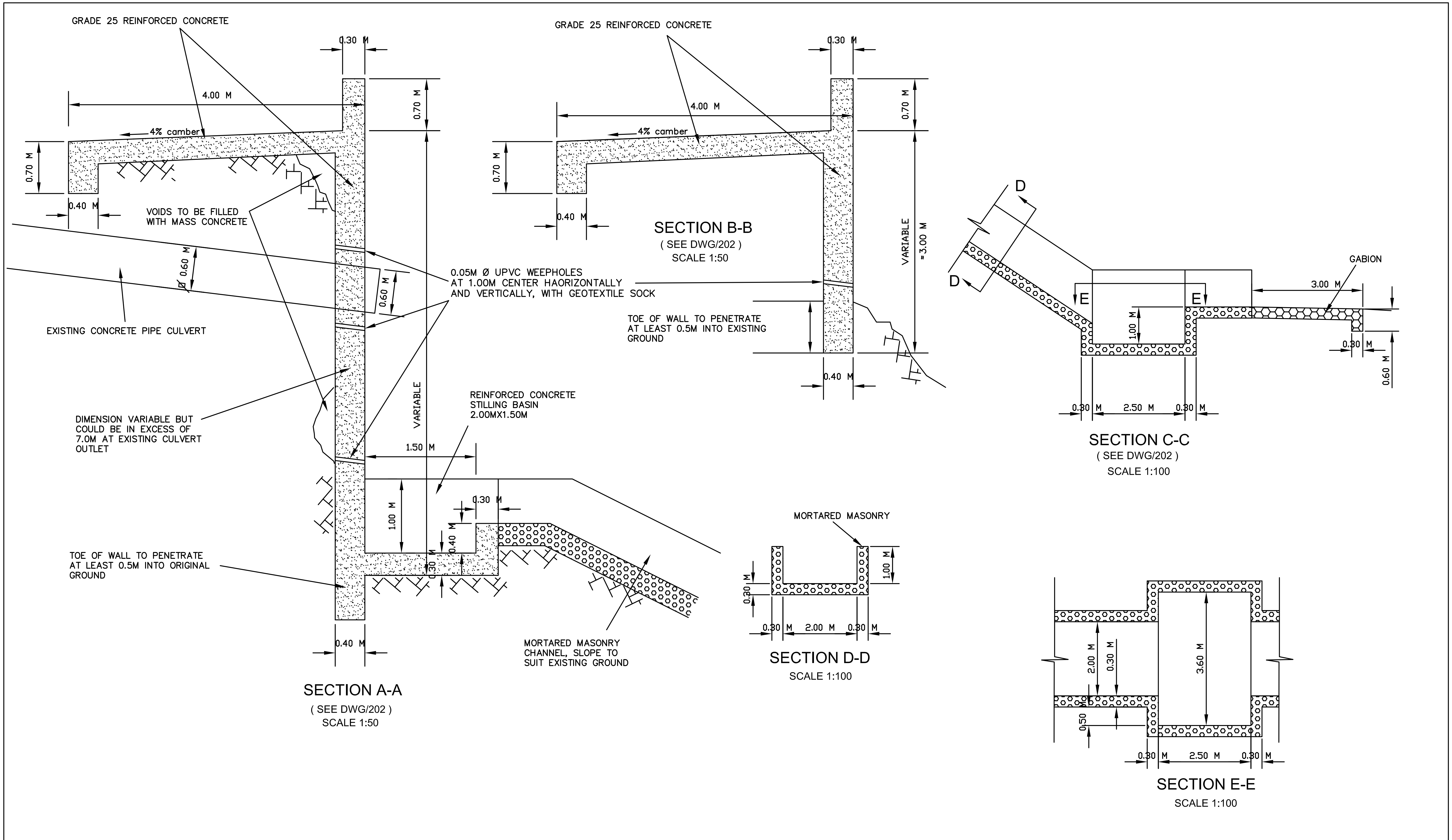

Project
MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title
ROAD 13 N - KM 257.1
CROSS SECTIONS

108031/DWG/203

Scale at A3 : VARIES		
Drw	App	Rev D
Chk	Date	Date Jan 09

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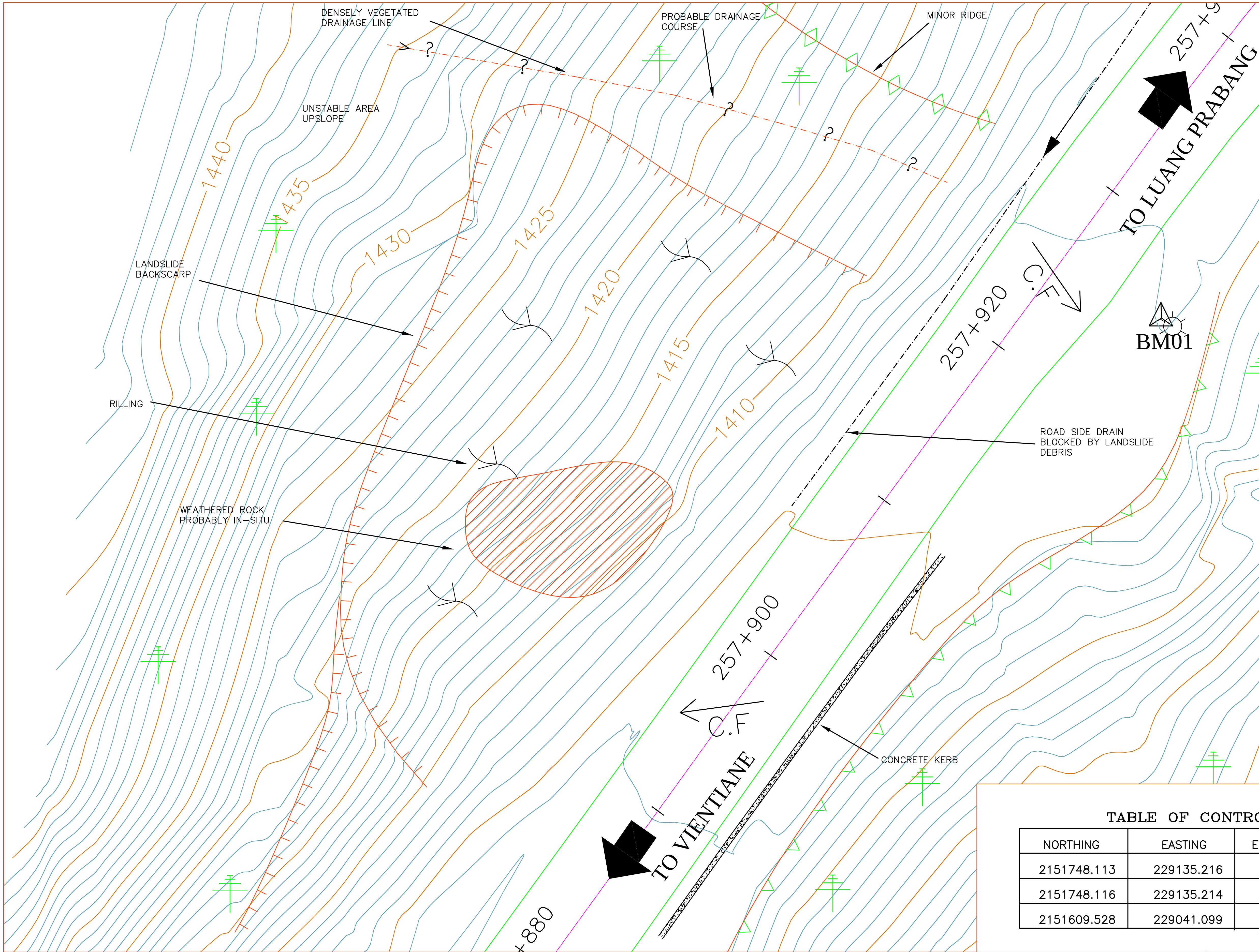

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- C.F ROAD CROSS FALL
- RILLS/EROSION
- 45° SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- HOUSE
- FOREST

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151748.113	229135.216	1409.324	BM3–1
2151748.116	229135.214	1409.324	BM3–2
2151609.528	229041.099	1399.987	BM3–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 257.9
SITE ASSESSMENT - ENGINEERING GEOLOGY

108031/DWG/300

Scale at A3 : 1/200

Drw	App	Rev B
Chk	Date	Date Jan 09

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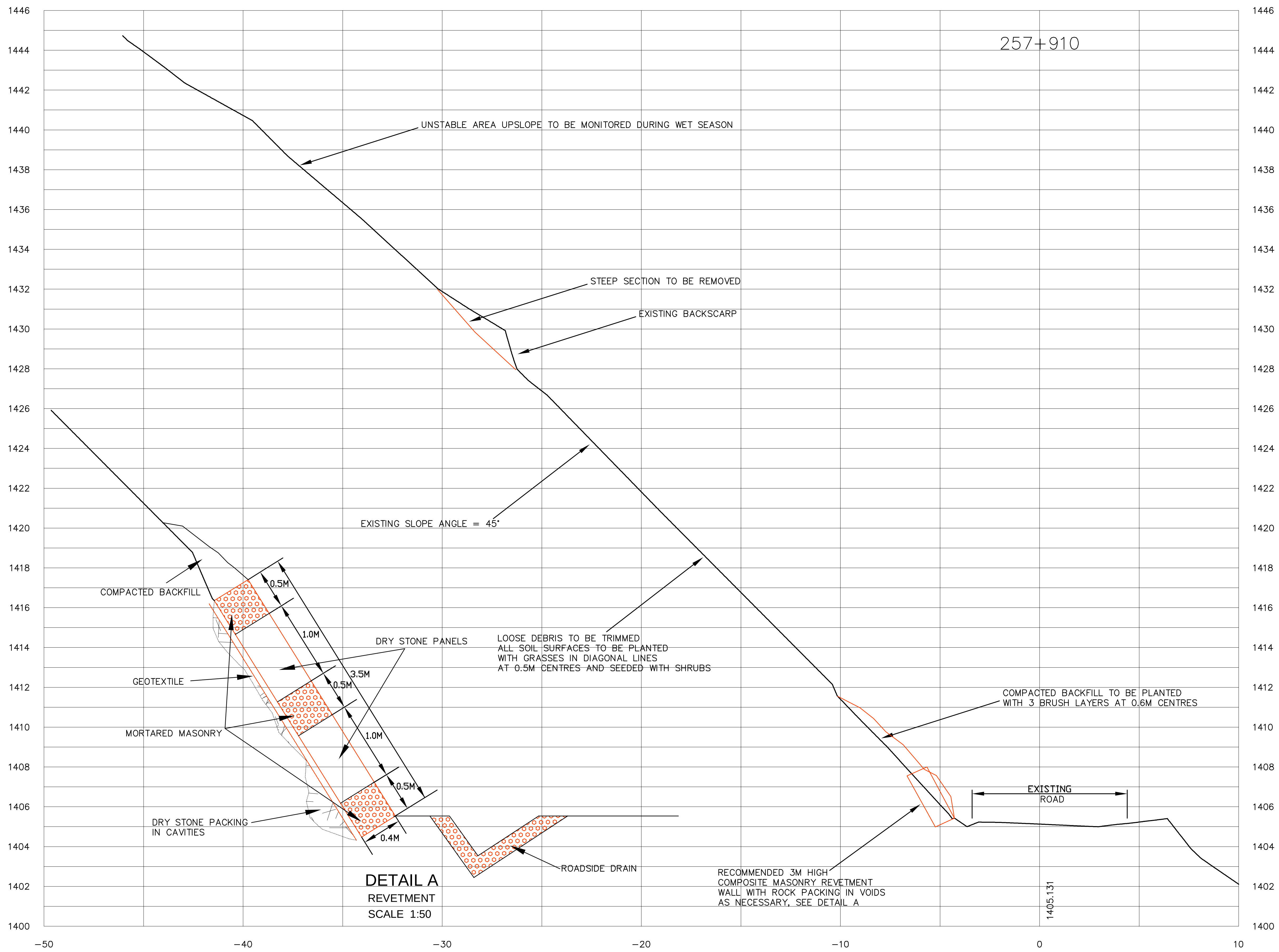

Project MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	Drawing Title ROAD 13 N - KM 257+910 CROSS SECTION AND RECOMMENED REMEDIAL WORK	108031/DWG/301 Scale at A3 : 1/200 Drw / App / Rev Chk / Date / Date

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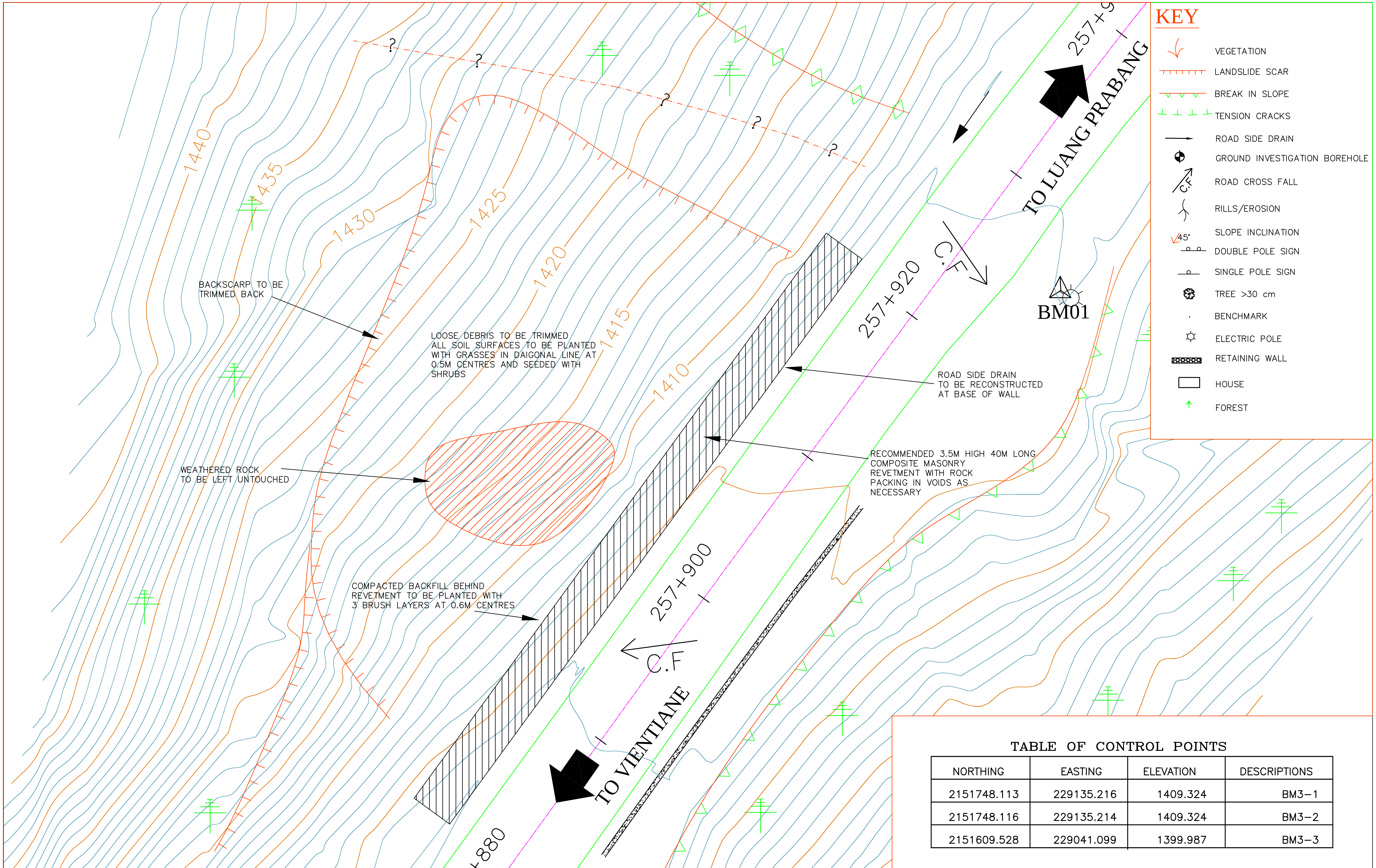

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151748.113	229135.216	1409.324	BM3–1
2151748.116	229135.214	1409.324	BM3–2
2151609.528	229041.099	1399.987	BM3–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM257.9
RECOMMENDED REMEDIAL WORKS

108031/DWG/302

Scale at A3 : 1/200

Drw	App	Rev A
Chk	Date	Date

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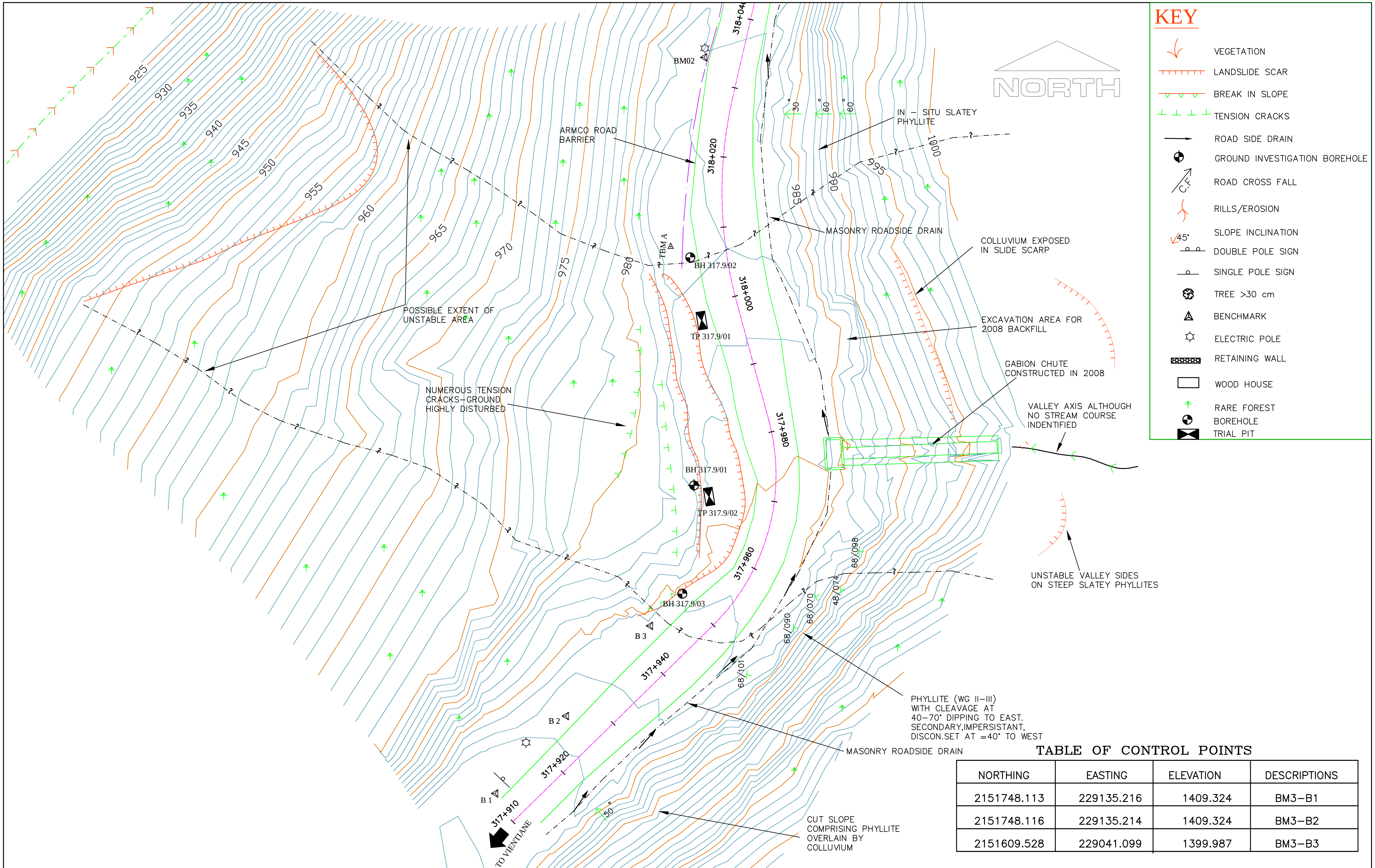

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151748.113	229135.216	1409.324	BM3–B1
2151748.116	229135.214	1409.324	BM3–B2
2151609.528	229041.099	1399.987	BM3–B3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 317.9

SITE ASSESSMENT ENGINEERING GEOLOGY

108031/DWG/400

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date

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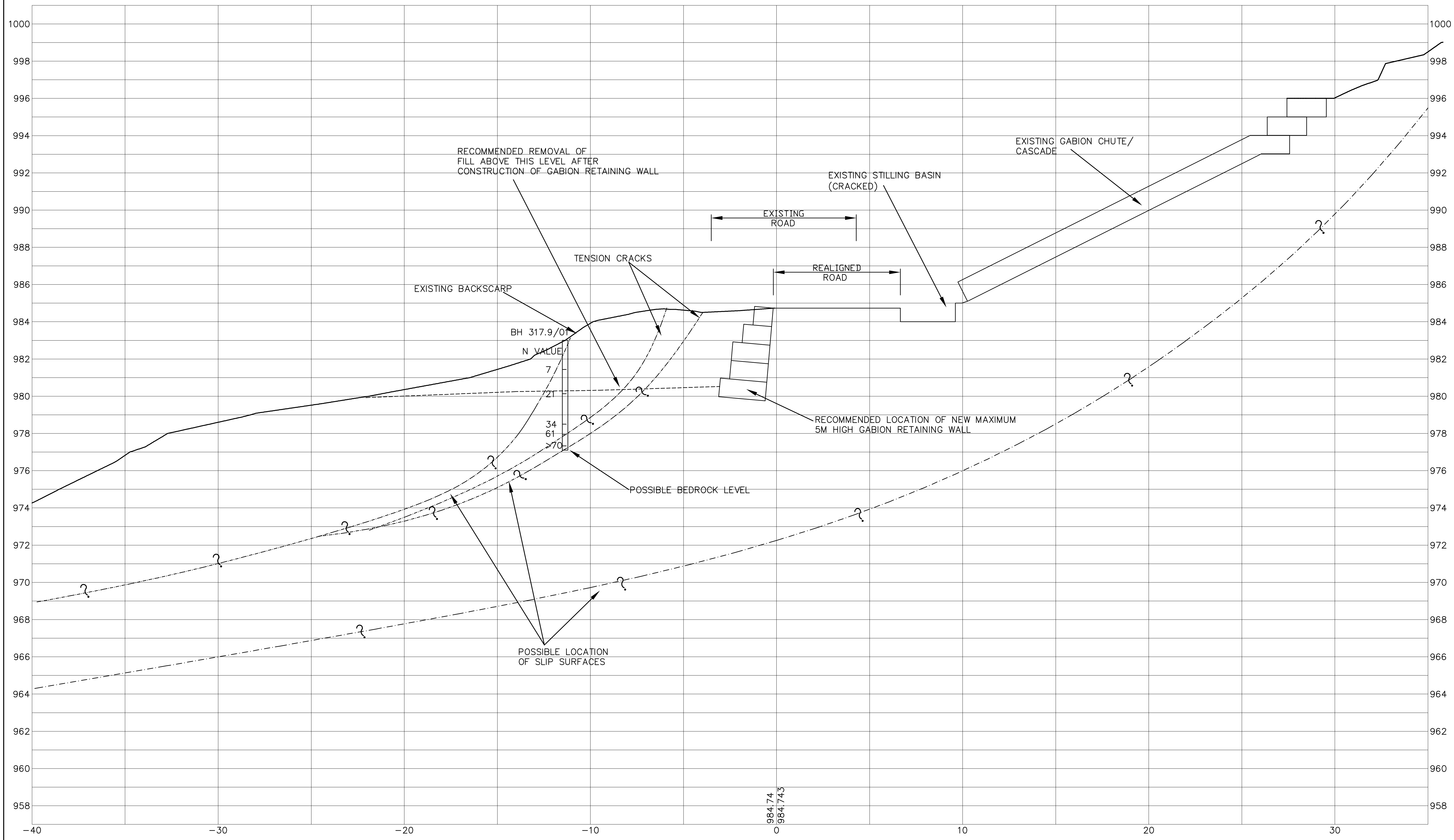

Project	Drawing Title	108031/DWG/401
MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	ROAD 13 N - KM 317+977 CROSS SECTION	Scale at A3 : 1/200

Drw	App	Rev A
Chk	Date	Date

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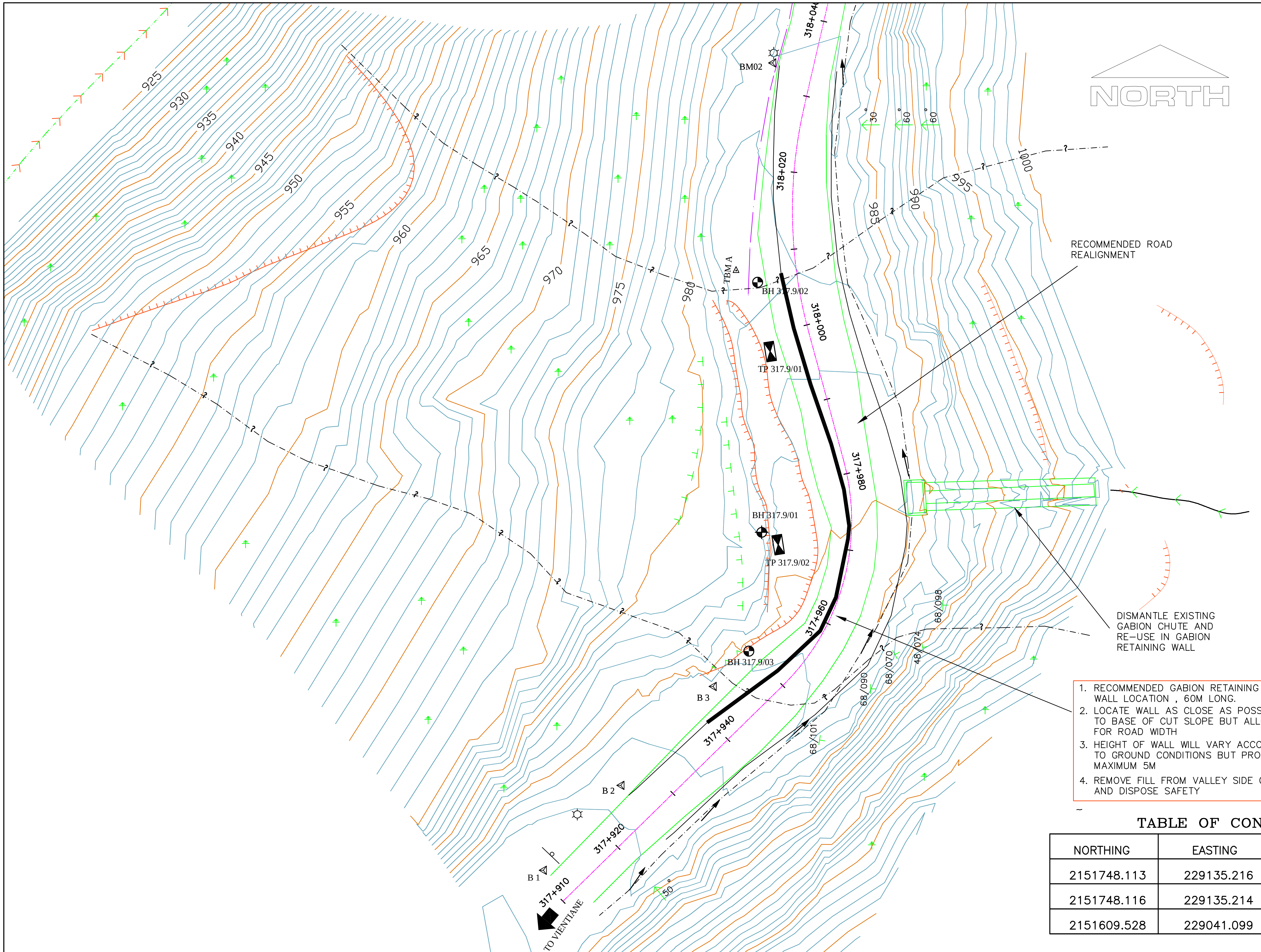

1. RECOMMENDED GABION RETAINING WALL LOCATION , 60M LONG.
2. LOCATE WALL AS CLOSE AS POSSIBLE TO BASE OF CUT SLOPE BUT ALLOWING FOR ROAD WIDTH
3. HEIGHT OF WALL WILL VARY ACCORDING TO GROUND CONDITIONS BUT PROBABLY MAXIMUM 5M
4. REMOVE FILL FROM VALLEY SIDE OF WALL AND DISPOSE SAFETY

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- ROAD CROSS FALL
- RILLS/EROSION
- SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- WOOD HOUSE
- RARE FOREST
- BOREHOLE
- TRIAL PIT

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
2151748.113	229135.216	1409.324	BM3–B1
2151748.116	229135.214	1409.324	BM3–B2
2151609.528	229041.099	1399.987	BM3–B3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 317.9
RECOMMENDED REMEDIAL WORKS

108031/DWG/402		
Scale at A3 : 1/500		
Drw	App	Rev A
Chk	Date	Date

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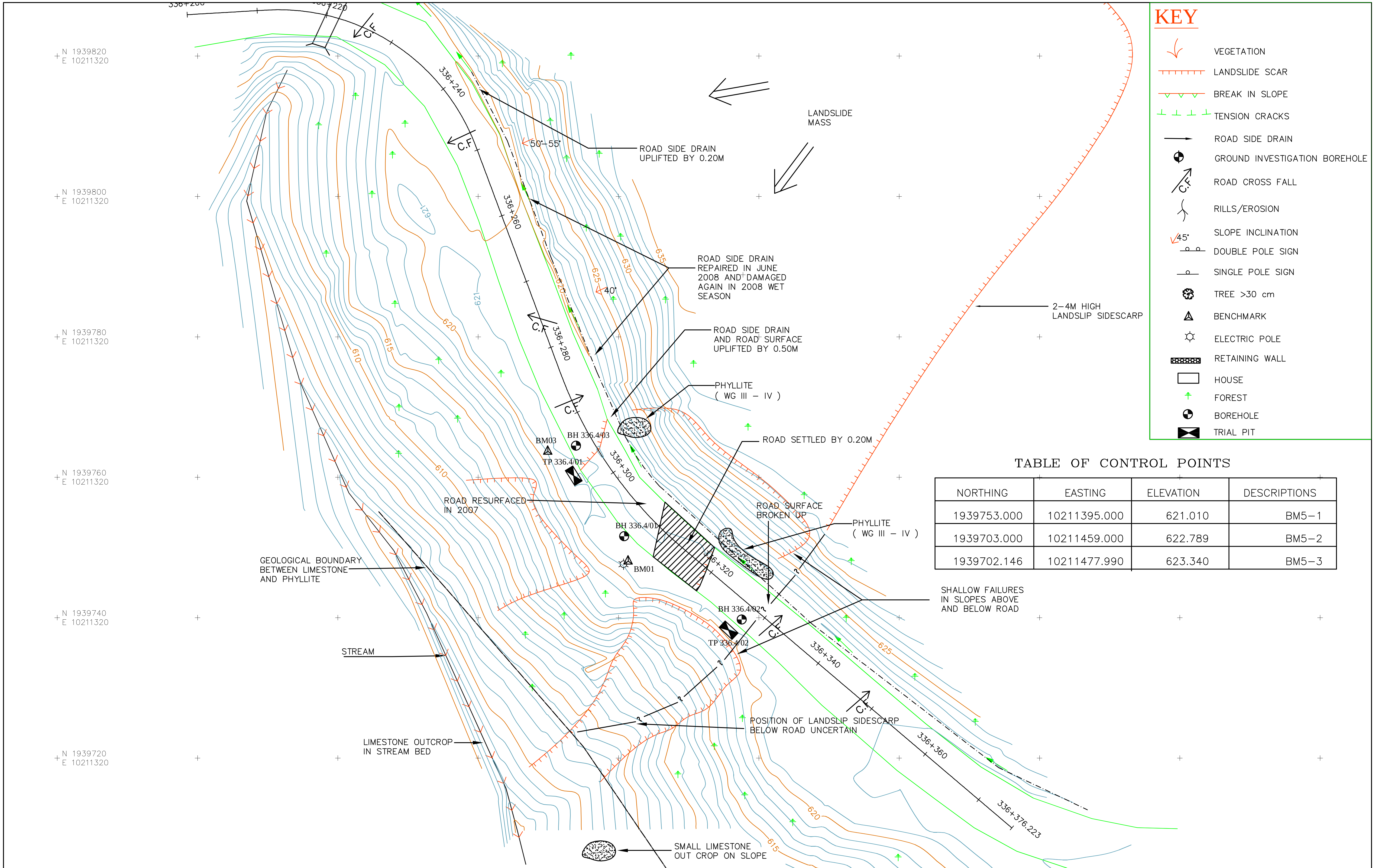

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
1939753.000	10211395.000	621.010	BM5–1
1939703.000	10211459.000	622.789	BM5–2
1939702.146	10211477.990	623.340	BM5–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 336.4
SITE ASSESSMENT - ENGINEERING GEOLOGY

108031/DWG/500

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date Jan 09

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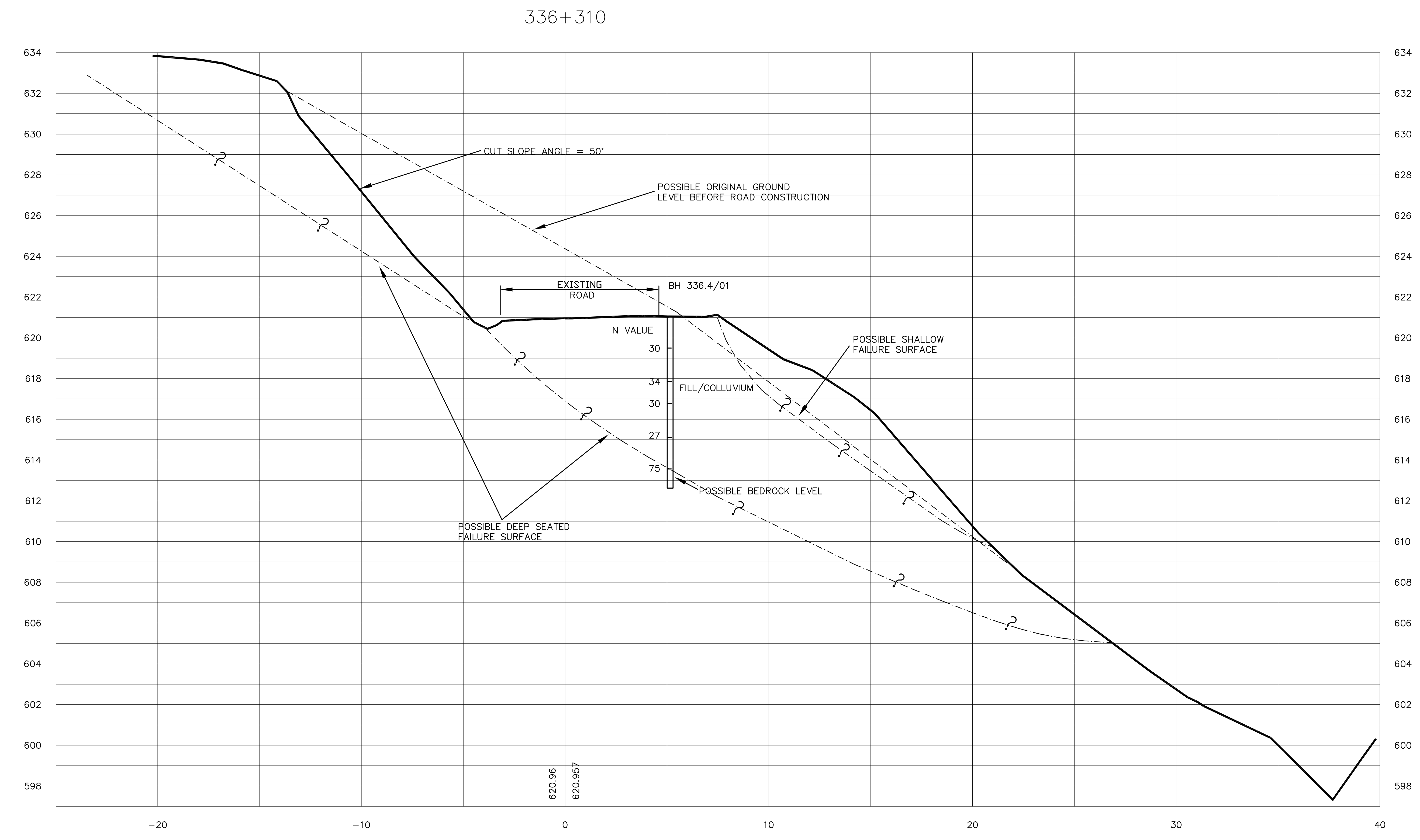

Project	Drawing Title			
MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	ROAD 13 N - KM 336+310 CROSS SECTION	108031/DWG/501		
		Scale at A3 : 1/200		
		Drw	App	Rev A
		Chk	Date	Date Jan 09

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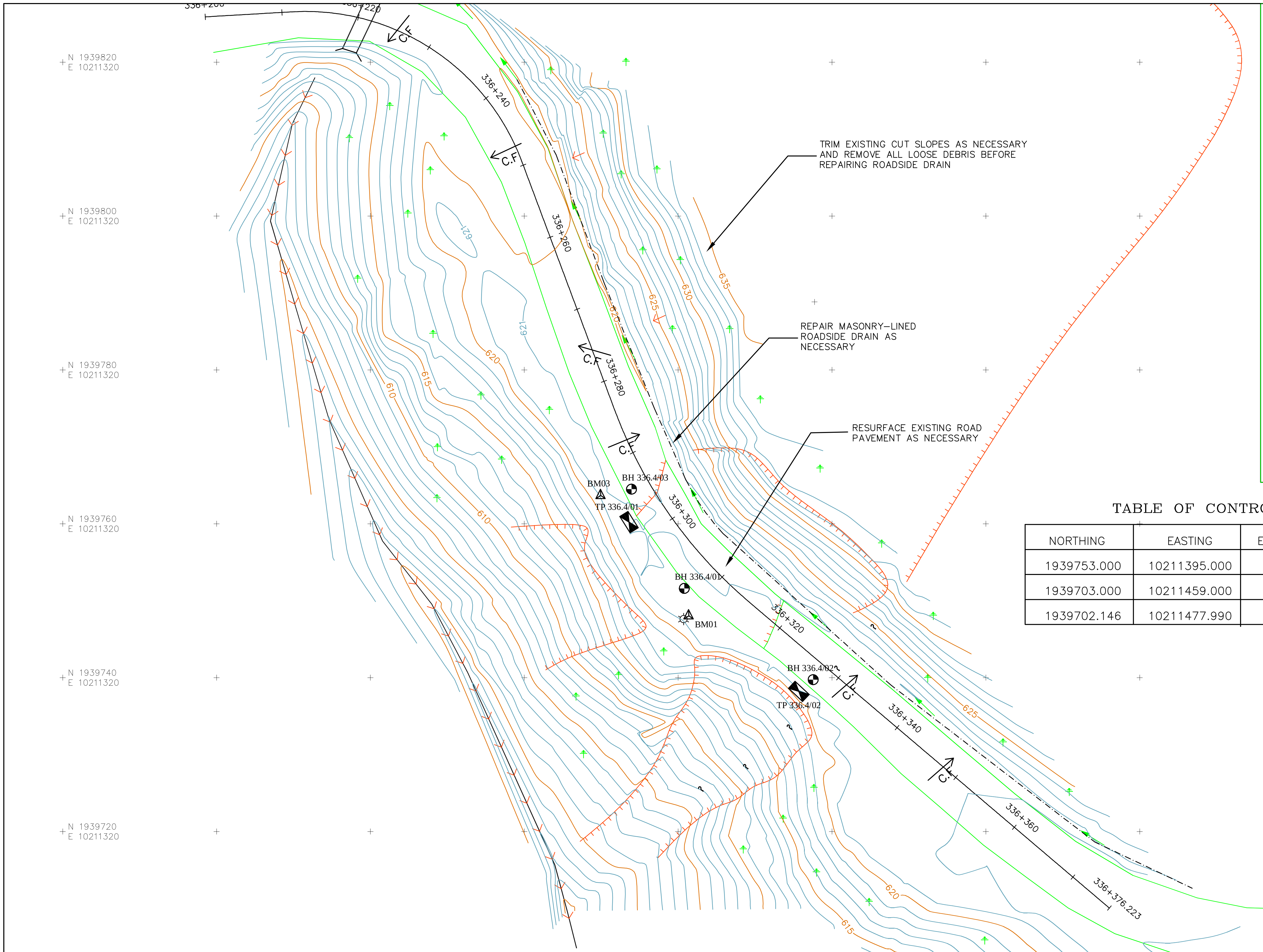

KEY

- VEGETATION
- LANDSLIDE SCAR
- BREAK IN SLOPE
- TENSION CRACKS
- ROAD SIDE DRAIN
- GROUND INVESTIGATION BOREHOLE
- ROAD CROSS FALL
- RILLS/EROSION
- 45° SLOPE INCLINATION
- DOUBLE POLE SIGN
- SINGLE POLE SIGN
- TREE >30 cm
- BENCHMARK
- ELECTRIC POLE
- RETAINING WALL
- HOUSE
- FOREST
- BOREHOLE
- TRIAL PIT

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
1939753.000	10211395.000	621.010	BM5–1
1939703.000	10211459.000	622.789	BM5–2
1939702.146	10211477.990	623.340	BM5–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 336.4
RECOMMENDED REMEDIAL WORKS

108031/DWG/502

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date Jan 09

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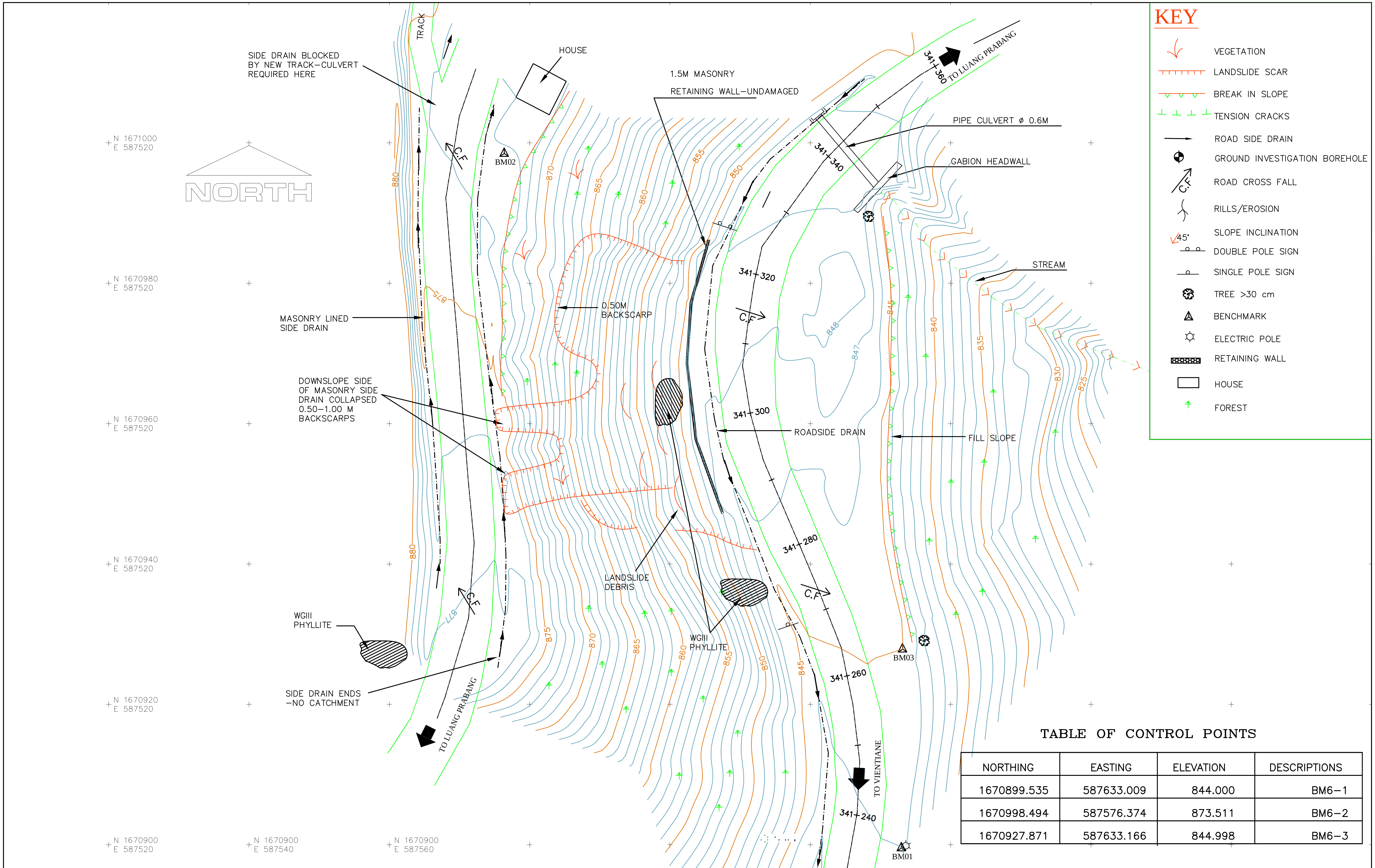

TABLE OF CONTROL POINTS

NORTHING	EASTING	ELEVATION	DESCRIPTIONS
1670899.535	587633.009	844.000	BM6–1
1670998.494	587576.374	873.511	BM6–2
1670927.871	587633.166	844.998	BM6–3

Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N - KM 341.2
SITE ASSESSMENT - ENGINEERING GEOLOGY

108031/DWG/600

Scale at A3 : 1/500

Drw	App	Rev A
Chk	Date	Date Jan 09

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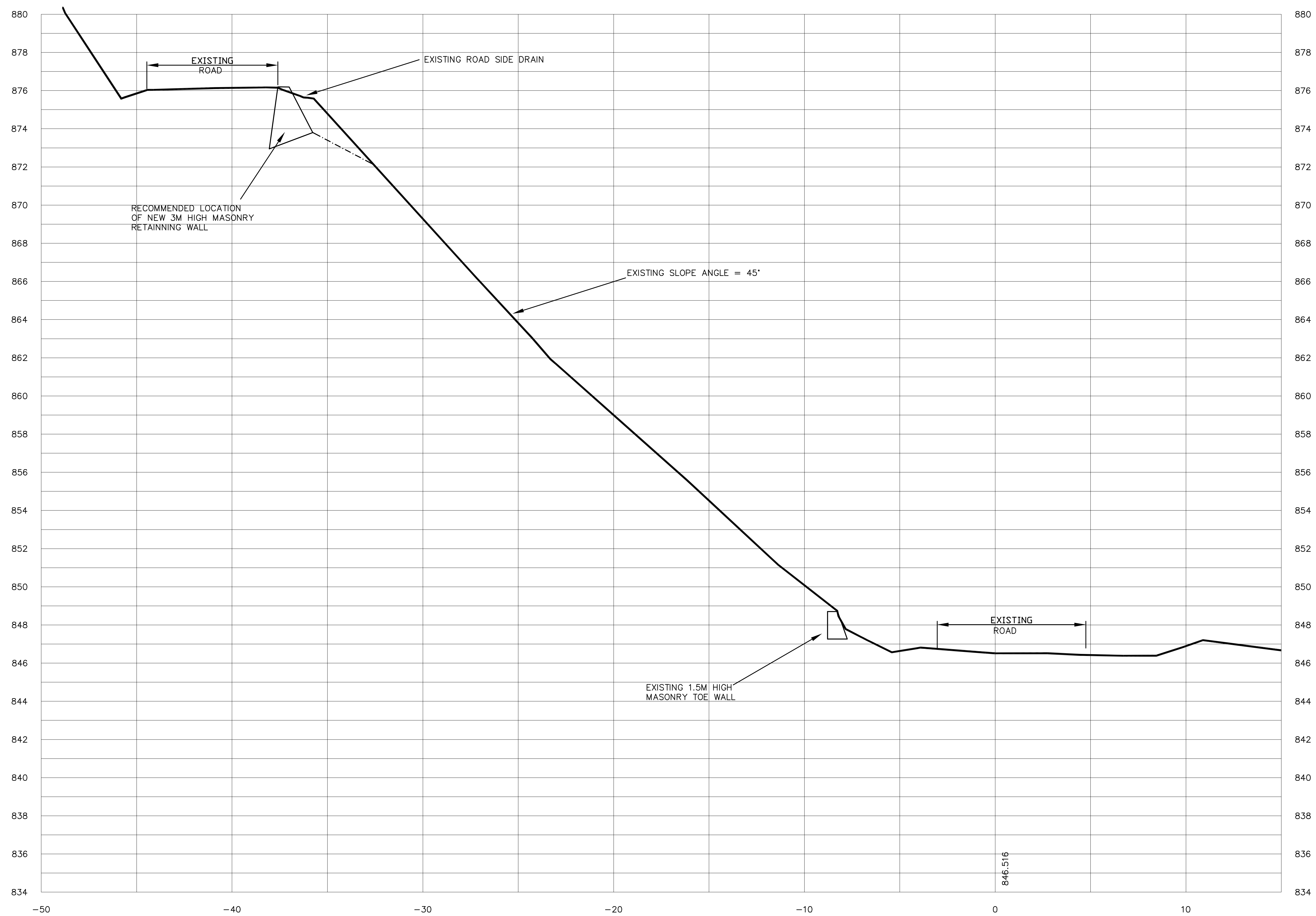
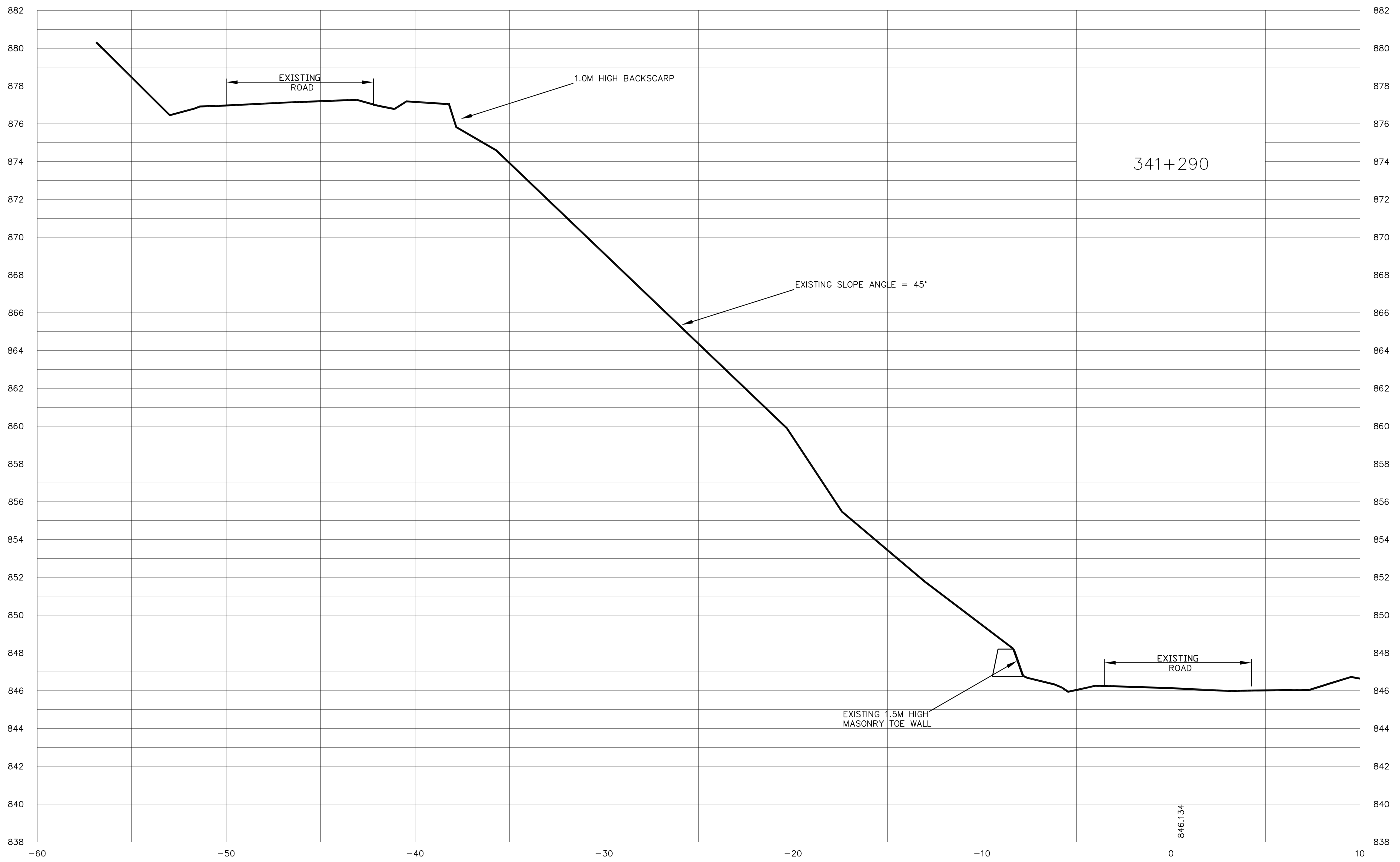


Project MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	Drawing Title ROAD 13 N, KM 341+297 CROSS SECTION	108031/DWG/601 Scale at A3 : 1/200 Drw / App / Rev A Chk / Date / Date Jan 09	ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ LAO CONSULTING GROUP SD & XP Consultants Group Scott Wilson www.scottwilson.com



Project

MPWT - SEACAP 21-03-DFID
SLOPE STABILISATION TRIALS
ON ROUTE 13N AND ROUTE 7

Drawing Title

ROAD 13 N, KM 341+290
CROSS SECTIONS

108031/DWG/602

Scale at A3 : 1/200

Drw	App	Rev A
Chk	Date	Date

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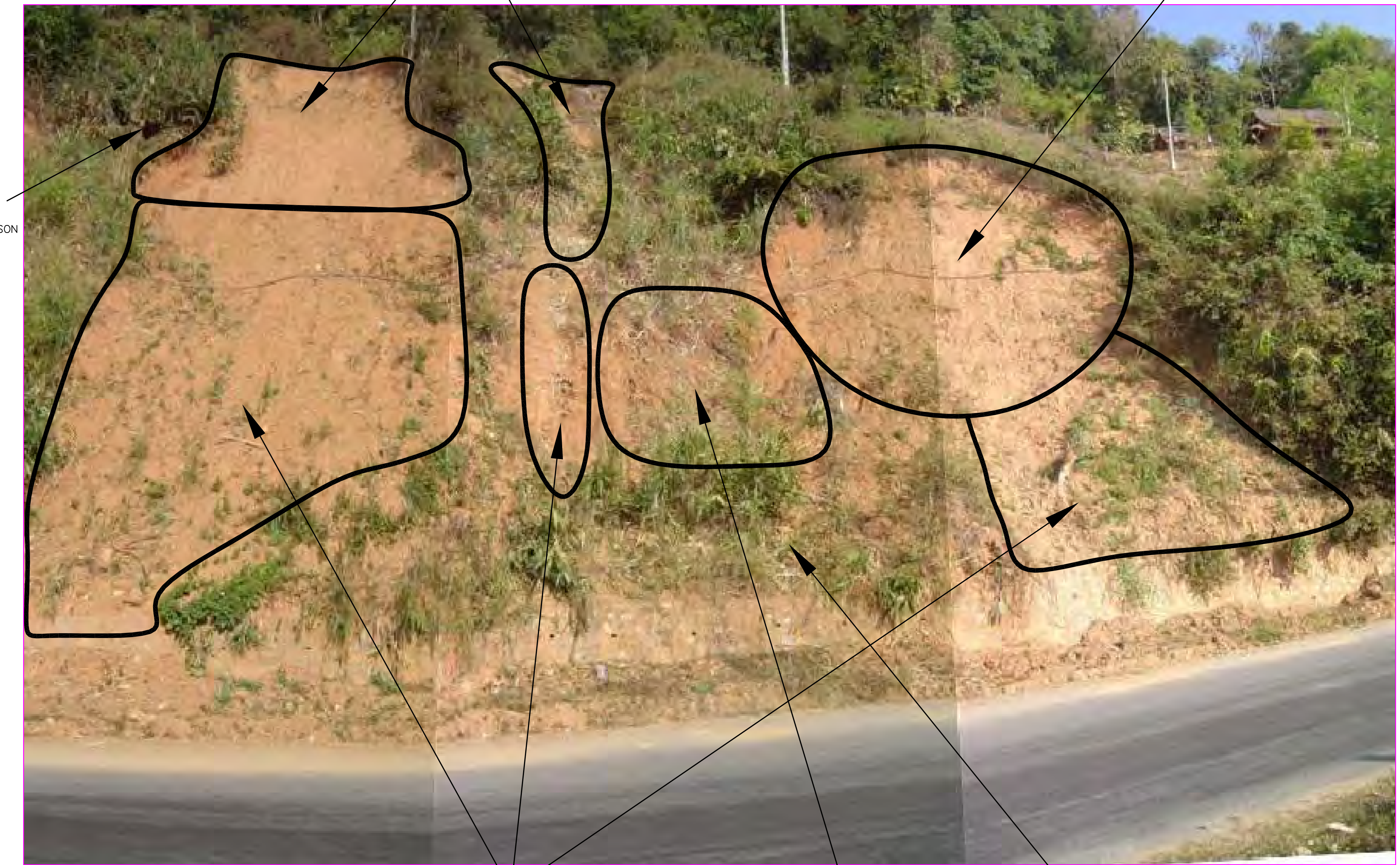

Project	Drawing Title	108031/DWG/602	
MPWT - SEACAP 21-03-DFID SLOPE STABILISATION TRIALS ON ROUTE 13N AND ROUTE 7	ROAD 13 N - KM 341.2 RECOMMENDED REMEDIAL WORKS	Scale at A3 : Drw / App / Rev C Chk / Date / Date Jan 09	ລາວ ຄອນຊາວຕິ້ງກຸບ ຈຳກັດ LAO CONSULTING GROUP SD & XP Consultants Group Scott Wilson www.scottwilson.com