APPRAISAL OF PERFORMANCE OF RECOMPACTED LOOSE FILL SLOPES

GEO REPORT No. 58

K.T. Law, C.F. Lee, M.T. Luan, H. Chen & X. Ma

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION

APPRAISAL OF PERFORMANCE OF RECOMPACTED LOOSE FILL SLOPES

GEO REPORT No. 58

K.T. Law, C.F. Lee, M.T. Luan, H. Chen & X. Ma

This report was originally produced in July 1998
under Consultancy Agreement No. GEO 14/97

First published, September 1999

Prepared by:

Geotechnical Engineering Office,
Civil Engineering Department,
Civil Engineering Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

This publication is available from:

Government Publications Centre,
Ground Floor, Low Block,
Queensway Government Offices,
66 Queensway,
Hong Kong.

Overseas orders should be placed with:

Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central,
Hong Kong.

Price in Hong Kong: HK$34
Price overseas: US$7.5 (including surface postage)

An additional bank charge of **HK$50** or **US$6.50** is required per cheque made in currencies other than Hong Kong dollars.

Cheques, bank drafts or money orders must be made payable to
The Government of the Hong Kong Special Administrative Region

PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
September 1999

FOREWORD

Since 1977 more than 200 loose fill slopes in Hong Kong have been upgraded under the Landslip Preventive Measures Programme. Approximately half of these upgraded slopes involved recompaction of the top 3 m in accordance with the recommendations of the 1976 Independent Review Panel for Fill Slopes. Surface recompaction has become the standard approach for rectifying substandard loose fill slopes where site conditions permit.

The main objective of this study is to carry out a systematic review of the performance of loose fill slopes upgraded using the surface recompaction technique and to review the adequacy of the recompaction approach. The study was carried out by a research team led by Professor C.F. Lee and Professor K.T. Law of the University of Hong Kong as consultants to the GEO under the Consultancy Agreement No. GEO 14/97. Mr K.K.S. Ho and Dr D.O.K. Lo of the Special Projects Division administered the consultancy.

The study has concluded that there is general improvement in the performance of the slopes after recompaction. The constraints and difficulties associated with the application of the recompaction method are generally surmountable and the hazard potential appears to have been reduced. Areas which require further attention or improvement are suggested by the consultants.

This Report, which contains the main text, is Volume 1 of the Main Report Series. Appendices 1 to 3 are contained in Volumes 2 to 5 which are available for inspection in the Civil Engineering Library.

P.L.R. Pang
Chief Geotechnical Engineer/Special Projects

EXECUTIVE SUMMARY

Many loose fill slopes in Hong Kong have been upgraded by recompacting the top 3m since 1977. This method originated from the recommendations of the 1976 Independent Review Panel for Fill Slopes. This practice has now become standard approach should the site conditions permit.

A review of the method has been conducted with the aim to assess the long term performance of these upgraded slopes, the practical problems in applying the method, the potential hazards and the possible improvements.

The study involves gleaning over files (up to 1996) at the Geotechnical Engineering Office (GEO) and contacting local consultants and government engineers for their experience. The information coming from these two sources tends to support each other. Together they show that the recompaction process produces a marked improvement on the performance of the slopes and the associated retaining walls. Some areas, however, need further attention. The constraints and difficulties associated with the method are surmountable and the hazard potential appears to be reduced.

The findings of the study can be summarised as follows:

1. There is a marked improvement in the long term performance of the fill slopes after recompaction. The recompaction of the top 3 m of fill leads to reductions in the settlement and horizontal movement problems. The slope cover performs much better after the LPM works due to better treatment of the cover and the smaller movement. Surface drainage systems are also performing better as they break up less frequently.

2. It should be recognised that recompaction does not completely eliminate the problems mentioned in Conclusion 1. Of particular importance is that cracks continue to develop especially in the transition zone between the uncompacted and the recompacted fills. It is recommended that criteria be established on the type, magnitude and location of the cracks to guide inspectors to identify potential problems and the need for remedial or preventive actions.

3. There is no improvement in the problem of blocked drainage which is the most frequently recorded problem in the long term performance. In fact the problem seems to deteriorate slightly after the LPM works, probably due to the more frequent use of vegetated cover. This problem can be serious as blocked drainage can lead to erosion of the slope. The problem, fortunately, is not difficult to be addressed. Regular inspection and maintenance will pay significant dividends here.

4. No improvement has been observed on the problems of groundwater seepage and leakage from water carrying services after the LPM works. This might be an indication of the poor performance of the drainage layer behind the recompacted fill. Since this drainage layer plays an important role in the performance of the slope, measures have to be taken to ensure that it performs adequately. Such measures may include the strengthening of construction

control to prevent contamination of the drainage layer and the use of suitable prefabricated geosynthetic drainage material.

5. Only two out of the total of 128 recompacted fill slopes have been reported to have failed over the last twenty years (not counting another two that failed in connection with water main bursts). Both failures involved very small volumes (1 to 2 m^3) that might be called erosion. Comparison with pre-GCO fill slope failure rate and considering appropriate facts, it is concluded that there is a noticeable drop in the failure rate of fill slopes after the LPM works.

6. Inadequate drainage during construction is the biggest problem as revealed by the records. This is somewhat different from the survey of the consultants who indicated that the stability of the temporary cut is the most serious problem. These two problems however are related in that they stem from too much rain water on the site. Together they give rise to the most common construction hazard in the form of erosion and washout failure. The problems can be resolved by scheduling the construction in the dry season or by proper design if the wet season cannot be avoided.

7. Limited working space for stockpiling fill and manipulating machinery are the common concerns during construction.

8. There is a marginal reduction in the potential of deep-seated failure after the LPM works because in this case the potential failure surface lies mainly in the loose uncompacted fill. If the watertable in the original uncompacted fill slope can rise to a level within the top 3m, a beneficial effect will occur in reducing the likelihood of a deep-seated failure in the subsequently recompacted slope. In this case the presence of the drainage layer placed underneath the top 3 m of recompacted fill will limit the rise of the watertable.

9. The recompacted soil will be unlikely to liquefy. The liquefaction potential of the underlying loose fill will be reduced because of the presence of the recompacted surface and the drainage layer. Together they reduce the amount of rain water infiltration and restrict the watertable rise to 3m below the surface.

10. Preliminary assessment using the updated seismic information for Hong Kong suggests that there is a significant improvement in the factor of safety after the LPM works. The safety factor of a loose fill slope before the LPM works in Hong Kong will momentarily drop below 1.0 for a ground motion of 10% exceedence over 50 years. This does not necessarily imply the slope will fail because of the momentary nature of the seismic force. However, a recompacted fill slope will have a safety factor exceeding 1.0 in similar conditions.

11. For a similar earthquake condition, the preliminary theoretical assessment shows that there is a significant rise in earth pressure on the retaining wall attached to the recompacted fill slope compared to that under static condition.

12. Other secondary recommendations and suggested improvements are given in Section 10.

CONTENTS

Page No.

Note: * denotes Appendices 1 to 3 are contained in Volumes 2 to 5 which are available for inspection in the Civil Engineering Library.

1. INTRODUCTION

Rapid economic development in Hong Kong in the 1950's and 60's brought about abundant construction activities for the provision of housing and infrastructures. Many of these activities involved cutting of slopes and filling of valleys. A shortage of skilled labour and resources at that time resulted in a construction practice that might be considered undesirable by today's standard. Consequently, a series of disastrous landslides occurred in the early and mid 1970's (Government of Hong Kong, 1977).

Following the 1976 Sau Mau Ping flowslide on a fill slope, an Independent Review Panel was set up by the Hong Kong Government for the recommendations of appropriate actions. To remedy existing dangerous fill slopes, the Panel made a series of recommendations, the pertinent sections of which are discussed below.

"The Panel considers that the minimum treatment would consist of removing the loose surface soil by excavating each suspect slope to a vertical depth of not less than 3 metres, and recompacting to an adequate standard. This recompaction along the slope and beyond the crest must be done in accordance with the recommendations of Section 5 following the requirements for new fills. Drainage of the fill behind the recompacted surface layer must also be provided at the toe of the slope."

It should be noted that the recompacting of the top 3m of soil and the associated surface treatments and drainage provisions are considered the minimum requirement "in order to eliminate incidents similar to those at Sau Mau Ping." In current practice, while this recommendation is generally followed for recompacting a slope, the thickness of recompaction seldom exceeds 3m.

For conducting the recompaction, the Panel also recommends that: "All remedial recompaction should start from the top of the slopes. If treatment of the entire slope has not been completed by the onset of the rains then, provided that the upper portion has been prevented from collapsing, the failure of the lower portion should not have such disastrous consequences. As a temporary measure only, incomplete portions should be covered with heavy canvas, properly secured, and regularly inspected in order to minimize infiltration during a rainstorm. It should be emphasized that this is purely an emergency measure and in no way reduces the need for the reconstruction discussed above."

The rationale for commencing the recompaction from the top of the slope is stated in this recommendation. In reality, however, this practice is impractical and may cause other types of problem as shown in a case record in Section 7. Therefore, all recompaction works have been conducted from the bottom up.

The current practice in Hong Kong for upgrading existing loose fill slopes has been described in the Geotechnical Manual for Slopes (1984) and by Lam (1980), Bowler and Phillipson (1982), and Yim and Siu (1997) and is summarised as follows.

The top 3m of loose fill is first excavated. Depending on the quality of the existing fill, it might be reused or borrowed material may have to be imported for recompaction. The process consists of placing fill in horizontal layers of a thickness ranging from 300mm to 400mm. The details of benching for placement of fill on existing ground are shown in Figure 1.1.

Included in the process is the construction of a drainage layer or granular filter behind the recompacted fill for groundwater control. The slope angle of the recompacted slope generally lies around 33°. In some cases, berms and/or toe retaining walls are incorporated to achieve the desired slope angle. A typical filter arrangement for a fill slope is shown in Figure 1.2.

In this study, a systematic review of the performance of the recompacted slopes is conducted. It is aimed at understanding how these upgraded slopes perform at the long term condition, the difficulty in using the method, the possible hazards and improvement associated with it.

The study involves gleaning over files at the Geotechnical Engineering Office (GEO) and contacting local consultants for sharing their expertise. The information coming from these two different sources tend to support each other. Together they show that the recompaction process produces a marked improvement on the observed performance of the slope and the attached retaining wall. The constraints and difficulties appear to be surmountable for those slopes for which this recompaction method has been applied. For the long term hazard potential, analysis shows that the recompaction process leads to some marginal reduction in the potential of deep-seated failure, significant decrease in liquefaction potential, and improved performance of the slope and the retaining wall during a credible earthquake occurrence in Hong Kong. The review leads to some suggestions and recommendations for improving the application of this method.

2. OBJECTIVES

The objectives of the project are listed as follows:

a) to appraise the long-term performance of recompacted loose fill slopes by reference to the available records in the GEO and from other readily available sources,

b) to review the site constraints posed to the surface recompaction technique and examine the range of problems encountered during the construction phase,

c) to conduct a hazard assessment of loose fill slopes upgraded by surface recompaction and evaluate the adequacy of the standard practice, and

d) to identify areas requiring further improvement in the design, construction and risk management practice for loose fill slopes and recommend suitable improvement.

3. METHODOLOGY

The main component of this study is to review existing information and experience in recompacting loose fill slopes in Hong Kong. Therefore the sources of such information and experience have to be identified and the relevant materials have to be extracted for the review.

3.1 SOURCES OF INFORMATION

Six sources of information (up to 1996) have been used in this study. They are listed in the following:

a) Maps from the Survey Division of the CED and lists of recompacted fill slopes and failed slopes from the Special Projects Division of the GEO. The maps marked the locations of slope failures, the corresponding incident numbers and the feature numbers of slopes in the vicinity.

b) Hong Kong Rainfall and Landslides Annual Reports covering the period from 1982 to 1996.

c) Files in the Design, Works and District Divisions of the GEO. These files contain information on the design, construction and problems of the recompacted slopes.

d) Landslide Database system of the GEO. This system contains description of all the reported slope failures.

e) Practicing geotechnical consultants in Hong Kong. The local experience of this group of experts has been consulted through a survey.

f) Interview with geotechnical engineers of the GEO and other Government Departments for their experience in constructing and maintaining recompacted slopes.

3.2 INFORMATION FROM THE GEO

3.2.1 Identification of failed upgraded slopes

Two lists were given to our study team at the beginning of the project. The first list, shown in Table 3.1, contains the slope numbers of all the upgraded slopes by means of recompaction under the Landslip Preventive Measures (LPM) Programme. The total number of slopes in this list is 130. Out of this list, information for two slopes was not available. In the following, therefore, the total number of recompacted slopes is taken as 128.

The second list is shown in Table 3.2. It contains 421 incidents of failures which were indicated in the Landslide Incident Report as having possibly involved a fill slope. In this second list, only 50 slopes have been identified by a slope number. In other words, the majority of the failures have not been identified with a slope number.

In order to identify the registration numbers of the fill slopes that might be involved in the failure list, two efforts have been made. The first is to examine the maps supplied by the Survey Division of the CED. These maps show the locations of the failures, some with a slope number of the failed slope. This examination adds 74 slopes that can be identified with the failures in the second list.

The second effort is to study the annual reports on Hong Kong Rainfall and Landslides. Such reports are available for 1984 through 1996 and for selected rainstorms in 1982 and 1983. This study produces a summary of different types of failure as shown in Table 3.3. There is, however, no additional fill slope that can be identified for addition to the failure list.

The first (upgraded) list has been checked against the second (failure) list to find out which recompacted slopes have been involved in a failure. This exercise uncovered five failures associated with five slope numbers. Two of the failures occurred after the slopes had been recompacted, one during recompaction and two before recompaction. Two more failures after the LPM works were noted from the files at GEO.

3.2.2 Files from various Divisions of the GEO

Relevant files in GEO's Design, Works and District Divisions have been gathered and reviewed. The review of the files has been conducted at the GEO offices in Homantin and in Kowloon Bay.

To facilitate the review, a comprehensive review form has been devised as shown in Form 3.1. This form contains summarized information existing in the files. There are ten main items in the form. It is aimed at recording three main aspects of a recompacted slope. The first deals with the characteristics of the slope including slope inclination, slope height, slope surface condition, soil characteristics, groundwater condition, drainage condition, and surrounding development and human activities. The second lists the recorded problems during the design and the construction phases. The third focuses on fill slopes that suffered significant problems including failure during the long term condition along with the weather records. It should be noted that only a portion of the desired information is available for any given slope. The information gathered has been used to assess the various aspects of the performance of the recompacted slopes.

3.3 FILES FROM MAUNSELL GEOTECHNICAL SERVICES LTD. AND BINNIE CONSULTANT LTD.

Maunsell Geotechnical Services Ltd. and Binnie Consultant Ltd. are two consulting companies employed by the GEO to compile part of the New Slope Catalogue for Hong Kong. They have been inspecting and recording registrable man-made slopes/retaining walls. In the course of their assignment, they have inspected some of the 128 recompacted slopes. Therefore their files may contain useful information to this study. Our research team was permitted to study those relevant cases for which the registration is complete. A total of 47 recompacted slopes have been made available for our study, 39 from Maunsell Geotechnical Services Ltd. and 8 from Binnie Consultant Ltd. These cases are identified in Table 4.5.

3.4 SURVEY OF PRACTICING GEOTECHNICAL ENGINEERS

Information gathered in the above steps on constraints and problems during design and construction has been supplemented by conducting a survey among active geotechnical firms in

Hong Kong and relevant government departments. Shown in Form 3.2, the survey form has been sent out to twenty consulting firms and eight government departments.

3.5 INTERVIEW OF GEOTECHNICAL ENGINEERS OF THE GEO AND OTHER GOVERNMENT DEPARTMENTS

Interviews have been conducted with engineers from the Design, Works and District Divisions. In addition, telephone interviews have been conducted with the Government Departments responding to the survey.

3.6 COMPILATION OF INFORMATION

The information obtained above has been grouped together to understand the following issues:

1) The effectiveness of recompacting the slope in terms of long term performance.

2) The site constraints for the recompaction process.

3) The difficulties encountered during the recompaction process.

4) Potential landslide hazards involving both the short term and the long term conditions. Possible failures along slip surfaces at depths greater than 3 m, i.e. in the zone without recompaction, has also been investigated.

3.7 ANALYTICAL STUDY

To understand the hazards due to seismic activities, an investigation has been conducted on our present understanding of the potential seismic activities in Hong Kong and the engineering behaviour of the fill material before and after compaction.

3.8 IMPROVEMENTS

Based on an overall review of existing experience and data, measures and recommendations are suggested for the improvement and wider application of the recompaction method.

4. RESULTS AND DISCUSSION OF EXISTING RECORDS

The information from the files of the various offices of the GEO and from Maunsell Geotechnical Services Ltd. and Binnie Consultant Ltd. is combined for entry in the review form. The original completed review forms for each of the cases are given in Appendix 1.

4.1 LONG TERM PERFORMANCE

4.1.1 Long term observations

The information in the review forms for observations of the long term condition is summarized in Table 4.1 through Table 4.5. Table 4.1 describes the conditions of the slopes prior to recompaction. The geometry and the material properties of each slope are listed. This is followed by problems recorded in the files. The problems are related to drainage condition, seepage and leakage, slope cover, and displacement. The drainage condition refers to the condition of surface drainage system and weepholes. Some of these systems suffer from blockage due to vegetation and soil washed down from the upper part of the slope. Some were broken possibly because of differential ground settlement and/or poor construction quality. Seepage and leakage include groundwater daylighting mostly near the slope toe or leakage of water apparently from water mains and sewers. The surface cover for the slope may be in the form of chunam, sprayed concrete, vegetation or bare soil. Some of these have been observed to develop cracks or have been eroded. The displacement refers to both settlement or horizontal movement. The magnitude of displacement is not normally recorded in the files. For more detailed information on each slope, one can turn to Appendix 1.

Table 4.2 is similar to Table 4.1 except the information pertains to the slopes after the LPM works have been carried out.

Table 4.3 records the problems observed for the retaining walls before the LPM. The drainage condition refers to the drainage channels on top and bottom of the retaining wall and weepholes on the face of the wall. Cracking in the wall may be in the vertical direction or inclined from the vertical.

Table 4.4 is similar to Table 4.3 except it applies to the condition after the LPM programme.

Table 4.5 lists the specific observed problems of the slopes. The slopes inspected by Maunsell Geotechnical Services Ltd. and Binnie Consultant Ltd. are identified in this table.

4.1.2 Long term slope performance before and after slope recompaction

Figure 4.1a and Figure 4.1b show a comparison of the long term problems before and after the LPM works. The comparison is expressed in terms of percentage of the number of slopes having a certain problem to the total number of recompacted slopes. It should be noted that the number of slopes having a certain problem is based on the available records. A comparison of the percentage of the problem occurring before and after the LPM works gives some idea on the effects of the LPM works. The comparison shows that, after the LPM works, there is a marked improvement in terms of displacement and cracked surface cover. The problem of seepage and leakage is about the same before and after the LPM works. Both before and after the LPM works, the largest problem is the blocked drainage system. Surprisingly, the problem is slightly more severe after the LPM works.

The improvement on displacement problem is substantial. Reductions of 73% and 43% are noted in the reported settlement and horizontal movement problems, respectively. This improvement seems reasonable as recompaction has reduced the compressibility of at least the top 3 m of fill.

There is about a 23% reduction in broken surface drainage systems after the LPM works. Two possible causes are responsible for the drainage system to break: poor quality work and movement of the soil supporting the drainage system. The records show that, 18% and 15%, respectively before and after the LPM works, of the broken drain cases are observed in association with reported settlement and/or movement problem. These numbers are probably on the low side as there have been no precise monitoring programme for the cases. Only fairly obvious settlements and/or movements are entered into the records. Nevertheless, these relatively low numbers suggest that a significant portion of the broken drains are caused by poor quality work. Thus, it will be cost effective to improve construction quality for reducing drain damage. Flexible joints may be useful for fills that are still settling.

The slope surface cover also performs much better after the LPM works. There are reductions of 63% and 38% in eroded and cracked covers, respectively. This improvement is consistent with the better treatment of the cover involved in the LPM works.

The lack of improvement on the seepage and leakage problem may indicate poor performance of the drainage layer placed behind the recompacted fill. In view of the importance of this drainage layer, as discussed in Section 9, for reducing the likelihood of a deep-seated failure and liquefaction potential of the underlying loose fill, effort must be directed in checking the effectiveness of this drainage layer.

The blockage of surface drainage and weepholes is usually caused by soil washed down from the upper part of the slope and by vegetation. Recompaction does not affect these causes and hence it will not reduce the blockage problem. In fact, there is a tendency to use hydroseeding for a vegetated cover during the LPM works. This may cause a higher possibility and hence a more severe problem of blockage as the vegetation takes root and becomes mature.

4.2 FAILURES OF RECOMPACTED SLOPES

One way to assess the effectiveness of the recompaction technique is to compare the rate of failure before and after the LPM works. Before this can be done, it is necessary to discuss briefly each of the failed recompacted slopes. Pertinent information and incident reports of the four failures are given in Appendix 3.

The first failure was associated with slope number 11NE-A/F12, at Tze Wan Shan Road. The volume of the failure was about 6m3. Several problems were plaguing the project ever since the beginning of the recompaction process. One of which was leakage of water from underground services. This problem was never clearly fixed. About a year after the upgrading works, the water main burst, resulting in a washout failure of the fill slope. Since the water main burst had a lot of destructive power to any type of slope, this failure cannot be ascribed to weakness inherent to the recompaction technique.

The second failure occurred during heavy rainfall at Tin Hau Temple Road with slope number 11SE-A/F61. This was a small failure of volume of about $2m^3$. In the records, the terms erosion and washout had both been used to describe this failure. A letter by an engineer of the Island Division of the GEO mentioned that a section of the U channel on the slope shown on design drawing was missing. The letter is attached as part of the pertinent information for this slope in Appendix 3. Surface water therefore could not be intercepted during the heavy rainfall and ran down the slope, gaining high velocity to erode the lower part of the slope. Similar failures at the site had been reported repeatedly following the completion of the LPM works and prior to this recorded incident. It appears therefore this erosion was possibly caused by the missing U channel.

The third failure occurred at slope number 7SW-D/FR10, Vista Do Vale, Tai Po Road. The failure occurred three months after the recompaction works. The volume involved in the failure was only 1 m^3. It can hardly be called a slide. The small volume of failure and the short time between the incident and the completion of upgrading, suggest that the probable cause of the incident was the presence of a small soft pocket not well compacted during the LPM works.

The fourth failure was located below Hui Kwong Street with slope number 11NE-D/F10. This slope was recompacted in 1977, one of the earliest loose fill slopes subjected to the recompaction method. The failure occurred in April, 1984, and was associated with a water main burst. The volume of the failed mass was about 160 m^3. This volume is considered major but the cause of failure is not due to weakness of the recompacted slope under the normal operating condition.

According to Wong and Ho (1997), the annual frequency of failure of pre-GCO (GEO) fill slope is 1 in 525. The Sau Mau Ping mud avalanche is an example of such failures that caused major damage. This figure was calculated based on all fill slope failures for which an incident report has been filed. Failures involving water main bursts were not included. Using the same basis (i.e., not counting the two failures associated with water main bursts), we find therefore only two failures of fill slopes after recompaction. This is statistically a small number but that is all that we now have. An approximate rate of failure can be obtained by considering the following assumptions:

(1) There is a population of 128 recompacted slopes.
(2) Recompaction of the top 3 m of fill was first used in 1977.
(3) There has been roughly a constant number of fill slopes recompacted each year.

The average age of a recompacted slope is ten years based on the above simplified assumptions. The annual rate of failure of recompacted fill slope is therefore equal to 1 in 640 years. By comparing with the pre-GCO slopes, this rate is only marginally improved. However if one looks at the two failures more closely, a clearer picture emerges.

The two failures involved very small volumes and might be traced to questionable construction workmanship. The missing section of U channel in slope number 11SE-A/F61 and the soft soil pocket in slope number 7SW-D/FR10 could have been avoided if the recompaction process had been conducted properly. Hence the failures might not have occurred. Consequently, one may not be able to blame a properly executed recompacting process being inadequate in preventing the failure. In other words, the actual rate of failure could have been much smaller. Considering these facts, one could say that there is a noticeable drop in the failure rate of the recompacted slopes.

4.3 LONG TERM RETAINING WALL PERFORMANCE BEFORE AND AFTER SLOPE RECOMPACTION

Figure 4.2a and Figure 4.2b show the types of problems related to retaining walls associated with the recompacted slopes and their frequency of occurrence. The percentage is calculated using 128 as the base even though some recompacted slopes do not have a retaining wall. The exact number of slopes having a retaining wall is not exactly known from the records as the presence of a wall may not be mentioned. The use of 128 is considered nominal. The data show the following observations related to the long term performance of the retaining wall.

Similar to the slopes, the most common problem is blockage of drainage system which includes weepholes and surface channels at the top and the bottom of the wall. Again there is hardly any difference in problem intensity before and after the LPM works. The same reasoning for slopes probably applies to retaining walls.

Apart from drain blockage, other performance aspects have been improved after the LPM works. There is a slight decrease in broken drainage system, a moderate decrease in seepage/leakage problem, and cracked walls, and a substantial decrease of wall movements.

4.4 LENGTH OF TIME FOR PROBLEM OCCURRENCE

Table 4.5 lists the slopes for which the construction date and the date of first recording a problem are both known. This provides an approximate length of time when problems start to develop after the completion of the LPM works. The information is summarized in Figure 4.3. This figure shows the annual average number of slopes with one or more recorded problems on a five year basis. The data suggest that there is a peak occurrence of problems during the period between 5 to 10 years after the LPM works. However, recognizing the incomplete nature of these data, one should not draw concrete conclusions without more data and investigation.

4.5 SITE CONSTRAINTS AND CONSTRUCTION PROBLEMS

A summary of the records on site constraints and construction problems is given in Figure 4.4a and Figure 4.4b. It should be noted that these are problems actually encountered and recorded. There may be other possible problems that have given rise to serious concerns such that the method of recompaction has not been used. The percentage in the table and the figure refers to the number of slopes with a certain problem divided by the total number of slopes with records of problems.

4.5.1 Site constraints

Five main site constraints have been identified: (1) difficult access, (2) limited working space, (3) mature trees, (4) road closure and traffic problems, and (5) underground utilities. It appears that these constraints do not seem to be serious as only about 10 % or less are noted with the recompacted slopes. One possible explanation is that, if these site constraints had been serious, the option of recompacting the slope probably might not have been chosen.

4.5.2 Construction problems

Seven main problems have been identified during construction: (1) failure of temporary cut, (2) site accidents, (3) cracks and movements, (4) severe runoff along gullies and washout, (5) heavy rain during construction, (6) inadequate drainage system during construction, and (7) quality control in the compaction process.

The records show that the largest problem is inadequate drainage system during construction followed by, heavy rain during construction, and cracks and movements. It is significant that all these three are associated with rainfall. A check on the timing of the 128 recompacted slopes reveals an interesting fact. There are a total of 97 cases with recorded timing for the construction. 94 cases or 97% of them were constructed wholly or partially during the wet season. Admittedly, in some of these cases, only preparation and finishing work was conducted in the wet season. The fact remains that there were a large number of cases in which part of the recompaction work was carried out in the wet season. That is the reason why the rain-associated problems stand out as the most prominent. This observation shows that it is highly desirable to complete the recompaction during the dry season. If the scale of the work requires construction period be longer than the dry season, proper measures against rainfall should form an integral part of the overall design for the upgrading works.

5. RESULTS FROM SURVEY

Eighteen out of twenty companies responded to our survey. One company gave two separate replies from different engineers. The return rate is more than 90%. As these firms collectively represent the majority of the geotechnical consultants in Hong Kong, their views therefore reflect the current thinking of the geotechnical profession on the questions being surveyed. The names of these firms who have generously spent time in filling out the survey form are given in Table 5.1.

All the eight Government Departments replied to our survey. Four of them replied by filling out the forms. Again their time is appreciated and their names are given in Table 5.2. The other four Departments, however, informed us that they had not been engaged in the maintenance and construction of fill slopes and therefore were not able to fill out the survey form.

Besides indicating their views by the preset choices in the survey, the respondents also added comments to further explain their replies. The results of their replies are therefore presented in two ways in this report. First, the results of the preset choices are shown in Figure 5.1 to Figure 5.4. Second, the additional comments are collected in Table 5.3.

5.1 LONG TERM PROBLEMS OF RECOMPACTED SLOPES

Figure 5.1a and Figure 5.1b summarize the long term problems of recompacted fill slopes from the consultants' perspective. They indicate that the most common problem is settlement and creep movement. This is followed in order by cracks on slope cover and the uncovered ground, blocked drainage, leaky services, and problems arising from sources outside the boundary of the slopes.

Additional comments on the long term slope performance include: (1) tension cracks at interface between the old and the new fill, (2) cracks in drainage and concrete slab on slope berms, and (3) blocked drainage by vegetation.

Apparently the results here are somewhat different from those as obtained from the existing records which show that drain blockage is the most common problem. A closer look at the response of the consultants reveals that the engineering profession is well aware of the drain blockage problem. According to the survey, 43% of the reply acknowledges the problem of drain blockage as compared to 61% for the settlement problem. The additional comments indicate both drain blockage and settlement are important long term problems. It may be concluded that both the engineering profession and the maintenance personnel concur that drain blockage is a common problem.

The fact that the consultants consider settlement is the most frequent problem is probably due to two reasons. The first is the loose fill beneath the recompacted fill will continue to creep because of the ongoing secondary compression even after the recompaction process. This will be reflected on the surface as cracks and settlement. Indeed the recompacted top layer has a higher tendency to crack, as it is stiffer and more brittle than the underlying loose fill. Second, there is always a transition zone between the recompacted and the uncompacted fill at the edge of recompaction zone. Cracks often develop in this zone because of the different behaviour of the adjoining soils.

5.2 SITE CONSTRAINTS AND CONSTRUCTION PROBLEMS

According to the survey, the most serious construction problem is lack of space for stockpiling fill material as shown in Figure 5.2a and Figure 5.2b. This is followed by three problems of equal importance: (a) difficult access, (b) lack of space of manipulating construction equipment, and (c) removal of mature trees. Failure of the temporary cut is next in seriousness followed by road closure and traffic problem, and accidents related to the recompaction process.

In the additional comments, 4 groups of problems have been mentioned. The most frequent one is the stability of the temporary cut and the associated rainy weather. The supply or disposal of fill follows next. Quality control on material and supervision is the next. This is followed by a number of problems that can be considered included in the preset choices or related to good practice.

By combining the preset choices and the comments, it appears that the engineering profession’s major concern of construction problem is the stability of temporary cut particularly during bad weather.

The concern of the stability of temporary cut may not be remote to the observed number 1 problem from the existing records, i.e., drainage system during construction. Both concerns stem from abundance of rainfall at the construction site. Hence avoidance of the rainy season for construction or designing measures to abate the adverse effects of the rain is highly desirable.

5.3 POTENTIAL HAZARDS

Figure 5.3a and Figure 5.3b show the consultants’ view on potential hazards or failures of recompacted fill slopes. Erosion leading to failure is their highest concern. This is followed by washout failure, deep-seated failure and liquefaction failure.

The additional comments emphasize the need for good practice to avoid long term problems or hazards. It is of interest to note that half the comments contend that hazards can normally be avoided if adequate compaction is carried out.

5.4 OTHER ISSUES

Figure 5.4a and Figure 5.4b show the consultants’ experience regarding the appropriate thickness of the fill to be compacted. The majority consider that the current practice of compacting the top 3 m is just right. On the question whether the thickness of the recompacted fill should depend on the failure consequence, the survey shows almost a dead heat with a slim majority of no.

6. RESULTS FROM DISCUSSION WITH GEOTECHNICAL ENGINEERS

Valuable insights have been gained by discussions with the following engineers who have many years of experience in upgrading slopes using the recompaction technique:

Mr. A. Watkins, Works Division, GEO
Mr. N.F. Chan, Works Division, GEO
Dr. A.C.O. Li, Works Division, GEO
Mr. C.M. Mak, Design Division, GEO
Mr. K.F. Man, Island Division, GEO
Mr. F.H. Li, Housing Department
Mr. H.W. Lam, Highway Department

In general the discussion centred around the four main areas of this study, i.e. long term performance, construction problems, hazards and possible improvement to current practice. While these areas have been covered in the survey and in the GEO files, the following summarizes more ideas in point form. Important issues related to some of these points will be discussed in later sections.

6.1 LONG TERM PERFORMANCE

- Catchpits are a nuisance. They tend to interrupt water flow and collect rubbish.
- The four Government Departments who responded to our survey claimed that they conduct regular inspection and maintenance of the slopes under their jurisdiction in accordance to the recommendations in Geoguide 5 (GEO, 1995).

6.2 CONSTRUCTION PROBLEMS

- The stability of temporary cuts either at the top of the slope or for access on site is a serious concern.
- Rockfill or even concrete has been used in place of compacted fill in several occasions where the slope is small.
- While laboratory registration with HOKLAS has improved quality of compaction control tests, there is still concern that supervision for testing needs improvement.
- Recompacting a slope with a busy highway at the top is always a problem. Because of the lack of room, a steep temporary cut is often made at top of the slope for the recompaction to start. Since the stability of this steep temporary cut is marginal, some form of strengthening is needed. Mini-piles or temporary soil nails have been used for the strengthening. While these are being installed, the loose fill at the top will settle and consequently, cracking develops at the pavement of the highway.
- The most likely place to form cracks is at the transition zone between the old loose fill and the new compacted fill.

6.3 HAZARDS

- Deep-seated failures, though a concern, have not been recorded for loose fill slope based on the experience of the engineers interviewed.
- On the question of liquefaction, the response varies from not sure to possible.

- Most do not think earthquake is a problem to loose fill stability in Hong Kong.

6.4 IMPROVEMENTS

- There is a receptive mood to use reinforced earth within the recompacted zone. It is believed that a steeper slope (1.4 to 1) may be possible. This is desirable for tight spots.
- There is a desire to reduce the thickness of the recompacted zone for ease for constructing the temporary cut. However, most feel that 3 m is about right. Some do feel that 3 m thick is acceptable for high slope but for small slope the requirement may be relaxed.
- Dynamic compaction had been tried on Hong Kong loose slopes. It is recognized that application is limited as most slopes are close to developed areas.
- Crib wall with backfill.
- Soil nailing to strengthen the loose fill.

7. A CASE HISTORY

This feature is located at the Lion Rock Tunnel Road with a slope number of 7SW-D/F53. Though this slope did not fail after recompaction, the problems encountered were as serious as a major failure. The main problem was the development of cracks at various parts of the slope after recompaction.

7.1 SITE DESCRIPTION

This slope is located at the eastern embankment of the Lion Rock Tunnel Road. Before recompaction, the slope angle averages at 35°, its height varies from 2 to 12 m and its length is about 200 m. About 70 m of this slope overlooks the 2-storey village houses of the Tsang Tai Uk.

Ground investigation indicates that the in situ dry density is as low as 58% of the standard compaction density. Because of this low degree of compaction and the close proximity of the houses, upgrading of the slope was carried out between November 1994 and June 1995. The upgrading works consisted of removing and recompacting the top 3 m of fill, reinstatement of the surface drainage system, hydroseeding and replanting the slope surface. To maintain operation of the Lion Rock Tunnel Road, the temporary cut at the crest was stabilized by 2 rows of mini piles that went all the way into the underlying alluvial deposits.

7.2 GEOLOGY

The slope consists of a soft sandy silt fill material of a maximum thickness of 11 m. This is underlain by two layers of alluvial deposits. The upper layer is a 2 m thick loose silty fine sand. The lower layer is composed of soft clay.

7.3 CHRONOLOGY OF RELEVANT EVENTS

The GEO started the upgrading works in November 1994. The mini piles were installed and the fill was excavated. About a month later, four 132 kV life cables were found buried along the toe of the slope. China Light and Power Company (CLP) admitted that they did not furnish the GEO this information at the time when the GEO asked for the utility information earlier. After some discussion, it was decided that CPL would dig a trench to locate the cable and backfill the trench to the required compaction standard. This would be followed by recompaction of the fill above the trench by the GEO. However, the backfilling of the trench was not up to standard. Consensus is reached that the GEO will continue the recompaction work and CPL would return to the site to recompact the trench from July 1995 to September 1995. During the recompaction of the trench, no records were available on the construction sequence nor was there any information on measures taken during a severe rainstorm in August 1995. In January 1996, extensive cracks were noted on the slopes. At the time of writing this report, remedial measures are still being planned. One of the options is to redo the whole slope by another round of recompaction.

7.4 LESSONS LEARNED

The first obvious lesson that can be gained in this case is to avoid excavating the toe once the upper part has been compacted. Such excavation will increase the shear stress in the slope. The increased shear stress will cause the compacted fill to dilate, leading to a looser state. The heavy rain will aggravate the situation if proper measures are not taken. Similar problems will be developed for any slope if the original recommendation by the Independent Review Panel to recompact starting from the top is followed.

Another lesson to learn is to watch out for soft underlying clays. According to some GEO engineers, it is suspected that the installation of the mini piles has induced significant excess pore pressure in the alluvial deposits. Such a notion is reasonable although the piezometers on site were not located at the right place to yield information to support or defeat it. As the excess pore pressure dissipates, settlement follows. The settlement contributes to the development of cracks on the slope surface. It is prudent, therefore, to assess possible consolidation effects arising from loading a soft clay.

This case emphasizes the need of good supervision for geotechnical work. The original failure of compacting the trench to standard and the lack of records of work procedures and progress are signs of poor site supervision of the utility company. Good supervision in the first place would probably have avoided the problem and helped in ascertaining the precise cause of the problem if it occurs.

8. BURIED WATER CARRYING SERVICES AND EMERGING ISSUES

8.1 BURIED WATER CARRYING SERVICES

The Independent Review Panel is clear on measures required for buried water carrying services to be placed in new fill slopes. It recommends that " ...all drains, services and other pipes should be prohibited from being placed in fill nearer to the crest of the slopes than a distance equal to its vertical height. Where such a restriction cannot be met then it is recommended that the pipes be laid in shallow lined channels with continuous covering, suitably drained and with inspection manholes at intervals."

For the treatment of services as part of the landslide preventive works to existing fill slopes, however, the Panel does not provide explicit recommendations. In a GEO report (1979), this issue is discussed at length with extensive reference to the Panel Report and a conclusion is drawn that "it is unlikely that leakage from services will cause surface instability and mud avalanches in recompacted slopes." On this basis, the GCO (GEO) practice is to ensure the recompacted process be carried out in an adequate way. This process includes the slope surface cover, compaction of the top 3m of soil and the provision of drains behind the recompacted layer. Service ducting is therefore not generally carried out as part of the preventive works on fill slopes.

In general, however, underground water-carrying services are taken seriously by the GEO and some have been diverted or have precautionary measures implemented, e.g. construction of a rockfill drainage blanket around the water main to direct any leakage away from the slope.

Buried services in a fill slope are subjected to continuing settlement even after the recompaction process because of secondary compression of the underlying loose fill. The total and/or differential settlement magnitude depends on the thickness and characteristics of the loose fill and the location of the services. This settlement, along with other possible inherent defects in the services, may lead to undesirable water leakage capable of triggering a landslide. Since the performance records described in Section 4.1.2 indicates no improvement in the leakage problem after the LPM, it is prudent therefore to conduct a regular programme of inspection for leakage from the services. Guidelines of such inspection are described in Geoguide 5 (1995) and the Code of Practice on Inspection and Maintenance of Water Carrying Services Affecting Slopes published by the Works Branch (1996). We have reviewed these documents and find that the guidelines therein are necessary and adequate provided the following two conditions are met:

1) The existence and location of the buried services should be clearly identified. There have been reports of inaccurate records on service locations that caused complications to design and construction (Bowler and Phillipson, 1982).

2) Well qualified professionals should be employed for the inspection. The Tze Wan Shan Road Failure (11NE-A/F12) mentioned in Section 4.2 is a case in point. Water leakage from the buried services was apparent on the surface during the reconstruction of the slope. However, repeated checking of the services did not fix the problem. Eventually, a washout failure caused by the bursting of a water main occurred a year after the completion of the reconstruction work.

8.2 EMERGING ISSUES

For the past twenty years, many slopes amenable to the application of the recompaction method have been strengthened in this way. There are still a lot of slopes that need to be upgraded. The use of the recompaction method, however, will become increasingly difficult because of several reasons. The first is the diminishing number of slopes for which this method can be applied. Many of the fill slopes recompacted in the earlier years were relatively large in width permitting ease of movement of the construction equipment. Increasingly, the remaining slopes are long in the up/down slope direction compared to the width. Secondly, continuous development has caused congestion and difficult access that discourage the use of this method. Thirdly, this method necessitates the disturbance or removal of trees that have matured on the slope surface over the years. Such disturbance or removal gives rise to concerns for the environment and slope stability.

The situation therefore warrants the consideration of other methods for the landslip preventive measures. Such measures may include fill stripping, retaining wall, partial recompaction, soil nails, use of cement stabilised soils, rockfill grouting, mini-piles, compaction grouting, jet grouting, etc.

9. ASSESSMENT OF POSSIBLE HAZARDS

In this section the hazards associated with the construction process and the long term condition of a recompacted slope are discussed. For the long term condition, slope stability and the earth pressure on the retaining wall are considered before and after the application of the LPM. Effects of potential seismic activities are also studied.

9.1 HAZARDS RELATED TO THE CONSTRUCTION PROCESS

The recompaction process often requires a steep temporary cut with marginal stability and bare slope surface with high erodability. The situation worsens when the construction period goes into the wet season. That is the reason why the records in the files show that inadequate drainage during construction is the biggest problem. This hazard, however, is controllable, even though the weather is not. The engineering profession has the insight and ability to address all potential failure modes in the design.

Manipulating heavy machinery on a steep slope overlooking a congested area is definitely hazardous. Accidents thus happened. Based on the discussion with the engineers, the survey and the records, however, this hazard is considered not serious. Of course, extra caution has to be exercised as in the case of Cloudview Road (slope number 11SE-A/FR64) where an excavator slid down the slope destroying the exterior wall of a school full of school children at the time of the accident. Fortunately none of them was hurt.

9.2 LONG TERM HAZARDS

Three potential long term hazards are discussed here: deep seated failure, seismic triggered failure and liquefaction.

9.2.1 Potential of deep-seated failure

In general, the potential of deep-seated failure increases with the decrease in the frictional component of the strength parameters of the soil. The frictional component can decrease when there is a rise of the pore water pressure or watertable.

It is understandable that the recompaction process only strengthens the top 3 m of fill. Deep-seated failure passing below the recompacted zone therefore will hardly be affected. If, for the moment, we only consider the effects on the strength parameters and not the effects of the watertable, the recompaction process does not bring any positive consequence on reducing the likelihood of a deep-seated failure. The potential of a deep-seated failure occurring in a loose fill slope therefore remains unchanged before and after the LPM works.

There might be a concern that by compacting the surface, the slope is now covered by a layer of less permeable material. Will this produce a membrane effect that will contain the flow of groundwater and increase the pore pressure in the slope with the consequence of a higher likelihood of a deep-seated failure? This question has been posed to a number of engineers during the interview but all feel that this is unlikely. We share the same feeling because of the installation of a drainage layer behind the recompacted layer as part of recompaction process. Should there be a rise in watertable, the drainage layer will divert the water such that no membrane effect can exist. Indeed this drainage layer will limit the maximum watertable to a level 3m beneath the surface. If the watertable before recompaction had reached beyond this level, the recompaction process would have reduced the likelihood of a deep-seated failure. If on the other hand, the watertable had never exceeded this level, the recompaction process would have no effect on the potential of a deep-seated failure.

For some site settings, e.g., valley sites with a large catchment where a substantial rise of watertable is possible, the drainage layer is still beneficial in restricting the height of the watertable. In this case, it is paramount that the drainage layer has to be operational. Hence, appropriate measures have to be in place to ensure the long term performance of the drainage layer. Such measures may include prevention of contaminating the drainage layer that could cause blockage and the use of prefabricated geosynthetic drainage material.

The relatively stiff top layer overlying a loose or soft layer may lead to cracks particularly at the transition zone between the uncompacted and recompacted soils. This may permit water to enter the lower part of the slope. If the drainage layer is placed properly, however, the water would be directed away.

Therefore the likelihood of a deep-seated failure in a loose fill slope in Hong Kong is marginally improved by recompacting the top 3 m of fill.

Based on the experience of engineers surveyed and interviewed, and on landslide records, there appears that no deep-seated failure had occurred in fill slope in the past. While this serves no assurance that such a failure will not occur, it does give an indication that such an event is rare.

9.2.2 Static liquefaction potential

Static liquefaction is likely only in loose saturated granular soils. For the top 3m of soil compacted to 95% of the maximum dry density, the soil is no longer loose. It therefore will be unlikely to liquefy even if it is saturated by infiltration of rain water.

On the other hand, the soil beneath the top recompacted layer is still loose. If it is not protected from saturating, liquefaction may be possible. Water for saturating the underlying fill may come from a rise in watertable or from rain water infiltration from the top. The rise of watertable is usually caused by a regional change of groundwater regime. The presence of the drainage layer as discussed in the last section also serves the same purpose here in restricting the rise of the watertable to 3 m below the surface. At the same shear stress level, the liquefaction potential increases with the decrease in effective stress. The restriction of the watertable rise associated with the recompaction process therefore reduces the liquefaction potential.

As for rain water infiltrating from the top, a wetting front penetrating into the soil will occur when the rainfall intensity exceeds the infiltration rate of the soil. The depth of penetration depends on a number of factors including the rainfall intensity, infiltration rate, degree of compaction and degree of saturation of the soil. When the top 3m of soil is recompacted, the wetting front will penetrate at a slower pace than before recompaction. Take the case of the loose fill involved in the 1976 Sau Mau Ping mudslide as an example. Based on the data in the Independent Review Panel Report (1977), the duration of the storm has to be doubled for the wetting front to penetrate the entire 3m of the recompacted soil. While the rainfall intensity of the 1976 disaster is not considered rare, the same storm with double the duration will be quite uncommon.

Furthermore, when the infiltration descends on to the drainage layer, the water will be largely directed to flow along the drainage layer. This is due to the law governing the flow of groundwater for two adjoining materials with a large difference in permeability. Hence the likelihood of saturating the underlying loose fill by infiltration through the overlying recompacted layer is much reduced. Consequently, a recompacted slope will have a lower potential for liquefaction as saturation of the loose fill by infiltrating rain water is less likely.

If indeed a sufficiently large storm occurs, or some buried service leaks, there is still the possibility of forcing a failure to occur below the recompacted layer. In this case, however, the top 3m of the sliding mass is dense and will be unlikely to liquefy during the sliding process. In addition, the drainage layer at the bottom of this recompacted layer will provide ready dissipation of any excess pore water pressure that might develop in the neighbourhood. Hence, such a failure will be less likely to degenerate into a mud avalanche. Consequently, we believe if such a slide does occur, it will have a lower speed, shorter run-out distance and will be less damaging than a flowslide that might occur in an uncompacted slope. We are, therefore, in agreement with the statements made on this aspect in the Independent Review Panel Report (1977).

9.2.3 Slope stability before and after LPM

In order to get a general understanding of fill slope safety, the stability of fill slopes before and after LPM Programme is checked for the static and the dynamic conditions and by using different available limit equilibrium methods. In the following analysis, the stability theory for an infinite slope and conventional stability analysis based on a circular failure surface have been used to calculate the factor of safety of fill slopes before and after the LPM Programme. Different fill strength parameters and representative slope geometry have been considered. Furthermore, the dynamic stability of the retaining wall related to the fill slopes have been evaluated using the Mononobe-Okabe method.

9.2.3.1 Stability analysis of fill slopes under static condition

1. Before LPM Programme

Most loose fill materials forming the slopes before recompaction are characterized by an almost cohesionless behaviour (c'= 0) with a friction angle ϕ' of 34° -36° for the saturated condition. Their relative compaction with respect to the maximum dry density is in the range of 75%-85%. The majority of the slope angle β varies from 30° to 35°.

The stability of an infinite slope consisting of dry cohesionless soils can be evaluated by the factor of safety F_s given by the following formula:

$$F_s = \frac{\tan\phi'}{\tan\beta} \tag{9.1}$$

Substituting the above typical values of soil friction angle and slope angle into this formula leads to F_s values of 0.96 to 1.04 for the fill slopes in Hong Kong before the LPM programme. This is low according to most standards and definitely falls short of the minimum guidelines (1.2) for upgrading existing slopes in the Geotechnical Manual for Slopes (GCO 1984). Therefore the stability of these fill slopes generally does not meet the current design standard.

Alternatively, the stability of these slopes can be evaluated by the conventional limit-equilibrium procedure based on the slip-circle concept. Such an analysis has been made in the design reports in the LPM Programme. By referring to the related design reports for the recompacted fill slopes from the GEO files, it is found that in most cases, the safety factor calculated by this method is lower than 1.2 and sometimes even less than unity.

The above calculations show that the fill slopes before the LPM Programme are marginal and below the current standard. Therefore upgrading is required for these fill slopes.

2. After LPM Programme

The current upgrading practice examined in this study is the recompaction of the top 3m of fill to 95% of the maximum dry density. Upon recompaction, the friction angle and unit weight will increase. The typical value of the friction angle ϕ' of the recompacted fill is generally larger than $37°$, and is 39° in most cases as recorded in the files. The inclination of the recompacted fill slopes ranges from 30.5° to 33.7°.

Based on the stability theory of infinite slope of dry soil, the factors of safety for the range of friction angle and slope inclination of the recompacted slopes have been calculated. The resulting values of the factor of safety vary between 1.13 and 1.38, suggesting that the recompaction has considerably improved the stability. The lowest value corresponds to the combination of the lowest ϕ' value (37°) and the steepest slope inclination (33.7°). This is slightly lower than the current standard. Therefore for slopes with fills having lower friction angle of fills, the inclination of the slopes recompacted may be reduced accordingly in order to meet the design requirement.

Similarly, the stability of these fill slopes can be evaluated by the conventional limit-equilibrium procedure based on the slip-circle concept. Again, such an analysis has been made in the design reports in the LPM Programme. For most cases, the safety factor calculated by this method is higher than 1.2.

The above discussion suggests that the stability of the fill slopes after the LPM Programme is acceptable and the calculated values of the factor of safety generally meet the current standard. Therefore the upgrading by recompacting the top 3m of slope can effectively improve the stability of the fill slopes that are potentially unstable before recompaction.

9.2.3.2 Stability analysis of fill slopes under seismic condition

In order to check the stability of fill slopes under earthquakes, the seismic loads exerted on the slope should be evaluated. Some research work related to the seismic stability analysis of slopes in Hong Kong has been done by Wong (1991). On the basis of the recent studies on the seismic hazard analysis of the Hong Kong region conducted by Lee et al. (1996), the design earthquake with 10% occurrence probability in 50 years will induce a peak acceleration at the bedrock of 75-115 *gal* in Kowloon, Hong Kong Island and other major parts of Hong Kong. Therefore the maximum acceleration used in the seismic design can be taken approximately as 100 *gal* (0.1*g*). At the same time, it is shown that the Arias Intensity of Hong Kong is about (6.95-7.30). Hence an approximate value of 7 can be used in the earthquake-resistant analysis in Hong Kong. According to the Chinese code, the peak acceleration corresponding to this seismic intensity is 0.1*g*. Therefore a peak acceleration $a_{\max}$ of 0.1 is used in the following analysis. It should be noted because of the preliminary nature of the analysis, the conclusion drawn from it should be considered tentative.

1. Before LPM Programme

For the stability analysis of slope under seismic condition, a pseudo-static horizontal seismically-induced inertial load is imposed on the slope as an additional static lateral load. It is represented by the product of the sliding mass and seismic acceleration. Based on the same assumption used in the static stability analysis for an infinite slope, the yield acceleration $a_y = a_c$ of the fill slope, corresponding to the limit equilibrium condition, can be assessed with the following equation:

$$a_y = k_y g = \tan(\phi' - \beta) g \tag{9.2}$$

where k_y is the yield value of pseudo-static seismic acceleration coefficient representing the ultimate earthquake-resistant capacity of the slope at which the factor of safety drops to 1.0.

For the fill slopes before the LPM Programme, the typical values of the friction angle of the fill and slope angle given above are substituted into the preceding relationship to obtain the yield seismic acceleration of the slopes. The calculated value is a_y = (0.02 to 0.105)g .Obviously the majority of values in this range lie below $a_{\max}$. Therefore the fill slopes before the LPM under earthquake condition may be transiently unstable from the standpoint of pseudo-static limit-equilibrium. This case is called overloading for which the seismically-induced movement of the potential sliding mass can be evaluated based on Newmark's rigid sliding block model (Newmark, 1965). On the basis of certain improvements of this model, some refined empirical relations between the lateral movement of the slope and the ratio of yield seismic acceleration to actual maximum seismic acceleration have been developed. Examples are Ambraseys and Srbulov (1995) and Sarma (1975). Recently, Pappin and Bowden (1997) used the correlation plot proposed by Sarma (1975) to evaluate landslide displacements due to earthquakes in Hong Kong. The following formula can be employed to represent the data produced by Sarma (1975)

$$U_m = \frac{C a_{\max} T^2}{4} 10^{\left(1.07 - 3.83 a_y / a_{\max}\right)} \tag{9.3}$$

where U_m is the maximum downward displacement, *T* is the natural period of the first mode of the slope or approximately dominant period of earthquake, which is defined as the period corresponding to the peak on the acceleration response spectrum of the input motion, *C* is calibration factor for the cases in which only horizontal seismic load is taken account. Further,

$$T = {4H}/{V_s} \tag{9.3a}$$

$$C = \cos(\phi' - \beta) / \cos\phi' \tag{9.3b}$$

where H is the height of the slope and V_s is the shear wave velocity of the soil.

For the typical case of $\phi' = 35^0$ and $\beta = 33.7^0$, $a_y = 0.023g$. For a typical H of 10*m* and V_s of 500*m/s*, the first natural period can be assessed to be 0.8*s*. Substituting these values together with $a_{\max} = 0.1g \cong 98cm/s^2$ into the preceding relation, the calculated magnitude of slope movement is about 30*cm*.

There is no doubt that the factor of safety of the fill slopes without upgrading will be lower than the required value of 1.2 while the lateral pseudo-static seismic load with the acceleration of 0.1*g* is considered. Hence the uncompacted fill slope is likely unstable under the earthquake condition under consideration based on this preliminary analysis.

2. After LPM Programme

Similar calculations can be done for the fill slopes after the LPM Programme. Using the representative values of friction angle and slope angle, i.e. $\phi' = 37^0 - 39^0$ and $\beta = 30.5^0 - 33.7^0$, the calculated yield acceleration will be in the range of (0.058 to 0.149)*g*. Then based on Sarma's empirical relation, the movement of the slope under overloading condition is about 1.38*cm* in the worst combination of friction angle and slope angle. This magnitude seems acceptable from the engineering practice.

As referred to earlier, design reports (stage 3 study report) on most recompacted slopes have a factor of safety against deep-seated failure higher than 1.2. According to Pappin and Bowden (1997), such recompacted fill slopes will not suffer significant damage or malfunction under earthquakes with a peak acceleration less than or equal to 0.1*g*.

9.2.4 Seismic earth pressure on retaining walls

The earth pressure of backfill on retaining wall can be obtained based on Coulomb's theory for the static condition. The extension of this theory to seismic condition was made by Mononobe and Okabe by using the pseudo-static concept. The general Mononobe-Okabe equation for active earth pressure is as follows (Das, 1994):

$$P_{ae} = \frac{1}{2}\gamma H^2 (1 - a_v) K_{ae} \tag{9.4}$$

in which

$$K_{ae} = \frac{\cos^2(\phi' - \theta - \alpha)}{\cos^2\theta \cos\alpha \cos(\delta + \theta + \alpha)\left\{1 + \left[\frac{\sin(\delta + \phi')\sin(\phi' - \beta - \theta)}{\cos(\delta + \theta + \alpha)\cos(\theta - \beta)}\right]^{1/2}\right\}^2} \tag{9.5}$$

and

$$\alpha = \tan^{-1}\left(\frac{a_h}{1 - a_v}\right) \tag{9.6}$$

where δ is the angle of friction between the wall and the soil, θ is the inclination of the wall back with the vertical, β is the slope angle of the backfills, a_h and a_v are respectively the horizontal and vertical components of the pseudo-static seismic acceleration coefficient. Note that, with no inertia forces from earthquakes, α will be equal to 0. Hence the coefficient of active earth pressure, K_{ae}, under the seismic condition will reduce to the static value of active earth pressure, K_a, given by Coulomb.

For the typical case of the recompacted fill slopes with a retaining wall, $\phi' = 38^0$, $\delta = \frac{2}{3}\phi' = 25.3^0$, $\beta = 33.7^0$, $\theta = 0$, the seismic earth pressure coefficient will be equal to 0.838 for $a_h = 0.1$, and $a_v = 0$ while the static earth pressure coefficient is only 0.385 for $a_h = a_v = 0$. Consequently, the earth pressure will be considerably increased under earthquakes and even doubled that of the static condition. Even though the dynamic earth pressure coefficients could be significantly larger than that in the static condition, the stability of the retaining wall may not be adversely affected because of the transient nature of the seismic loading.

10. IMPROVEMENTS AND RECOMMENDATIONS

Based on the above review, a number of improvements and recommendations on the practice of recompacting fill slope are made in the following. These are broadly divided into measures related to construction and to long term performance.

10.1 CONSTRUCTION MEASURES

1. Attempt should be made to carry out the construction in the dry season. If work has to be conducted within the wet season, proper measures should be designed as an integral part of the project to prevent slope failure during construction.

2. Current construction method and details for the surface drainage systems should be reviewed. A significant portion of the broken system has been attributed to poor construction quality or practice. Improved construction practice and the use of flexible joints are possible measures. Limited experience by the GEO suggests that chevron pattern drains appear to perform better than the flat channels on berms.

3. The transition zone between the recompacted and the uncompacted fills is susceptible to cracking because of the difference in mechanical behaviour of the two materials. Careful recompaction should be exercised in this zone. If flexible joints for a drainage system are to be installed, this zone is a suitable location for such a joint.

10.2 MEASURES RELATED TO LONG TERM PERFORMANCE

1. This review shows that the drainage layer behind the recompacted fill plays an important role in reducing the likelihood of deep-seated failure and soil liquefaction. While no direct problem has been documented regarding the performance of this drainage layer, the lack of improvement in the problems of groundwater seepage and leakage from water carrying services after the LPM works may be an indication that some drainage layers may not be functioning as expected. Some measures should be implemented to ensure this layer will perform effectively. Possible measures include preventing the drainage layer from contamination that could cause blockage and the use of suitable prefabricated geosynthetic drainage material.

2. Regular inspection and maintenance should be carried out as this is a small price to pay for a substantial return. While the current GEO guidelines on frequency of inspection appear to be adequate, some criteria should be established on the type, magnitude and location of the cracks to guide inspectors to identify potential problems.

3. As there is a marked improvement in the key areas of long term performance, the practice of recompacting the top 3m of slope should continue.

4. The marked improved performance of the present practice of recompaction to a 1 on 1.5 slope suggests the possibility of steepening the recompacted slope. Such a steepened slope may still be safe if the recompacted layer is reinforced with an appropriate material such as the geogrid. Slope steepening will alleviate construction problems in congested areas and

widen the applicability of the recompaction method. Study should be conducted to examine this possibility.

10.3 MONITORING PROGRAMME

Some of the issues raised in this review may be examined more closely with a long term monitoring programme of a certain recompacted slope displaying some problems or distress. The monitoring will throw light on the penetration of the wetting front during a rainstorm, development of cracks and ground movements, performance of surface drainage and the subsurface drainage layer, etc. Such information will give specific quantitative data for improving the design and construction of the recompaction technique.

11. CONCLUSIONS

A study has been conducted to review the effectiveness of upgrading loose fill slopes by recompacting the top 3 m of material. This practice has been used for about twenty years. A lot of experience and records are available for the study. Records of the Geotechnical Engineering Office have been reviewed. The majority of geotechnical consulting firms and relevant Government Departments have been surveyed. The information gained has been used to examine the long term performance of recompacted loose fill slopes, the site constraints and construction difficulties for the practice, and the hazards facing the recompaction works. The review shows that there is a general improvement in the performance of the slope after recompaction. There are certain areas, however, requiring attention. The results of the review are summarized as follows:

1. There is a marked improvement in the long term performance of the fill slopes after recompaction. The recompaction of the top 3 m of fill leads to reductions in the settlement and horizontal movement problems. The slope cover performs much better after the LPM works due to better treatment of the cover and the smaller movement. Surface drainage systems are also performing better as they break up less frequently.

2. It should be recognized that recompaction does not completely eliminate the problems mentioned in Conclusion 1. Of particular importance is that cracks continue to develop especially in the transition zone between the uncompacted and the recompacted fills. It is recommended that criteria be established on the type, magnitude and location of the cracks to guide inspectors to identify potential problems.

3. There is no improvement in the problem of blocked drainage which is the most frequently recorded problem in the long term performance. In fact the problem seems to deteriorate slightly after the LPM works, probably due to the more frequent use of vegetated cover. This problem can be serious as blocked drainage can lead to erosion of the slope. The problem, fortunately, is not difficult to be addressed. Regular inspection and maintenance will pay significant dividends here.

4. No improvement has been observed on the problems of groundwater seepage and leakage from water carrying services after the LPM works. This might be an indication of the poor performance of the drainage layer behind the recompacted fill. Since this drainage layer plays an important role in the performance of the slope, measures have to be taken to ensure that it performs adequately. Such measures may include the strengthening of construction control to prevent contamination of the drainage layer and the use of suitable prefabricated geosynthetic drainage material.

5. Only two out of the total of 128 recompacted fill slopes have been reported to have failed over the last twenty years (not counting another two that failed in connection with water main bursts). Both failures involved very small volumes (1 to 2 m^3) that might be called erosion. Comparison with pre-GCO fill slope failure rate and considering appropriate facts, it is concluded that there is a noticeable drop in the failure rate of fill slopes after the LPM works.

6. Inadequate drainage during construction is the biggest problem as revealed by the records. This is somewhat different from the survey of the consultants who indicated that the stability of the temporary cut is the most serious problem. These two problems however are related in that they stem from too much rain water on the site. Together they give rise to the most common construction hazard in the form of erosion and washout failure. The problems can be resolved by scheduling the construction in the dry season or by proper design if the wet season cannot be avoided.

7. Limited working space for stockpiling fill and manipulating machinery are the common concerns during construction.

8. There is a marginal reduction in the potential of deep-seated failure after the LPM works because in this case the potential failure surface lies mainly in the loose uncompacted fill. If the watertable in the original uncompacted fill slope can rise to a level within the top 3m, a beneficial effect will occur in reducing the likelihood of a deep-seated failure in the subsequently recompacted slope. In this case the presence of the drainage layer placed underneath the top 3m of recompacted fill will limit the rise of the watertable.

9. The recompacted soil will be unlikely to liquefy. The liquefaction potential of the underlying loose fill will be reduced because of the presence of the recompacted surface and the drainage layer. Together they reduce the amount of rain water infiltration and restrict the watertable rise to 3 m below the surface.

10. Preliminary assessment using the updated seismic information for Hong Kong suggests that there is a significant improvement in the factor of safety after the LPM works. The safety factor of a loose fill slope before the LPM works in Hong Kong will momentarily drop below 1.0 for a ground motion of 10% exceedence over 50 years. This does not necessarily imply the slope will fail because of the momentary nature of the seismic force. However, a recompacted fill slope will have a safety factor exceeding 1.0 in similar conditions.

11. For a similar earthquake condition, the preliminary theoretical assessment shows that there is a significant rise in earth pressure on the retaining wall attached to the recompacted fill slope compared to that under static condition.

12. Other secondary recommendations and suggested improvements are given in Section 10.

13. REFERENCES

Ambraseys, N. and Srbulov, M. (1995). Earthquake Induced Displacements of Slopes. *Soil Dynamics and Earthquake Engineering*, Vol.14, pp.59-71.

Bowler, R.A. and Phillipson, H.B. (1982). Landslip Preventive Measures - A Review of Construction. *Hong Kong Engineer*, Oct., pp.13-31.

Civil Engineering Department (1996). *CED Standard Drawings*, Hong Kong.

Das, B.M. (1994*). Principles of Geotechnical Engineering (Third Edition).* PWS Publishing Company, Boston.

GCO (1979). *Landslide Preventive Works on Poorly Compacted Fill Slopes, The Effect and Treatment of Services (GCO Report No. 1/79*). Geotechnical Control Office, Hong Kong, 20 p.

GCO (1984). *Geotechnical Manual for Slopes (Second edition).* Geotechnical Control Office, Hong Kong, 295 p.

GEO (1995). *Guide to Slope Maintenance (Geoguide 5)*. Geotechnical Engineering Office, Hong Kong, 92 p.

Government of Hong Kong (1977). *Report on the Slope Failures at Sau Mau Ping, August 1976,* 103 p.

Lam, B.M.T. (1980). *An Appraisal of the Landslide Preventive Works to Fill Slopes in Hong Kong.* M.Sc.(Eng) Dissertation, Department of Civil and Structural Engineering, the University of Hong Kong, 80 p.

Lee, C.F., Ding, Y.Z., Huang, R.H., Yu, Y.B., Guo, G., Chen, P.L. and Huang, X.H. (1996). *Seismic Hazards Analysis of Hong Kong Region (GEO Report No. 65)*, Geotechnical Engineering Office, Hong Kong, 145 p.

Newmark, N.M. (1965). Effects of Earthquakes on Dams and Embankments. *Geotechnique*, Vol.15, pp.139-160.

Pappin, J.W. and Bowden, A.J.H. (1997). The Likelihood of Earthquake Induced Landslides in Hong Kong. *Proceedings, Annual Seminar on Slope Engineering in Hong Kong.* The Hong Kong Institution of Engineers, pp.177-184.

Sarma, S.K. (1975). Seismic Stability of Earth Dams and Embankments. *Geotechnique,* Vol.24, pp.743-761.

Wong, H.N. (1991). *Evaluation of Seismic Stability of Slopes in Hong Kong.* M.Sc. Dissertation, Imperial College, the University of London.

Wong, H. N. and Ho, K.K.S. (1997). Overview of Risk of Old Man-made Slopes and Retaining walls in Hong Kong. *Proceedings, Annual Seminar on Slope Engineering in Hong Kong*, The Hong Kong Institution of Engineers, pp.193-200.

Works Branch (1996). *Code of Practice on Inspection & Maintenance of Water Carrying Services Affecting Slopes*, Hong Kong.

Yim, K.P. and Siu, C.K. (1998). Stability Investigation and Preventive Works Design for Old Fill Slopes in Hong Kong, *Proceedings, Annual Seminar on Slope Engineering in Hong Kong*, The Hong Kong Institution of Engineers, pp.295-302.

LIST OF TABLES

Table 3.1 - List of the Recompacted Fill Slopes (LPM Programme) under Investigation

SLOPE_NUM	NORTHING	EASTING	DISTRICT	LOCATION	MAIN_OFF	PRO_WORKS	CONTRACT
11NE-D/F 3	820526.000	841386.000	ME	UNITED CHRISTIAN HOSPITAL	ArchSD	RECONSTRUCTION	
11NE-D/FR 7			ME	SAU MAU PING ESTATE	ArchSD	RECOMPACTION BACK FILLING	
11NE-C/F 5			ME	HING NING ROAD	ArchSD	RECONSTRUCTION	697/78
11NE-C/F 6			ME	HING NING ROAD	ArchSD	RECONSTRUCTION	697/78
11NW-D/F 102			MW	KOWLOON HOSPITAL	ArchSD	RECOMPACTION	432/79
11NW-B/FR 23	821896.000	837125.000	ME	LOK FU ESTATE	ArchSD	EXCAVATION,RETAINING WALL & RECOMPACTION	432/1979
11NW-B/FR 24			ME	LOK FU ESTATE	ArchSD	EXCAVATION,RETAINING WALL & RECOMPACTION	432/1979
11NW-B/FR 35			MW	LI CHENG UK	ArchSD	RECOMPACTION & RETAINING WALL	433/79
7SW-C/F 8			MW	CHUEN YUEN SCHOOL	ArchSD	RECOMPACTION & RETAINING WALL	439/80
11NW-D/F 141			MW	KING'S PARK GARDEN	ArchSD	RECOMPACTION	466/81
11SW-A/FR 53			IW	HOSPITAL ROAD	ArchSD	FILL SLOPE RECONSTRUCTION	16/GCO/83
11SW-A/F 52			IW	HOSPITAL ROAD	ArchSD	FILL SLOPE RECONSTRUCTION	16/GCO/83
11SW-A/FR 54	*816325.000	*833080.000	IW	HOSPITAL ROAD	ArchSD	FILL SLOPE RECONSTRUCTION	16/GCO/83
11SW-B/FR 42			IE	LEIGHTON HILL	ArchSD	FILL SLOPE STABILIZATION	GC/84/04
11NW-D/F 97	*819170.594	*835787.184	ME	KING'S PARK	ArchSD	FILL SLOPE STABILIZATION	GC/84/03
13NE-A/FR 38			MW	MA PO PING PRISON	ArchSD	FILL SLOPE STABILIZATION	GC/85/05
11NW-B/FR 69	821682.000	836953.000	ME	KOWLOON TSAI PARK	ArchSD	FILL SLOPE STABILIZATION	GC/85/07
11NW-B/FR 36			MW	ABOVE LI CHENG UK SWIMMING POOL	ArchSD	SPRAYED CONCRETE & RECOMPACTION	GE/94/02
11SE-A/FR 64			I	22 CLOUDVIEW ROAD, NORTH POINT	ArchSD	SKIN WALL, RECOMPACTION & SOIL NAILS	GE/93/01
11SE-A/FR 7			I	62 CLOUDVIEW ROAD (INCLUDING 11SE-A/CR192)	ArchSD	RECOMPACTION	GE/94/02
11SW-C/FR 1			I	QUEEN MARY HOSPITAL	ASD	RECOMPACTION	GE/95/01
11SW-C/F 24	812429.000	831913.000	I	POK PO WAN, WAH FU ESTATE	ASD	RECOMPACTION, ROCKFILL & RETAINING WALL	GE/96/04
11SW-D/F 53			I	STUBBS ROAD VICTORIA HEIGHTS	ASD	RETAINING WALL & COMPACTED ROCKFILL	GE/96/04
11NE-B/F 58			ME	ANDERSON ROAD	DLO	FILL RECOMPACTION	GE/95/01
6SE-D/F 47	*825800.000	*828100.000	MW	YAU KOM TAU VILLAGE	DLO/ HyD	RECOMPACTION	GC/88/06
11SW-D/FR 21			IW	WATFORD ROAD	DLO/ PRIVAT	FILL SLOPE STABILIZATION	4/GCO/83
11SW-D/FR 20			ME	WATTFORD ROAD	DLO/ PRIVAT	FILL SLOPE STABILIZATION	16/GCO/83
11NE-D/F 109			ME	LAM TIN ESTATE	HD	RECONSTUCTION	
11NE-D/FR 4			ME	SAU MAU PING ESTATE	HD	RECOMPACTION	409/1977
11SE-D/F 3	813566.000	842430.000	I	WAN TSUI ESTATE	HD	RECONSTRUCTION	160/82
7SW-C/F 3			MW	SHEK LEI ESTATE BLOCK 3	HD	RECOMPACTION	405/1977
7SW-C/F 4			MW	KWAI HING ESTATE	HD	RECOMPACTION	405/1977
7SW-C/F 6			MW	KWAI SHING ESTATE (EAST)	HD	RECOMPACTION	405/1977
7SW-C/F 10			MW	KWAI CHUNG ESTATE	HD	RECOMPACTION	405/1977
11NE-A/F 6			ME	TZE LOK ESTATE	HD	RECOMPACTION	407/1977
11SE-D/F 7	813484.000	842576.000	I	CHAI WAN ESTATE	HD	RECOMPACTION	408/1977
11NE-D/F 1			ME	SAU MAU PING ESTATE	HD	PARTLY RECONSTRUCTED (PWD 687 OF 1977)	409/1977
11NW-A/FR 6			MW	LAI CHI KOK COTTAGE AREA	HD	RECOMPACTION & RETAINING WALL	406/1977
11NW-A/FR 7			MW	LAI CHI KOK COTTAGE AREA	HD	RECOMPACTION	406/1977
11NW-B/F 39			MW	LI CHENG UK ESTATE	HD	RECOMPACTION & RETAINING WALL	433/79
7SW-C/FR 37			MW	KWAI SHING ESTATE BLOCK 9	HD	RECOMPACTION	439/80
11SW-C/F 19			IW	TIN WAN ESTATE	HD	FILL SLOPE STABILIZATION	4/GCO/83
11SW-C/F 20			IW	TIN WAN ESTATE	HD	FILL SLOPE STABILIZATION	4/GCO/83
11NW-B/F 2			ME	UPPER PAK TIN ESTATE	HD	FILL SLOPE STABILIZATION	4/GCO/83
11SW-A/FR 47	815775.000	830965.000	I	SAI WAN ESTATE	HD	RECONSTRUCTION	HA183/85
11SW-A/FR 49	815757.000	831005.000	I	SAI WAN ESTATE	HD	RECONSTRUCTION	HA183/85

Table 3.1 - List of the Recompacted Fill Slopes (LPM Programme) under Investigation (continued)

SLOPE_NUM	NORTHING	EASTING	DISTRICT	LOCATION	MAIN_OFF	PRO_WORKS	CONTRACT
11SW-A/FR 50	815777.000	831040.000	I	SAI WAN ESTATE	HD	RECONSTRUCTION	HA183/85
11NE-A/F 12	*823329.000	*838607.000	ME	TZE WAN SHAN ESTATE	HD	FILL SLOPE STABILIZATION	GC/84/02
11NE-A/F 75			ME	TZE WAN SHAN ESTATE	HD	FILL SLOPE STABILIZATION	GC/84/02
11NE-D/FR 43			ME	NEAR LAM TIN ESTATE BLOCK 22 & 23	HD	RECOMPACTION	GC/84/02
11NE-A/F 11			ME	TZE WAN SHAN ESTATE	HD	RECOMPACTION	GC/86/04
11NE-A/F 73			ME	TZE WAN SHAN ESTATE	HD	RECOMPACTION	GC/86/04
11NW-A/FR 69			MW	LAI KING HILL ROAD, KWAI CHUNG	HD	RECOMPACTION	GE/93/01
11SE-D/FR 24	813972.000	842076.000	I	JUNCTION OF CHAI WAN ROAD & HING WAH ESTATE	HD	RECOMPACTION	GE/94/02
11SE-C/F 21			I	OPPOSITE 135 TAI HANG ROAD	HD	RECOMPACTION	GE/94/02
7SW-C/FR 13			MW	LEI MUK SHUE ESTATE	HD/ HyD	RECOMPACTION	405/1977
11NE-B/FR 31			ME	ANDERSON ROAD	HyD	RECONSTRUCTION	
11NE-C/F 1			ME	KUNG LOK ROAD	HyD	RECONSTRUCTION	
11NW-A/F 44			MW	CHO YIU CHUEN	HyD	RECOMPACTION	H158.01
11NW-D/FR 25			MW	PRINCESS MARGARET ROAD	HyD	RECONSTRUCTION	687/77
11SW-D/FR 1			I	STUBBS ROAD	HyD	RECONSTRUCTION	
11SW-D/FR 4			I	STUBBS ROAD	HyD	RECONSTRUCTION	688/77
11SW-D/FR 48			I	LINGNAN SCHOOL	HyD	RECONSTRUCTION	688/77
11SE-A/FR 9			I	CLOUDVIEW ROAD	HyD	RECONSTRUCTION	697/79
7SW-C/FR 2	825060.000	832199.000	MW	SHEK LEI ESTATE BLOCK 3 #	HyD	RECOMPACTION,ROCK ANCHOR & RETAINING WALL	433/79
11NW-B/F 8			MW	LUNG CHEUNG ROAD	HyD	RECOMPACTION	432/79
11SE-A/FR 11			I	LAI TAK TSUEN	HyD	RECOMPACTION	437/79
11NW-A/F 9			MW	CASTLE PEAK ROAD ABOVE KAU WA KENG	HyD	RECOMPACTION & RETAINING WALL	439/80
11NW-B/FR 43			MW	SO UK ESTATE	HyD	RECOMPACTION & FACING SLAB	439/80
11SW-D/F 69			I	STUBBS ROAD	HyD	RECOMPACTION & RETAINING WALL	439/80
7SW-C/F 31			MW	CASTLE PEAK ROAD ABOVE KCTL292	HyD	RECOMPACTION	466/81
11SW-B/FR 56			IW	KENNEDY ROAD	HyD	FILL SLOPE RECONSTRUCTION	2/GCO/82
11NW-A/FR 65			MW	CHO YIN CHUEN	HyD	RECOMPACTION	4/GCO/83
11SW-B/FR 59			IW	KENNEDY ROAD	HyD	FILL SLOPE RECONTRUCTION	4/GCO/83
11NW-B/FR 42			ME	SO UK ESTATE	HyD	FILL SLOPE STABILIZATION	4/GCO/83
12NW-C/FR 7			ME	CLEARWATER BAY ROAD	HyD	FILL SLOPE STABILIZATION	GC/84/02
11NW-A/FR 5			MW	CHING CHEUNG ROAD	HyD	CASSION WALL & RECOMPACTION	16/GCO/83
15NE-C/F 46			IE	WONG MA KOK ROAD	HyD	CLEARANCE & FILL SLOPE STABILIZATION	GC/84/02
11SE-A/F 34			IE	TIN HAU TEMPLE ROAD	HyD	FILL SLOPE STABILIZATION	16/GCO/83
11SW-A/FR 23			IW	POKFIELD ROAD	HyD	FILL SLOPE STAB.	GC/84/03
11SE-A/FR 48			I	FORTRESS HILL ROAD	HyD	RECOMPACTION & HORIZONTAL DRAIN	GC/85/05
11SW-A/F 32			IW	KOTEWALL ROAD	HyD	FILL SLOPE STABILIZATION	GC/85/06
11NW-A/F 23			MW	LAI KING HILL ROAD	HyD	RECOMPACTION	GC/85/07
11SW-D/FR 7			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/85/06
11SW-D/FR 135			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/85/06
7NW-D/FR 1			ME	TAI PO KAU, CHUNG TSAI YUEN	HyD	RECOMPACTION & TRIM	GC/87/11
11SW-D/F 32			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/86/03
11SW-D/FR 26			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/86/03
11SW-D/F 33			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/86/03
11SW-D/FR 29			IW	PEAK ROAD	HyD	FILL SLOPE STABILIZATION	GC/86/03
11SE-A/F 30			IE	TIN HAU TEMPLE ROAD	HyD	RECOMPACTION	GC/88/05
15NE-B/F 25			I	RED HILL ROAD	HyD	FILL SLOPE RECOMPACTION	GC/88/05

Table 3.1 - List of the Recompacted Fill Slopes (LPM Programme) under Investigation (continued)

SLOPE_NUM	NORTHING	EASTING	DISTRICT	LOCATION	MAIN_OFF	PRO_WORKS	CONTRACT
11SE-A/F 61	*816377.000	*838118.000	I	TIN HAU TEMPLE ROAD	HyD	RECOMPACTION	GC/89/13
11NE-A/F 96			ME	NEW CLEAR WATER BAY ROAD	HyD	RECOMPACTION	GC/90/06
11SW-C/N 1			I	BAGUIO VILLAS REMEDIAL WORKS	HyD	PROTECTIVE WALLS, DRAINAGE & STABILIZE FILL SLOPE	GC/90/01
7SW-D/FR 10	*825690.000	*835915.000	ME	VISTA DA VALE, TAI PO ROAD	HyD	RECOMPACTION OF TOP 3M FILL EMBANKMENT	GC/90/06
11SW-D/FR 112			I	ADJACENT TO 11 MAGAZINE GAP ROAD	HyD	RECOMPACTION	GE/93/01
11SW-C/FR 88			I	POKFULAM ROAD	HyD	FILL SLOPE RECOMPACTION	GE/95/01
11NE-B/T 190			ME	CLEAR WATER BAY ROAD	HYD	COMPACTED ROCKFILL & SPRAYED CONCRETE	GE/96/04
11NE-B/F 56			ME	BETWEEN ACCESS ROAD TO SWAN VILLAS	HYD	RECOMPACTION	GE/96/05
11SW-B/FR 124	815080.000	834370.000	I	BOWEN ROAD	HYD	ROCKFILL, SOIL NAILS & SKIN WALL	GE/96/04
11NE-B/F 11			ME	CLEAR WATER BAY ROAD	HYD	RECOMPACTION & HYDROSEEDING	GE/96/04
7SW-D/F 53	826175.000	837493.000	MW	LION ROCK TUNNEL ROAD	UNALLOCATED	RECOMPACTION	GE/94/02
11SE-B/FR 28			I	LEI YUE MUN BARRACKS	USD	RECOMPACTION	GE/96/05
7SW-C/FR 97			MW	TSUEN WAN SERVICE RESERVOIR	WSD	RECONSTRUCTION	-
11SW-D/F 70			I	ABERDEEN	WSD	RECONSTRUCTION	697/78
7SW-C/FR 100			MW	TSUEN WAN SERVICE RESERVOIR #	WSD	RECOMPACTION	407/1980
11NW-D/F 118			MW	HO MAN TIN RESERVOIR	WSD	RECOMPACTION & EXCAVATION	432/79
11SE-A/FR 15			I	TIN HAU TEMPLE ROAD	WSD	RECOMPACTION & RETAINING WALL	434/79
11SW-A/FR 20	815631.000	831159.000	I	KENNEDY TOWN SERVICE RESERVOIR	WSD	RECOMPACTION	439/80
11NW-D/FR 119			ME	MA TAU WAI SERVICE RESERVOIR	WSD	FILL SLOPE STABILIZATION	GC/87/11
11SW-A/FR 87			I	MOUNT DAVIS SERVICE RESERVOIR (SIFT PFL 42)	WSD	RECOMPACTION & RETAINING WALL	GE/95/17
11NE-D/FR 16			ME	KWUN TONG ESTATE		RECONSTRUCTION	
11SE-A/FR 21			I	LAI TAK TSUEN		RECONSTRUCTION	688/77
11SE-C/F 14	814694.000	838305.000	I	CLEMENTI ROAD		RECONSTRUCTION	
11SE-C/FR 1			I	WONG NAI CHUNG GAP ROAD		RECONSTRUCTION	688/77
11SE-D/F 2			I	CHAI WAN, HONG MAN STREET		RECOMPACTION	2/GCO/82
11SE-D/FR 5			I	LOK MAN ROAD		RECONSTRUCTION	
11SW-B/F 43			IE	LEIGHTON HILL		FILL SLOPE STABILIZATION	
11SW-D/FR 5			I	KENNEDY ROAD		RECONSTRUCTION	699/78
11SW-D/FR 18	*814285.000	*833825.000	I	PEAK SCHOOL		RECONSTRUCTION	688/77
11NE-D/FR 10			ME	SAU MAU PING		RECOMPACTION (SMP10 INCLUDING 11NE-D/C 42)	409/1977
11NW-B/FR 51			MW	SO UK ESTATE		RECOMPACTION	406/1977
11SW-A/FR 1			I	POKFULAM ROAD		RECONSTRUCTION	696/78
11SW-A/FR 65			I	MOUNT DAVIS		RECOMPACTION	696/78
11NW-B/FR 38			MW	LEI CHENG UK ESTATE		RECOMPACTION & RETAINING WALL	433/79
11NW-D/FR 44	819068.000	836777.000	MW	KING'S PARK SERVICE RESERVOIR		CAMPACT FILL & HYDROSEEDING & EXCAVATION	439/80
11NW-D/F 117			MW	HO MAN TIN HIGH LEVEL SERVICE RESERVOIR		RECOMPACTION & RETAINING WALL	439/80
11NW-B/FR 53			ME	SO UK ESTATE BEHIND CARNATION HOUSE		RECOMPACTION	466/81
11SE-A/FR 10	816452.000	838651.000	IE	MAN KIU COLLEGE (CLOUD VIEW ROAD)		FILL SLOPE STABILIZATION	4/GCO/83

Table 3.2 - List of 421 Incidents of Failures of Slopes

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
HK82/37			Fill Slope	Washout	0.00	813350.000	836410.000
HK82/40			Fill Slope	Landslide	0.00	814300.000	831740.000
HK82/47			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	816290.000	840830.000
HK82/64			Fill Slope	Washout	0.00	813930.000	843210.000
HK83/10/2			Fill Slope	Washout	0.00	0.000	0.000
HK83/9/3			Fill Slope	Landslide	40.00	0.000	0.000
HK83/9/5			Fill Slope	Landslide	1250.00	0.000	0.000
HK83/9/6			Fill Slope	Landslide	0.00	0.000	0.000
HK84/4/2		11SW-D/F107	Fill Slope	Washout	45.00	814380.000	835260.000
HK84/8/1			Fill Slope	Washout	10.00	814535.000	837385.000
HK84/9/3		11SW-D/F149	Fill Slope	Distress of slope	0.00	814198.000	834850.000
HK85/4/4			Fill Slope	Landslide	1.50	815238.000	838210.000
HK85/6/5		11SW-A/F224	Fill Slope	Landslide	625.00	815740.000	831275.000
HK85/7/1			Fill Slope	Washout	40.00	813986.000	837128.000
HK85/8/1			Fill Slope	Washout	1.00	815239.358	841593.593
HK85/8/5			Fill Slope	Landslide	5.00	813390.000	832292.000
HK85/9/9			Fill Slope	Washout	0.20	815581.794	840631.996
HK86/10/3			Fill Slope	Landslide	2.00	811734.000	835134.000
HK86/5/3			Fill Slope	No geotechnical concern - flooding	0.00	815878.978	839975.286
HK86/5/5			Fill Slope	Washout	2.00	809481.000	839817.000
HK86/7/2			Fill Slope	Landslide	40.00	813816.000	832096.000
HK86/7/4			Fill Slope	Landslide	3.00	812773.000	831925.000
HK86/8/10			Fill Slope	Landslide	1.50	811720.000	835125.000
HK86/9/1			Fill Slope	Landslide	1.00	808839.000	839642.000
HK86/9/2			Fill Slope	Landslide	1.00	812358.000	833190.000
HK86/9/5			Fill Slope	Washout	0.00	811706.000	835122.000
HK87/1/1			Fill Slope	No geotechnical concern - no failure	0.00	811720.000	835105.000
HK87/2/2	A		Fill Slope	Washout	2.00	812260.000	833000.000
HK87/2/2	B		Fill Slope	Washout	2.00	812265.000	833000.000
HK87/3/4			Fill Slope	Landslide	1.00	811728.000	835120.000
HK87/4/2			Fill Slope	Landslide	1.20	811705.000	835065.000
HK87/5/9	A		Fill Slope	Landslide	5.00	815160.000	833422.000
HK87/6/1			Fill Slope	Landslide	12.00	813900.000	843060.000
HK87/6/9			Fill Slope	Landslide	4.00	814728.000	833500.000
HK88/1/1			Fill Slope	Washout	3.00	0.000	0.000
HK88/1/1	A		Fill Slope	Washout	3.00	813794.000	837718.000
HK88/1/1	B		Fill Slope	Washout	3.00	813788.000	837720.000
HK88/1/1	C		Fill Slope	Washout	3.00	813765.000	837722.000
HK88/2/2			Fill Slope	Boulder threat	0.00	815510.000	840530.000
HK88/7/1			Fill Slope	Washout	0.50	816051.000	833613.000
HK89/4/1			Fill Slope	Washout	300.00	810100.000	840820.000
HK89/5/59			Fill Slope	Washout	10.00	814120.000	835628.000
HK89/6/8			Fill Slope	Washout	2.00	809114.000	839500.000
HK90/9/1			Fill Slope	Landslide	3.00	813705.000	832225.000
HK91/3/1			Fill Slope	No geotechnical concern - structural failure: Collapse of silts.	0.00	814118.000	831639.000
HK91/3/2			Fill Slope	Washout	150.00	809551.000	839940.000
HK91/7/2			Fill Slope	Landslide	20.00	810140.000	843467.000
HK92/11/3			Fill Slope	Washout	3.00	811153.000	837973.000
HK92/4/20			Fill Slope	Rock fall	2.00	815095.000	836220.000
HK92/5/103		11SW-B/FR86	Fill Slope	Washout	3.00	815079.000	837140.000
HK92/5/121			Fill Slope	Washout	6.50	814054.000	831415.000
HK92/5/125			Fill Slope	No geotechnical concern - flooding	0.00	813415.000	832225.000
HK92/5/128			Fill Slope	Landslide	1.00	813415.000	832225.000
HK92/5/129			Fill Slope	Distress of slope	1.00	813400.000	832250.000
HK92/5/133			Fill Slope	Distress of slope	5.00	815340.000	834575.000
HK92/5/134			Fill Slope	Washout	0.00	0.000	0.000
HK92/5/134	A	11SE-A/F17	Fill Slope	Washout	0.00	816206.000	838236.000
HK92/5/134	B	11SE-A/F17	Fill Slope	Washout	0.00	816200.000	838241.000
HK92/5/134	C	11SE-A/F17	Fill Slope	Washout	0.00	816195.000	838245.000
HK92/5/134	D	11SE-A/F17	Fill Slope	Washout	0.00	816196.000	838260.000
HK92/5/134	E	11SE-A/F17	Fill Slope	Washout	0.00	816182.000	838256.000
HK92/5/134	F	11SE-A/F17	Fill Slope	Washout	0.00	816158.000	838276.000
HK92/5/134	G	11SE-A/F17	Fill Slope	Washout	0.00	816149.000	838285.000
HK92/5/134	H	11SE-A/F17	Fill Slope	Washout	0.00	816138.000	838295.000
HK92/5/140		11NE-C/FR190	Fill Slope	Landslide	150.00	808821.000	838960.000
HK92/5/141		15NE-A/F41	Fill Slope	Distress / dislodgement of slope surface protection	0.00	809550.000	839935.000
HK92/5/161			Fill Slope	Washout	1.00	814830.000	837865.000
HK92/5/162			Fill Slope	Distress / dislodgement of slope surface protection	1.00	815130.000	830146.000
HK92/5/163			Fill Slope	Washout	45.00	815107.000	830114.000
HK92/5/176			Fill Slope	Washout	1.00	815630.000	840020.000
HK92/5/177			Fill Slope	Landslide	30.00	815630.000	839970.000
HK92/5/38			Fill Slope	Landslide	500.00	0.000	0.000
HK92/5/41			Fill Slope	Landslide	120.00	0.000	0.000
HK92/5/50			Fill Slope	Washout	20.00	814353.000	837508.000
HK92/5/57			Fill Slope	Washout	8.00	813111.224	831860.805
HK92/5/7			Fill Slope	Washout	0.00	0.000	0.000
HK92/5/74			Fill Slope	Washout	5.00	814740.000	833600.000
HK92/5/84			Fill Slope	Landslide	10.00	814615.000	837305.000
HK92/6/15			Fill Slope	Washout	8.00	812260.000	832055.000

Table 3.2 - List of 421 Incidents of Failures of Slopes (continued)

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
HK92/6/22			Fill Slope	Washout	20.00	813060.000	839980.000
HK92/7/14			Fill Slope	Washout	0.00	816103.000	838211.000
HK92/7/9			Fill Slope	Washout	0.60	811100.000	837700.000
HK92/9/8			Fill Slope	Rock fall	0.00	816102.000	838214.000
HK93/11/1			Fill Slope	Washout	3.00	811243.000	837457.000
HK93/12/2			Fill Slope	Landslide	45.00	810246.000	840882.000
HK93/6/14			Fill Slope	Washout	200.00	0.000	0.000
HK93/6/15			Fill Slope	Washout	40.00	810068.000	842722.000
HK93/6/19			Fill Slope	Washout	120.00	811513.000	837522.000
HK93/6/3			Fill Slope	Landslide	150.00	812392.000	837747.000
HK93/6/8			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	8.00	814885.000	837750.000
HK94/10/3			Fill Slope	Washout	7.00	811340.000	837315.000
HK94/12/1			Fill Slope	Landslide	5.00	0.000	0.000
HK94/12/1	A		Fill Slope	Washout	5.00	816300.000	838103.000
HK94/12/1	B		Fill Slope	Washout	5.00	816321.000	838106.000
HK94/5/1		11SE-D/F33	Fill Slope	Landslide	65.00	812879.000	837938.000
HK94/7/11			Fill Slope	Landslide	16.00	814012.000	831241.000
HK94/7/55			Fill Slope	Landslide	40.00	808604.000	838845.000
HK94/7/67		11SE-A/F61	Fill Slope	Washout	2.00	816377.000	838118.000
HK94/8/19		11SW-B/FR72	Fill Slope	Washout	20.00	815358.319	834896.963
HK94/8/3			Fill Slope	Rock fall	0.08	813587.000	832165.000
HK94/9/2			Fill Slope	Landslide	10.00	813830.000	841735.000
HK95/4/2			Fill Slope	Washout	15.00	809504.000	839253.000
HK95/8/31			Fill Slope	Landslide	120.00	812175.000	842020.000
HK95/8/32			Fill Slope	Landslide	10.00	808974.000	839734.000
HK95/8/61			Fill Slope	Washout	20.00	811665.000	835042.000
HK95/8/94			Fill Slope	Landslide	8.00	811400.000	843420.000
HK95/8/95		15NE-C/F32	Fill Slope	Landslide	45.00	808470.000	840145.000
HK96/6/3		11SW-C/F77	Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	3.00	0.000	0.000
K82/15			Fill Slope	Landslide	50.00	822656.406	835248.759
K82/24			Fill Slope		50.00	819018.756	841936.790
K82/26			Fill Slope	Washout	50.00	819222.000	842250.000
K82/45			Fill Slope		50.00	821240.000	840900.000
K82/56			Fill Slope	Landslide	0.00	823566.641	838239.764
K83/10/1			Fill Slope	Landslide	3.00	0.000	0.000
K83/10/2			Fill Slope	Washout	3.00	820038.631	842185.484
K83/10/3			Fill Slope	Washout	2.00	820276.328	842049.789
K83/10/8			Fill Slope	Landslide	20.00	818909.425	842625.216
K83/11/1			Fill Slope	Landslide	6.00	0.000	0.000
K83/11/3		11NE-B/FR45	Fill Slope	Washout	3.00	0.000	0.000
K83/5/3			Fill Slope	Landslide	6.00	819973.630	842094.891
K83/6/10			Fill Slope	Landslide	2.00	820476.484	841867.714
K83/6/12			Fill Slope	Washout	32.00	820475.985	841867.201
K83/6/26			Fill Slope	Landslide	0.00	822590.279	836311.555
K83/9/32			Fill Slope	Landslide	0.50	820038.911	842183.461
K83/9/43			Fill Slope	Landslide	1.00	818454.697	842554.774
K84/10/2			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	822366.551	839225.869
K84/10/4			Fill Slope	Washout	0.00	820919.772	841708.168
K84/4/1		11NE-D/F10	Fill Slope	Washout	160.00	820000.000	841600.000
K84/4/2			Fill Slope	Washout	3.00	820814.894	841631.486
K84/4/3			Fill Slope	Washout	15.00	820293.000	842036.000
K84/5/13			Fill Slope	Distress / dislodgement of slope surface protection	0.00	818635.000	836677.000
K84/5/4			Fill Slope	Washout	0.00	822919.000	835699.000
K84/6/17		11NW-B/FR76	Fill Slope	Landslide	2.50	822380.000	835080.000
K84/6/18			Fill Slope	Washout	50.00	820850.000	840650.000
K84/6/2			Fill Slope	Washout	0.00	820100.000	842132.000
K84/6/5			Fill Slope	Landslide	0.00	820084.000	842152.000
K84/8/4			Fill Slope	Landslide	20.00	818015.000	842745.000
K84/8/5			Fill Slope	Washout	0.50	820250.000	842030.000
K84/9/1		11NW-B/FR10	Fill Slope	Landslide	0.00	822725.000	836420.000
K84/9/2			Fill Slope	Landslide	1.50	823681.496	838759.173
K85/3/4			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	2.00	818210.000	842460.000
K85/3/6			Fill Slope	No geotechnical concern	0.20	818112.709	842626.528
K85/4/10			Fill Slope	Landslide	3.00	817263.287	842851.353
K85/5/1			Fill Slope	Landslide	2.00	818224.196	842500.126
K85/5/2			Fill Slope	Landslide	0.00	818604.763	842149.180
K85/6/30			Fill Slope	Landslide	2.00	821950.767	839644.201
K85/6/9			Fill Slope	Landslide	1.00	819900.000	842400.000
K85/7/3			Fill Slope	Landslide	0.33	818453.971	842552.484
K85/8/12			Fill Slope	Landslide	3.00	821952.052	839644.925
K85/8/18			Fill Slope	Landslide	4.00	818910.749	842620.927
K85/8/3	A		Fill Slope	Landslide	3.00	822736.873	834484.557
K85/8/8		11NE-A/F1	Fill Slope		25.00	823418.000	838045.000
K85/9/15			Fill Slope	Landslide	0.00	818113.702	842627.809
K85/9/5	A		Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	818113.211	842626.789
K86/10/2	A	11NE-A/F12	Fill Slope	Washout	0.00	823329.000	838607.000
K86/10/2	B		Fill Slope	Washout	0.00	823329.000	838607.000
K86/2/2			Fill Slope	Landslide	3.00	0.000	0.000
K86/2/2	A		Fill Slope	Landslide	3.00	817948.000	842839.000

Table 3.2 - List of 421 Incidents of Failures of Slopes (continued)

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
K86/2/2	B		Fill Slope	Landslide	3.00	817957.000	842858.000
K86/2/2	C		Fill Slope	Landslide	3.00	817940.000	842840.000
K86/5/12			Fill Slope	Landslide	2.00	821775.000	839795.000
K86/6/17			Fill Slope	Landslide	3.00	822075.000	839595.000
K86/6/3			Fill Slope	Washout	0.60	822528.000	838895.000
K86/6/32			Fill Slope	Washout	0.00	819660.000	836888.000
K86/6/6		11NW-D/F97	Fill Slope	Washout	0.00	819170.594	835787.184
K86/7/13			Fill Slope	Landslide	0.00	817822.000	842778.000
K86/8/9			Fill Slope	Landslide	8.00	822520.000	834842.000
K87/3/3			Fill Slope	Landslide	2.00	820485.000	841955.000
K87/4/1			Fill Slope	Landslide	5.00	820330.000	842048.000
K87/4/4			Fill Slope	Washout	0.00	820257.000	841993.000
K87/4/5			Fill Slope	Distress / dislodgement of slope surface protection	0.50	821920.000	839815.000
K87/7/19			Fill Slope	Landslide	15.00	822735.000	834475.000
K87/7/5			Fill Slope	Landslide	5.00	820250.000	842064.000
K88/10/1			Fill Slope	Washout	120.00	822670.000	836740.000
K88/3/2			Fill Slope	Washout	1.00	820280.000	842040.000
K88/4/1			Fill Slope	Landslide	5.00	823555.000	838235.000
K88/6/3			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.50	821237.000	841630.000
K88/6/5			Fill Slope	Washout	2.00	822707.000	834495.000
K88/6/6			Fill Slope	Landslide	5.00	820848.000	841846.000
K88/7/10			Fill Slope	Boulder threat	1.00	822040.000	839650.000
K88/7/9			Fill Slope	Washout	5.00	820570.000	842060.000
K88/8/6			Fill Slope	Landslide	0.00	822745.000	834470.000
K89/1/1			Fill Slope	Landslide	5.00	822045.000	839650.000
K89/10/1			Fill Slope	Landslide	2.00	820190.000	842045.000
K89/12/1			Fill Slope	Failure of rubble foundation	0.00	822731.000	834500.000
K89/4/1			Fill Slope	Landslide	1.50	821953.590	839645.643
K89/4/7			Fill Slope	Landslide	1.50	821951.056	839645.461
K89/5/1			Fill Slope	Washout	0.00	821910.000	839600.000
K89/5/115			Fill Slope	Washout	0.00	817550.000	843050.000
K89/5/118			Fill Slope	No geotechnical concern - tree fallen	0.00	817000.000	842760.000
K89/5/25			Fill Slope	Washout	200.00	820120.000	840560.000
K89/5/28			Fill Slope	Landslide	20.00	822718.000	838154.000
K89/5/4			Fill Slope	Washout	2.00	0.000	0.000
K89/5/4	A		Fill Slope	Washout	2.00	819685.000	836310.000
K89/5/4	B		Fill Slope	Washout	2.00	819690.000	836325.000
K89/5/6			Fill Slope	Washout	0.00	822595.000	839390.000
K89/5/60			Fill Slope	Washout	0.00	817165.000	842913.000
K89/5/63			Fill Slope	Washout	0.00	821995.000	839475.000
K89/5/64			Fill Slope	Washout	0.00	822090.000	839610.000
K89/5/65			Fill Slope	Washout	0.00	821970.000	839590.000
K89/5/66			Fill Slope	Washout	0.00	821965.000	839585.000
K89/5/7			Fill Slope	Landslide	50.00	819500.000	835840.000
K89/5/70			Fill Slope	Washout	0.00	822010.000	839580.000
K89/5/73			Fill Slope	Washout	0.00	822600.000	839395.000
K89/5/77		11NW-D/FR147	Fill Slope	Washout	5.00	820290.000	836005.000
K89/5/83			Fill Slope	Washout	0.00	822504.000	839353.000
K89/6/21			Fill Slope	Washout	0.00	820265.000	842080.000
K89/6/3	B		Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	5.00	820975.000	835975.000
K89/8/3			Fill Slope	Washout	0.00	821890.000	839725.000
K90/2/1			Fill Slope	Washout	0.00	822655.000	833810.000
K90/2/2			Fill Slope	Landslide	1.00	820115.000	842235.000
K90/5/2			Fill Slope	Rock fall	15.00	820900.000	841750.000
K90/6/11			Fill Slope	Landslide	10.00	820060.000	842225.000
K90/6/7			Fill Slope	Washout	0.00	820355.000	840585.000
K90/8/1			Fill Slope	Landslide	3.00	818260.000	841630.000
K91/3/1			Fill Slope		4.00	0.000	0.000
K91/3/1	A		Fill Slope	Landslide	4.00	819950.000	842225.000
K91/3/1	B		Fill Slope	Landslide	4.00	819950.000	842225.000
K91/3/2			Fill Slope	Landslide	2.00	819950.000	842230.000
K91/6/2			Fill Slope	Washout	5.00	823560.000	838275.000
K92/4/2			Fill Slope	Distress / dislodgement of slope surface protection	0.01	817550.000	843040.000
K92/4/7			Fill Slope	Washout	1.50	822420.000	839875.000
K92/5/3			Fill Slope	Landslide	3.00	817630.000	843145.000
K92/5/6			Fill Slope	Washout	30.00	0.000	0.000
K92/5/6	A		Fill Slope	Washout	65.00	822462.000	840280.000
K92/5/6	B		Fill Slope	Washout	30.00	822435.000	840277.000
K92/5/8			Fill Slope	Washout	2.50	817947.000	842692.000
K93/12/2			Fill Slope		33.00	0.000	0.000
K93/12/2	A		Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	33.00	818050.000	842930.000
K93/12/2	B		Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	33.00	818035.000	842935.000
K93/6/3			Fill Slope		3.00	822941.000	837216.000
K93/6/5			Fill Slope	Landslide	6.00	816560.000	842794.000
K94/7/15		11NW-F/FR147	Fill Slope	Landslide	45.00	820293.000	836024.000
K94/8/11			Fill Slope	Landslide	5.00	821131.000	841723.000
K94/8/6		11NW-B/F16	Fill Slope	Landslide	15.00	822337.000	836688.000
K95/7/3			Fill Slope	Landslide	1.00	817970.000	841680.000
K95/8/5			Fill Slope	Landslide	7.00	819100.000	842700.000

Table 3.2 - List of 421 Incidents of Failures of Slopes (continued)

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
ME84/5/2			Fill Slope	Washout	2.10	826258.000	835720.000
ME84/6/1			Fill Slope	Washout	3.00	827150.000	836827.000
ME85/6/7			Fill Slope	Landslide	0.00	825395.000	836817.000
ME85/6/8			Fill Slope	Landslide	15.00	824978.000	836455.000
ME86/12/1			Fill Slope		0.00	826180.000	835715.000
ME86/7/14			Fill Slope	Landslide	30.00	827990.000	837870.000
ME86/7/4			Fill Slope	Washout	250.00	832620.000	837220.000
ME86/7/8			Fill Slope	Landslide	65.00	826650.000	835030.000
ME87/3/1			Fill Slope	Washout	2.00	823800.000	845000.000
ME87/6/6			Fill Slope	Distress of slope	0.00	824980.000	834945.000
ME87/7/23			Fill Slope	Washout	10.00	825080.000	835550.000
ME87/7/6			Fill Slope	Washout	1.00	828871.000	838275.000
ME89/3/3			Fill Slope	Landslide	1.00	835475.000	855250.000
ME89/5/26			Fill Slope	Washout	20.00	821955.000	843230.000
ME89/5/30			Fill Slope	Washout	10.00	824360.000	834590.000
ME89/5/8			Fill Slope	Retaining Wall failure	50.00	821640.000	842300.000
ME89/5/80			Fill Slope	Washout	20.00	833000.000	831000.000
ME89/5/91			Fill Slope	Washout	2.00	837410.000	829640.000
ME90/2/1			Fill Slope	Washout	5.00	824800.000	834950.000
ME90/6/10			Fill Slope	Landslide	12.00	829595.000	842615.000
ME90/6/5			Fill Slope	Washout	3.00	830055.000	842335.000
ME90/9/1			Fill Slope	Landslide	8.00	0.000	0.000
ME92/4/10			Fill Slope	Washout	0.00	824400.000	843655.000
ME92/5/10	B		Fill Slope	Washout	2.00	821955.000	843325.000
ME92/5/20			Fill Slope	Landslide	10.00	819490.000	846700.000
ME92/5/33			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.50	827400.000	836340.000
ME92/5/35			Fill Slope	Landslide	0.30	845660.000	848120.000
ME92/5/49			Fill Slope	Landslide	5.00	817710.000	848270.000
ME92/6/2			Fill Slope	Landslide	0.50	834360.000	834790.000
ME92/7/13			Fill Slope	Landslide	6.00	829670.000	837325.000
ME92/7/2			Fill Slope	Distress of slope.	50.00	827280.000	845010.000
ME93/10/15			Fill Slope	Landslide	84.00	825435.000	844560.000
ME93/10/5			Fill Slope	Landslide	40.00	827770.000	837635.000
ME93/2/1			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	826865.000	845830.000
ME93/5/5			Fill Slope	Landslide	8.00	0.000	0.000
ME93/6/13			Fill Slope	Landslide	80.00	826842.000	845565.000
ME93/6/14		8SW-C/FR6	Fill Slope	Landslide	30.00	826855.000	845835.000
ME93/6/15			Fill Slope	Landslide	45.00	828320.000	846635.000
ME93/6/26			Fill Slope	Landslide	1.00	835827.000	837060.000
ME93/8/4			Fill Slope	Washout	3.00	826920.000	845615.000
ME93/9/41			Fill Slope	Landslide	7.00	826715.000	845200.000
ME94/8/1			Fill Slope	Landslide	20.00	822365.000	843555.000
ME94/8/12			Fill Slope	Landslide	10.00	821575.000	842716.000
ME94/8/16		3SE-B/FR15	Fill Slope	Landslide	10.00	841510.000	842105.000
ME94/8/17		3SE-B/F5	Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	10.00	840220.000	842690.000
ME94/9/11			Fill Slope		10.00	846670.000	835180.000
ME94/9/12			Fill Slope	Landslide	1.00	822555.000	843500.000
ME94/9/9			Fill Slope	Washout	10.00	842920.000	844850.000
ME95/10/12			Fill Slope	Landslide	0.00	820170.000	843090.000
ME95/10/8	C		Fill Slope	Landslide	1.50	835580.000	835175.000
ME95/8/14			Fill Slope	Landslide	5.00	821530.000	842345.000
ME95/8/20			Fill Slope	Landslide	4.00	819545.000	846430.000
ME95/8/39			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	816973.000	848290.000
ME95/8/44			Fill Slope	Landslide	1.50	823472.000	843893.000
ME95/9/2			Fill Slope	Washout	2.00	821610.000	842880.000
ME95/9/5			Fill Slope	Landslide	5.00	833100.000	834970.000
ME96/10/4		3SE-D/F6	Fill Slope	Landslide	5.00	838395.000	843080.000
ME96/10/5			Fill Slope	Landslide	3.00	824893.000	840770.000
ME96/4/3			Fill Slope	Landslide	25.00	832983.000	836935.000
ME96/6/17			Fill Slope	Washout	5.00	844760.000	832555.000
ME96/6/20			Fill Slope	Landslide	5.00	0.000	0.000
ME96/6/9			Fill Slope	Landslide	48.00	845645.000	840940.000
ME96/9/10			Fill Slope	Landslide	10.00	846120.000	837330.000
ME96/9/11			Fill Slope	Washout	5.00	846290.000	838480.000
MW84/6/1			Fill Slope	Washout	5.00	825900.000	828433.000
MW86/1/1			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	825173.000	832690.000
MW86/3/1		7SW-C/FR63	Fill Slope	Landslide	200.00	825100.000	830935.000
MW86/6/1		6SE-C/F9	Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	2.00	825800.000	825800.000
MW86/6/2			Fill Slope	Landslide	30.00	825080.000	823690.000
MW86/7/2			Fill Slope	Landslide	30.00	825125.000	831425.000
MW87/7/13			Fill Slope	Landslide	20.00	825673.000	818207.000
MW87/8/1			Fill Slope	Landslide	3.00	0.000	0.000
MW87/8/17			Fill Slope	Landslide	10.00	826250.000	832785.000
MW87/8/26			Fill Slope	Landslide	15.00	826620.000	832430.000
MW87/8/27			Fill Slope	Landslide	0.00	827045.000	832200.000
MW87/8/3			Fill Slope	Landslide	100.00	824810.000	830545.000
MW88/5/1			Fill Slope	Washout	32.00	825393.000	832767.000
MW88/5/5			Fill Slope	Washout	30.00	827650.000	816210.000
MW88/7/15		6SE-D/F47	Fill Slope	Washout	10.00	825800.000	828100.000

Table 3.2 - List of 421 Incidents of Failures of Slopes (continued)

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
MW88/7/24			Fill Slope	Landslide	1.00	823290.000	823995.000
MW88/9/1		6SE-C/FR2	Fill Slope	Washout	3.50	825615.000	826130.000
MW88/9/2			Fill Slope	Landslide	5.00	824745.000	831098.000
MW88/9/3			Fill Slope	Landslide	10.00	835955.000	816410.000
MW88/9/5		7SW-L/F20	Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	3.50	825430.000	832500.000
MW89/5/116		6SE-C/FR2	Fill Slope	Landslide	10.00	825620.000	826130.000
MW89/5/15			Fill Slope	Washout	42.00	825990.000	830855.000
MW89/5/33	A		Fill Slope	Landslide	200.00	825950.000	820570.000
MW89/5/33	B		Fill Slope	Landslide	80.00	825885.000	820640.000
MW89/5/45			Fill Slope	Landslide	40.00	826665.000	829550.000
MW89/5/86			Fill Slope	Landslide	200.00	824080.000	820970.000
MW89/6/1			Fill Slope		3.00	0.000	0.000
MW89/6/1	B		Fill Slope	Landslide	3.00	826995.000	831322.000
MW89/6/2			Fill Slope	Landslide	8.00	826820.000	829335.000
MW89/6/3			Fill Slope	Landslide	3.00	826780.000	829310.000
MW89/6/8			Fill Slope	Landslide	10.00	831800.000	812500.000
MW89/7/22			Fill Slope	Landslide	1.00	0.000	0.000
MW90/12/1			Fill Slope	Washout	60.00	826635.000	829230.000
MW90/7/2			Fill Slope	Washout	20.00	828795.000	815980.000
MW90/8/1			Fill Slope	Landslide	2.00	824580.000	832075.000
MW90/9/7			Fill Slope	Landslide	0.50	824572.000	832085.000
MW91/6/9			Fill Slope	Landslide	6.00	828000.000	814820.000
MW91/9/1			Fill Slope	Washout	2.50	823660.000	831080.000
MW92/3/1			Fill Slope	Washout	0.50	822570.000	832545.000
MW92/4/6			Fill Slope	Washout	3.00	828762.000	815980.000
MW92/5/19			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	0.000	0.000
MW92/5/22			Fill Slope	Washout	0.00	826085.000	832655.000
MW92/5/24			Fill Slope	Washout	0.00	825750.000	837400.000
MW92/5/25			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	30.00	824350.000	834600.000
MW92/5/3		11NW-B/F48	Fill Slope	Washout	50.00	822700.000	833830.000
MW92/5/34			Fill Slope	Distress / dislodgement of slope surface protection	1.00	809900.000	829790.000
MW92/5/37			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	808910.000	830410.000
MW92/6/1			Fill Slope	Washout	3.00	828825.000	816085.000
MW92/6/21			Fill Slope	Landslide	40.00	812390.000	806390.000
MW92/6/27			Fill Slope	Washout	10.00	830590.000	816750.000
MW92/6/31			Fill Slope	Washout	30.00	826170.000	835740.000
MW92/7/12			Fill Slope	Landslide	6.00	838000.000	830100.000
MW92/7/15			Fill Slope	Landslide	20.00	825200.000	823630.000
MW92/7/16			Fill Slope	Landslide	6.00	807420.000	821290.000
MW93/11/126			Fill Slope	Landslide	3.00	810942.000	817923.000
MW93/11/128			Fill Slope	Landslide	20.00	809900.000	810350.000
MW93/11/129		13NE-B/FR21	Fill Slope	Landslide	173.00	811175.000	813380.000
MW93/11/132		9SW-D/FR13	Fill Slope	Landslide	1000.00	0.000	0.000
MW93/11/132	A	9SW-D/FR13	Fill Slope	Landslide	1000.00	813850.000	806250.000
MW93/11/132	B	9SW-D/FR13	Fill Slope	Landslide	1000.00	813800.000	806225.000
MW93/11/132	C	9SW-D/FR13	Fill Slope	Landslide	1000.00	813850.000	806275.000
MW93/11/27		10SW-C/F11	Fill Slope	Landslide	30.00	813530.000	817675.000
MW93/11/33			Fill Slope	Landslide	0.00	0.000	0.000
MW93/11/47			Fill Slope	Landslide	5.00	825265.000	817650.000
MW93/11/49			Fill Slope	Landslide	45.00	806075.000	816800.000
MW93/11/72			Fill Slope	Landslide	150.00	822500.000	833745.000
MW93/4/1			Fill Slope	Washout	2.00	0.000	0.000
MW93/5/1			Fill Slope	Landslide	20.00	826700.000	831067.000
MW93/5/3			Fill Slope	Landslide	4.00	825060.000	832645.000
MW93/6/39		7SW-D/FR10	Fill Slope	Washout	1.00	825690.000	835915.000
MW93/6/51			Fill Slope	Landslide	20.00	825453.000	835370.000
MW93/6/52			Fill Slope	Landslide	5.00	825739.000	837475.000
MW93/6/53			Fill Slope	Landslide	1000.00	825815.000	826520.000
MW93/6/59			Fill Slope	Washout	1.00	826335.000	829995.000
MW93/6/84		3SW-C/F10	Fill Slope	Landslide	20.00	837348.000	832613.000
MW93/9/15			Fill Slope	Washout	2.00	839143.000	830841.000
MW93/9/16			Fill Slope	Landslide	4.50	828950.000	815915.000
MW93/9/20			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	0.00	824560.000	832093.000
MW94/7/14			Fill Slope	Landslide	4.00	809004.000	830351.000
MW94/7/34		6SE-D/FR32	Fill Slope	Landslide	45.00	826785.000	829660.000
MW94/7/39			Fill Slope	Landslide	4.00	809014.000	830335.000
MW94/7/63		7SW-D/FR33	Fill Slope	Landslide	100.00	824480.000	836075.000
MW94/7/72			Fill Slope	Landslide	15.00	825720.000	818805.000
MW94/7/75			Fill Slope	Washout	20.00	831425.000	817815.000
MW94/7/80			Fill Slope	Landslide	4.00	815825.000	822205.000
MW94/8/20			Fill Slope	Washout	4.00	842600.000	828050.000
MW94/8/4			Fill Slope	Subsidence(loss of ground, significant settlement on flat land)	7.50	825035.000	823740.000
MW94/8/43			Fill Slope	Landslide	10.00	825423.412	819175.619
MW94/9/8			Fill Slope	Washout	10.00	846670.000	835180.000
MW95/4/2			Fill Slope	Washout	30.00	0.000	0.000
MW95/8/10			Fill Slope	Landslide	20.00	826290.000	832750.000
MW95/8/12			Fill Slope	Landslide	20.00	823740.000	832505.000
MW95/8/24			Fill Slope	Landslide	1.50	824310.000	834580.000
MW96/3/1			Fill Slope	Landslide	10.00	0.000	0.000

Table 3.2 - List of 421 Incidents of Failures of Slopes (continued)

INCID	INSUB	FEATURE	TYPES	TYPE	SCALE	NORTHING	EASTING
MW96/9/2			Fill Slope	Distress / dislodgement of slope surface protection	1.00	826210.000	835715.000
NT82/10			Fill Slope	Washout	50.00	825660.000	823870.000
NT82/112			Fill Slope	Washout	50.00	823700.000	823860.000
NT82/119			Fill Slope	Washout	0.50	815950.476	847480.868
NT82/120	A		Fill Slope	Washout	0.00	826479.907	829867.215
NT82/120	B		Fill Slope	Washout	0.00	826479.907	829867.215
NT82/120	C		Fill Slope	Washout	0.00	826479.907	829867.215
NT82/144			Fill Slope	Landslide	50.00	837119.369	836849.645
NT82/180			Fill Slope	Landslide	50.00	0.000	0.000
NT82/180	A		Fill Slope	Landslide	50.00	827650.000	817100.000
NT82/180	B		Fill Slope	Washout	50.00	827650.000	817100.000
NT82/180	C		Fill Slope	Landslide	50.00	827650.000	817100.000
NT82/181			Fill Slope	Landslide	0.00	0.000	0.000
NT82/202			Fill Slope	No geotechnical concern - no failure	0.00	828947.155	815612.500
NT82/25			Fill Slope	Landslide	50.00	829000.000	837570.000
NT82/273			Fill Slope		50.00	819795.000	843335.000
NT82/3			Fill Slope	Landslide	0.00	0.000	0.000
NT82/50			Fill Slope	Landslide	0.00	825760.460	824090.264
NT82/7			Fill Slope	Landslide	50.00	824875.277	823449.439
NT82/8/19			Fill Slope	Landslide	0.00	0.000	0.000
NT82/8/72			Fill Slope	Washout	300.00	822845.000	832815.000
NT82/8/75			Fill Slope	Washout	200.00	827100.000	832080.000
NT82/86			Fill Slope	Landslide	50.00	825850.000	817920.000
NT82/89			Fill Slope	Landslide	50.00	825633.003	817817.289
NT82/98			Fill Slope	Landslide	50.00	835380.000	835350.000
NT83/11/1			Fill Slope	Washout	6.00	824770.351	834904.582

Table 3.3 - Summary of Different Types of Failure During 1982-1996

Year	No. of Fill Slope Failure (major)	Total No. of Failure (major)	Percentage (%)	Maximum Rainfall (mm) (GEO Raingauges)		Remarks
				24-hours	1-hour	
May,1982	30 (6)	421 (94)	7.1	394.3	110.0	28 deaths, 120 injured
August,1982	12 (2)	204 (--)	6	362.4	68.3	5 deaths, 3 injured
June,1983	19 (1)	160 (37)	12	346.7	69.4	1 death, 12 injured
1984	14 (1)	120 (8)	12	248.0	79.0	1 injured (30 May, 16 Jun. & 11 Oct.)
1985	13 (1)	254 (10)	5	301.0	74.0	7 injured (25 Jun. & 6 Sep.)
1986	18 (3)	233 (11)	8	315.0	79.0	1 injured (12 May, 6 Jun., 4 &12Jul., 11 Aug.)
1987	14 (1)	307 (9)	4.6	314.0	73.0	7 injured (29~30 July)
1988	15 (1)	157 (5)	10	265.0	79.0	1 injured (19~20 July)
1989	22 (5)	620 (56)	3.5	552.0	56.0	2 deaths, 8 injured (1~2 May & 20~21 May)
1990	12 (2)	99 (6)	12	276.0	91.0	30 Jun.~1 Jul. & 10~11 Sep.
1991	9 (1)	88 (4)	10	206*	65.0	The total rainfall was 74% of the yearly average of 2214.3mm.
1992	55 (6)	641 (26)	8.6	385.0	110.0	Annual rainfall was 21% higher than average (8 May, 13~14 Jun. & 18 Jul)
1993	38 (10)	827 (93)	4.6	374.0	117.0	Annual rainfall was 6% higher than average (11~12, 16~17 Jun., 25~27 Sep. & 5 Nov.)
1994	29 (2)	436 (36)	6.6	954.0	185.0	Annual rainfall was 23% higher than average (20 Jun.,22~26 Jul, 6~7 & 16~17 Aug.)
1995	21 (3)	295 (27)	7.1	467.5	106.0	Annual rainfall was 24% higher than average
1996	14 (1)	153 (4)	9.2	348.0	93.0	Annual rainfall was 2% higher than average

Legend:
(Date) The majority of the recorded landslides occurred during or shortly after the heaviest storms on the mentioned date
* Hong Kong Observatory (formerly known as Royal Observatory)

Table 4.1 - Records of Problems with Slopes before LPM Programme

Slope Number	Height (m)	Inclination (deg.)	Fill Thickness (m)	ϕ (deg)	γ (kN/m^3)	Drainage Condition[1]		Seepage/	Surface Cover		Displacement		Others[3]
						Blocked[2]	Broken	Leakage	Eroded	Cracked	Settlement	Movement	
11NE-D/F 3	>5	x	x	x	x	0	0	0	0	yes	0	0	0
11NE-D/FR 7	5~7	35	x	x	x	yes	0	0	0	0	0	0	yes
11NE-C/F 5	x	x	x	x	x	0	0	0	yes	0	0	0	0
11NE-C/F 6	10	35	x	x	x	0	0	0	0	0	yes	0	yes
11NW-D/F 102	12~15	30~45	x	x	x	0	0	0	0	0	0	0	0
11NW-B/FR 23	15	35	x	x	x	0	0	0	0	yes	0	yes	0
11NW-B/FR 24	15	35	x	x	x	0	0	0	0	0	0	yes	yes
11NW-B/FR 35	20	35	x	x	x	0	0	0	0	0	0	0	0
7SW-C/F 8	20	26	x	x	x	yes	0	0	0	0	yes	0	0
11NW-D/F 141	20	35	x	x	x	yes	0	0	0	0	0	0	0
11SW-A/FR 53	4~10	35~45	x	35	16	yes	0	0	0	0	0	0	yes
11SW-A/F 52	x	x	x	x	x	x	x	x	x	x	x	x	x
11SW-A/FR 54	10	30	x	x	x	yes	0	0	0	0	0	0	yes
11SW-B/FR 42	12~25	35~40	3~7	35	18	yes	0	0	0	yes	yes	yes	0
11NW-D/F 97	30	35	x	34	17	x	x	x	x	x	x	x	x
13NE-A/FR 38	5.5~7	30~42	x	36	19	yes	0	0	0	0	0	0	yes
11NW-B/FR 69	10	40	3~6	36	18	yes	0	0	0	yes	0	0	0
11NW-B/FR 36	20	33~37	x	37	x	0	0	0	0	0	0	0	0
11SE-A/FR 64	5~20	35	0~4.5	36	18	0	0	0	0	yes	yes	yes	yes
11SE-A/FR 7	7	30~40	5~9	35	16	yes	0	0	0	yes	0	0	0
11SW-C/FR 1	13	35	10	35	18	yes	0	0	0	0	0	0	0
11SW-C/F 24	15	34~45	9	34	17.3	0	yes	yes	yes	0	0	0	yes
11SW-D/F 53	42	20~40	9	31	17	yes	yes	0	yes	yes	0	yes	yes
11NE-B/F 58	30	33	10~15	35	19	0	0	yes	0	0	0	0	yes
6SE-D/F 47	11	40	x	x	x	0	0	0	0	yes	0	0	0
11SW-D/FR 21	10	35	x	x	x	0	yes	0	0	0	0	0	0
11SW-D/FR 20	5~10	30	x	35	17.5	x	x	x	x	x	x	x	x
11NE-D/F 109	12	40	x	x	x	0	0	yes	0	0	0	0	0
11NE-D/FR 4	20	35	x	x	x	yes	0	0	0	0	0	0	yes
11SE-D/F 3	2~15	30~40	x	x	x	yes	0	0	0	0	0	0	0
7SW-C/F 3	2	26	x	x	x	x	x	x	x	x	x	x	x
7SW-C/F 4	20	37	x	x	x	yes	0	0	0	0	0	0	yes
7SW-C/F 6	x	x	x	x	x	x	x	x	x	x	x	x	x
7SW-C/F 10	20	32	x	x	x	0	0	0	0	0	0	0	0
11NE-A/F 6	x	x	x	x	x	0	0	0	yes	0	0	0	0
11SE-D/F 7	18	30	x	37	x	yes	0	0	0	0	0	0	yes
11NE-D/F 1	30	35	x	x	x	yes	0	0	0	0	0	0	yes
11NW-A/FR 6	12	35	x	x	x	0	0	0	yes	0	0	0	0
11NW-A/FR 7	22	35	x	x	x	0	0	0	0	0	0	0	0
11NW-B/F 39	25~30	35	x	x	x	yes	0	0	yes	0	0	0	0
7SW-C/FR 37	x	x	x	x	x	x	x	x	x	x	x	x	x
11SW-C/F 19	x	x	x	x	x	x	x	x	x	x	x	x	x
11SW-C/F 20	x	x	x	x	x	x	x	x	x	x	x	x	x
11NW-B/F 2	x	x	x	37	18	x	x	x	x	x	x	x	x
11SW-A/FR 47	13	30	x	x	x	yes	0	yes	0	0	0	0	0

Table 4.1 - Records of Problems with Slopes before LPM Programme (continued)

Slope Number	Height (m)	Inclination (deg.)	Fill Thickness (m)	ϕ (deg)	γ (kN/m^3)	Drainage Blocked[2]	Condition[1] Broken	Seepage/ Leakage	Surface Eroded	Cover Cracked	Displacement Settlement	Displacement Movement	Others[3]
11SW-A/FR 49	15	40	x	x	x	0	0	0	0	0	0	0	0
11SW-A/FR 50	15	35	x	x	x	0	0	0	0	0	0	0	0
11NE-A/F 12	8	35	x	35	18	0	0	0	0	0	0	0	0
11NE-A/F 75	x	x	x	35	18	x	x	x	x	x	x	x	x
11NE-D/FR 43	4.5	35	x	x	x	yes	0	yes	0	yes	yes	0	yes
11NE-A/F 11	8	35	1.5~8.5	x	x	0	0	yes	0	0	0	0	0
11NE-A/F 73	7~14	32~35	x	36	17.8	0	0	0	0	0	0	0	0
11NW-A/FR 69	6	40	1.5~4.0	40	18	yes	0	yes	0	0	yes	0	0
11SE-D/FR 24	30	35	11.5	35	18	yes	yes	0	0	0	0	0	0
11SE-C/F 21	30	33	3	35	18	0	0	0	0	0	0	0	yes
7SW-C/FR 13	18	35	x	x	x	yes	0	0	0	0	0	0	0
11NE-B/FR 31	20~40	35	x	x	x	0	0	0	0	yes	0	0	yes
11NE-C/F 1	20~25	35	x	x	x	0	0	0	yes	0	0	0	yes
11NW-A/F 44	20	35	8~10	40	x	yes	0	0	yes	yes	0	yes	yes
11NW-D/FR 25	10	35	x	x	x	0	yes	0	yes	0	yes	0	0
11SW-D/FR 1	50	35	3.0~3.5	x	x	yes	yes	0	0	yes	yes	0	0
11SW-D/FR 4	x	x	x	x	x	x	x	x	x	x	x	x	x
11SW-D/FR 48	15	34	x	36	x	x	x	x	x	x	x	x	x
11SE-A/FR 9	x	x	x	x	x	x	x	x	x	x	x	x	x
7SW-C/FR 2	x	x	x	x	x	x	x	x	x	x	x	x	x
11NW-B/F 8	30~40	35	x	x	x	0	0	0	0	0	0	0	0
11SE-A/FR 11	15	35	x	x	x	yes	0	0	0	0	0	0	0
11NW-A/F 9	x	x	x	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 43	15~20	35	x	x	x	0	yes	yes	0	0	0	0	0
11SW-D/F 69	x	x	x	x	x	x	x	x	x	x	x	x	x
7SW-C/F 31	x	x	x	x	x	x	x	x	x	x	x	x	x
11SW-B/FR 56	30.5	31	x	35	18.7	yes	0	0	yes	0	0	0	0
11NW-A/FR 65	13	35	7	x	x	yes	0	0	yes	0	0	0	0
11SW-B/FR 59	2~4.5	27	35	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 42	9	35~40	x	39	x	0	0	0	0	0	0	0	0
12NW-C/FR 7	x	x	3	x	x	x	x	x	x	x	x	x	x
11NW-A/FR 5	15	35	x	39	x	yes	0	0	0	0	0	0	yes
15NE-C/F 46	6.8~13	50	x	35	18	yes	0	yes	0	0	0	0	yes
11SE-A/F 34	20~40	35~40	x	35	x	0	yes	0	0	yes	0	0	yes
11SW-A/FR 23	18	34~40	2~4.5	34	18	yes	yes	0	0	0	0	0	0
11SE-A/FR 48	20	34	x	38	19	yes	0	0	0	0	0	0	0
11SW-A/F 32	12	35	5~7	35	18.1	yes	0	0	yes	0	yes	0	0
11NW-A/F 23	15~20	35	x	x	x	x	x	x	x	x	x	x	x
11SW-D/FR 7	30	34	x	35.4	20.8	0	0	0	0	0	0	0	0
11SW-D/FR 135	30	35~40	2~7	36	20	yes	yes	0	yes	0	0	0	yes
7NW-D/FR 1	17.2	17~33	7.5~8	37	18	0	yes	0	yes	0	0	0	yes
11SW-D/F 32	6	45	2	35	x	0	0	0	0	0	0	yes	0
11SW-D/FR 26	6	50	1~6.5	36	18	0	0	0	0	yes	yes	0	0
11SW-D/F 33	5	45	2~8	38	18	0	0	yes	0	yes	yes	yes	0
11SW-D/FR 29	25	36	2~3	35	18	yes	0	yes	yes	0	0	0	0

Table 4.1 - Records of Problems with Slopes before LPM Programme (continued)

Slope Number	Height (m)	Inclination (deg.)	Fill Thickness (m)	ϕ (deg)	γ (kN/m³)	Drainage Blocked[2]	Condition[1] Broken	Seepage/ Leakage	Surface Eroded	Cover Cracked	Displacement Settlement	Displacement Movement	Others[3]
11SE-A/F 30	12	30~42	2~4	39	18	yes	0	yes	0	yes	0	0	0
15NE-B/F 25	15	30	7.5	30	17	0	0	0	yes	yes	yes	0	0
11SE-A/F 61	13	25~40	5~14	32	19	0	0	0	0	0	0	0	yes
11NE-A/F 96	9	30	x	x	x	x	x	x	x	x	x	x	x
11SW-C/N 1	x	x	x	x	x	x	x	x	x	x	x	x	x
7SW-D/FR 10	16	34	x	35	17	yes	yes	0	0	0	0	0	0
11SW-D/FR 112	6	30	13	33	18	yes	0	0	0	yes	0	0	yes
11SW-C/FR 88	x	x	0.5~2.5	35	x	yes	0	0	0	0	0	0	0
11NE-B/T 190	2	30	x	x	x	x	x	x	x	x	x	x	x
11NE-B/F 56	12	35	3~8	33.5	19	yes	yes	0	0	0	0	0	0
11SW-B/FR 124	12	35~40	x	33	17	0	0	0	0	0	0	0	0
11NE-B/F 11	10	33~35	8~12.4	33	18	yes	yes	0	0	0	0	0	0
7SW-D/F 53	2~12	35	x	35	19	yes	0	0	0	0	0	0	0
11SE-B/FR 28	8	38	5.5	35	19	yes	0	0	0	0	0	0	yes
7SW-C/FR 97	10	35	x	37.4	x	0	0	0	0	0	0	0	0
11SW-D/F 70	32	35	x	x	x	x	x	x	x	x	x	x	x
7SW-C/FR 100	35	30~40	>10	x	x	yes	0	0	0	0	0	0	0
11NW-D/F 118	x	x	x	x	x	0	0	0	0	0	0	0	0
11SE-A/FR 15	15	35	x	x	x	yes	0	0	0	0	0	0	0
11SW-A/FR 20	6	30	x	x	x	yes	yes	0	0	0	0	0	0
11NW-D/FR 119	30	34	x	35	18	0	0	0	0	0	0	0	yes
11SW-A/FR 87	4	35	x	33.4	x	x	x	x	x	x	x	x	x
11NE-D/FR 16	5	35	x	x	x	yes	0	0	0	0	0	0	0
11SE-A/FR 21	11.5	30.5~35	7	36	18	0	0	0	0	0	0	0	yes
11SE-C/F 14	12	40	x	x	x	0	0	0	0	0	0	0	0
11SE-C/FR 1	18	35	10	33	19	yes	0	0	yes	0	0	0	0
11SE-D/F 2	15	30	x	x	x	0	0	0	0	0	0	0	0
11SE-D/FR 5	2~20	30	x	36	17.5	0	0	0	0	0	0	0	0
11SW-B/F 43	13	30	3~7	35	18	yes	0	0	0	yes	yes	yes	0
11SW-D/FR 5	8	40	x	36.5	x	0	0	yes	yes	0	0	0	yes
11SW-D/FR 18	x	x	x	x	x	x	x	x	x	x	x	x	x
11NE-D/FR 10	28	35	x	x	x	0	0	0	yes	0	yes	0	0
11NW-B/FR 51	30	35	x	x	x	0	0	0	0	0	0	0	yes
11SW-A/FR 1	50	32	x	x	x	yes	0	yes	0	yes	0	0	yes
11SW-A/FR 65	60	30	x	x	x	yes	yes	0	0	0	0	0	0
11NW-B/FR 38	25~30	35	x	x	x	0	0	0	yes	0	0	0	0
11NW-D/FR 44	10	35	x	x	x	0	0	0	0	0	0	0	0
11NW-D/F 117	6	30	x	x	x	0	0	0	0	0	0	0	0
11NW-B/FR 53	25	35	x	x	x	0	0	0	yes	0	0	0	yes
11SE-A/FR 10	x	22~34	x	36	17.5	0	yes	0	0	yes	0	0	0

Notes:
1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Including previous instability, failure, slips, erosion, cracks, washout, etc.
x Information not available or no inspection report.
0 No observed problem during inspection.

Table 4.2 - Records of Problems with Slopes after LPM Programme

Slope Number	φ (deg)	γ (kN/m³)	Drainage Condition[1] Blocked[2]	Drainage Condition[1] Broken	Seepage/ Leakage	Surface Cover Eroded	Surface Cover Cracked	Displacement Settlement	Displacement Movement	Others[3]
11NE-D/F 3	x	x	x	x	x	x	x	x	x	x
11NE-D/FR 7	x	x	x	x	x	x	x	x	x	x
11NE-C/F 5	x	x	x	x	x	x	x	x	x	x
11NE-C/F 6	x	x	yes	0	0	0	0	0	0	0
11NW-D/F 102	x	x	yes	0	0	0	yes	0	0	0
11NW-B/FR 23	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 24	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 35	x	x	0	0	yes	0	0	0	0	0
7SW-C/F 8	x	x	yes	0	0	0	0	yes	0	0
11NW-D/F 141	x	x	x	x	x	x	x	x	x	x
11SW-A/FR 53	39	19	yes	0	yes	0	0	0	0	0
11SW-A/F 52	x	x	0	0	yes	0	0	0	0	0
11SW-A/FR 54	x	x	yes	0	0	0	0	0	0	0
11SW-B/FR 42	39	x	yes	0	0	0	0	0	0	0
11NW-D/F 97	39	20	x	x	x	x	x	x	x	x
13NE-A/FR 38	39	21.3	yes	0	yes	0	0	0	0	0
11NW-B/FR 69	39	20.6	yes	0	0	0	0	0	0	0
11NW-B/FR 36	x	x	yes	0	0	0	0	0	0	0
11SE-A/FR 64	39	18	0	0	0	0	0	0	0	0
11SE-A/FR 7	x	x	0	0	0	0	0	0	0	0
11SW-C/FR 1	x	x	yes	0	0	0	0	0	0	yes
11SW-C/F 24	39	19~21	x	x	x	x	x	x	x	x
11SW-D/F 53	38	19	yes	yes	0	0	yes	0	0	0
11NE-B/F 58	38	19	x	x	x	x	x	x	x	x
6SE-D/F 47	x	x	yes	0	0	0	0	0	0	yes
11SW-D/FR 21	x	x	yes	yes	0	0	0	0	0	0
11SW-D/FR 20	x	x	yes	yes	0	0	0	0	0	0
11NE-D/F 109	x	x	x	x	x	x	x	x	x	x
11NE-D/FR 4	x	x	yes	0	yes	0	0	0	0	0
11SE-D/F 3	x	x	yes	0	0	0	0	0	0	0
7SW-C/F 3	x	x	yes	0	0	0	0	0	0	0
7SW-C/F 4	x	x	yes	0	0	0	yes	0	0	0
7SW-C/F 6	x	x	x	x	x	x	x	x	x	x
7SW-C/F 10	x	x	yes	0	0	0	0	0	0	0
11NE-A/F 6	x	x	x	x	x	x	x	x	x	x
11SE-D/F 7	x	x	yes	0	0	0	0	0	0	0
11NE-D/F 1	x	x	yes	0	0	0	0	0	0	0
11NW-A/FR 6	x	x	x	x	x	x	x	x	x	x
11NW-A/FR 7	x	x	x	x	x	x	x	x	x	x
11NW-B/F 39	x	x	yes	0	0	0	0	0	0	0
7SW-C/FR 37	x	x	x	x	x	x	x	x	x	x
11SW-C/F 19	x	x	x	x	x	x	x	x	x	x
11SW-C/F 20	x	x	x	x	x	x	x	x	x	x
11NW-B/F 2	39	21.3	x	x	x	x	x	x	x	x
11SW-A/FR 47	x	x	yes	0	yes	0	0	0	0	0

Table 4.2 - Records of Problems with Slopes after LPM Programme (continued)

Slope Number	ϕ (deg)	γ (kN/m^3)	Drainage Condition[1]		Seepage/	Surface Cover		Displacement		Others[3]
			Blocked[2]	Broken	Leakage	Eroded	Cracked	Settlement	Movement	
11SW-A/FR 49	x	x	yes	0	0	0	0	0	0	0
11SW-A/FR 50	x	x	yes	0	yes	0	0	0	0	0
11NE-A/F 12	39	20	0	yes	0	0	yes	0	yes	0
11NE-A/F 75	39	20	0	0	0	0	0	0	0	0
11NE-D/FR 43	x	x	x	x	x	x	x	x	x	x
11NE-A/F 11	x	x	x	x	x	x	x	x	x	x
11NE-A/F 73	39	21.3	x	x	x	x	x	x	x	x
11NW-A/FR 69	x	x	0	0	0	0	0	0	0	0
11SE-D/FR 24	39	18	0	yes	0	0	yes	0	0	0
11SE-C/F 21	39	19	x	x	x	x	x	x	x	x
7SW-C/FR 13	x	x	0	0	yes	0	0	0	0	0
11NE-B/FR 31	x	x	x	x	x	x	x	x	x	x
11NE-C/F 1	35	19	yes	0	0	0	0	0	0	0
11NW-A/F 44	0	0	0	0	0	0	0	0	0	0
11NW-D/FR 25	x	x	yes	0	0	yes	0	yes	0	0
11SW-D/FR 1	x	x	0	0	yes	0	0	0	0	0
11SW-D/FR 4	x	x	0	yes	0	0	yes	yes	yes	0
11SW-D/FR 48	39	x	yes	0	0	0	yes	0	0	0
11SE-A/FR 9	x	x	x	x	x	x	x	x	x	x
7SW-C/FR 2	x	x	x	x	x	x	x	x	x	x
11NW-B/F 8	x	x	x	x	x	x	x	x	x	x
11SE-A/FR 11	x	x	x	x	x	x	x	x	x	x
11NW-A/F 9	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 43	x	x	yes	0	0	0	0	0	0	0
11SW-D/F 69	x	x	x	x	x	x	x	x	x	x
7SW-C/F 31	x	x	yes	yes	0	0	yes	0	0	0
11SW-B/FR 56	x	x	0	0	0	yes	0	0	0	0
11NW-A/FR 65	x	x	yes	yes	0	0	yes	0	0	0
11SW-B/FR 59	39	x	x	x	x	x	x	x	x	x
11NW-B/FR 42	39	x	yes	0	yes	0	0	0	0	0
12NW-C/FR 7	x	x	x	x	x	x	x	x	x	x
11NW-A/FR 5	x	x	0	0	0	0	0	0	0	0
15NE-C/F 46	39	20	0	0	yes	yes	0	0	0	0
11SE-A/F 34	39	x	0	0	0	0	0	0	x	yes
11SW-A/FR 23	36	19	0	0	0	0	0	yes	0	0
11SE-A/FR 48	39	21.3	x	x	x	x	x	x	x	x
11SW-A/F 32	39	21.3	yes	0	0	0	0	0	0	0
11NW-A/F 23	x	x	yes	yes	0	yes	0	0	0	0
11SW-D/FR 7	37	x	0	0	0	0	0	0	yes	0
11SW-D/FR 135	39	20	0	0	0	0	0	0	0	0
7NW-D/FR 1	x	x	x	x	x	x	x	x	x	x
11SW-D/F 32	39	20	x	x	x	x	x	x	x	x
11SW-D/FR 26	39	20	yes	0	0	yes	0	0	0	0
11SW-D/F 33	39	20	yes	0	0	0	0	0	0	0
11SW-D/FR 29	39	20	x	x	x	x	x	x	x	x

Table 4.2 - Records of Problems with Slopes after LPM Programme (continued)

Slope Number	φ (deg)	γ (kN/m³)	Drainage Condition[1] Blocked[2]	Drainage Condition[1] Broken	Seepage/ Leakage	Surface Cover Eroded	Surface Cover Cracked	Displacement Settlement	Displacement Movement	Others[3]
11SE-A/F 30	39	18	x	x	x	x	x	x	x	x
15NE-B/F 25	39	19	yes	0	0	0	0	0	0	0
11SE-A/F 61	39	19	yes	0	0	yes	0	0	0	yes
11NE-A/F 96	x	x	x	x	x	x	x	x	x	x
11SW-C/N 1	x	x	x	x	x	x	x	x	x	x
7SW-D/FR 10	39	19	yes	yes	0	yes	yes	0	0	0
11SW-D/FR 112	x	x	0	0	0	0	0	0	0	yes
11SW-C/FR 88	34	x	x	x	x	x	x	x	x	x
11NE-B/T 190	x	x	yes	yes	0	0	0	0	0	0
11NE-B/F 56	38	x	x	x	x	x	x	x	x	x
11SW-B/FR 124	42	20	x	x	x	x	x	x	x	x
11NE-B/F 11	38	19	x	x	x	x	x	x	x	x
7SW-D/F 53	39	19	0	0	0	0	yes	0	yes	0
11SE-B/FR 28	38	19	0	0	0	0	0	0	0	0
7SW-C/FR 97	x	x	yes	0	0	0	0	0	0	0
11SW-D/F 70	x	x	yes	0	0	0	0	0	0	0
7SW-C/FR 100	x	x	x	x	x	x	x	x	x	x
11NW-D/F 118	x	x	yes	0	0	0	0	0	0	0
11SE-A/FR 15	x	x	yes	0	0	0	0	0	0	0
11SW-A/FR 20	x	x	yes	0	0	0	0	0	0	0
11NW-D/FR 119	x	x	yes	0	0	0	0	0	0	0
11SW-A/FR 87	38	x	x	x	x	x	x	x	x	x
11NE-D/FR 16	x	x	yes	0	0	0	0	0	0	0
11SE-A/FR 21	40	20	0	0	yes	0	0	0	0	0
11SE-C/F 14	x	x	0	0	0	0	0	0	0	0
11SE-C/FR 1	x	x	yes	yes	0	0	0	0	0	0
11SE-D/F 2	39	21.3	x	x	x	x	x	x	x	x
11SE-D/FR 5	38	19	0	0	0	0	0	0	0	0
11SW-B/F 43	x	x	yes	0	yes	0	yes	0	0	0
11SW-D/FR 5	39	x	yes	0	0	0	0	0	0	0
11SW-D/FR 18	x	x	x	x	x	x	x	x	x	x
11NE-D/FR 10	x	x	0	0	0	yes	0	0	0	0
11NW-B/FR 51	34	x	0	0	yes	0	0	0	0	yes
11SW-A/FR 1	x	x	yes	0	0	0	yes	0	yes	yes
11SW-A/FR 65	x	x	x	x	x	x	x	x	x	x
11NW-B/FR 38	x	x	x	x	x	x	x	x	x	x
11NW-D/FR 44	x	x	yes	yes	0	0	0	0	0	0
11NW-D/F 117	x	x	yes	0	0	0	0	0	0	0
11NW-B/FR 53	x	x	x	x	x	x	x	x	x	x
11SE-A/FR 10	39	x	yes	0	0	0	0	0	0	0

Notes:
1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Including flooding, washout, etc. after LPM

x Information not available or no inspection report.
0 No observed problem during inspection.

Table 4.3 - Records of Problems with Retaining Walls before LPM Programme

Slope Number	Drainage Condition[1] Blocked[2]	Broken	Seepage/ Leakage	Wall Cracked	Movement /tilting	Others[3]
11NE-D/F 3	x	x	x	x	x	x
11NE-D/FR 7	0	0	yes	0	0	yes
11NE-C/F 5	x	x	x	x	x	x
11NE-C/F 6	n	n	n	n	n	n
11NW-D/F 102	0	0	0	0	0	0
11NW-B/FR 23	yes	0	0	0	0	0
11NW-B/FR 24	yes	0	0	0	0	0
11NW-B/FR 35	x	x	x	x	x	x
7SW-C/F 8	n	n	n	n	n	n
11NW-D/F 141	n	n	n	n	n	n
11SW-A/FR 53	0	0	0	0	0	0
11SW-A/F 52	n	n	n	n	n	n
11SW-A/FR 54	0	0	0	0	0	0
11SW-B/FR 42	yes	0	yes	yes	yes	yes
11NW-D/F 97	n	n	n	n	n	n
13NE-A/FR 38	0	0	0	yes	0	0
11NW-B/FR 69	0	0	0	0	0	0
11NW-B/FR 36	0	0	yes	0	0	0
11SE-A/FR 64	0	0	0	yes	yes	0
11SE-A/FR 7	x	x	0	0	0	0
11SW-C/FR 1	yes	0	yes	0	0	0
11SW-C/F 24	n	n	n	n	n	n
11SW-D/F 53	n	n	n	n	n	n
11NE-B/F 58	n	n	n	n	n	n
6SE-D/F 47	n	n	n	n	n	n
11SW-D/FR 21	n	n	n	n	n	n
11SW-D/FR 20	0	0	yes	0	0	0
11NE-D/F 109	n	n	n	n	n	n
11NE-D/FR 4	yes	0	0	0	0	0
11SE-D/F 3	yes	0	x	0	x	0
7SW-C/F 3	yes	0	0	0	0	0
7SW-C/F 4	n	n	n	n	n	n
7SW-C/F 6	x	x	x	x	x	x
7SW-C/F 10	n	n	n	n	n	n
11NE-A/F 6	x	x	x	x	x	x
11SE-D/F 7	n	n	n	n	n	n
11NE-D/F 1	n	n	n	n	n	n
11NW-A/FR 6	0	0	yes	0	0	0
11NW-A/FR 7	0	0	yes	0	0	0
11NW-B/F 39	n	n	n	n	n	n
7SW-C/FR 37	x	x	x	x	x	x
11SW-C/F 19	x	x	x	x	x	x
11SW-C/F 20	x	x	x	x	x	x
11NW-B/F 2	x	x	x	x	x	x
11SW-A/FR 47	yes	0	yes	yes	0	0
11SW-A/FR 49	0	x	x	x	0	x
11SW-A/FR 50	0	0	yes	0	0	0
11NE-A/F 12	n	n	n	n	n	n
11NE-A/F 75	n	n	n	n	n	n
11NE-D/FR 43	yes	0	yes	0	0	yes
11NE-A/F 11	n	n	n	n	n	n
11NE-A/F 73	n	n	n	n	n	n
11NW-A/FR 69	yes	yes	yes	yes	0	0
11SE-D/FR 24	yes	0	0	0	0	0
11SE-C/F 21	x	x	0	0	0	0
7SW-C/FR 13	yes	yes	yes	0	0	0
11NE-B/FR 31	n	n	n	n	n	n
11NE-C/F 1	n	n	n	n	n	n
11NW-A/F 44	n	n	n	n	n	n
11NW-D/FR 25	x	x	yes	x	0	x
11SW-D/FR 1	yes	yes	yes	yes	yes	0
11SW-D/FR 4	x	x	x	x	x	x
11SW-D/FR 48	x	x	x	x	x	x
11SE-A/FR 9	x	x	x	x	x	x
7SW-C/FR 2	x	x	x	x	x	x
11NW-B/F 8	n	n	n	n	n	n
11SE-A/FR 11	yes	0	0	0	0	0
11NW-A/F 9	x	x	x	x	x	x
11NW-B/FR 43	0	0	0	0	0	0
11SW-D/F 69	x	x	x	x	x	x

Table 4.3 - Records of Problems with Retaining Walls before LPM Programme (continued)

Slope Number	Drainage Condition[1] Blocked[2]	Drainage Condition[1] Broken	Seepage/ Leakage	Wall Cracked	Movement /tilting	Others[3]
7SW-C/F 31	x	x	x	x	x	x
11SW-B/FR 56	yes	0	x	yes	x	x
11NW-A/FR 65	x	x	x	x	x	x
11SW-B/FR 59	x	x	x	x	x	x
11NW-B/FR 42	0	0	0	0	0	0
12NW-C/FR 7	x	x	x	x	x	x
11NW-A/FR 5	0	0	0	0	0	0
15NE-C/F 46	n	n	n	n	n	n
11SE-A/F 34	x	x	x	x	x	x
11SW-A/FR 23	0	0	0	0	0	0
11SE-A/FR 48	yes	0	0	x	yes	0
11SW-A/F 32	yes	0	x	0	0	0
11NW-A/F 23	n	n	n	n	n	n
11SW-D/FR 7	x	x	x	x	x	x
11SW-D/FR 135	x	x	0	0	0	0
7NW-D/FR 1	yes	0	yes	0	0	0
11SW-D/F 32	n	n	n	n	n	n
11SW-D/FR 26	0	0	0	yes	yes	0
11SW-D/F 33	x	x	0	x	x	0
11SW-D/FR 29	0	0	0	0	0	0
11SE-A/F 30	n	n	n	n	n	n
15NE-B/F 25	n	n	n	n	n	n
11SE-A/F 61	n	n	n	n	n	n
11NE-A/F 96	x	x	x	x	x	x
11SW-C/N 1	x	x	x	x	x	x
7SW-D/FR 10	yes	x	yes	x	0	x
11SW-D/FR 112	yes	yes	0	0	0	0
11SW-C/FR 88	x	x	x	x	x	x
11NE-B/T 190	x	x	x	x	x	x
11NE-B/F 56	n	n	n	n	n	n
11SW-B/FR 124	0	x	yes	0	0	x
11NE-B/F 11	yes	yes	x	yes	0	0
7SW-D/F 53	x	x	x	x	x	yes
11SE-B/FR 28	yes	0	0	yes	0	
7SW-C/FR 97	0	0	0	0	0	0
11SW-D/F 70	x	x	x	x	x	x
7SW-C/FR 100	0	0	0	0	0	0
11NW-D/F 118	n	n	n	n	n	n
11SE-A/FR 15	n	n	n	n	n	n
11SW-A/FR 20	n	n	n	n	n	n
11NW-D/FR 119	0	0	0	0	0	0
11SW-A/FR 87	x	x	x	x	x	x
11NE-D/FR 16	yes	x	yes	yes	0	x
11SE-A/FR 21	yes	0	yes	0	0	0
11SE-C/F 14	n	n	n	n	n	n
11SE-C/FR 1	n	n	n	n	n	n
11SE-D/F 2	x	x	x	x	x	x
11SE-D/FR 5	n	n	n	n	n	n
11SW-B/F 43	yes	yes	yes	yes	yes	0
11SW-D/FR 5	yes	0	0	0	0	0
11SW-D/FR 18	x	x	x	x	x	x
11NE-D/FR 10	x	x	x	x	x	x
11NW-B/FR 51	0	0	0	0	yes	0
11SW-A/FR 1	0	0	x	yes	0	0
11SW-A/FR 65	x	x	x	x	x	x
11NW-B/FR 38	x	x	x	x	0	x
11NW-D/FR 44	0	0	yes	0	0	0
11NW-D/F 117	n	n	n	n	n	n
11NW-B/FR 53	0	0	0	0	0	0
11SE-A/FR 10	x	x	0	0	0	x

Notes: 1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Including flooding, washout, etc. after LPM.
x Information not available or no inspection report.
n Non-exist. 0 No observed problem during inspection.

Table 4.4 - Records of Problems with Retaining Walls after LPM Programme

Slope Num.	Drainage Condition[1]		Seepage/ Leakage	Wall Cracked	Movement /tilting	Others[3]
	Blocked[2]	Broken				
11NE-D/F 3	x	x	x	x	x	x
11NE-D/FR 7	x	x	x	x	x	x
11NE-C/F 5	x	x	x	x	x	x
11NE-C/F 6	n	n	n	n	n	n
11NW-D/F 102	yes	0	yes	yes	0	0
11NW-B/FR 23	x	x	x	x	x	x
11NW-B/FR 24	x	x	x	x	x	x
11NW-B/FR 35	x	x	x	x	x	x
7SW-C/F 8	n	n	n	n	n	n
11NW-D/F 141	n	n	n	n	n	n
11SW-A/FR 53	0	0	yes	0	0	0
11SW-A/F 52	n	n	n	n	n	n
11SW-A/FR 54	yes	0	yes	yes	0	yes
11SW-B/FR 42	yes	0	0	yes	0	yes
11NW-D/F 97	x	x	x	x	x	x
13NE-A/FR 38	yes	0	yes	0	0	0
11NW-B/FR 69	yes	0	0	0	0	0
11NW-B/FR 36	0	0	0	0	0	0
11SE-A/FR 64	0	0	0	0	0	0
11SE-A/FR 7	0	0	0	0	0	0
11SW-C/FR 1	yes	0	0	yes	0	0
11SW-C/F 24	x	x	x	x	x	x
11SW-D/F 53	0	0	0	0	0	0
11NE-B/F 58	n	n	n	n	n	n
6SE-D/F 47	n	n	n	n	n	n
11SW-D/FR 21	0	0	0	0	0	0
11SW-D/FR 20	yes	0	0	0	0	0
11NE-D/F 109	n	n	n	n	n	n
11NE-D/FR 4	n	n	n	n	n	n
11SE-D/F 3	x	x	x	x	x	x
7SW-C/F 3	yes	0	0	0	0	0
7SW-C/F 4	n	n	n	n	n	n
7SW-C/F 6	x	x	x	x	x	x
7SW-C/F 10	n	n	n	n	n	n
11NE-A/F 6	x	x	x	x	x	x
11SE-D/F 7	x	x	x	x	x	x
11NE-D/F 1	n	n	n	n	n	n
11NW-A/FR 6	x	x	x	x	x	x
11NW-A/FR 7	x	x	x	x	x	x
11NW-B/F 39	n	n	n	n	n	n
7SW-C/FR 37	x	x	x	x	x	x
11SW-C/F 19	x	x	x	x	x	x
11SW-C/F 20	x	x	x	x	x	x
11NW-B/F 2	x	x	x	x	x	x
11SW-A/FR 47	yes	0	yes	0	0	0
11SW-A/FR 49	0	x	yes	0	0	x
11SW-A/FR 50	0	0	yes	0	0	yes
11NE-A/F 12	0	yes	0	0	yes	0
11NE-A/F 75	x	x	x	x	x	x
11NE-D/FR 43	x	x	x	x	x	x
11NE-A/F 11	n	n	n	n	n	n
11NE-A/F 73	x	x	x	x	x	x
11NW-A/FR 69	0	0	0	0	0	0
11SE-D/FR 24	0	0	yes	0	0	0
11SE-C/F 21	x	x	x	x	x	x
7SW-C/FR 13	0	0	yes	0	0	0
11NE-B/FR 31	x	x	x	x	x	x
11NE-C/F 1	yes	0	yes	0	0	0
11NW-A/F 44	x	x	x	x	x	x
11NW-D/FR 25	yes	x	0	0	0	x
11SW-D/FR 1	0	0	yes	0	0	0
11SW-D/FR 4	x	x	x	x	x	x
11SW-D/FR 48	0	0	0	0	0	0
11SE-A/FR 9	x	x	x	x	x	x
7SW-C/FR 2	x	x	yes	x	x	x
11NW-B/F 8	x	x	x	x	x	x
11SE-A/FR 11	0	0	0	yes	0	0
11NW-A/F 9	x	x	x	x	x	x
11NW-B/FR 43	yes	0	0	0	0	0
11SW-D/F 69	x	x	x	x	x	x

Table 4.4 - Records of Problems with Retaining Walls after LPM Programme (continued)

Slope Num.	Drainage Condition[1]		Seepage/ Leakage	Wall Cracked	Movement /tilting	Others[3]
	Blocked[2]	Broken				
7SW-C/F 31	x	x	x	x	x	x
11SW-B/FR 56	x	x	x	x	x	x
11NW-A/FR 65	yes	yes	0	0	0	x
11SW-B/FR 59	x	x	x	x	x	x
11NW-B/FR 42	yes	0	0	0	0	0
12NW-C/FR 7	x	x	x	x	x	x
11NW-A/FR 5	0	0	0	0	0	0
15NE-C/F 46	0	0	0	0	0	0
11SE-A/F 34	x	x	x	x	x	x
11SW-A/FR 23	0	0	0	0	0	yes
11SE-A/FR 48	x	x	x	yes	x	x
11SW-A/F 32	yes	0	0	0	0	0
11NW-A/F 23	x	x	x	x	x	x
11SW-D/FR 7	x	x	x	x	x	x
11SW-D/FR 135	0	0	0	0	0	0
7NW-D/FR 1	x	x	x	x	x	x
11SW-D/F 32	x	x	x	x	x	x
11SW-D/FR 26	x	x	x	x	x	x
11SW-D/F 33	0	0	0	0	0	0
11SW-D/FR 29	x	x	x	x	x	x
11SE-A/F 30	n	n	n	n	n	n
15NE-B/F 25	0	0	0	0	0	0
11SE-A/F 61	x	x	x	x	x	x
11NE-A/F 96	x	x	x	x	x	x
11SW-C/N 1	x	x	x	x	x	x
7SW-D/FR 10	x	x	x	x	0	x
11SW-D/FR 112	0	0	0	0	0	0
11SW-C/FR 88	x	x	x	x	0	x
11NE-B/T 190	x	x	x	x	x	x
11NE-B/F 56	n	n	n	n	n	n
11SW-B/FR 124	x	x	x	x	x	x
11NE-B/F 11	x	x	x	x	x	x
7SW-D/F 53	x	x	x	x	x	x
11SE-B/FR 28	0	0	0	0	0	0
7SW-C/FR 97	yes	0	0	0	0	0
11SW-D/F 70	n	n	n	n	n	n
7SW-C/FR 100	0	yes	yes	yes	yes	0
11NW-D/F 118	n	n	n	n	n	n
11SE-A/FR 15	yes	0	0	0	0	0
11SW-A/FR 20	yes	0	0	0	0	0
11NW-D/FR 119	yes	0	0	0	0	0
11SW-A/FR 87	x	x	x	x	x	x
11NE-D/FR 16	yes	x	0	0	0	x
11SE-A/FR 21	0	0	0	0	0	0
11SE-C/F 14	n	n	n	n	n	n
11SE-C/FR 1	n	n	n	n	n	n
11SE-D/F 2	x	x	x	x	x	x
11SE-D/FR 5	0	0	0	0	0	0
11SW-B/F 43	yes	yes	yes	yes	0	0
11SW-D/FR 5	0	0	0	0	0	0
11SW-D/FR 18	0	0	0	x	x	x
11NE-D/FR 10	x	x	x	x	x	x
11NW-B/FR 51	x	x	x	x	x	x
11SW-A/FR 1	0	0	0	0	0	0
11SW-A/FR 65	x	x	x	x	x	x
11NW-B/FR 38	x	x	x	x	x	x
11NW-D/FR 44	yes	yes	0	0	0	0
11NW-D/F 117	n	n	n	n	n	n
11NW-B/FR 53	x	x	x	x	x	x
11SE-A/FR 10	yes	0	0	yes	0	x

Notes: 1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Including flooding, washout, etc. after LPM.
x Information not available or no inspection report.
n Non-exist. 0 No observed problem during inspection.

Table 4.5 - Data for Slope Recompaction and Data when Problems were Observed after LPM Programme

	Slope Number	Date of Commencement	Date of Completion	Observation		Contract
				Date	Problem	
	11NE-D/F 3					
	11NE-D/FR 7			x	x	
	11NE-C/F 5		07-Nov-79			697/78
	11NE-C/F 6		07-Nov-79	30-May-83	blocked	697/78
#	11NW-D/F 102	16-Dec-79	18-Sep-80	4-Jul-95	partially blocked	432/79
	11NW-B/FR 23	16-Dec-79	26-Mar-81	x	x	432/1979
	11NW-B/FR 24	16-Dec-79	26-Mar-81	x	x	432/1979
	11NW-B/FR 35	30-Jul-80	12-Aug-81	x	x	433/79
#	7SW-C/F 8	19-Mar-81	16-May-82	17-Nov-95	subsidence,blocked	439/80
	11NW-D/F 141		01-May-83	x	x	466/81
#	11SW-A/FR 53		30-Aug-85	19-Jul-95	major flow	16/GCO/83
	11SW-A/F 52		30-Sep-85	28-Jul-95	seepage	16/GCO/83
#	11SW-A/FR 54		30-Sep-85	19-Jul-95	minor cracks on toe wall	16/GCO/83
#	11SW-B/FR 42	02-Jan-86	28-Jun-86	24-Sep-95	cracked,blocked	GC/84/04
	11NW-D/F 97	26-Aug-85	02-Feb-88	x	x	GC/84/03
#	13NE-A/FR 38	09-Feb-87	04-Feb-88	16-Jun-97	blocked,seepage	GC/85/05
#	11NW-B/FR 69	04-Feb-88	15-Oct-88	9-Sep-96	partially blocked	GC/85/07
#	11NW-B/FR 36	15-Nov-94	01-Jul-95	9-Dec-95	blocked	GE/94/02
	11SE-A/FR 64	01-Aug-94	31-Mar-96	x	x	GE/93/01
	11SE-A/FR 7	01-Sep-95	20-Jul-96	24-Jun-92	0	GE/94/02
#	11SW-C/FR 1	17-Jun-96	11-Mar-97	5-Mar-96	blocked, cracked	GE/95/01
	11SW-C/F 24	15-Nov-96	12-Oct-97	x	x	GE/96/04
#	11SW-D/F 53	01-Oct-96	27-Jan-98	2-Jan-96	blocked,cracked	GE/96/04
	11NE-B/F 58	20-Aug-96	20-Jun-97	x	x	GE/95/01
*	6SE-D/F 47	01-Nov-89	16-Oct-90	3-Dec-96	blocked	GC/88/06
*	11SW-D/FR 21	15-Jun-84	04-Sep-84	4-Mar-93	blocked,broken	4/GCO/83
*	11SW-D/FR 20		01-Jan-85	12-Sep-96	blocked	16/GCO/83
	11NE-D/F 109			x	x	
#	11NE-D/FR 4			10-Jan-96	partially blocked, seepage	409/1977
#	11SE-D/F 3			30-Jan-97	partially blocked	160/82
	7SW-C/F 3		01-Aug-77	30-Jan-97	partially blocked	405/1977
#	7SW-C/F 4		01-Aug-77	21-Jun-95	partially blocked,cracked	405/1977
	7SW-C/F 6		01-Aug-77	x	x	405/1977
#	7SW-C/F 10	01-Jan-77	01-Aug-77	10-Oct-95	partially blocked	405/1977
	11NE-A/F 6		01-Sep-77			407/1977
#	11SE-D/F 7		01-Sep-77	30-Jan-97	partially blocked,cracked	408/1977
#	11NE-D/F 1		01-Oct-77	12-Dec-95	blocked	409/1977
	11NW-A/FR 6		01-Nov-77	x	x	406/1977
	11NW-A/FR 7		01-Nov-77	x	x	406/1977
#	11NW-B/F 39	30-Jul-80	25-Oct-81	12-Nov-94	x	433/79
	7SW-C/FR 37	07-Apr-81	21-Mar-82			439/80
	11SW-C/F 19	01-Oct-83	29-Jun-84	x	x	4/GCO/83
	11SW-C/F 20	01-Oct-83	29-Jun-84	x	x	4/GCO/83
	11NW-B/F 2	05-Sep-84	19-Jan-85			4/GCO/83
#	11SW-A/FR 47			21-May-96	blocked,ponding	HA183/85
#	11SW-A/FR 49			22-Nov-96	seepage	HA183/85
#	11SW-A/FR 50			21-May-96	seepage	HA183/85
	11NE-A/F 12	25-Feb-85	25-Oct-85	3-Oct-86	water main bursted,eroded,cracked	GC/84/02
	11NE-A/F 75	25-Feb-85	25-Oct-85	x	x	GC/84/02
	11NE-D/FR 43	20-Nov-85	29-Mar-86	x	x	GC/84/02
	11NE-A/F 11	26-Oct-87	06-Mar-89	x	x	GC/86/04
	11NE-A/F 73	26-Oct-87	06-Mar-89	x	x	GC/86/04
	11NW-A/FR 69	01-Nov-93	30-Apr-94	15-Mar-95	0	GE/93/01
#	11SE-D/FR 24	01-Sep-95	18-Jun-96	30-Jan-97	cracked	GE/94/02
	11SE-C/F 21	01-Sep-95	23-Aug-96	x	x	GE/94/02
	7SW-C/FR 13	01-Jan-77	01-Aug-77	18-Jan-84	seepage	405/1977
	11NE-B/FR 31			x	x	
#	11NE-C/F 1			19-Jul-95	(83~97) seepage	
	11NW-A/F 44		Mid-Mar-95	x	x	H158.01
#	11NW-D/FR 25			30-Mar-95	cracked	687/77
	11SW-D/FR 1	77~78	79	24-Jul-97	seepage	
	11SW-D/FR 4			1-Jun-95	cracked	688/77
	11SW-D/FR 48			26-May-87	blocked	688/77
	11SE-A/FR 9		16-Apr-80	x	x	697/79
	7SW-C/FR 2	06-Feb-80	13-Aug-80	20-Mar-89	seepage	433/79
	11NW-B/F 8	18-Dec-79	29-Nov-80	x	x	432/79
	11SE-A/FR 11	22-Sep-80	26-Apr-81	17-Jul-86	cracked	437/79
	11NW-A/F 9	18-Mar-81	25-Apr-82			439/80
#	11NW-B/FR 43	01-Sep-81	09-May-82	17-Oct-95	partially blocked	439/80
	11SW-D/F 69	31-Aug-81	31-Oct-82			439/80

Table 4.5 - Data for Slope Recompaction and Data when Problems were Observed after LPM Programme (continued)

	Slope Number	Date of Commencement	Date of Completion	Observation		Contract
				Date	Problem	
	7SW-C/F 31		01-Nov-82	8-Sep-95	cracked/blocked	466/81
	11SW-B/FR 56		30-Mar-84	x	x	2/GCO/82
#	11NW-A/FR 65	08-Oct-83	31-Dec-84	13-Oct-95	cracked	4/GCO/83
	11SW-B/FR 59	31-Jan-83	27-Jan-85			4/GCO/83
#	11NW-B/FR 42	01-Oct-83	28-Mar-85	10-Oct-95	blocked	4/GCO/83
	12NW-C/FR 7	08-Feb-85	30-Oct-85			GC/84/02
	11NW-A/FR 5		01-Feb-86	x	x	16/GCO/83
	15NE-C/F 46	12-Aug-85	29-Aug-86	8-Aug-94	depression	GC/84/02
	11SE-A/F 34		17-Sep-86			16/GCO/83
	11SW-A/FR 23	26-Aug-85	18-Oct-86	28-Sep-95	settlement	GC/84/03
	11SE-A/FR 48	17-Feb-86	18-Mar-87	24-Jun-94	cracked	GC/85/05
#	11SW-A/F 32	10-Jul-86	10-Aug-87	3-May-95	partially blocked	GC/85/06
	11NW-A/F 23	11-Dec-86	12-May-88	13-Sep-94	very high risk	GC/85/07
	11SW-D/FR 7	10-Jul-86	24-May-88	4-Sep-97	movement	GC/85/06
	11SW-D/FR 135	10-Jul-86	22-Aug-88	21-Nov-89	0	GC/85/06
	7NW-D/FR 1	12-Sep-88	08-Jan-90	x	x	GC/87/11
	11SW-D/F 32	13-Jul-89	30-Mar-90	x	x	GC/86/03
	11SW-D/FR 26	12-May-89	21-Jun-90	20-May-97	erosion,debris	GC/86/03
*	11SW-D/F 33	24-May-89	17-Aug-90	12-Aug-96	partially blocked	GC/86/03
	11SW-D/FR 29	11-Jun-89	17-Aug-90	x	x	GC/86/03
	11SE-A/F 30	15-Nov-89	22-Nov-90	x	x	GC/88/05
*	15NE-B/F 25	05-Oct-90	19-Jul-91	16-Oct-96	partially blocked	GC/88/05
	11SE-A/F 61	01-Sep-91	20-Aug-92	1-Aug-94	washout (scale: $2m^3$)	GC/89/13
	11NE-A/F 96	25-Oct-91	14-Oct-92	x	x	GC/90/06
	11SW-C/N 1	09-Jun-92	16-Dec-92	x	x	GC/90/01
	7SW-D/FR 10	01-Aug-92	19-Mar-93	14-Mar-94	cracked,eroded,blocked	GC/90/06
	11SW-D/FR 112	28-Dec-94	09-Oct-95	x	x	GE/93/01
	11SW-C/FR 88	15-Nov-95	02-Dec-96			GE/95/01
*	11NE-B/T 190	14-Sep-96	11-Apr-97	17-Jan-97	cracked,blocked, small flow	GE/96/04
	11NE-B/F 56	23-Nov-96	22-May-97	x	x	GE/96/05
#	11SW-B/FR 124	15-Nov-96	11-Jun-97			GE/96/04
	11NE-B/F 11	01-Sep-96	30-Jun-97	x	x	GE/96/04
	7SW-D/F 53	15-Nov-94	30-Jun-95	6-Feb-96	with cracks,movement	GE/94/02
	11SE-B/FR 28	23-Nov-96	22-Apr-97	x	x	GE/96/05
*	7SW-C/FR 97			20-Nov-96	partially blocked,cracked	-
	11SW-D/F 70		29-Mar-80	27-Nov-96	partially blocked	697/78
*	7SW-C/FR 100	26-Mar-80	17-May-80	28-Feb-94	with cracks,movement,seepage	407/1980
#	11NW-D/F 118	16-Dec-79	24-Nov-80	31-Mar-95	partially blocked	432/79
#	11SE-A/FR 15	20-Sep-80	09-Aug-81	19-Oct-95	blocked	434/79
#	11SW-A/FR 20	19-Mar-81	25-Oct-81	22-Nov-96	partially blocked,cracked	439/80
#	11NW-D/FR 119	19-Sep-89	08-Oct-90	13-Jul-95	blocked	GC/87/11
	11SW-A/FR 87	05-Mar-96	17-Mar-97			GE/95/17
	11NE-D/FR 16					
#	11SE-A/FR 21			1-Feb-96	seepage (source unclear)	688/77
#	11SE-C/F 14			24-Jul-96	0	
#	11SE-C/FR 1			29-Jan-96	partially blocked,cracked	688/77
	11SE-D/F 2			x	x	2/GCO/82
	11SE-D/FR 5			21-Oct-92	0	
#	11SW-B/F 43			28-May-96	blocked,broken,chunam damaged,seepage	
	11SW-D/FR 5			21-May-96	partially blocked	699/78
	11SW-D/FR 18					688/77
	11NE-D/FR 10		01-Oct-77	16-Apr-84	washout	409/1977
	11NW-B/FR 51		01-Nov-77	1-Nov-88	water weeping from strand holes	406/1977
	11SW-A/FR 1		06-Jan-80	30-Nov-90	heaved,cracked,blocked	696/78
	11SW-A/FR 65		06-Jan-80	x	x	696/78
	11NW-B/FR 38	30-Jul-80	30-Dec-81			433/79
#	11NW-D/FR 44	04-Aug-81	04-Feb-82	8-Jul-96	blocked,cracked	439/80
#	11NW-D/F 117	16-Mar-81	22-Aug-82	31-Mar-95	partially blocked	439/80
	11NW-B/FR 53		01-Jan-83	x	x	466/81
#	11SE-A/FR 10	10-Oct-83	14-May-84	21-Jan-97	blocked	4/GCO/83

Notes: x Information not available or no inspection report.
0 No observed problem during inspection.
* Inspected by Binnie Consultants Ltd.
# Inspected by Maunsell Geotechnical Services Ltd.

Table 5.1 - List of Geotechnical Consultants in Hong Kong Participating in the Survey

Atkins Haswell
Babtie BMT (Hong Kong) Ltd.
Binnie Consultants Ltd.
C.M. Wong and Associates Ltd.
ESA Consulting Engineers Ltd.
Fugro (Hong Kong) Ltd.
Golder Associates (HK) Ltd.
Greg Wong & Associates Ltd.
Halcrow Asia Partnership Ltd.
MAA Engineering Consultants (HK) Ltd.
Maunsell Geotechnical Services Ltd.
Mitchell McFarlane Brentnall & Partners Internation Ltd.
Mott Connell Ltd.
Mouchel Asia Ltd.
Ove Arup & Partners Hong Kong Ltd.
Pypun Engineering Consultants Ltd.
Scott Wilson Kirkpatrick (Hong Kong) Ltd.
SMEC Asia Ltd.

Table 5.2 - Names of Government Departments Participating in the Survey

Architectural Services Department
Highways Department
Housing Department
Water Supplies Department

Table 5.3 - Summary of Comments by Consultants on Survey

(A) Problems with recompaction process

- Temporary slope protection against heavy rainfall
- Extra loading on retaining wall below the slope, due to compaction
- Initial cut must be designed and stabilized before any recompaction can take place
- Method chosen for recompaction must take into account for damage to existing utilities or foundations
- Need for importing other fill to mix to achieve required compaction
- Need experienced supervisory staff
- Disposal of unsuitable fill material
- Temporary cuts need to be designed
- Disposal of unsuitable fill material
- Adverse weather condition
- Need quality control with cement stabilized fill material
- Lack of suitable material
- Traffic congestion due to truck movement
- Overfill

(B) Long term problems

- Tension cracks likely at interface between old and new fill
- Cracks on surface drainage and concrete slab on slope berms due to ground settlement
- When recompaction quality is poor, long term problems can arise.
- Blocked drainage needing clearance
- Blocked drainage by vegetation cover

(C) Hazards after recompaction

- Design should address all potential failure
- Surface should be protected with hydroseed/shotcrete
- Deep seated failure may occur when groundwater table is high in the slope
- Washout due to failure of water bearing services. If compaction is properly carried out, erosion and liquefaction should not occur. Deep seated failure is not usually related to recompaction
- No hazards after recompaction. The slope angle should be designed to avoid failure and provide an adequate factor of safety. Correct compaction will preclude liquefaction
- Hazards can normally be avoided if recompaction is carried out in a careful controlled manner
- Many mature trees will not survive the construction process
- If careful design forms part of the decision to choose a recompaction option, the above (erosion and deep seated failure) might be problem but not perceived as serious

Table 5.3 - Summary of Comments by Consultants on Survey (continued)

(D) Miscellaneous

- Stability of earth retaining structure below the slope during construction
- Consolidation settlement in soil underlying the compacted fill
- Ensuring the density of the recompacted fill during recompaction works
- Foundation of of buildings or access road etc. may be affected by the recompaction process
- Problem with steep temporary cut slopes
- Shoring support to temporary cut slopes

(E) Improvements

- May use GEO probe for a quick check on the results of compaction, and on the uniformity of the compacted soil
- Surface protection against erosion e.g. vegetation on slope surface
- Use of cement stabilized soil to increase strength parameters of soil and reduce reliance on compaction
- Improve subsurface drainage to fill slope
- Use rockfill as recompaction material
- Not generalized 3m. Locally deeper to incorporate geogrid etc.
- Recompaction with geogrid; recompaction with cement stabilized soil
- Employ experienced supervisors
- Define acceptable fill types, the compaction properties and post-compaction characteristics of which can be predicted and relied upon
- The critical item is adequate site supervision and adequate testing before and during recompaction
- Use of geogrid will improve the compaction process. Other methods such as soil nailing or provision of trench drains may be appropriate in some situations
- Use concrete cover and hydroseed slope surface
- Excavation and recompaction processes should be carried out within the dry seasons (i.e. between October and April)
- Recompaction with geogrid is one of the improvement for long term performance
- Geogrid, improve subsoil and surface drainage, tree shrub planting

LIST OF FIGURES

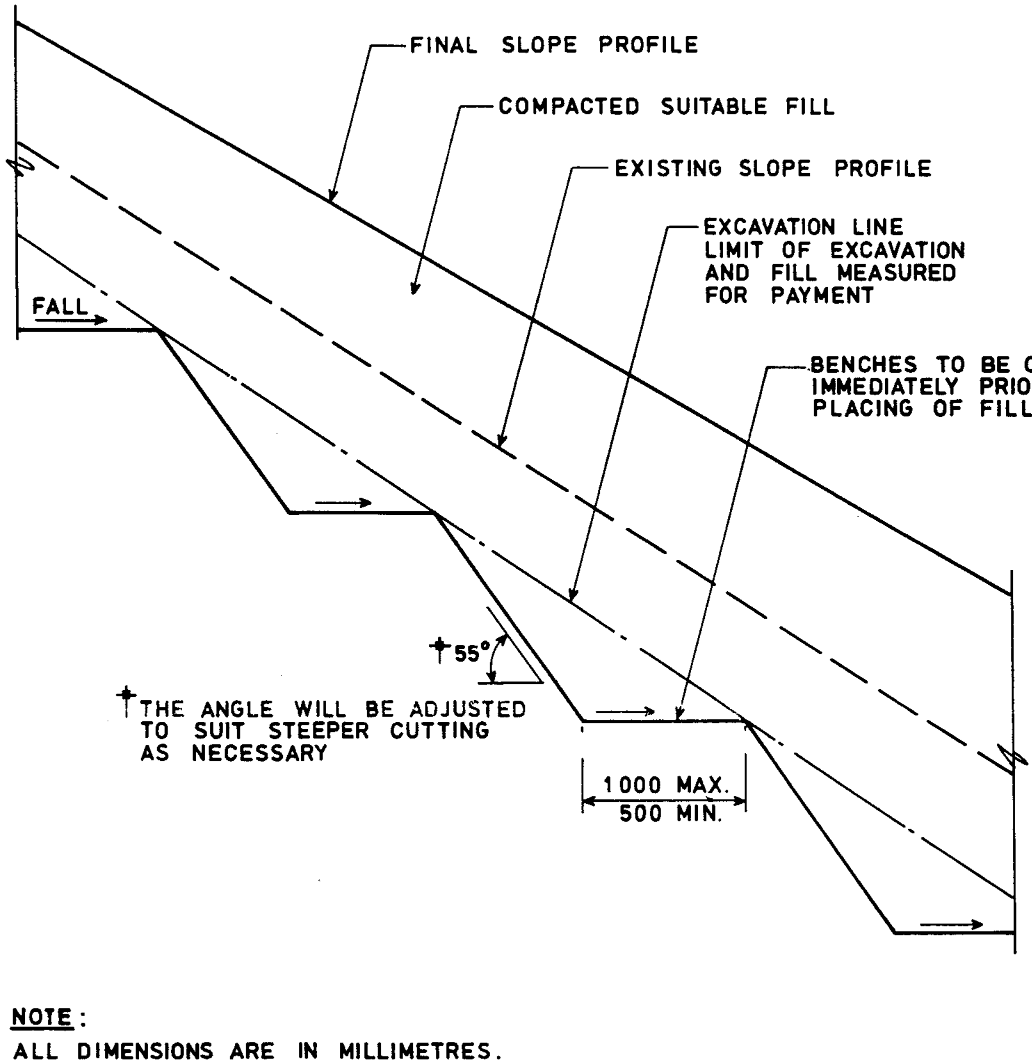
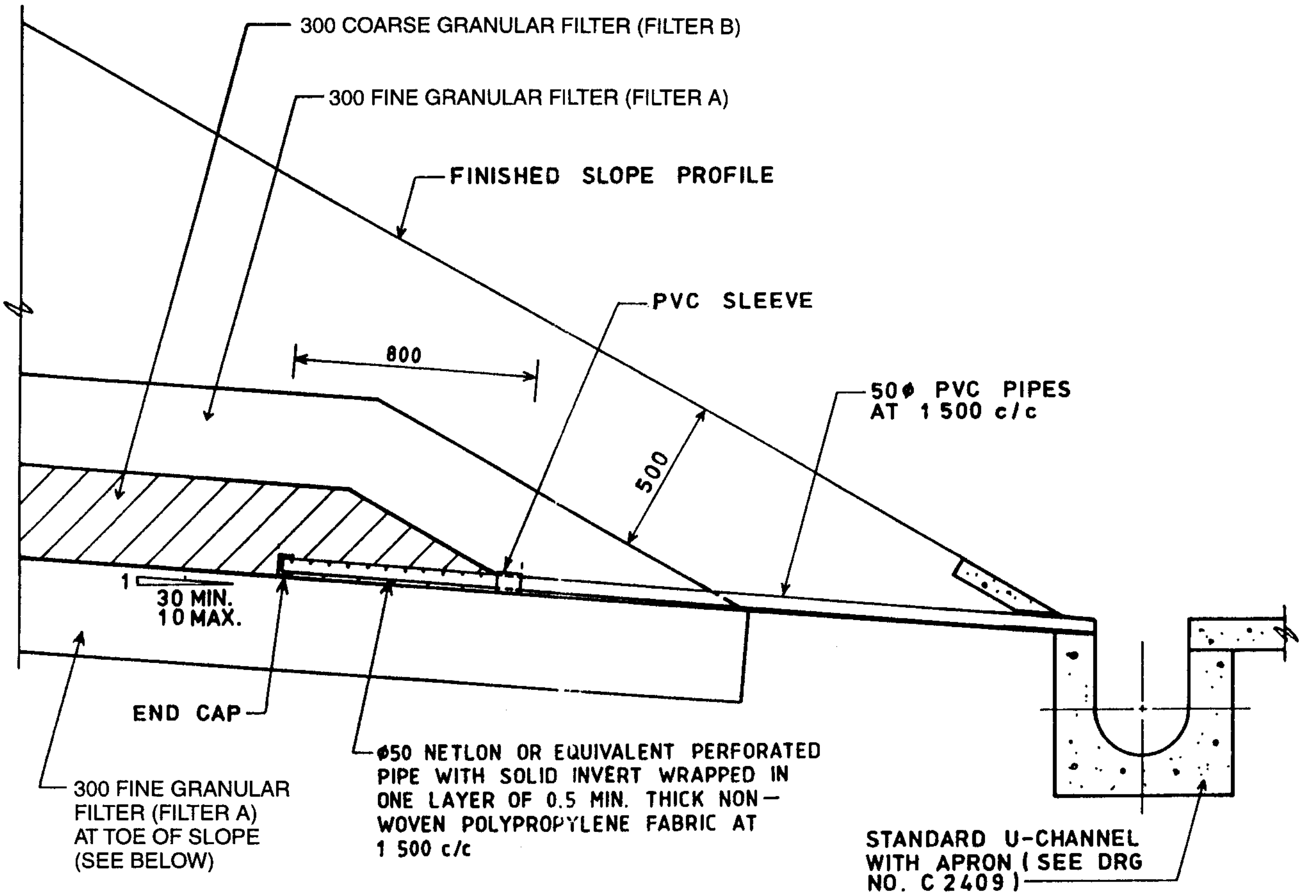
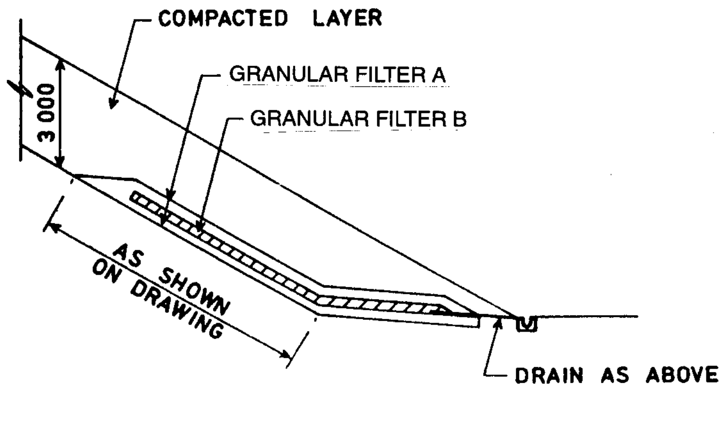


Figure 1.1 - Details of Benching for Placement of Fill on Existing Ground (Civil Engineering Department, 1996)



TYPICAL SECTION

SCALE 1 : 25



TYPICAL SLOPE TOE ARRANGEMENT

SCALE 1 : 200

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. FINE GRANULAR FILTER (FILTER A) SERVES AS FILTER FOR SOIL.
3. COARSE GRANULAR FILTER (FILTER B) SERVES AS FILTER FOR FINE GRANULAR FILTER.
4. GRANULAR FILTER SHALL BE DESIGNED BY THE CONTRACTOR IN ACCORDANCE WITH WBTC No. 4/91.

Figure 1.2 - Filter Blanket for Fill Slope (Civil Engineering Department, 1996)

Figure 4.1a - Results on Observed Problems from Inspections of Slopes before and after LPM Programme

		Before LPM			After LPM		
		No.	%	Notation[3]	No.	%	Notation[3]
Drainage Condition[1]	Blocked[2]	50	39	B1	54	42	A1
	Broken	17	13	B2	13	10	A2
Seepage / Leakage		14	11	B3	14	11	A3
Surface Cover	Eroded	21	16	B4	8	6.3	A4
	Cracked	21	16	B5	13	10	A5
Displacement	Settlement	14	11	B6	4	3.1	A6
	Movement	9	7.0	B7	5	3.9	A7

Notes:
1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Notation used in the following histogram.

The above information is based on Table 4.1 and Table 4.2 with the answer "yes" in 128 fill slopes.

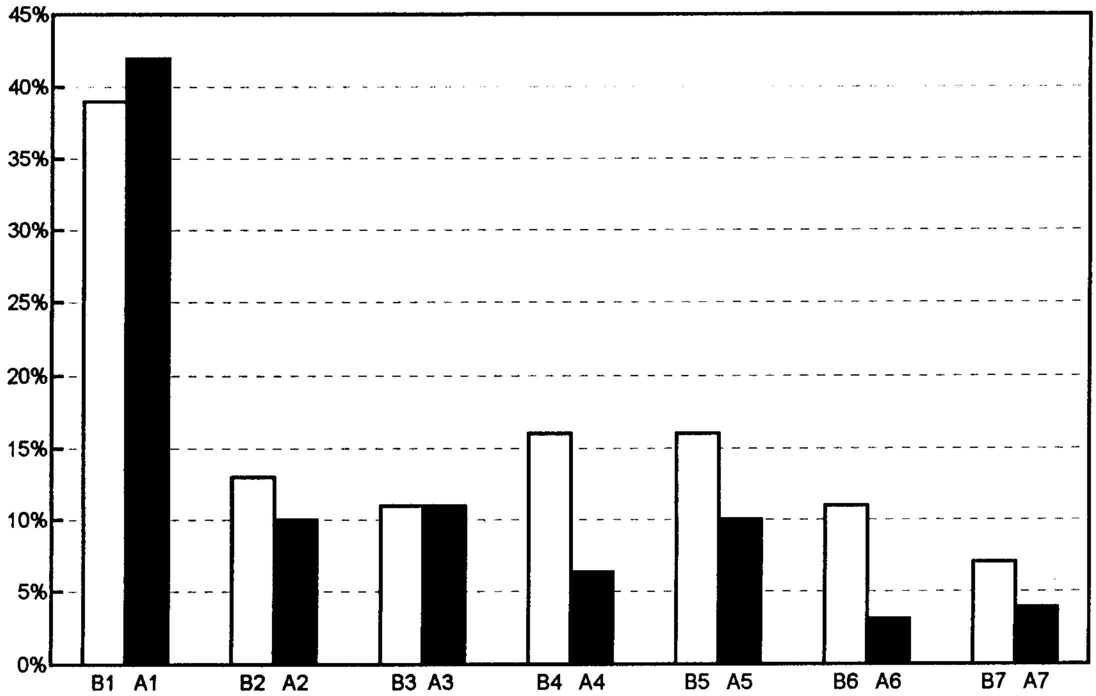


Figure 4.1b - Histogram showing the Occurrence Frequency of Observed Problems from Inspections of Slopes before and after LPM Programme

Figure 4.2a - Results on Observed Problems from Inspections of Retaining Walls before and after LPM Programme

		Before LPM			After LPM		
		No.	%	Notation[3]	No.	%	Notation[3]
Drainage Condition[1]	Blocked[2]	26	20	C1	23	18	D1
	Broken	6	4.7	C2	5	3.9	D2
Seepage / Leakage		21	16	C3	14	11	D3
Wall Cracked		13	10	C4	9	7.0	D4
Movement / Tilting		7	5.5	C5	2	1.6	D5

Notes:

1. Including weepholes and surface drainage channels;
2. Partially and/or totally blocked;
3. Notation used in the following histogram.

The above information is based on Table 4.3 and Table 4.4 with the answer "yes" in 128 slopes.

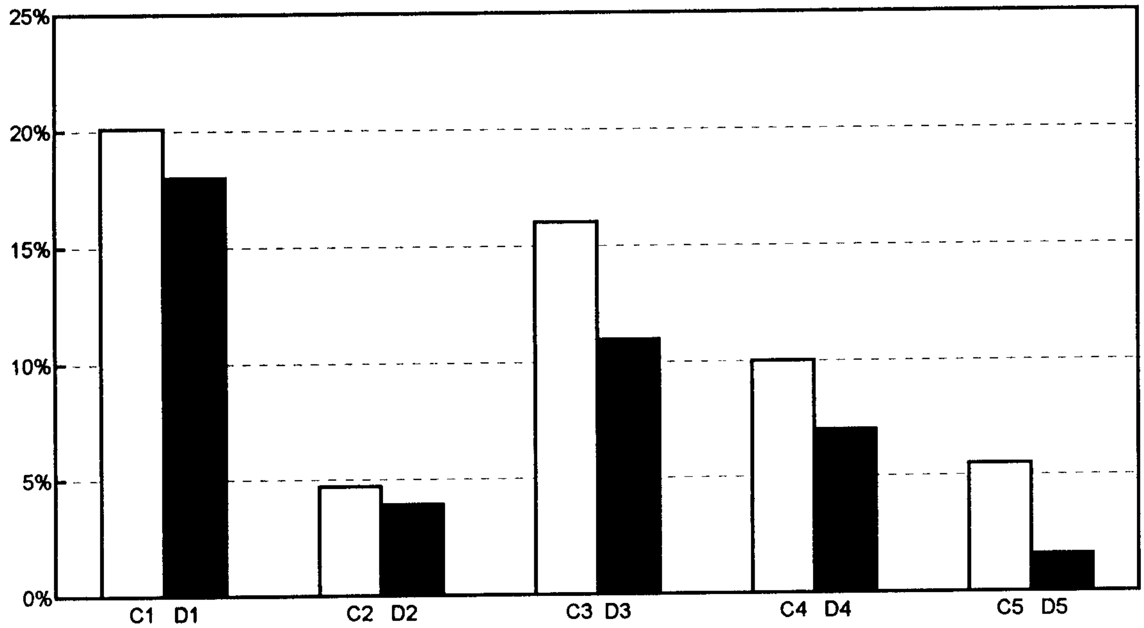


Figure 4.2b - Histogram showing the Occurrence Frequency of Observed Problems from Inspections of Retaining Walls before and after LPM Programme

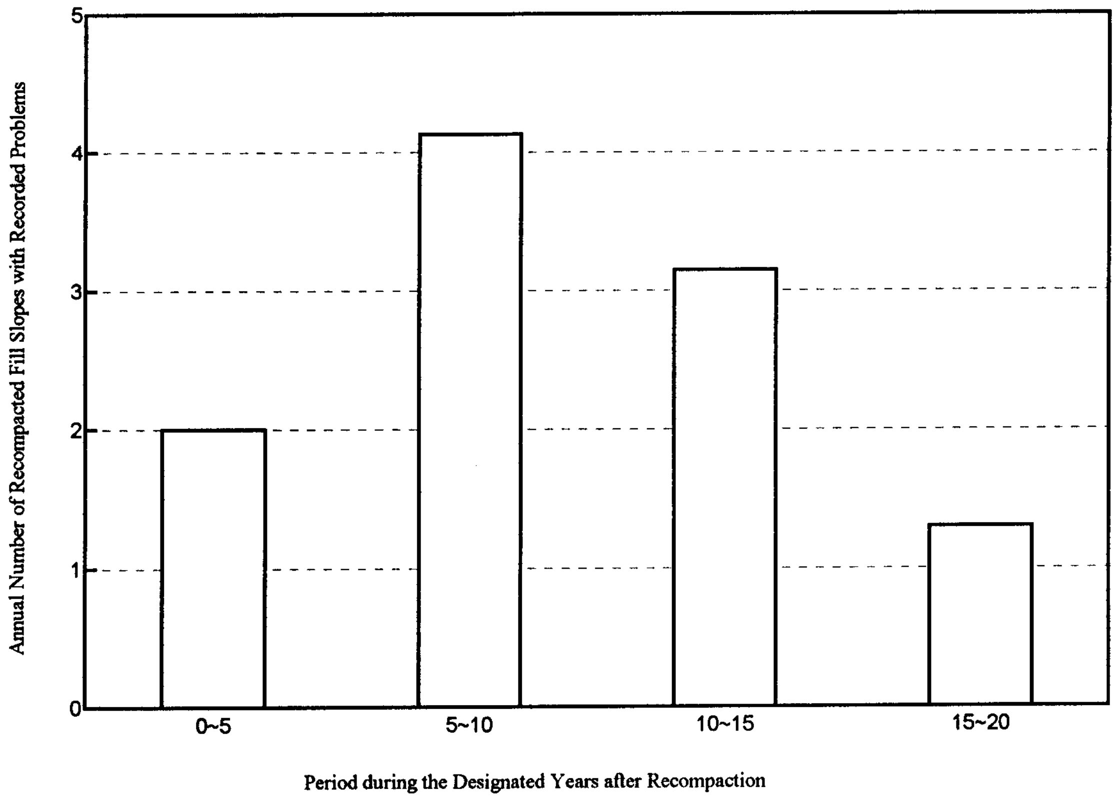


Figure 4.3 - Number of Slopes having Problems versus Time after Recompaction

Figure 4.4a - Results on Site Constraints and Construction Problems from Inspections of Recompacted Fill Slopes before and after LPM Programme

No.	%	**Site Constraints**	Notation Used in the Following Histogram
2	6	Difficult access	s1
4	12	Limited working space	s2
4	12	Mature trees	s3
1	3	Road closure and traffic problems	s4
5	15	Underground utilities	s5
		Construction Problems	
4	12	Failure of temporary cut	c1
5	15	Accidents	c2
7	21	Cracks and movements	c3
5	15	Severe runoff along gullies and washout	c4
7	21	Heavy rain during construction	c5
10	30	Inadequate drainage system during construction	c6
4	12	Quality control	c7

Note: The above information is based on the 33 features with construction problems.

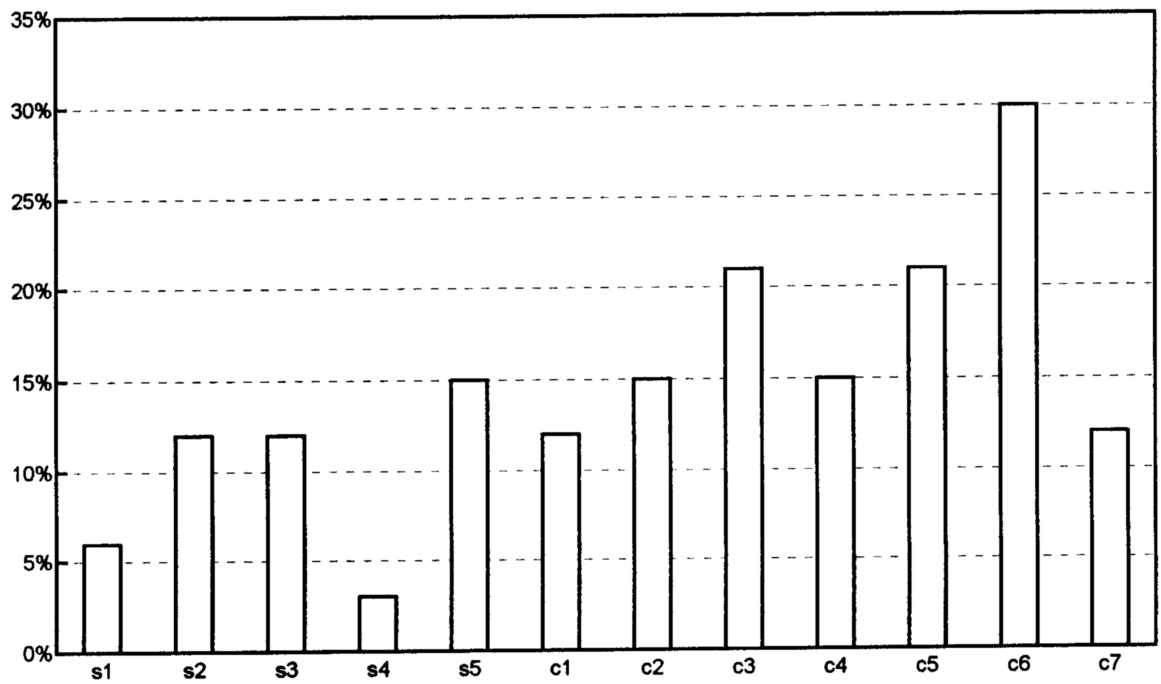


Figure 4.4b - Histogram showing the Occurrence Frequency of Site Constraints and Construction Problems from Inspections of Recompacted Fill Slopes before and after LPM Programme

Figure 5.1a - Results on Long-term Problems of Recompacted Fill Slopes Based on Survey of Consultants

No.	%	Long-term Problems	Notation Used in the Following Histogram
10	43	Blocked drainage due to ground settlement	A1
12	52	Cracks on slope cover and tension cracks in the uncovered ground	A2
14	61	Settlement/creep movement	A3
9	39	Leaky services	A4
6	26	Problems arising from sources outside the boundary of the slope	A5
2	9	Others	A6

Note: The above information is based on the 23 survey forms received.

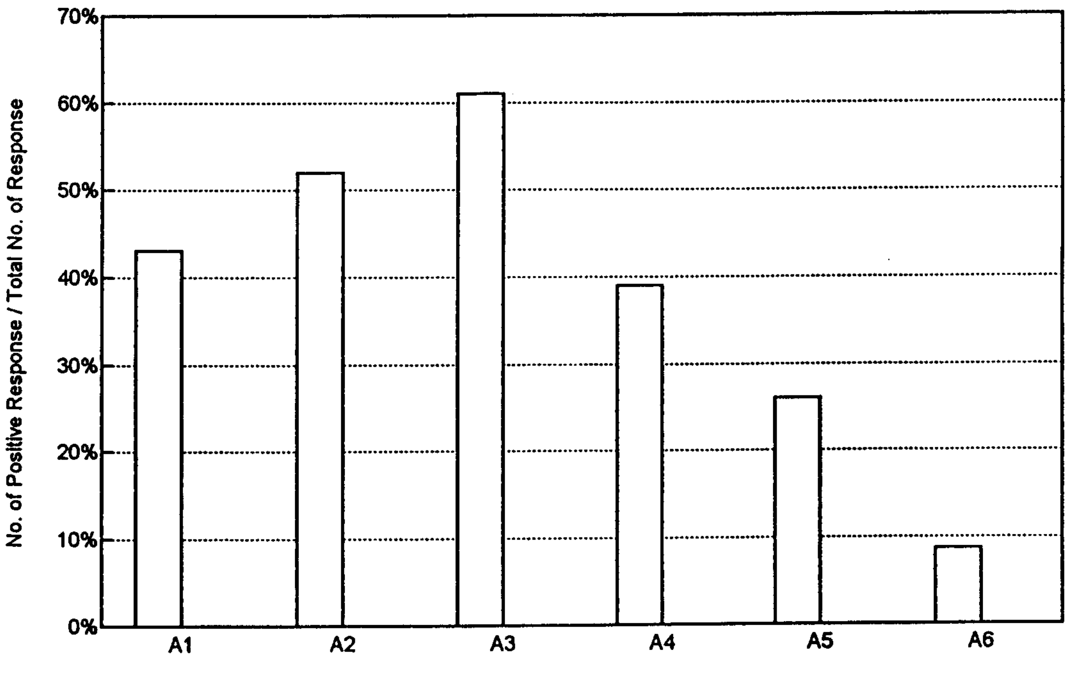


Figure 5.1b - Histogram of Long-term Problems of Recompacted Fill Slopes Based on Survey of Consultants

Figure 5.2a - Results on Site Constraints and Construction Problems of Recompacted Fill Slopes Based on Survey of Consultants

No.	%	Problems with Recompaction Process	Notation Used in the Following Histogram
14	61	Failure of temporary cut (*minor/major)	B1
16	70	Difficult access	B2
16	70	Lack of space for manipulating construction equipment	B3
20	87	Lack of space for stockpiling fill material	B4
16	70	Removal of mature trees	B5
9	39	Road closure and traffic problems	B6
8	35	Accidents related to the recompaction process (e.g. equipment falling down the slope)	B7
5	22	Others	B8

Notes:

1. *Minor failure refers to failure smaller than $50m^3$ while major failure involves a failure of $50m^3$ or above;
2. The above information is based on the 23 survey forms received.

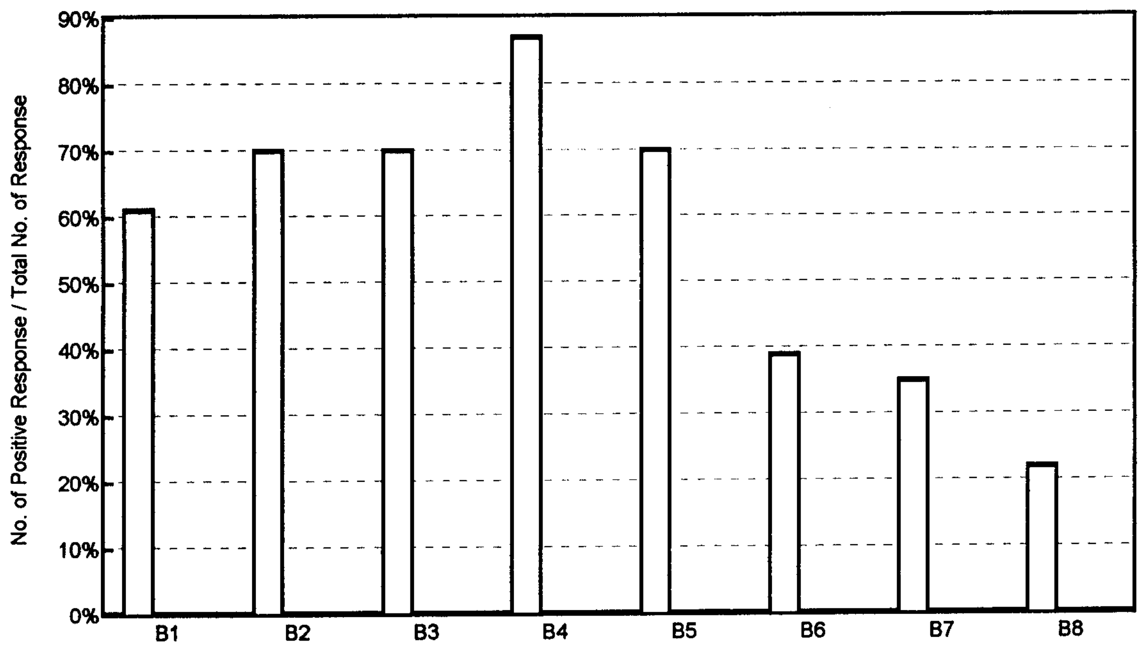


Figure 5.2b - Histogram of Site Constraints and Construction Problems of Recompacted Fill Slopes Based on Survey of Consultants

Figure 5.3a - Results on Potential Hazards or Failures of Recompacted Fill Slopes Based on Survey of Consultants

No.	%	Hazards After Recompaction	Notation Used in the Following Histogram
12	52	Erosion leading to potential failure	C1
11	48	Washout failure	C2
6	26	Deep seated failure	C3
5	22	Liquefaction failure	C4
2	8.7	Others	C5

Note: The above information is based on the 23 survey forms received.

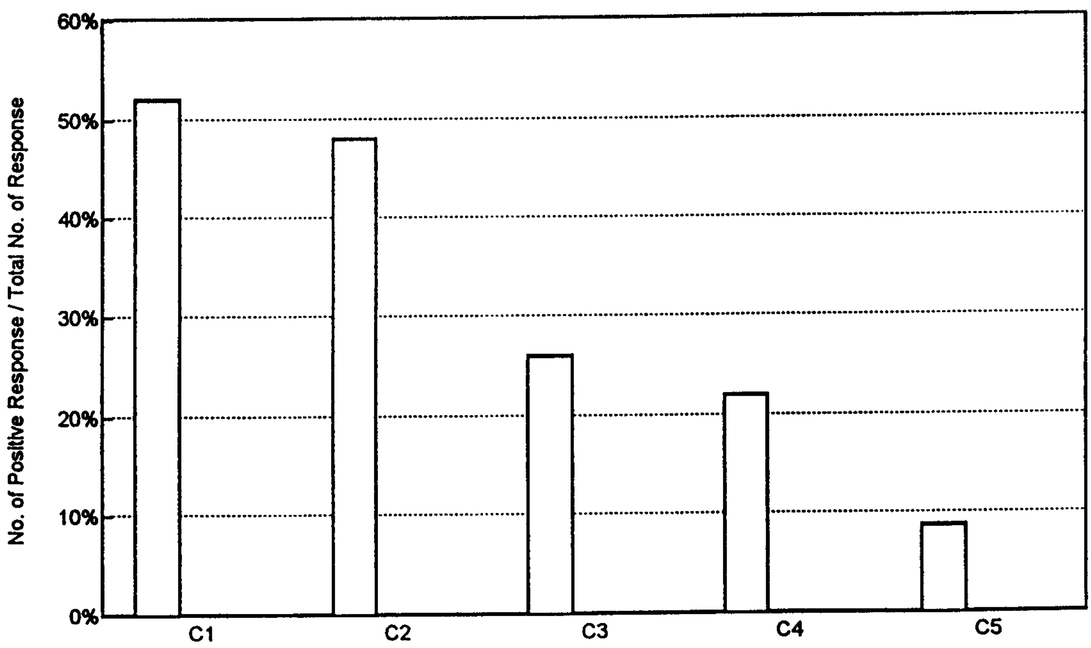


Figure 5.3b - Histogram of Potential Hazards or Failures of Recompacted Fill Slopes Based on Survey of Consultants

Figure 5.4a - Results on the Other Issues on Recompacted Fill Slopes Based on Survey of Consultants

No.	%	Miscellaneous	Notation Used in the Following Histogram
The thickness of top 3m fill recompaction is:			
2	9	too thin	D1
13	57	just right	D2
1	4	too thick	D3
Should the recompaction thickness be related to the consequence of failure?			
7	30	yes	E1
8	35	no	E2

Note: The above information is based on the 23 survey forms received.

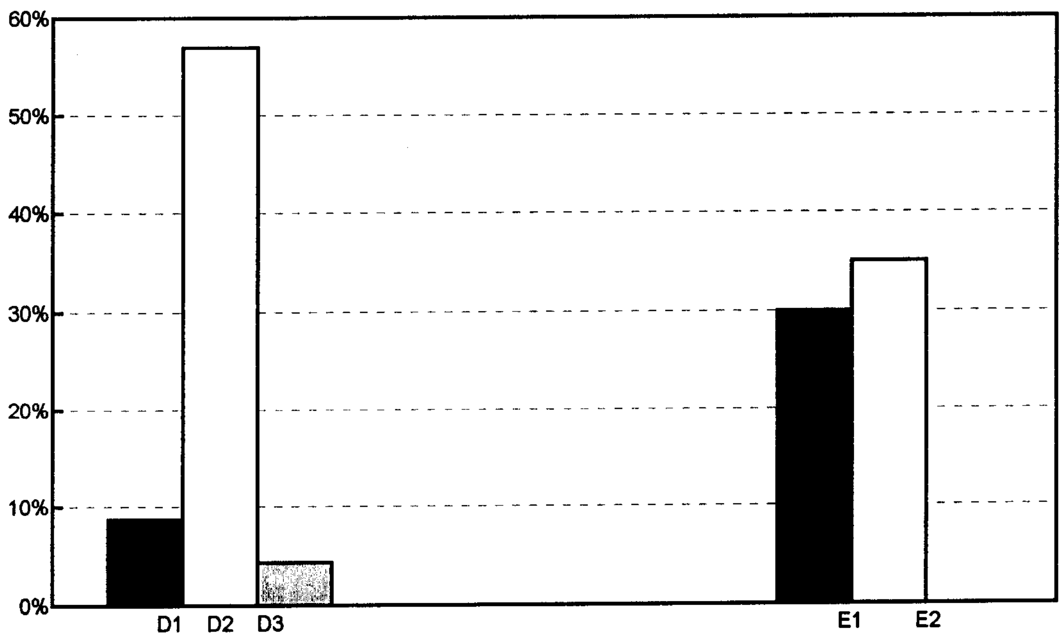


Figure 5.4b - Histogram showing the Data of the Other Issues on Recompacted Fill Slope Based on Survey of Consultants

LIST OF FORMS

Form 3.1

THE UNIVERSITY OF HONG KONG
DEPARTMENT OF CIVIL AND STRUCTURAL ENGINEERING

REVIEW FORM FOR RECOMPACTED FILL SLOPE PERFORMANCE

1. General Description

Feature No.: ____________________ Contract No.: ____________________
Location (District): ________________________________ Related File Nos.: ______________
Duration of Project : Commencement : ______________ Completion : ____________________
Present Status of Project: ☐ under Construction ☐ under Maintenance
Current Responsibility: ☐ Arch SD ☐ HyD ☐ USD ☐ HD
☐ WSD ☐ DLO ☐ Other ( )

2. Slope Geometry before LPM Program

Slope Geometry : Height (m):_____ Length (m):_____ Inclination:__________

Berm Details: ☐ None
☐ Yes : No. ______ Width (m) : _____ Location: ________________

Nearby Structures/Services:
☐ at crest ____
☐ at toe ____
☐ on slope____
☐ underground ____

Retaining Walls:
☐ None
☐ Yes, Location: ____________ No. ____ Height (m) : ____ Type: ______________
Drainage Condition Size(mm) Spacing(m)(H/V) Condition/Flow
☐ Weephole:
☐ Channels: ☐U ☐ J
☐ on top
☐ at toe
Seepage Condition: ________________________________
Properties of Backfill: c' = (kPa); ϕ' = (Deg.) ; γ = (kN/m^3)
Soil-Wall Friction: ______________ Wall-Base Friction: ______________
FOS in design
☐against sliding: ☐against overturning: ☐for bearing capacity:

3. Surface Loads

Surcharge: ☐ No ☐Yes, Location: ☐ at crest ☐ at toe ☐ on slope
Intensity (kPa) and Extent (m): ____

4. Groundwater Condition

Perched/Ground Watertable (m): ____
Design/Assumed Ground Watertable (m): ________________________________
Piezometric Head (m): ____

5. Drainage Condition and Surface Protection before LPM Program

Drainage Condition	Size(mm)	Spacing(m)(H/V)	Condition/Flow
☐ Weepholes:			
☐ Channels: ☐U ☐J			
☐on slopes			
☐at crest			
☐at toe			
☐elsewhere			

☐ Catchpits: ☐at crest ☐at toe ☐on-slope Condition: ____________

☐ Raking drains: ☐at crest ☐at toe ☐on-slope Condition: ____________

Seepage Condition ______________________________

Surface Protection

☐Sealed (e.g. shotcrete, chunam) :

☐poor (with serious cracks/cavities, shallow depressions) ☐fair ☐good

☐Vegetated (e.g. grass, shrubs) :

☐poor (with serious cracks/cavities, shallow depressions) ☐fair ☐good

☐Bare soil or rock: ☐ with serious cracks/cavities, erosion

☐Natural ground: ☐ with serious cracks/cavities, erosion

6. Pre-Recompaction Soil Characteristics

Material Description	Thickness (m)	c' (kPa)	ϕ' (Deg)	γ (kN/m^3)	K (cm/sec)	SPT (N)

In-Situ Dry Density (Mg/m^3): __________ Max. Dry Density (Mg/m^3): __________

Relative Compacting Degree(%) : __________ In-Situ Void Ratio: __________

FOS in Design

☐against shallow failure: ______________________________

☐against deep-seated failure: ______________________________

FOS estimated (by the infinite-slope theory): ______________________________

7. Causes for LPM Projects

8. LPM Projects Taken

☐ Recompaction

Recompacted Depth (m): ____________ Gradient: ____________________________

Berm Details: ☐ None ☐ Yes : No. ___ Width (m): _____ Location: ____________

Properties: c' = (kPa); ϕ' = (Deg.) ; γ = (kN/m^3)

In-Situ Dry Density (Mg/m^3):______ Max. Dry Density (Mg/m^3): __________

Relative Compacting Degree(%) : __________ In-Situ Void Ratio: ____________

FOS in Design

☐against shallow failure: ____

☐against deep-seated failure: ____

FOS estimated (by the infinite-slope theory): ___________________________________

☐ **Retaining Wall**

☐Unchanged ☐New (LPM), Location: _________

Type : ________________________ Height/Length (m): ________

Unit Weight (kN/m^3): _______ Soil-Wall Friction: ______ Wall-Base Friction: ______

Properties of Backfill: c' = (kPa); ϕ' = (Deg.) ; γ = (kN/m^3)

Drainage Condition Size(mm) Spacing(m)(H/V) Condition/Flow

☐ Weephole:

☐ Channel: ☐U ☐J

☐on slope

☐at crest

☐at toe

☐elsewhere

☐ Catchpits: ☐at crest ☐at toe ☐on-slope Condition: _____________

☐ Raking drains: ☐at crest ☐at toe ☐on-slope Condition: _____________

FOS in design

☐against sliding: ☐against overturning: ☐for bearing capacity:

☐ Drainage System

☐ Channels (☐U/☐J) at: ☐ crest ☐ toe ☐ on-slope Size(mm): ______

☐ Weepholes: Size(mm)/Spacing(m): ______________________

☐ Drainage blanket at: ☐ crest ☐ toe

☐ Catchpits at: ☐ crest ☐ toe ☐ on-slope

☐ Raking drains : ☐ crest ☐ toe ☐ on-slope

☐Surface Protection

☐ Tree along: ☐ crest ☐ toe ☐ on-slope

☐ Landscaping: ☐ hydroseeding ☐ woodland planting

☐ Surface protection: ☐ sealed (e.g. shotcrete, chunam) ☐ vegetated (e.g. grass, shrubs)

☐ Cutting or Regrading ☐cutting ☐ regrading

☐ Cement-Stabilized Fill

☐Soil Nails

Type and Purpose:____________ Length (m) : ____________

Inclination (Deg): ____________ Spacing (m) (H/V): ______

☐Others

9. Descriptions of Failure after Recompaction

☐No

☐Yes, Date and Time of Failure: ____________________

Coordinates of Center of Failure: _______ E ______N

Type of Failure:

☐ Sliding ______________________________

☐ Liquefaction ______________________________

☐ Washout ______________________________

☐ Others ______________________________

Causes of Failure: ______________________________

Consequence of Failure:

☐ Persons killed ☐ Persons injured ☐ Construction site affected

☐ Building lot affected ☐ Others ____________

Failure Occurred during:

☐ Construction ☐ Upgrading ☐ Maintenance

☐ Rainfall (☐Wet season ☐ Dry season) ☐ Others

Rainfall Record:

☐ Max. 1 hr. Rainfall (mm): ______ ☐ Max. 24 hr. Rainfall (mm): ________

Relationship between Rainfall and Failure: ☐ Direct/Major ☐ Indirect/Minor

Maximum Dimensions of Failure Mass: Depth (m) _______, Horizontal Length (m) ______

Estimated Angle of Reach: _______ Estimated Mass Volume (m^3): ________________

Sketch of Failure and Typical Sections (attached if available):

10. Historical Events and Remarks

11. Problems

11.1 Problems during Construction

11.2 Problems during Long-Term Condition

12. Suggestions by Reviewer

Name of Reviewer: ____________________ Date : ____________________________

Form 3.2

SURVEY FORM ON RECOMPACTED FILL SLOPE PERFORMANCE

DEPARTMENT OF CIVIL AND STRUCTURAL ENGINEERING
THE UNIVERSITY OF HONG KONG

Problems with recompaction process

- ☐ difficult access
- ☐ lack of space for manipulating construction equipment
- ☐ lack of space for stockpiling fill material
- ☐ removal of mature trees
- ☐ road closure
- ☐ others ____

____

Remarks including innovative solutions

____

____

____

Long term problems

- ☐ washout failure
- ☐ blocked drainage
- ☐ cracks on cover
- ☐ settlement
- ☐ others ____

____

Remarks

____

____

____

Hazards

- ☐ failure during construction
- ☐ deep seated failure
- ☐ liquefaction failure
- ☐ others ____

Remarks

____

____

Name of organization/engineer surveyed ______________________________

____

Date ______________