THE REPUBLIC OF MAURITIUS
MINISTRY OF PUBLIC INFRASTRUCTURE AND LAND TRANSPORT (MPI)

THE PROJECT OF LANDSLIDE MANAGEMENT IN THE REPUBLIC OF MAURITIUS

FINAL REPORT

SUMMARY REPORT

March 2015

JAPAN INTERNATIONAL COOPERATION AGENCY

KOKUSAI KOGYO CO., LTD.
NIPPON KOEI CO., LTD.
CENTRAL CONSULTANT INC.
FUTABA INC.

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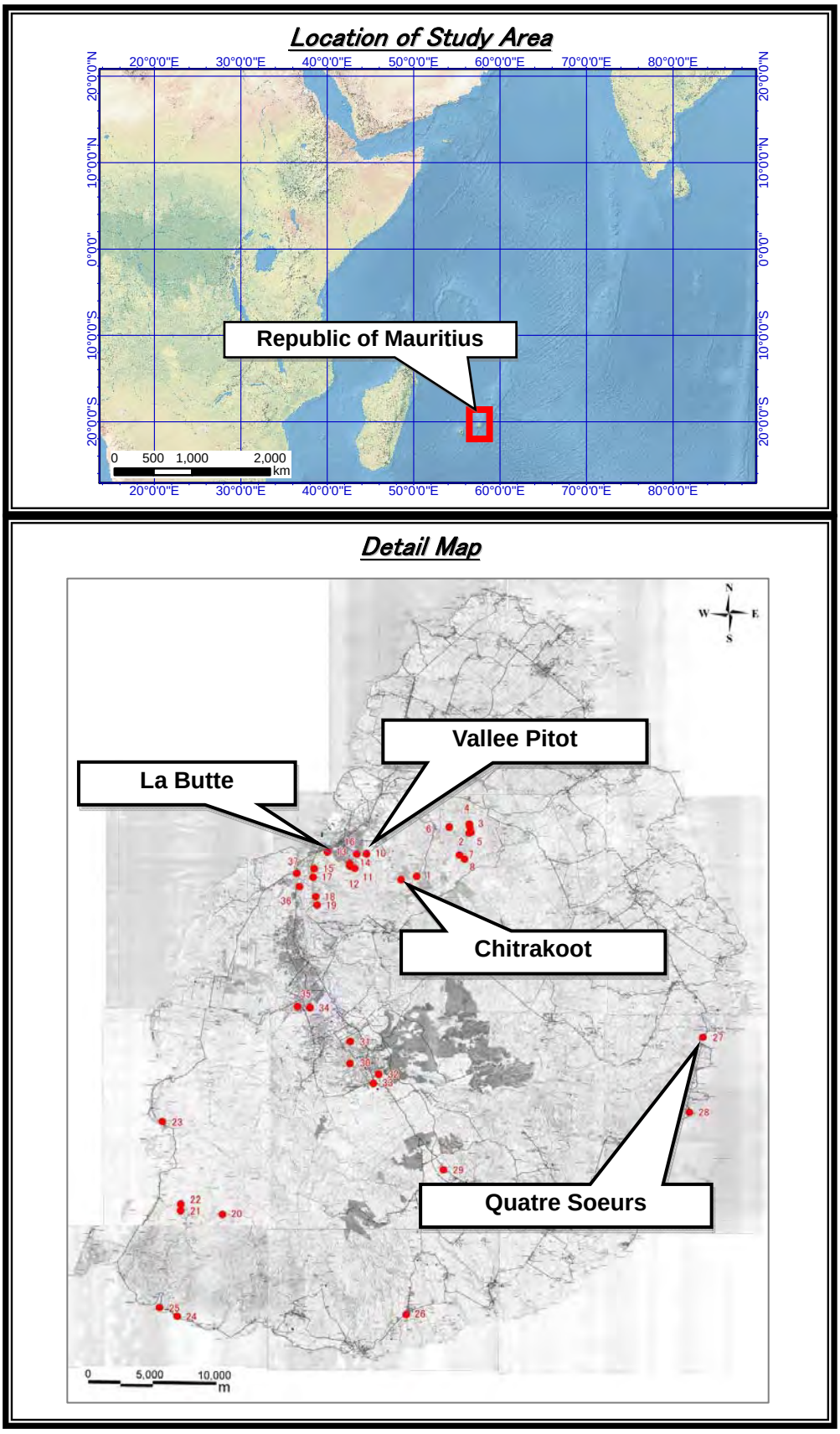

Location Map

Rate of Currency Translation

1 USD = 34.959 Rs

= 119.68 JPY

100 Rs = 3.098 USD

= 370.75 JPY

Rs: Mauritius Rupee

As of March 1st, 2015

Photos of the Project (1)

Courtesy visit to the Deputy Prime Minister and Minister of MPI, 28th May 2012

Conclusion on commencement of the Project, 30th May 2012

1st Steering Committee, 29th May 2012

2nd Steering Committee, 1st Nov. 2012

3rd Steering Committee, 21st Nov. 2013

4th Steering Committee, 19th Jan. 2015

Photos of the Project (2)

1st Stakeholder Meeting (Chitrakoot), 22nd Sep. 2012

2nd Stakeholder Meeting (Quatre Soeurs), 12th Apr. 2013

5th Stakeholder Meeting (Vallee Pitot), 12th Dec. 2014

1st Technical Transfer Seminar, 10th Oct. 2012

2nd Technical Transfer Seminar, 20th Nov. 2013

3rd Technical Transfer Seminar, 20th Jan. 2015

Photos of the Project (3)

Site visit by IOC, 13th Jun. 2012

4th Technical Workshop【Landuse Policy】, 30th Jul. 2012

5th Technical Workshop【Aerial Photo Interpretation】, 6th Sep. 2012

10th Technical Workshop【Stability Analysis and Countermeasures】, 5th Mar. 2013

1st Training in Japan,
24th Nov. ~ 15th Dec. 2012

2nd Training in Japan,
17th Aug. ~ 8th Sep. 2013

Photos of the Project (4)

Boring Survey (Quatre Soeurs), 2nd Oct. 2012

Technical Guidance on Horizontal Drilling for Landslide Countermeasure Works (Chitrakoot), 30th Oct. 2014

2nd Site Meeting for the Construction of Landslide Countermeasure Works (Chitrakoot), 1st Sep. 2014

Completed Countermeasure Work【River Type-3】, 12th Dec. 2014

Completed Countermeasure Work【Bridge Type-3】, 12th Dec. 2014

Completed Countermeasure Work【Horizontal Drainage】, 12th Dec. 2014

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12. Soil Test and Water Quality
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14. Review and Recommendation for the Planning Policy Guidance
15. Result of Stability Analysis
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23. Minutes of 3rd Advisory Committee in Japan
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28. Calculation of Pile Work
29. Results of Stability Analysis of Slope behind the Drainage
30. Consideration of the Cross Section for Drainage
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Abbreviations

Abbreviation	English
AAP	Africa Adaptation Programme
AC	Advisory Committee
AF	Adaptation Fund
AFD	Agence Française de Développement
AFP	Adaptation Fund Programme
BA	Building Act
BLUPG	The Building and Land Use Permit Guide
CCIC	Climate Change Information Center
C/P	Counterpart
CA	Capacity Assessment
CADMAC	Climate Change Adaptation and Disaster Management Committee
CC	Crisis Committee
CCD	Climate Change Division
CD	Capacity Development
CD	Consolidated Drained test
CDEMA	Caribbean Disaster Emergency Management Agency
CEB	The Central Electricity Board
CONDC	The Cyclone and Other Natural Disasters Committee
CONDS	Cyclone and Other Natural Disasters Scheme
CSO	Central Statistics Office
CU (CU-bar)	Consolidated Undrained test
CWA	The Central Water Authority
DEM	Digital Elevation Model
DRR	Disaster Risk Reduction
EU	European Union
F/S	Feasibility Study
FAS	First Aid Service
Fs	Safety Factor/Factor of Safety
GDP	Gross Domestic Product
GIS	Government Information Service
GIS	Geographic Information System
GL	Ground Level
GSMaP	Global Satellite Mapping of Precipitation
HFA	Hyogo Framework for Action
IC/R	Inception Report
ICZM	Integrated Coastal Zone Management
IEC	Information, Education, and Communication
IOC(COI)	Indian Ocean Commission (Commission de l'Océan Indien)
IP	Plasticity Index/(Index of Plasticity)
ISO	International Organization for Standardization
JET	JICA Expert Team
JICA	Japan International Cooperation Agency

JICE	Japan International Corporation Center
LDRM	Landslide Disaster Risk Management
LGA	Local Government Act, 2003
LL	Liquid Limit
LMU	Landslide Management Unit
M/M	Minutes of Meeting
Mauritius	The Republic of Mauritius
MBC	Mauritius Broadcasting Corporation
MEHR	Ministry of Education and Human Resources
MESDDBM	Ministry of Environment, Sustainable Development, Disaster and Beach Management
MGCW	Ministry of Gender Equality, Child Development and Family Welfare
MHL	Ministry of Housing and Lands
MHQL	Ministry of Health and Quality of Life
MID	Maurice Ile Durable
MLG	Ministry of Local Government & Outer Islands
MoESD	Ministry of Environment and Sustainable Development
MoFED	Ministry of Finance and Economic Development
MPI	Ministry of Public Infrastructure and Land Transport
MMS	Mauritius Meteorological Services
MSS	Ministry of Social Security, National Solidarity and Reform Institutions
MTEF	Medium-Term Expenditure Framework
MTL	Ministry of Tourism and Leisure
MTSRT	Ministry of Tertiary Education, Science, Research and Technology
NDOCC	National Disaster and Operations Coordination Centre
NDRMCC	National Disaster Risk Reduction and Management Center
NDS	National Development Strategy
NDU	National Development Unit
NGO	Non-Governmental Organization
ODA	Official Development Assistance
OPS	Outline Planning Schemes
P.Fs	Planning/Designed Factor of Safety
P/R	Progress Report
PBB	Programme-Based Budgeting
PDA	Planning and Development Act
PEFA	Public Expenditure and Financial Accountability
PFM	Public Financial Management
PIU	Planning and Implementation Units
PL	Plastic Limit
PMO	Prime Minister’s Office
PMS	Performance Management System
PPG	Planning Policy Guidance
PS	Permanent Secretary
PVC	Polyvinyl Chloride
R/D	Record of Discussion
RRU	Repair and Rehabilitation Unit
SC	Steering Committee

SIDS	Small Island Developing States
SPT	Standard Penetration Test
SWI	Soil Water Index
TAS	Treasury Accounting System
TCPA	Town and Country Planning Act
The Disasters Scheme	The Cyclone and Other Natural Disasters Scheme
The Project	The Project of Landslide Management in the Republic of Mauritius
TICAD IV	The Fourth Tokyo International Conference on African Development
TRMM	Tropical Rainfall Measuring Mission
UNDP	The United Nations Development Programme
WCDR	World Conference on Disaster Reduction

Digest

This report is a Final Report (hereinafter F/R) which covers the results of all activities for the Project of Landslide Management in the Republic of Mauritius (hereinafter the Project) according to the Record of Discussion (hereinafter R/D) agreed upon between the Ministry of Public Infrastructure and Land Transport (hereinafter MPI), of the Republic of Mauritius (hereinafter Mauritius) and the Japan International Cooperation Agency (hereinafter JICA).

As for the introduction in **Chapter 1**, the background/outcomes/scope/schedule of the Project and the main activities are described.

JICA has dispatched 14 experts (hereinafter JET, or JICA Expert Team) who specialize in investigation, analysis, design and countermeasures of landslides. The Project is conducted with members of the Repair and Rehabilitation Unit/ Landslide Management Unit (hereinafter RRU/LMU) in MPI as Counterparts (hereinafter the C/P) from May 2012 to March 2015.

The objectives of the Project are; 1) Formulation of a landslide management plan to establish a landslide monitoring system, 2) Implementation of the F/S and pilot project to examine, carry out and learn specific approaches, 3) Improvement of landslide management skills at RRU/LMU and other related institutions.

For the basic survey in **Chapter 2**, the topography, the geology, landslide inventory, existing countermeasures, social survey, organizations and systems and economic survey on the entire Mauritius area are described.

Mauritius is a volcanic island with a volcanic plateau of 300 - 400m formed by these craters. The island consists of basaltic flows and the geological history began approximately 10 million years ago and there were two cycles of volcanic activity involved in the formation of the island. The average annual rainfall amount is about 2,000mm and almost 70% is concentrated during the rainy season (December - May). Many large-scale cyclones occur during the rainy season, causing most of the landslide disasters to occur during this season.

Reconnaissance has been conducted for the 32 landslide hazard areas selected in the "Cyclone and Other Natural Disasters Scheme 2011-2012 (hereinafter the Disaster Scheme)" and several of the 32 landslide hazard areas were divided, bringing the total to 37 areas. The 37 hazard areas are classified into nine (9) kinds of disasters: landslide, slope failure, rock fall, debris flow, stream erosion, damage of embankment, wall damage, house damage, and land subsidence (cave-in). A landslide inventory and a hazard evaluation have been implemented for the 37 areas based on aerial photo interpretation, site survey and checking for existing countermeasures.

Social condition such as land use, population, poverty and water resource and economical condition such as economic indices (GDP, etc.), economic policy and budget have been organized. The questionnaire for 300 households has revealed the resident consciousness for landslide disasters, countermeasures and evacuation, which is a fundamental data for the policy of measures.

Regarding the organizations and systems, the Disaster Scheme mentions the responsibility and roles of 7 ministries and 11 organizations for emergency situations on natural disasters, especially that National Disaster Risk Reduction and Management Centre (hereinafter

NDRRMC) in Prime Minister Office undertakes a main role in disaster planning and coordination for every level on the central/local governments and establishes strategies for the disasters. RRU/LMU conducts monitoring, investigation, emergency response for landslides.

Under the landslide management plan 1 (survey and result) in **Chapter 3**, the identification of landslide hazard areas, topographic survey, geological survey, monitoring, geophysical exploration, drilling survey, field reconnaissance, disaster inspection, the review and recommendation for the Disaster Scheme as well as the Planning Policy Guidance (hereinafter PPG) and preparation of "Technical Guideline for initial survey" and "Procedure Manual for landslides" are described.

The targeted landslides in the Project are three (3) sites, Chitrakoot, Quatre Soeurs and Vallee Pitot by the hazard evaluation and the request form MPI. The following investigations and analyses have been conducted.

Table List of the Investigations and Analyses in the 3 Priority Areas (JET)

		Chitrakoot	Quatre Soeurs	Vallee Pitot
Topographic survey	plan map (1/500)	1.8 km^2 (1800m×1000m)	0.16 km^2 (400m×400m)	0.005km^2 (70m×70m)
	cross section (1/100)	3 lines	1 line	1 line
Site reconnaissance		1 set	1 set	1 set
Laboratory test	physical test	6 samples	2 samples	
	dynamics test	3 samples		
	water quality	10 samples	7 samples	
Monitoring	rain gauge	1	1	
	extensometer	4	2	2
	inclinometer	2		
	strain gauge	2	2	
	ground water level meter	2	2	
	ground water level (manual)		6	
Geophysical exploration	elastic wave exploration	6 lines (1955m)		
	two-dimensional resistivity exploration	6 lines (1925m)		
Drilling survey		6 holes (260m)	2 holes (42m)	
Survey on damage to houses		1 set	1 set	1 set

In addition to the above mentioned investigations and analyses, a disaster inspection has been implemented for the 37 hazard areas in the Disaster Scheme so that the areas have been classified into three (3) ranks (A, B, C) according to their level of risk. The issues and proposal on the early warning and evaluation protocol in the Disaster Scheme as well as the development control of landslides in the PPG have been discussed. "Technical Guideline for initial survey" and "Procedure Manual for landslides" have been published based on these investigations and analyses.

Under the landslide management plan 2 (analysis and interpretation) in **Chapter 4**, the geological interpretation, the interpretation for monitoring, the analysis for soil water index, stability analysis and susceptibility assessment are described.

The features and the policy of countermeasures have been discussed on the three (3) priority sites based on the results of the landslide management plan 1 in Chapter 3.

In Chitrakoot, although the entire block, which was presumably activated in 2005 and 2008, has already become stable, two small blocks, “A block (L=300m, W=150m)” and “B block (L=100m, W=200m)”, have been activated. The presumed slip surface is around GL-6m at the boundary between the base rock (Basalt) and the soft surface/colluvial soil. The landslide moves downward intermittently by rising of groundwater with rainfall so that the safety factor Fs is assumed to be 0.98. The rainfall is flooded on the surface due to poor drainage system, which would become a trigger by penetrating excessively into the ground of the landslide area. Therefore the establishment of surface and subsurface drainage systems is urgently needed.

In Quatre Soeurs, there seems to be an entire block by topographical interpretation, which is unclear and stable now. Although two small blocks, “A block (L=60m, W=50m)” and “B block (L=150m, W=100m)”, were presumably activated by 230mm accumulative rainfall in 2005 and 2008, they have been stabilized in the Project period. Since the landslides are stabilized, the safety factor Fs is assumed to be 1.00. The rainfall is flooded on the surface due to poor drainage system, which would become a trigger by penetrating excessively into the ground of the landslide area.

In Vallee Pitot, a small block, “A block (L=40m, W=40m)”, has been activated. The entire block (L=80m, W=100m) started to be activated in February 2013. It is presumed that the type is a surface landslide in colluvial soil/sand/clay. The landslide moves downward intermittently by rising of groundwater with rainfall so that the safety factor Fs is assumed to be 0.98. The rainfall is flooded on the surface due to poor drainage system, which would become a trigger by penetrating excessively into the ground of the landslide area.

In addition, thresholds of the early warning and evacuation using the Soil Water Index have been discussed by data in Mauritius Meteorological Service and of the Global Satellite Map of Precipitation (GSMaP) in Chitrakoot and Quatre Soeurs where there are history records on landslides.

For the Feasibility Study (hereinafter F/S) in priority areas in **Chapter 5**, the priority sites and pilot project sites, policy of countermeasures, Environmental Impact Assessment, the Pilot Project evaluation, the promotion of fund raising and the organizational reinforcement plan are described.

JET decided Chitrakoot as a Pilot site based on the landslide investigation, risk assessment, economic loss, countermeasure cost and request from MPI. For Chitrakoot, especially highest risk area “A block”, structural countermeasures such as drainage ditches by horizontal drilling were planned in order to avoid excessive water supply into the landslide area and to drain water safely away from the area. Environmental Impact Assessment has been conducted and their mitigation plan was reflected to the countermeasures. The pilot project evaluations (pre, interim, post) have been implemented from the viewpoints of relevance, effectiveness, efficiency, impact and sustainability.

In Quatre Soeurs, the Mauritius Government is negotiating with local residents in the landslide area to relocate them to a safer place and has had meetings with them more than ten (10) times since 2010. JET has supported MPI regarding the preparation of the explanation materials and the meetings. Although the Mauritius Government has proposed a place to relocate the residents, an agreement has not been reached with the residents, therefore the relocation has not yet been completed.

In Vallee Pitot, since a landslide block started to activate through February to May in 2013, the land mass destroyed a channel (20m) and has blocked it completely. JET proposed to C/P that emergency responses and permanent countermeasures after geological survey and monitoring and has discussed with MPI regarding this matter. MPI started the geological surveys and the monitoring there and is planning countermeasures.

Budget allocation after 2014 for the 37 hazard areas (including the three (3) priority sites) in the Disaster Scheme has been promoted by proposing the policy of investigation and countermeasures. MPI applied the budget for investigation/analysis/design/supervision for the 37 areas; 16,500,000Rs in 2014, 55,650,000Rs in 2015, 40,100,000Rs in 2016 and 44,700,000Rs in 2017.

Regarding the organizational reinforcement plan, JET proposed tasks to be conducted by organizing the current issues and purposes on RRU/LMU and has fulfilled, as mid/long term objectives, the request of six (6) full-time engineers, the budget application and the concretization of responsibility/role of related organizations, from standpoints of technological improvement, personnel securement and improvement of administrative ability. In addition, some of C/Ps have been dispatched to Japan to study at graduate university (two (2) years) and to train in disaster management (two (2) months).

For the Pilot Project in **Chapter 6**, the structural countermeasure in Chitrakoot, the early warning and evacuation system in the targeted three (3) sites, IEC (Information, Education and Communication) and stakeholder meetings are described.

As for the structural countermeasures in Chitrakoot, JET and C/P have implemented the basic design/detailed design/cost estimation/construction plan/bidding/contract/construction/ supervision for a large-scale channel, a horizontal drilling, an open/blind ditch, a surface ditch, a river improvement (widening and revetment work), a bridge and a collecting channel for the purposes of limiting the inflow of water into the landslide area and draining of water away from the landslide area. Since it takes time (around one (1) year) to get an official approval of land use for construction in Mauritius, JET and C/P prioritize the construction with consideration of safety and decided that JET would implement the higher prioritized works as a pilot project before the rainy season (December in 2014) and MPI would implement the remaining works after the rainy season with their own budget. The contract for the pilot project was awarded by competitive bidding in June 2014 at MPI office to a local construction company for 14,045,723Rs (lowest price). The construction was started on August 2014 and completed in December 2014 (around five (5) month). During the pilot project, the structure and alignment of the channel and vegetation works were locally modified and the river improvement at the bottom part (L=47m) was canceled because of a complaint from a landowner. The canceled works will be conducted by MPI after the rainy season. The monitoring such that using as groundwater level meters, extensometers and pipe strain gauges will be continuously conducted to identify the effectiveness of the countermeasures after the construction.

Regarding the early warning system, JET proposed new thresholds at which to issue warnings based on extensometer readings and house damage obtained in the monitoring of the Project. This proposal was the result of investigations looking into issues of the current system in the Disaster Scheme. The proposed threshold is; “preparation (pre stage)” is 20mm/month in extensometer or new cracks in houses, “warning (stage 1)” is 5mm/hour in extensometer or crack opening in houses, “evacuation (stage 2)” is 20mm/hour in extensometer or additional

cracks in/around houses, "warning lifted (stage 3)" is 0mm/hour in extensometer or no anomalies in houses. The revolving lights (red and yellow) and sirens have been installed to enable voluntary evacuation using the thresholds. The yellow light informs "warning (stage 1)" and the red light and siren inform "evacuation (stage 2)". Liaison members and communication system as well as evacuation routes/areas for the early warning and evacuation have been established. MPI will continuously work to raise awareness of local residents under normal conditions, and check the areas and give advice to NDRRMC in emergency condition.

For IEC in the Project, JET has supported MPI to transmit the related information such as disaster, warning, evacuation and land use etc. through various media to residents. One of the main activities of IEC is stakeholder meetings for the residents in the three (3) priority areas, which were held five (5) times at the beginning of the Project, at the completion of implementation plan (draft), at the finalization of the implementation plan, at the beginning of the pilot project and at the end of the pilot project to get consensus and understanding from the residents. JET ascertained the level of understanding of the residents of the three (3) priority areas on how to respond to an early warning or evacuation order by questionnaire, and proposed measures and activities to be conducted by MPI. Newsletters in English/French (No.1-5) and "Landslide Disaster Prevention Handbook" were published and distributed to the local residents as well as the related organizations.

With respect to the technical transfer in **Chapter 7**, methodology and structure of the technical transfer, workshop, technical transfer seminar, training in Japan, Steering Committee and advisory committee in Japan are described.

In order to conduct effective technical transfers, the methodology and structure have been reconsidered based on the purposes and issues of OJT (On-the-Job Training), the Pilot Project, and the training in Japan. JET is composed of four (4) technical groups; a management group, an investigation/analysis group, a design/construction group and a soft countermeasure group for smooth technical transfer. MPI, as one entire team, has received technical training from all four (4) groups so that MPI has been able to understand whole knowledge and technology on the management and countermeasure on landslides.

In addition to the OJT, three (3) technical transfer seminars on the landslide countermeasures and 13 workshops on certain themes such as aerial photo interpretation and stability analysis etc. were held through the Project period. The trainings in Japan were held on November 20th – December 15th in 2012 and August 14th – September 8th in 2013 (both for 26 days) with participation of five (5) C/P members for each training (total ten (10) members). The Steering Committees in Mauritius and the Advisory Committee in Japan were held four (4) times for each committee to confirm the policy/methodology/results/discussion on the Project.

As for environment, climate change adaptation and disaster management in **Chapter 8**, the landslide management plan and the climate change adaptation plan have been discussed and proposed to the Government of Mauritius based on all of the activities in the Project.

As for the proposal for future tasks in **Chapter 9**, the tasks for each item on landslides in the Project have been summarized. Proposals on formulation of a landslide management plan in Mauritius are summarized as follows in consideration of the hypotheses for mechanisms and countermeasures on landslides.

1. The following basic surveys are necessary to grasp the landslide activities, volumes,

areas and the relation with circumferences.

2. The Disaster Scheme and the PPG are reviewed to propose the early warnings and evaluation protocols and other soft countermeasures.
3. The current activities on landslides are determined by the stability analysis using landslide cross sections based on the basic surveys.
4. The relations among the activities, groundwater level and rainfalls are discussed with the results of the monitoring.
5. Best countermeasures (hard and soft) are considered from the viewpoint of the activities, priorities, request form residents, and budgets.
6. For hard countermeasures, suitable drainage works are selected based on the results of the investigation on surface/ground water conditions. Horizontal drilling is judged to be effective from the results of the pilot project.
7. For soft countermeasures, early warning/evaluation system using a threshold for each landslide is operated. The soft countermeasures are useful until the completion of the construction of hard countermeasures.

Chapter 1

Introduction

1 Introduction

1.1 General

This report is a Final Report (hereinafter F/R) which covers the results of all activities for the Project of Landslide Management in the Republic of Mauritius (hereinafter the Project) according to the Record of Discussion (hereinafter R/D) agreed upon between the Ministry of Public Infrastructure and Land Transport (hereinafter MPI), of the Republic of Mauritius (hereinafter Mauritius) and the Japan International Cooperation Agency.

JICA dispatches 14 experts (hereinafter JET, or JICA Expert Team) who specialize in investigation, analysis, design and countermeasure on landslide. The Project is conducted with members of the Repair and Rehabilitation Unit/ Landslide Management Unit (hereinafter RRU/LMU) in MPI as Counterparts (hereinafter the C/P) from May 2012 to March 2015.

1.2 Objectives of the Project

1.2.1 Objective

The goal is to have the Feasibility Study (hereinafter F/S) and landslide management plan approved by the Government of Mauritius, and for the relevant organizations to implement them.

1.2.2 Desired Outcome

The risk of landslides and other slope disasters is reduced, and the safety for the residents in the landslide area is secured.

1.2.3 Outcome of the Project

1) Formulation of a landslide management plan to establish a landslide monitoring system.

2) Implementation of the F/S and pilot project to examine, carry out and learn specific approaches.

3) Improvement of landslide management skills at RRU/LMU and other related Institutions.

1.3 Scope of the Project

1.3.1 Project Areas

The project area is the Mauritius Island, and the JICA Expert Team prioritize 37 high risk areas designated in the Cyclone and Other Natural Disasters Scheme (hereinafter the Disasters Scheme).

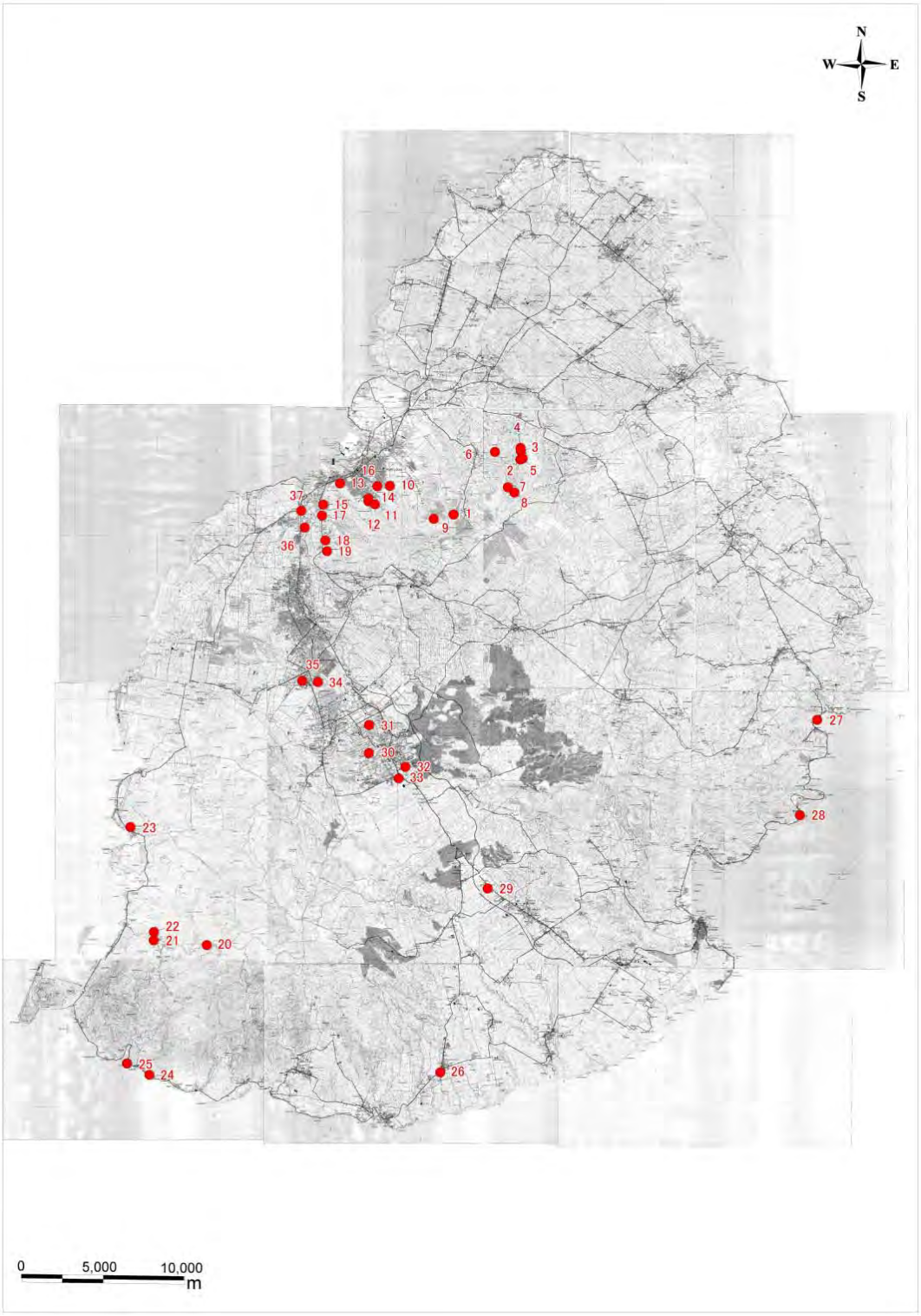


Figure 1.3.1 Location Map of the Project Area (source: JET)

1.3.2 List of JICA Expert Team and Counterparts

The C/P of the Project is MPI and, the C/P members are mainly composed of RRU/LTU in Civil Engineering Division in MPI.

The names of the JICA Expert Team (hereinafter JET) members and counterparts are listed below. Table 1.4.1 indicates the role of each member.

Table 1.3.1 List of JICA Expert Team and Counterparts (source: JET)

	JICA Experts	Field of Expertise	Counterpart (MPI)
1	Kensuke ICHIKAWA	Chief adviser	Mahmad Reshad JEWON Deevarajan CHINASAMY Vishwahdass RAMDHAN Selvanaden Pearia ANADACHEE Mohammad Khalid MOSAHEB Rameswurdass RAMDHAN Lalitsingh BISSESSUR Bhoopendra DABYCHARUN
2	Takeshi KUWANO	Vice chief adviser/ Landslide management	
3	Tomoharu IWASAKI	Landslide survey and analysis	
4	Fumihiko YOKOO	Landslide monitoring	
5	Yoji KASAHARA	Geophysical prospecting	
6	Masami SUGITA	GIS/Topographic survey	
7	Takashi HARA	Design/Cost estimation	
8	Takayoshi KURATA	Water quality management/ environmental and social consideration	
9	Yoshizumi GONAI	Policy and planning of urban development and land use	
10	Shingo ICHIKAWA	Institution/system analysis/capacity development 1	
11	Yurie KAWABATA	Information, education and communication	
12	Yosuke YAMAMOTO	Coordinator/Landslide management assistant	
13	Haruka YOSHIDA	Coordinator/Institution/system analysis/capacity development 2	
14	Makoto TOKUDA	Coordinator/Policy and planning of urban development and land use assistant	

1.4 Major Activities

The following components have been conducted from the commencement of the Project in May 2012 up to now.

- Component 1 “Basic survey”
- Component 2 “Formulation of a Landslide Management Plan”,
- Component 3 “Implementation of the Feasibility Study (F/S) in Priority Areas”
- Component 4 “Implementation of the Pilot Project”

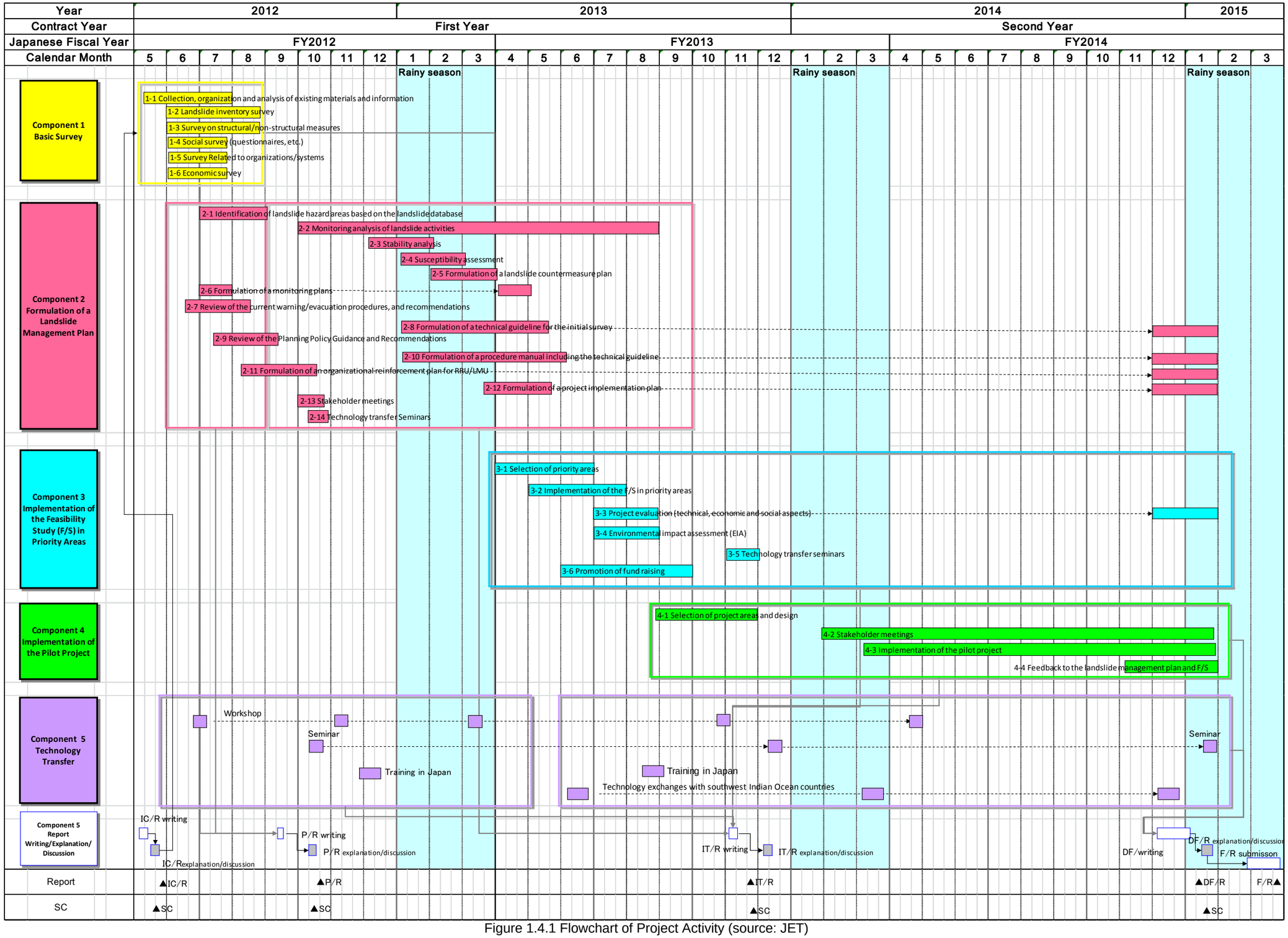


Figure 1.4.1 Flowchart of Project Activity (source: JET)

Chapter 2

Basic Survey

2 Basic Survey

2.1 Topography

It is a volcanic island with craters distributed continuously from north to south of the island. A volcanic plateau of 300 - 400m is formed by these craters, with the highest peak being Mt. La Petite Riviere Noire (828m) in the southwest of the island.

2.2 Geology and Rainfall

The island is a volcanic island and the basaltic flows are classified into 3 groups which are ancient lava series, intermediate lava series and recent lava series. The geological history began approximately 10 million years ago and there were two cycles of volcanic activity involved in the formation of the island.

2.3 Landslide Inventory Survey

In the landslide inventory survey, a reconnaissance will be conducted for the 32 landslide hazard areas selected in the "Cyclone and Other Natural Disasters Scheme 2011-2012". However, as a result of having investigated the sites, several of the 32 landslide hazard areas were divided, bringing the total to 37 areas.

Table 2.3.1 Revised 37 Landslide Hazard Areas (source: JET)

No.	Area name
Pamplemousses/Riviere du Rempart District Council	
1	Temple Road, Creve Coeur
2	Congomah Village Council (Ramlakhan)
3	Congomah Village Council (Leekraj)
4	Congomah Village Council (Frederick)
5	Congomah Village Council (Blackburn Lanes)
6	Les Mariannes Community Centre (Road area)
7	Les Mariannes Community Centre (Resident area)
8	L'Eau Bouillie
Municipality of Port Louis	
9	Chitrakoot, Vallee des Pretres
10	Vallee Pitot (near Eidgah)
11	LePouce Street
12	Justice Street (near Kalimata Mandir)
13	Mgr. Leen Street and nearby vicinity, La Butte
14	Pouce Stream
15	Old Moka Road, Camp Chapelon
16	Boulevard Victria, Montague Coupe
Black River District Council	
17	Pailles : (i) access road to Les Guibies and along motorway, near flyover bridge
18	Pailles : (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)
19	Pailles : (iii) soreze regin
20	Plaine Champagne Road, opposite "Musee Touche Dubois"
21	Chamarel : (i) near Reataurant Le Chamarel
22	Chamarel : (ii) Roadside
23	Gremde Riviere Noire Village Hall
24	Baie du Cap : (i) Near St Francois d'Assise Church
25	Baie du Cap :(ii) Maconde Region
GRAND PORT/SAVANNE DISTRICT COUNDIL	

26	Riviere des Anguilles, near the bridge
27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa
29	Cave in at Union Park, Rose Belle
MUNICIPALITY OF CUREPIPE	
30	Trou-AUX-Cerfs
31	River Bank at Cite L'Oiseau
32	Louis de Rochecouste (Riviere Seche)
33	Piper Morcellement Piat
MUNICIPALITY OF QUATRE BORNES	
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues
35	Cavernous Area at Mgr Leen Avenue and Bassin
MUNICIPALITY OF BEAU BASSIN/ROSE HILL	
36	Morcellement Hermitage, Coromandel
37	Montee S, GRNW

2.3.1 Classification of Hazard Area

The 37 landslide hazard areas, selected based on the "Cyclone and Other Natural Disasters Scheme 2011-2012", includes several disaster forms besides landslides (the object of this project). Therefore the 37 hazard areas are classified into 9 kinds of disasters.

Table 2.3.2 Classification of Hazard Area (source: JET)

General classification			Sub classification			Summary
Disaster	Slope	15 areas	Landslide	6	areas	Can be classified as a Landslide Hazard Area
			Slope failure	7	areas	Because it is not a "Landslide", it cannot be classified as a Landslide Hazard Area
			Rock fall	1	areas	
			Debris flow	1	areas	
	Other	22 areas	Stream erosion	10	areas	
			Damage of Embankment	4	areas	
			Damage of wall	5	areas	
			Damage of house	1	areas	
			Cavern	2	areas	
				Total 37	areas	

2.3.2 Site Reconnaissance

a. Aerial Photographic Interpretation

The aerial photograph interpretation for landslides was carried out for 13 hazard areas, out of a total of 37, that were classified as a landslide or a slope failure.

Table 2.3.3 Summary of the Aerial Photograph Interpretation (source: JET)

No	Area name	Classification	Interpreted or Not	Aerial photo No.(Year)	Summary
6	Les Mariannes Community Centre	Slope failure	Interpreted	R720-R721 (1998)	Behind the slope failure at the roadside, a landslide body margin without main scarp has been confirmed.
9	Chitrakoot,	Landslide	Interpreted	1922-1923 (1999)	A clear main landslide was confirmed, and the definite margin of the several landslides were interpreted around it.
10	Vallee Pitot	Landslide	Not interpreted	1919-1920 (1999)	Because a target area is small, the aerial photo cannot identify it. Around a target area, the certain landslide landforms were not confirmed.
13	La Butte	Landslide	Interpreted	1917-1918 (1999)	The landslide of La Butte occurred in 1986, and the definite margin of a landslide was confirmed by aerial photograph interpretation.
15	Old Moka Road	Landslide	Interpreted	1916-1917 (1999)	A landslide body margin without main scarp has been confirmed, and the landslide topography is not clear.
17	Pailles: (i) access road to Les Guibies	Slope failure	Not interpreted	1913-1914 (1999)	Because a target area is small, the aerial photo cannot identify it. Around a target area, the certain landslide landforms were not confirmed.
19	Pailles : (iii) soreze regin	Slope failure	Not interpreted	0502-0503 (1997)	Because it is later than the photography year, as for the disaster occurrence of the target area, the aerial photograph cannot confirm it. Around a target area, the certain landslide landforms were not confirmed.
20	Plaine Champagne Road	Slope failure	Interpreted	R656,R657 (1998)	It was confirmed that the colluvium distributed around slope failure area. The cause of the slope failure is thought to be weak colluvium.
27	Quatre Soeurs	Landslide	Interpreted	R243,R244 (1991)	The definite margin of several landslides was interpreted around the disaster area.
28	Bambous Virieux	Slope failure	Not interpreted	1568-1569 (1991)	The target area could not be identified on the aerial photo because it is too small.
30	Trou-AUX-Cerfs	Slope failure	Not interpreted	1395-1396 (1997)	It could not be confirmed on the aerial photo because the slope failure occurred after the photo was taken. No clearly distinguishable landslide landforms could be confirmed in the target area.
34	Candos Hill at Lall Bahadoor Shastri	Landslide	Not interpreted	1780-1781 (1991)	The target area could not be identified on the aerial photo because it is too small. No clearly distinguishable landslide landforms could be confirmed in the target area.
36	Morcellement Hermitage, Coromande	Slope failure	Not interpreted	1914-1915 (1999)	The target area could not be identified on the aerial photo because it is too small. No clearly distinguishable landslide landforms could be confirmed in the target area.

b. Result of Site Reconnaissance

The landslide hazard evaluation by site reconnaissance found three areas with high scores (6 points in total), Chitrakoot area, Vallee Pitot area, and Quatre Soeurs area.

Table 2.3.4 Description of Scoring Sheet for Evaluating Landslide Hazard (source: JET)

Category			Score	Description
Phenomenon on the Site	Landslide landforms and characteristics	Obvious	2	Definite landslide
		Slight	1	Undefined landslide, or slope failure
		None	0	Not a landslide
	Damage to buildings, houses	Obvious	2	Heavy damage, situation is urgent
		Slight	1	Light damage, not urgent
		None	0	No damage
History	Existing record of Landslide (documents or oral record)	Obvious	2	Definite document and oral record exists
		Slight	1	Undefined document and oral record exists
		None	0	No existing record

Table 2.3.5 Result of Landslide Hazard Evaluation (source: JET)

No.	Area name	Kind of the disaster		Score of landslide hazard evaluation			
		General classification	Sub classification	Landslide landforms and characteristic	Damage to buildings, houses	Existing record of landslides	Total
9	Chitrakoot, Vallee des Pretres	Slope	Landslide	2	2	2	6
10	Vallee Pitot (near Eidgah)	Slope	Landslide	2	2	2	6
13	Mgr. Leen Street and nearby vicinity, La Butte	Slope	Landslide	2	1	2	5
15	Old Moka Road, Camp Chapelon	Slope	Landslide	2	1	0	3
27	Quatre Soeurs,	Slope	Landslide	2	2	2	6
34	Candos Hill	Slope	Landslide	2	1	0	3

2.3.3 Inventory and Location Map

As a result of site reconnaissance, the characteristics and evaluation of the landslides were compiled and made into a landslide inventory and a landslide location map.

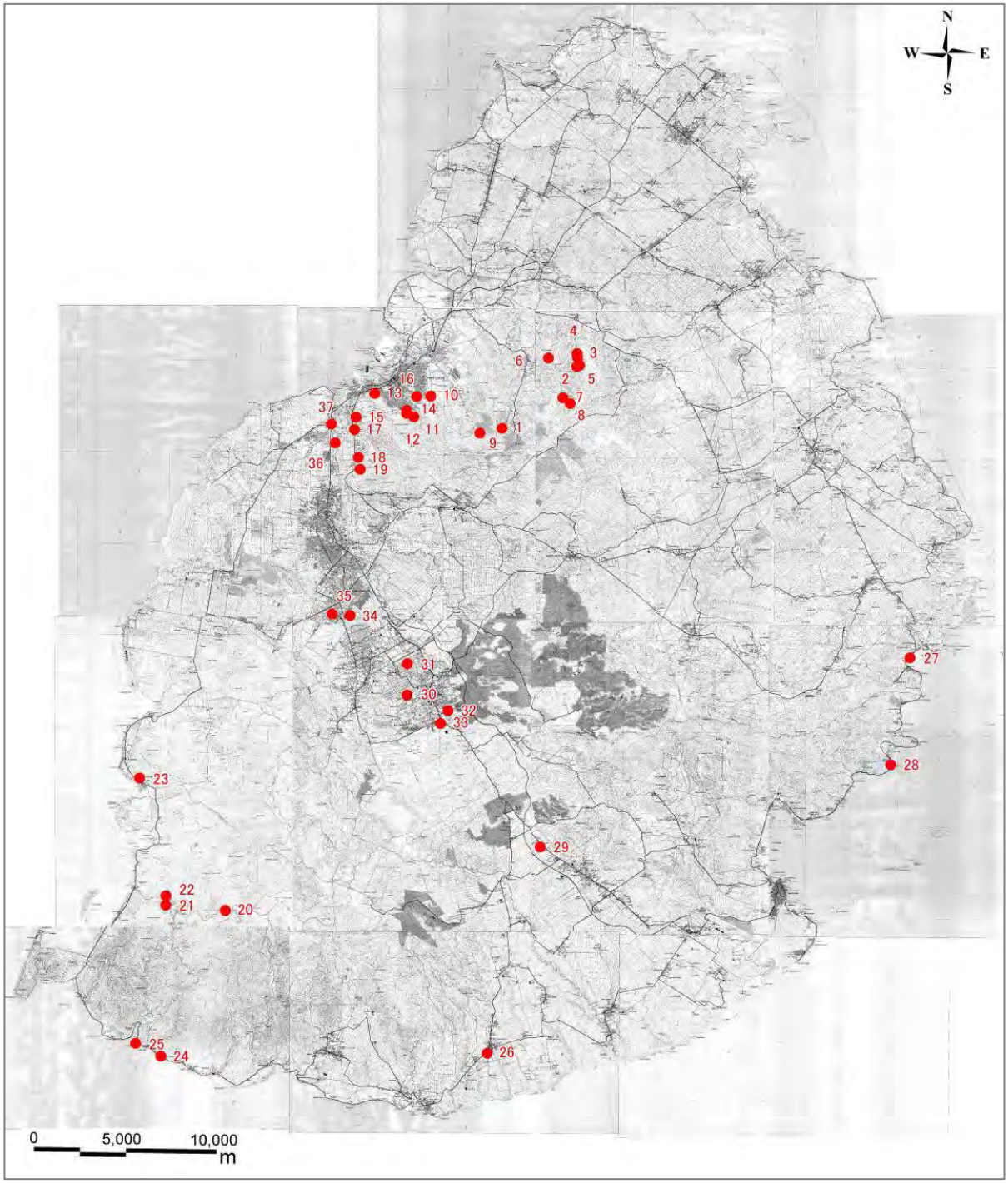


Figure 2.3.1 Landslide Location Map (source: JET)

Table 2.3.6 Landslide Inventory (source: JET)

(1):Landslide landforms and characteristic, (2):Damage on construction and houses, (3):Existing record of Landslide

no.	Area name	Summary of the field investigation and interview	Kind of the disaster		Score of landslide hazard evaluation			
			General classification	Sub classification	(1)	(2)	(3)	Total
1	Temple Road, Creve Coeur	Deformation on the concrete block wall and house caused by embankment deformation at the front yard (parking area) was confirmed. Another problem was inadequate surface drainage causing surface water from mountains to flow directly at houses during heavy rain.	Other	Damage of wall	–	–	–	–
2	Congomah Village Council (Ramlakhan)	A small stream flows under the road through a concrete pipe culvert, however, because it is too small it causes flooding and bank erosion during heavy rain.	Other	Stream erosion	–	–	–	–
3	Congomah Village Council (Leekraj)	A 1m high retaining wall that was constructed to build the road was reported to be leaning but it was found to be stable and no slope failure was observed.	Other	Damage of wall	–	–	–	–
4	Congomah Village Council (Frederick)	The 1m high retaining wall along the road was found to have collapsed due to erosion by surface water flow during rainy season.	Other	Damage of wall	–	–	–	–
5	Congomah Village Council (Blackburn Lanes)	A slope failure was confirmed on the side of the road.	Other	Damage of Embankment	–	–	–	–
6	Les Mariannes Community Centre (Road area)	There are a few slope failures and a lanslide in this site. The slope at the roadside collapsed during heavy rain in 2010 and a section of road was washed away. Since then, a retaining wall has been constructed and the site is currently stable.	Slope	Slope failure	–	–	–	–
7	Les Mariannes Community Centre (Resident area)	There appeared to be bank erosion on the left bank above the bridge.	Other	Stream erosion	–	–	–	–
8	L'Eau Bouillie	The cracks have been spotted on the road surface due to the deterioration of bearing capacity of the roadbed. However, the cracks have been repaired.	Other	Damage of Embankment	–	–	–	–
9	Chitrakoot, Vallee des Pretres	A clear landslide was confirmed. A landslide was reported to have damaged houses and a school after heavy rain in 2005. Drilling investigation and monitoring have been carried out, but not sufficiently. No countermeasures have been implemented. Therefore, a detailed investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide	2	2	2	6
10	Vallee Pitot (near Eidgah)	Lately, housing developments are growing rapidly in this area. A landslide boundary of 35m x 20m was clearly detected. Several houses have been damaged and some cracks were observed. The situation of the damage was also reported in the newspaper.	Slope	Landslide	2	2	2	6
11	LePouce Street	Insufficient surface drainage means rain water concentrates in low area and erodes roads and houses in its path. Damage is negligible at present, although the maintenance of the surface drainage will be necessary.	Other	Stream erosion	–	–	–	–
12	Justice Street (near Kalimata Mandir)	An embankment has been constructed to build up the road, which caused an adjacent retaining wall to be pushed out and deformed. Insufficient surface drainage causing accumulation of groundwater could also be a factor causing this deformation.	Other	Damage of wall	–	–	–	–
13	Mgr. Leen Street and nearby vicinity, La Butte	The landslide of La Butte occurred in 1986, and many houses and a school were damaged. As for this landslide, countermeasures were carried out in 1998, therefore further investigation of the landslide is unnecessary. However, Port Louis City wants to continue the monitoring on this landslide in the future.	Slope	Landslide	2	1	2	5

14	Pouce Stream	Every side of the channel is covered by concrete. The water level rises until the upper edge of the channel and erode beyond this point in the rainy season. The gabion has been set up at the lower part of slope at the channel and no damage has been reported yet. However, the deteriotion of the concrete wall is remarkable and the extention of the wall height will be necessary. Therefore, further investigation and countermeasures are advisable.	Other	Stream erosion	–	–	–	–
15	Old Moka Road, Camp Chapelon	The landslide topography is not clear, but five houses and two retaining walls were damaged while the spring water was spotted in two places. There are two possible causes of this, creep transformation of weak surface soil or a shallow landslide. Therefore, landslide investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide	2	1	0	3
16	Boulevard Victria, Montague Coupe	The gabion was installed on the cut-slope when the road was constructed. There is no record of damage for this site but the angle of the wall is steep.Therefore, the observation of this wall is advisable.	Other	Damage of wall	–	–	–	–
17	Pailles : (i) access road to Les Guibies and along motorway, near flyover bridge	The slope failure has been spotted along the cut-slope (5m height) at the roadside of highway. The surface of the cut-slope has been weathered, and it is eroded by rain.	Slope	Slope failure	–	–	–	–
18	Pailles : (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Insufficient drainage is causing erosion at the base of the water tank. Immediate remedial work is needed.	Other	Stream erosion	–	–	–	–
19	Pailles : (iii) soreze regin	Falling rocks at the upper slope and shallow slope failure at the middle and lower slope occurred in an area of housing. There is only slight damage for now, although shallow slope failure and cracks have been confirmed.	Slope	Slope failure	–	–	–	–
20	Plaine Champagne Road, opposite "Musee Touche Dubois"	Retaining walls have been constructed as countermeasures where the slope failure has been confirmed. It is currently stable, although there were a few cracks spotted in the retaining walls which are believed to be due to substandard construction.	Slope	Slope failure	–	–	–	–
21	Chamarel : (i) near Reataurant Le Chamarel	Cracks in the road shoulder have occurred due to a lack of bearing capacity . It is caused by insufficient soil compaction.	Other	Damage of Embankment	–	–	–	–
22	Chamarel : (ii) Roadside	Deformation of the road has been confirmed at the shoulder of the road due to a lack of bearing capacity. The embankment of stone masonry wall and retaining wall were constructed but it is insufficient.	Other	Damage of Embankment	–	–	–	–
23	Gremde Riviere Noire Village Hall	The crack at the base of village hall area and edge of concrete basketball court has been confirmed. However, the surrounding structures are not affected, therefore it is considered unlikely this damaged was caused by landslides. Rather it is likely to be caused by lack of bearing capacity of the ground or a problem with the structure itself.	Other	Damage of house	–	–	–	–
24	Baie du Cap : (i) Near St Francois d'Assise Church	A debris flow has occurred in the past and a block wall has since been constructed. Also, small surface failures have been observed frequently in this area.	Slope	Debris flow	–	–	–	–
25	Baie du Cap :(ii) Maconde Region	A new road was built to reduce the damage from rock falls. However, rock falls and small rock failures are also a frequent occurance along the new road. The rocks are weathered, and there is a high possibility of rock fall in future.	Slope	Rock fall	–	–	–	–
26	Riviere des Anguilles, near the bridge	There are many houses built on the cliff here. The cliff is weathered severly and stream erosion occurs frequently. Therefore, the house will need to be relocated.	Other	Stream erosion	–	–	–	–

27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide activity has been confirmed at the Quatre Soeurs area where many houses have been damaged. The groundwater level at the lower part of the landslide is high and is causing instability in the landslide. Drilling investigation and monitoring have been carried out, but not sufficiently. Further investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide	2	2	2	6
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure was confirmed at the backyard of the house. No damge on the house was reported although the soil of the slope approached near the house. A retaining wall has been constructed independently.	Slope	Slope failure	–	–	–	–
29	Cave in at Union Park, Rose Belle	A cavity (4m x 4m x 3m depth) due to land subsidence was observed in the residential area. No damage was caused to the houses and the cavity was filled in with soil. Similar situation was confirmed nearby.	Other	cavern	–	–	–	–
30	Trou-AUX-Cerfs	The slope failure in the crater of the volcano occurred during heavy rainfall in 2005. The possibility of slope failure on the rear side is low. However, the slope failure on both sides can be expected.	Slope	Slope failure	–	–	–	–
31	River Bank at Cite L'Oiseau	Bank erosion and flooding is common in the rainy season when the river water level rises. There are more damage on the left side of the riverbank due to the strong collision of water. However, past damage has been restored by constructing a retaining wall.	Other	Stream erosion	–	–	–	–
32	Louis de Rochecouste (Riviere Seche)	The bank erosion and flood are common in the rainy season. The base of the houses have been eroded and the retaining wall of the houses are inclined.	Other	Stream erosion	–	–	–	–
33	Piper Morcellement Piat	The bank erosion and flood are remarkable in the rainy season. However, the past damage has been restored by constructing the retaining wall.	Other	Stream erosion	–	–	–	–
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	A clear landslide site was confirmed at the backyard of the house. The landslide topography and slope are clear while the spring water has been observed. The scale of this lanslide is small (40m x 35m) and no house on the lanslide area. Only slight crack has been confirmed on the retaining wall.	Slope	Landslide	2	1	0	3
35	Cavernous Area at Mgr Leen Avenue and Bassin	A cavity was reported during the house construction but it was filled with concrete. There is no further danger at this site.	Other	cavern	–	–	–	–
36	Morcellement Hermitage, Coromandel	At this slope, slope failure occurred in 2010, and a road was destroyed. After a retaining wall was made as a countermeasure, large-scale slope failures have not been found. However, the stone blocks from on top of the retaining wall have fallen down. This is likely caused by the ground behind the retaining wall sinking due to lack of compaction of the backfilling soil.	Slope	Slope failure	–	–	–	–
37	Montee S, GRNW	Weathered outcrops were detected on both sides of the bank. The erosion is remarkable in the rainy season.	Other	Stream erosion	–	–	–	–

2.3.4 GIS Database

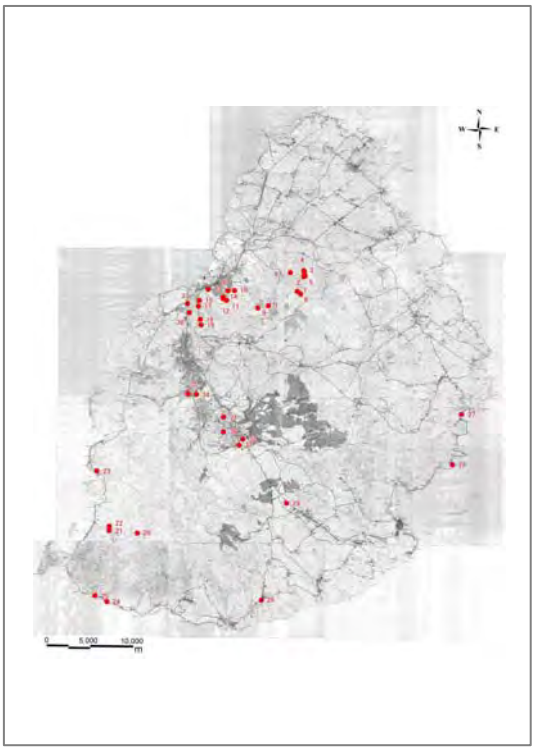


Figure 2.3.2 Landslide Survey Location Map (Base Map: Topographic Map(1:25,000))(source: JET)

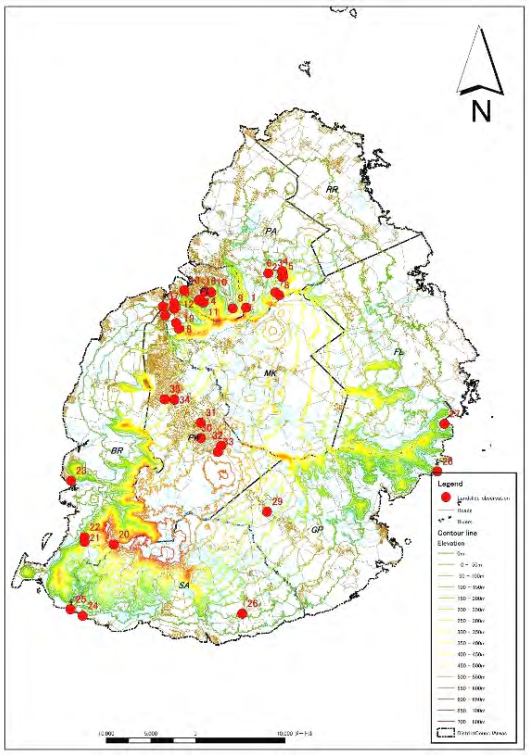


Figure 2.3.3 Landslide Survey Location Map (Base Map: Roads, River, Contour Line, Province Boundary)(source: JET)

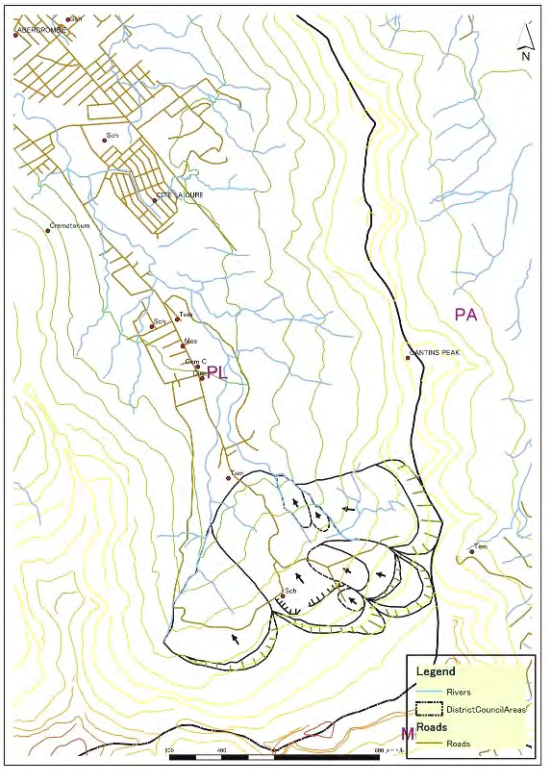


Figure 2.3.4 Landslide Distribution Map, Chitrakoot Area (source: JET)

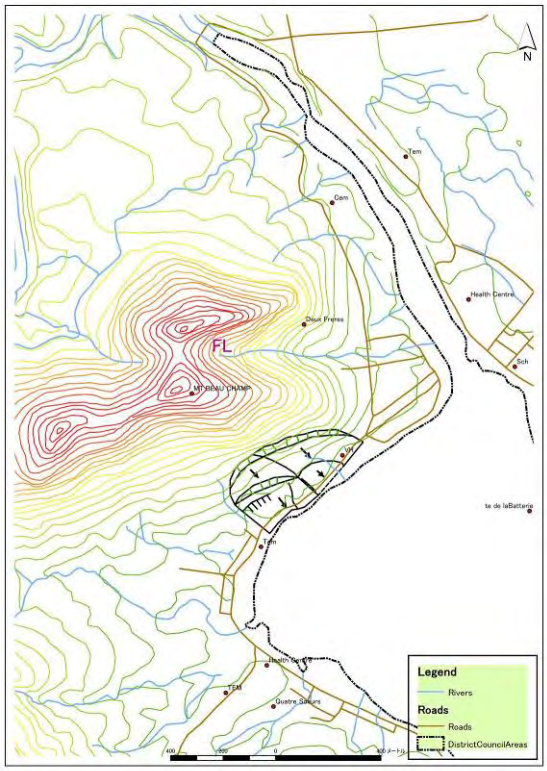


Figure 2.3.5 Landslide Distribution Map, Quatre Soeurs Area (source: JET)

2.4 Existing Countermeasures

2.4.1 Structural Countermeasures

The only landslide for which structural countermeasures have been carried out is that in La Butte area. The landslide of La Butte occurred in 1986, and many houses and a school were damaged. Countermeasures were undertaken in 1998 by help of Japan, and it has been stable since. However, Port Louis City wants to continue the monitoring on this landslide in the future.

Table 2.4.1 The Structural Countermeasures of Landslide Hazard Area (6 Areas) (source: JET)

Manage -ment no.	Area name	Kind of the disaster	Structural countermeasures
9	Chitrakoot, Vallee des Pretres	Landslide	Non
10	Vallee Pitot (near Eidgah)	Landslide	Non
13	Mgr. Leen Street and nearby vicinity, La Butte	Landslide	Pile works: 6 lines Drainage wells: 4 wells horizontal drain works: 42 pipes
15	Old Moka Road, Camp Chapelon	Landslide	Non
27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	Non
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	Non

2.4.2 Non-Structural Countermeasures

Landslide monitoring equipment was confirmed in Chitrakoot, Quatre Soeurs and La Butte. The following table shows the contents of monitoring equipment and their condition.

Table 2.4.2 Current Condition of Landslide Monitoring in Mauritius (source: JET)

District	Contents of Landslide Monitoring
Chitrakoot	Three extensometers were confirmed to exist. Two of them are working. The data is measured by a Mauritian construction company.
Quatre Soeurs	Six boreholes for groundwater monitoring were confirmed to exist. These were installed in March 2011, and were used for monitoring until May 2011. It is able to use those boreholes, but the monitoring has not been implemented.[1]
La Butte	Sixteen extensometers were installed and had been used for monitoring, but the monitoring and maintenance have not been implemented from 2011. Two of sixteen extensometers, three of seven tiltmeters and two of ten groundwater piezometers are functional.[2]

2.5 Social Survey

2.5.1 Basic Information Survey

This survey was implemented to collect the basic information for the review of the PPG, IEC (Information Education Communication) activities (such as enhancement of awareness of the disaster mitigation and evacuation drill/exercises), the feasibility study and the pilot project. The data collection results are shown as below.

a. Land Use

Table 2.5.1 Land Use Changes as per Category in Mauritius during the Period 1986 to 2010[3]

Land use category	Area (ha)			Change [%]
	1986	2010	Difference	
Agriculture (sugar cane and other)	90,000	77,418	-12,582	-14
Abandoned sugar cane lands	n/a	1,468	1,468	n/a
Forest, shrub, and grazing land	65,400	68,946	3,546	5
Built-up area	25,000	28,070	3,070	12
Infrastructure (roads, footpaths)	3,465	7,879	4,414	127
Inland water resource system	2,610	2,719	109	4
Total	186,475	186,500		

b. Distribution of the Population

In Mauritius, all the towns starting from the capital city of Port Louis to the town of Curepipe, are situated along a corridor/main motorway. All these urban areas have many services and amenities ranging from government offices to libraries. The rest of the settlements consist of villages.

c. Distribution of Poverty

Among the 5 Municipal Wards with the lowest poverty rates in 2001/02, 4 remained in the same position in 2006/07. These are Wards 1 & 2 of Quatre Bornes, Ward 4 of Beau Bassin / Rose Hill and Ward 3 of Vacoas-Phoenix. However, Ward 1 of Vacoas-Phoenix which ranked 4th in 2001/02 (poverty rate of 2.6%) dropped to rank 18 in 2006/07 (poverty rate of 4.7%).

There were 48 Municipal Village Council Areas where poverty was not highly prevalent (with a rate below 5%) in 2001/02. In 2006/07 the number decreased to 20. In 2001/02 there were 4 Municipal Village Council Areas with high poverty rate (above 15%). In 2006/07, the number increased to 15.

d. Water Resources

Table 2.5.2 Water Utilization[4]

Purpose	Surface Water		Groundwater	Total
	River-run Off-takes	Storage		
Domestic, Industrial and Tourism	38	48	113	199
Industrial (private boreholes)	-	-	10	10
Agricultural	370	76	22	468

Hydropower	131	174	-	305
Overall Utilization	539	298	145	982

(Unit: million cubic meter per year)

2.5.2 Attitude Survey about Landslide Disasters

The attitude survey was implemented to collect the basic information for the review of the PPG and IEC (Information Education Communication) activities (such as enhancement of awareness of the disaster mitigation and evacuation drill/exercises). The following table shows the summary of the survey.

a. Summary of Simple Tabulation Results of All Respondents

Main points obtained by the simple tabulation are shown in the following table as a summary of simple tabulation results.

Table 2.5.3 Summary of Simple Tabulation Results of All Respondents (source: JET)

Item	Content
Basic Information	・ Impartial responses were obtained from whole Mauritius. ・ Impartial responses were obtained from each age and sex. ・ Length of residence: 30% were 11-30 years and 31-50 years ・ Land ownership of the residents: Over 85% of respondents own land and house
Awareness about landslide disaster and experience	・ Recognition of landslide: 70% of respondents knew of landslides ・ Method of information acquisition about landslides: main responses were TV, radio, newspaper, word of mouth
Recognition about the early warning system	・ About 60% of respondents do not know about the existing early warning system. ・ Needs of warning system: 97% of respondents need the warning system ・ Necessary information for warning system: Evacuation sites, Hazardous spot around your residence, Timing of evacuation, Evacuation route
Recognition about the development/building restrictions	・ 86% of respondents know the existing development/building restrictions ・ Method of information acquisition about restrictions: Word of mouth, TV, radio, newspaper ・ Recognition of development restriction in slope area: About 75% of respondents know the restrictions.
Establishment of the landslide caution zone	・ About 97％ of respondents agree to the establishment of the landslide caution zone
Hazard map	・ About 97% of respondents agree to publicity of hazard map
Restriction in the landslide caution zone	・ Needs of development/building restriction and advice for building by Local Authority: About 95％ of respondents agree to the restriction and regulation ・ Relocation from the caution zone to safe area: About 90% of respondents agree to the relocation. ・ Assistance for relocation by government: Main responses were financial assistance, to secure alternative land and to secure alternative house
Evacuation exercise	・ Evacuation action in landslide occurrence: Main responses were to report the situation to the Authority, evacuate voluntarily, evacuate with family/neighbors at recommendation of Authority

	・ About 90% of respondents are aware of participation to the evacuation drill/exercise

b. Comparison of Simple Tabulation Result of the 3 Pilot Sites (Chitrakoot, Quatre Soeurs, Vallée Pitot)

The following table shows the summary of simple tabulation results of questions about development restrictions and relocation.

The respondents at all pilot sites approve of the development restrictions and relocation. The three districts are positive regarding development restrictions and relocation, but different levels of positive awareness about the development restrictions and relocation are confirmed as shown in the following table.

Table 2.5.4 Comparison of awareness in the three pilot sites (source:JET)

	Development restrictions	Relocation
Chitrakoot	・ The majority have opinion of "Agree"	・ The majority have opinion of "Agree"/"Strongly agree" with or without assistance by government
QuatreSoeurs	・ The majority have opinion of "Strongly Agree"	・ The majority have opinion of "Strongly agree" with or without assistance by government
Vallée Pitot	・ Generally "Agree" ・ The residents have the lowest percentage of "Strongly Agree" of the three pilot sites	・ Generally "Agree" ・ 10-20% residents have opinion of "Disagree"/"Strongly Disagree" ・ The percentage of "Agree"/ "Strongly Agree" is increased by government assistance ・ The residents have the lowest percentage of "Strongly Agree" of the three pilot sites

2.6 Organizations and Systems

2.6.1 Organizational and Institutional Formation

The Government of Mauritius designates the responsibilities of the natural disaster management to the several ministries and organizations. In terms of landslide disaster management, seven ministries and 11 organizations share the roles and responsibilities according to the 'National Disasters Scheme 2014'.

a. Main Authorities of the Disaster Management

The Cyclone and Other Natural Disasters Committee, which is composed of 21 ministries, nine local authorities and 14 public-private organizations, had functioned as the main body of the general disaster management for over thirty years[5]. However, it was replaced by a National Disaster Risk Reduction and Management Council in October 2013. According to the National Disasters Scheme 2014, the National Disaster Risk Reduction and Management Council is responsible for coordination of all stakeholders in order to implement the disaster risk reduction policies and strategies, and to promote effective disaster risk management. Together with the National Disaster Risk Reduction and Management Council, a National Disaster Risk Reduction and Management Centre (NDRRMC) has been set up under the Prime Minister's Office (PMO) to develop a disaster risk reduction strategy and plan at all levels. While the NDRRMC is a permanent body, an Emergency Operations Command (EOC) will be activated under the NDRRMC when a serious disaster occurs. A Crisis Committee will also be operated depending on the magnitude and severity of the disaster and will supervise the disaster response operations, decide the disaster response measures and issue evacuation orders. In addition, Local Disaster Risk Reduction and Management Centres (LDRRMC) have been established to coordinate all disaster risk reduction and management activities in their respective areas as well as to conduct an annual simulation exercise for tsunami/high waves, torrential rain and landslides.

Table 2.6.1 Main Authorities of Disaster Management (source: JET)

Organization	Type and members	General missions for disaster management
National Disaster Risk Reduction and Management Council (Council)	➢ Permanent ➢ The Council consists of: - The Secretary to Cabinet and Head of the Civil Service - The Financial Secretary; - The Supervising Officer of the Prime Minister's Office; - The Commissioner of Police; - The Supervising Officer of the Ministry responsible for the subject of public utilities; - The Supervising Officer of the Ministry responsible for the subject of Environment; - The Supervising Officer of the Ministry responsible for the subject of local government; - The Supervising Officer of the Ministry responsible for the subject of public infrastructure; - The Supervising Officer of the Ministry responsible for the subject of social security; - The Supervising Officer of the Ministry responsible for the subject of social welfare centres; - The Island Chief Executive, Rodrigues; - The General Manager, Outer Islands Development Corporation; - The Chief Fire Officer, Mauritius Fire and Rescue Service; - The Director, Mauritius Meteorological Services; - A representative of the Mauritius Employers' Federation; - A representative of the Joint Economic Council; - A representative of the Mauritius Red Cross Society; and - 2 representatives from other non-governmental organisations, to be appointed by the Minister.	➢ Replacing the responsibilities of the CONDC in October 2013 ➢ The Council is responsible for coordinating the implementation of:- (1) The National Risk Reduction and Management Policy approved by the Minister. (2) The National Disaster Risk Reduction and Management Strategic Framework and Plan developed by the National Disaster Risk Reduction and Management Centre (NRDDMC); ➢ Promoting safety and resilience at all levels by utilizing knowledge, innovation and education; and ➢ Coordinating the implementation of the obligations of the State of Mauritius under disaster management treaties.
Prime Minister's Office (PMO)		
National Disaster Risk Reduction and Management Centre (NDRRMC)	➢ Permanent	➢ Planning, organizing, coordinating and monitoring of disaster risk reduction and management activities at all levels ➢ Developing a disaster risk reduction and management strategy
Emergency Operation Command (EOC	➢ Occasional ➢ The EOC consists of the representatives from the following organisations: - Ministries/Departments; - Other emergency services; - NGOs - Private sector companies	➢ Being responsible for coordination during the preparedness, response and recovery phases of any disaster;
Crisis Committee	➢ Occasional (depending on the magnitude and severity of a disaster) ➢ The Crisis Committee consists of:	➢ Supervising the organisations which undertake disaster response

		- The Secretary to Cabinet and Head of the Civil Service, who shall be the chairperson; - The Commissioner of Police - The Director-General of the NDRRMC; and - Such other person as the chairperson of the Crisis Committee may determine.	operations; ➢ Taking appropriate measures in order to provide effective relief assistance; and ➢ Issuing evacuation order.
	Government Information Service (GIS)	➢ Permanent	➢ Being a communications hub of the Government; ➢ Disseminating accurate information in a timely manner, with a view to stimulate public support; ➢ Providing information to the government in order to facilitate decision making; and ➢ Acting as the interface between the government and the local/international media.
Local Disaster Risk Reduction and Management Committee (LDRRMC)		➢ Permanent ➢ The LDRRMC consists of: - The Lord Mayor of a Municipal City Council, Mayor of a Municipal Town Council or Chairperson of a District Council; - A representative of the Ministry responsible for the subject of public infrastructure; - A representative of the Ministry responsible for the subject of social security; - A representative of the Ministry responsible for the subject of environment and sustainable development; - A representative of the Ministry responsible for the subject of education; - A representative of the Ministry responsible for the subject of local government; - A representative of the Ministry responsible for the subject of social welfare centres; - A representative of the Mauritius Meteorological Services; - A representative of the Mauritius Police Force; - A representative of the Mauritius Fire and Rescue Service; - The Chief Executive of the Municipal City Council, Municipal Town Council or District Council; - The assistant Chief Executive of the Village Council; - A representative of the Central Electricity Board; - A representative of the Central Water Authority; - A representative of the Road Development Authority; - A representative of the Wastewater Management Authority; - A representative of the Water Resources Unit of the Ministry responsible for the subject of public utilities; - A representative of the Mauritius Red Cross Society.	➢ Coordinating all disaster risk reduction and management activities within their respective areas of jurisdiction; ➢ Conducting an annual simulation exercise for tsunami/high waves, torrential rain and landslide in their area of jurisdiction;

Reference: Prime Minister's Office (2014) 'National Disasters Scheme 2014'.

b. Organizations of Landslide Disaster Management[5]

The task of landslide monitoring was previously undertaken by the National Development Unit (NDU). It has been transferred to the Landslide Management Unit (LMU) which was established in the Civil Engineering Section in the Ministry of Public Infrastructure (MPI) in September 2009.

In line with the LMU, the table below shows the other main organizations which are responsible for landslide disaster management.

Table 2.6.2 Main Ministries and Organizations in charge of Landslide Disaster Management (source: JET)

Organization	Organizational type	General missions relating to landslide disaster management
Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping (MPI)	permanent	➢ National Development Unit (NDU) - Conducting site survey - Responsible for large scale river disasters ➢ Landslide Management Unit (LMU) - Enhancing capacity of landslide monitoring - Conducting site survey - Responsible for large scale landslide disasters ➢ Road Development Authority (RDA) - Conducting site survey - Responsible for large scale disasters on the road
National Disaster Risk Reduction and Management Centre NDRRMC)	permanent	➢ Gathering information relating to landslide disasters ➢ Coordinating all related stakeholders when landslide disaster occurs ➢ Issuing national disaster scheme
Police	permanent	➢ Provides warning to all inhabitants based on information from NDRRMC ➢ Supporting evacuation of inhabitants
Mauritius Meteorological Service (MMS)	permanent	➢ Providing rainfall data
Local Authorities	permanent	➢ Conducting site survey with MPI/LMU, MPI/NDU and MPI/RDA ➢ monitoring
Ministry of Housing and Land (MHL)	permanent	➢ Updating the Planning Policy Guidance (PPG)
Ministry of Health and Quality of Life (MHQL)	permanent	➢ Preparing medical and para-medical staff, special ward and ambulances
Ministry of Social Security, National Solidarity and Reform Institutions	permanent	➢ Providing emergency shelters
Ministry of Gender Equality, Child Development and Family Welfare	permanent	➢ Providing emergency shelters
Ministry of Education and Human Resources	permanent	➢ Closing all educational institutions in the affected areas
Ministry of Information and Communication Technology	permanent	➢ Establishing the effective ways to disseminate information to the public with the collaboration of Mauritius Telecom and other mobile operators
Government Information Service (GIS)	permanent	➢ Preparing illustrated posters and film strips to inform the dangers of landslide to the public
Mauritius Fire and Rescue Service	permanent	➢ Assisting evacuation if requested by the NDRRMC

Central Water Authority (CWA)	permanent	➢ Closing the valves on the pipelines in the landslide affected areas ➢ Supplying water to the emergency shelters ➢ Reopening the valves in the reconstruction phase
Central Electricity Board	permanent	➢ Cutting off the power supply in the landslide affected areas ➢ Resupplying electricity in the reconstruction phase
Mauritius Broadcasting Corporation (MBC)	permanent	➢ Broadcasting the warning in emergency situations
Mauritius Red Cross	Permanent	➢ Assisting evacuation if requested by the NDRRMC
St. John Ambulance	Permanent	➢ Assisting evacuation if requested by the NDRRMC

Reference: Prime Minister's Office (2014) 'National Disasters Scheme 2014'

2.7 Economic Survey

2.7.1 National Economic Indicators

The Gross Domestic Product (GDP), GDP per capita and GDP growth in Mauritius are summarized in the following table.

Table 2.7.1 GDP, GDP Per Capita and GDP Growth[6]

Item	2010	2011	2012	2013
GDP (current US$)	9,718,331,363	11,252,405,860	11,442,063,228	11,938,403,909
GDP per capita (current US$)	7,587	8,750	8,862	9,210
GDP growth (annual %)	4.1	3.9	3.2	3.2

2.7.2 National Economic Policies in Mauritius

Since 2010, the Government of Mauritius embarked on a second generation reform programme to continue improving the country's competitiveness as it transits to more diversified export markets, and ensures the inclusive growth for the entire population. The key elements of this reform are the improvement of (i) delivery of public services, including the civil service and public enterprises; (ii) infrastructure development, to overcome critical bottlenecks, particularly on transportation; (iii) skills enhanced through the improved productivity; (iv) social protection to provide opportunities for vulnerable population; and (v) further liberalization of non-tariff measures to improve trade competitiveness.

2.7.3 Fiscal policy for 2014

The Government of Mauritius sets the economic and social policies for Budget 2014 in order to achieve its goal of pursuing economic prosperity as well as social well-being.

a.1 Policies to enhance further investment and economic growth

The Government of Mauritius aims at strengthening the following in order to enhance further investment and economic growth.

- Stabilization of macro economy and promotion of economic development.
- Public investment: Investing in infrastructure of airports and seaports which enables to increase the movement of goods, services and people, and widen the economic activities.
- Supporting the traditional economic sectors and developing the new economic architecture: Together with continuous support for the traditional sectors of tourism, financial services and agro industry, new economic pillars such as ocean and renewable energy are enhanced.

- Supporting the Small and Medium Enterprises (SMEs): The Government provides the favorable measures including introduction of SMS financial schemes and loans to SMEs without guarantee.

- Human resource development: As human capital is recognised as a high-impact accelerator to economic growth and social well-being, 14.8 billion Mauritius rupees are allocated to the education sector to support pre-primary schools, primary schools, secondary and tertiary education, and lifelong learning.

- Improvement of working environment: The Government provides the comfortable working environment with consideration of wages, safety and health of the domestic and foreign workers.

- Enhancement of public sector: The Government of Mauritius aims at improving accountability and performance management of the public institutions in order to seek the most effective and efficient manners to deliver public services to the citizens.

a.2 Policies to further enhance modern, inclusive and caring society

The policies focusing on social security in 2014 are as follows:

- Modernizing health care system: The Government of Mauritius provides 9.2 billion Mauritius rupees for the public health care in 2014 which will be used for training and recruiting health care personnel, reducing two major killer diseases of diabetes and cancer, and building the hospitals.

- Natural disaster risk reduction: Based on the fact that the greater impact of natural disasters have occurred recently, the Government allocates budget for developing institutions such as a fully staffed National Risk Reduction and Management Centre, providing IT based early warning and emergency alert system, funding for emergency work and recruiting human resources.

- Consolidating the social safety nets: The Government of Mauritius strengthens the social safety nets to support the vulnerable people, for example, increasing pensions for elderly people as well as social and benefits for children, and providing budget for vulnerable families living below the Poverty Intervention Line, people with disabilities and women at risk including domestic violence.

- Promoting sports and culture: sports and cultural facilities are constructed and upgraded, and musical instruments are provided.

- Improvement of living conditions: The Government provides budget for housing programmes for improving living conditions, changes the conditions on loans, and provides social housing.

- Improvement of public services: As government’s rapid and efficient services for the public are required, the Government allocates 200 million rupees for improving the procedures with maximum use of technology.

- Increase of consumption: The Government of Mauritius stimulates the economy through increasing consumers’ purchasing power with the improvement of their earning

capacities, creation of higher productivity jobs and VAT refund for certain products.

- Maximizing the development potential of Rodrigues and Agalega: Investment on tourism and social economic development are enhanced.

2.7.4 Fiscal Policy of the Ministry of Public Infrastructure (MPI) 2014-2016

Table 2.7.2 Budget for the MPI[7]

Code	Programmes and Sub Programmes	2014 estimates	2015 planned	2016 planned
321	**Policy and Strategy Development for Public Infrastructure ,Land Transport and Maritime Services**	**146,790,000**	**149,090,000**	**151,875,000**
322	**Construction and Maintenance of Government Buildings and Other Assets**	**561,694,000**	**529,310,000**	**529,277,000**
32202	Design and supervision of the construction of Building and related Infrastructure	156,616,000	165,641,000	168,991,000
32203	Maintenance, Repairs and Rehabilitation of Buildings and Other Assets.	300,848,000	254,259,000	248,945,000
32204	Design, Construction and Maintenance of Electrical Systems in Public Buildings (ESD)	109,410,000	104,230,000	111,341,000
323	**Construction and Maintenance of Roads and Bridges**	**912,000,000**	**1,197,200,000**	**1,372,400,000**
32301	Construction and Rehabilitation of Roads and Bridges	-	-	-
32302	Maintenance of Roads and Bridges	-	-	-
324	**Land Transport Management**	**1,464,989,000**	**1,404,934,000**	**1,413,838,000**
32401	Road Transport Management	1,258569,000	1,257,364,000	1,250,730,000
32402	Traffic Management and Road Safety	207,420,000	147,570,000	153,108,000
325	**Maritime Safety and Development**	**91,376,000**	**72,681,000**	**71,426,000**
404	**Community-Based Infrastructure and Public Empowerment**	**441,702,000**	**341,594,000**	**334,257,000**
405	**Land Drainage and Watershed Management**	**430,217,000**	**317,001,000**	**242,213,000**
	Total	**4,049,768,000**	**4,011,810,000**	**4,115,286,000**

2.7.5 Budget for LMU

The annual budget for the LMU from 2015 to 2017 is shown in the following table.

Table 2.7.3 budget for the LMU from 2015 to 2017 (source: JET)

Item	Classification of Disaster	2015	2016	2017
Vat component for Countermeasure Construction Works				
Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
Consultancy Services for Countermeasure Construction Works				
Chitrakoot (Block A) - Section 2	landslide	400,000		
Vallee Pitot (near Eidgah)	landslide	450,000		
Morcellement Hermitage, Coromandel	Slope failure	250,000		
L'Eau Bouillie	Damage of embankment	250,000		
Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000		
Pailles Soreze region	Slope failure	500,000		
Riviere des Anguilles, near the bridge	Stream erosion	450,000		
Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	landslide	250,000		
Piper Morcellement Piat	Stream erosion	150,000		
Temple Road, Creve Coeur	Damage of wall	100,000		
Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
Congomah Village Council (Leekraj)	Damage of wall	100,000		
Congomah Village Council (Frederick)	Damage of wall	100,000		
Congomah Village Council (Blackburn Lanes)	Damage of embankment	100,000		
Les Mariannes Community Centre (Road area)	Slope failure	100,000		
Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
Le Pouce Street	Stream erosion	100,000		
Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
Pouce Stream	Stream erosion	300,000		
Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
Trou-Aux-Cerfs	Slope failure	100,000		
River Bank at Cite L'Oiseau	Stream erosion	100,000		
Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
Montee S, GRNW	Stream erosion	100,000		
Chitrakoot (Block B)	Landslide		400,000	
Construction on countermeasures				
Chitrakoot (Block A) - Section 2	Landslide	8,000,000		

Vallee Pitot (near Eidgah	landslide	9,000,000		
Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
Chitrakoot (Block B)	Landslide		6,000,000	
L'Eau Bouillie	Damage of embankment		5,000,000	
Pailles: (i) access road to Les Guibies	Slope failure		7,000,000	
Pailles: (iii) Soreze region	Slope failure		3,000,000	
Riviere des Anguilles, near the bridge	Stream erosion		9,000,000	
Piper Morcellement Piat	Stream erosion		3,000,000	
Temple Road, Creve Coeur	Damage of wall			Will be decided based on the detail survey
Remote Monitoring System				
Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
Consultancy Services for Investigation				
Old Moka Road, Camp Chapelon	Landslide	575,000		
Candos Hill, LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	125,000		
Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000
Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
Overtime Work for LMU		1,200,000	1,200,000	1,200,000
Maintenance and Repairs of Equipments		1,000,000	1,000,000	1,000,000
	TOTAL	**55,650,000**	**40,100,000**	**44,700,000**

Reference: interview survey with MPI/LMU

Reference for Chapter 2

[1] Ministry of Public Infrastructure Land Transport and Shipping (2011): Geotechnical Report for Suspected Landslide at Quatre Soeurs
[2] Dr. A. Chan Chim Yuk, Faculty of Engineering, University of Mauritius (2006): Monitoring of Geotechnical Works at the Site of the La Butte Landslide
[3] 2010 Land use map of Mauritius, 2010, Mauritius Sugar Industry Research Institute
[4] V. Proag, Water resources management in Mauritius, 2006, European Water 15/16
[5] Prime Minister's Office (2014) 'National Disasters Scheme 2014'
[6] World Bank (2014) 'GDP' <http://data.worldbank.org/indicator>.
[7] Ministry of Finance and Economic Development (2014) 'Budget Speech 2014: budget for MPI', <http://mof.gov.mu/English/Documents/Budget2014/PBB2014/VPMMPI.pdf>.

Chapter 3

Landslide Management Plan 1
(Survey and Results)

3 Landslide Management (Survey and Results)

3.1 Landslide Hazard Area

The high priority landslide hazard areas chosen are: Chitrakoot, Quatre Soeurs, Vallee Pitot

Table 3.1.1 Results of Landslide Hazard Area Selection (source: JET)

Area name	Selection criteria			Result	Summary
	Score of landslide hazard evaluation	Request from MPI	Landslide size		
Chitrakoot, Vallee des Pretres	6	Request	Large scale (L=1500 m, W=700m)	○	**Landslide Hazard Area** Active large-scale landslide (L=1,500m, W=700m). Because more than 10 houses have been damaged, immediate measures are expected. MPI has requested an investigation and measures.
Vallee Pitot (near Eidgah)	6	No-request	Small scale (L=35m, W=20m)	○	**Landslide Hazard Area** Active small-scale landslide (L=35m, W=20m). Because three houses have been damaged and were reported in a newspaper, immediate measures are expected. This is a typical example of a landslide that is affecting urban development.
Mgr. Leen Street and vicinity, La Butte	5	No-request	Middle scale (L=350m, W=600m)		**Excluded** The countermeasure was done with the support of Japan. Because it is now quite stable, the urgency of measures is low.
Old Moka Road, Camp Chapelon	3	No-request	Middle scale (L=200m, W=100m)		**Excluded** Deformation by landslide was confirmed but the movement is slower than in Chitrakoot and Quatre Soeurs and is not affecting surrounding houses. Further observation is necessary although the urgency of measures is low.
Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	6	Request	Middle scale (L=350m ,W=400m)	○	**Landslide Hazard Area** Active middle-scale landslide (L=350m,W=400m), Because several houses have been damaged, immediate measures are expected. MPI has requested an investigation and measures.
Candos Hill at Lallbahadoor Shastri and Mahatma Gandhi Avenues	3	No-request	Small scale (L=40m, W=35m)		**Excluded** Small scale. There are no houses that need protecting within the landslide area. Further observation is necessary, although the urgency of measures is low.

3.2 Topographic Survey

In order to conduct landslide investigation and analysis, small scale plan maps and cross-section-surveying data are needed. In the main investigation, cross-section surveying and creation of plan maps were performed in (approximately) the following three areas.

Table 3.2.1 Table of Quantities of Survey Areas (source: JET)

No.	Name	Plan map (Area)	Cross section Profile
1	Chitrakoot	1.8km^2 (1,800m X 1000m)	Cross section profile of three directions.
2	Quatre Soeurs	0.16km^2 (400m X 400m)	Cross section profile of one direction.
3	Vallee Pitot	0.005km^2 (70m X 70m)	Cross section profile of one direction.

3.3 Geological Survey

3.3.1 Geology of the Landslide Area

a. Chitrakoot

Chitrakoot district is situated on a low slope at the foot of the steep bedrock. The bedrock is mainly composed of basaltic lava and also other volcanic products, while it develops joints parallel to the lower slope. Furthermore, plastic to liquid state of soils are found at the foot of the lower slope where multiple springs are observed.

b. Quatre Soeurs

According to the Geological Map of Mauritius, the area at the foot of the mountain are located on superficial colluvium constituted mainly of pebbles and gravels that result from the dismantling of the upper slope old basaltic lavas of the Beau Champ Mountain. The ancient formations of the Beau Champ Mountains are marked by high slopes (sloping at 48°towards the sea on the site) and relieves generated from the presence of dykes or intrusive plugs which have been cleared and shaped by weathering and erosion. The gradient of the hills is flatter on the seaward side, while on the inland side there are steep cliffs.

3.3.2 Laboratory Test

Laboratory soil tests will be conducted when the ground investigation is conducted if required. There are basically two major laboratory soil tests for determining stability of landslide, namely: 1) mechanical tests, and 2) physical tests. While mechanical testing is used to understand the strength property of slip surface which affects the result of stability evaluation, physical testing is used to review the test results and grasp the general characteristics of the ground.

a. Results of past Laboratory Soil Tests

a.1 Chitrakoot

Table 3.3.1 Results of Physical Test (source: JET)

Drilling No.	Depth (m)	Geology	Specific gravity (g/cm^3)	Moisture content (%)	Atterberg Limits (%)		Bulk Unit Wt (kN/m^3)
					LL	PL	
BPP5	2.00～2.50	Colluvium	2.790	42.0	89.0	34.0	17.84
	7.00～8.00	Highly weathered basalt	2.780	38.0	65.0	35.0	18.20
BPP6	7.25～7.80	Highly weathered basalt	2.810	52.0	58.0	39.0	16.69
BPP8	4.50～5.00	Colluvium	2.780	50.0	61.0	31.0	17.37
	8.00～8.50	Highly weathered basalt		31.0	49.0	29.0	18.91
	12.00～12.75	Highly weathered basalt	2.670	52.0	54.0	30.0	17.22
BPP9	2.60～2.93	Highly weathered basalt	2.640	42.6	74.0	30.0	16.61
	4.10～4.54	Weathered basalt	2.780	38.0	60.0	32.0	17.48
	7.30～7.85	Highly weathered basalt	2.750	26.0	56.0	35.0	17.76
BPP13	1.53～2.20	Colluvium	2.780	38.0	60.0	32.0	18.88
	3.30～3.66	Colluvium	2.780	36.0	71.0	31.0	18.81
	5.50～6.00	Highly weathered basalt		34.0			
BPP14	4.85～5.40	Colluvium		42.0	72.0	44.0	
BPP15	7.50～8.00	Colluvium		35.0	55..0	32.0	
	9.00～9.50	Colluvium		27.0	59.0	30.0	
BPP16	3.15～3.65	Wet plastic clay		40.0	64.0	33.0	17.98
	5.00～5.50	Wet plastic clay		33.0	57.0	25.0	18.83
	7.00～7.50	Weathered tuff		51.0			
BPP18	3.00～3.50	Colluvium		35.0	57.0	34.0	
	5.50～6.00	Weathered tuff		34.0	77.0	46.0	17.88

Table 3.3.2 Results of Physical Test (source: JET)

Drilling No.	Depth (m)	Geology	Specific gravity (g/cm^3)	Moisture content (%)	Atterberg Limits(%)		Bulk Unit Wt (kN/m^3)
					LL	PL	
BPI2	8.00～8.40	Colluvium	2.820	30.0	75.0	34.0	
	12.05～12.70	Highly weathered basalt		29.0	67.0	38.0	
BPI4	5.40～6.00	Highly weathered basalt		54.0	66.0	34.0	17.06
BPI9	3.10～3.65	Colluvium	2.800	41.0	66.0	39.0	
	6.00～6.50	Weathered tuff		44.0	73.0	37.0	
	8.40～9.00	Highly weathered basalt		47.0	73.0	37.0	
	10.00～10.56	Weathered tuff		55.0	73.0	37.0	
BPI10	3.00～3.50	Colluvium		29.0	63.0	35.0	
	4.50～5.00	Highly weathered basalt		45.0	70.0	45.0	
	5.50～6.00	Highly weathered basalt		49.0	75.0	50.0	
	6.50～7.00	Highly weathered basalt		39.0	75.0	48.0	
	8.00～8.40	Weathered tuff	2.780	36.0	82.0	46.0	17.33
	9.00～9.50	Weathered tuff		38.0	65.0	46.0	
	10.00～10.50	Highly weathered basalt		27.0	58.0	38.0	

Table 3.3.3 Results of Shear Box Test (source: JET)

Drilling No.	Depth (m)	Geology	Moisture content (%)	Bulk.U. Wt (kN/m^3)	Shear strength parameters			
					Peak Values		Residual Values	
					C_1 (kN/m^2)	φ_1 (°)	C_{1r} (kN/m^2)	φ_{1r} (°)
BPI-4	5.40～6.00	Clay and silt	39.6	17.06	11	22	14	21
BPI-10	8.00～8.40	Weathered tuff	36.9	17.33	27	25	19.5	23
BPP-6	7.25～7.80	Highly weathered basalt	52.0	16.63	12	28		
BPP-8	4.50～5.00	Colluvium	50.0	17.24	28.5	29		
BPP-8	12.00～12.75	Highly weathered basalt	52.0	17.08	26	30		

Table 3.3.4 Results of Triaxial Compression (source: JET)

Drilling No.	Depth (m)	Geology	Moisture content (%)		Before consolidation		Shear strength parameters	
			Before	After	Bulk.U. Wt (kN/m^3)	Dry.U. Wt (kN/m^3)	C_1 (kN/m^2)	φ_1 (°)
BPP5	8.35～8.85	Highly weathered basalt	38.3	39.6	19.2	13.9	38.7	30.5
BPP8	11.00～11.50	Highly weathered basalt	55.2	53.4	17.8	11.5	94.0	14.3

a.2 Quatre Soeurs

Table 3.3.5 Results of Physical Test (source: JET)

Drilling No.	Depth (m)	Geology	Natural Moisture content (%)	Atterberg Limits			Bulk Unit Wt (kN/m^3)
				LL (%)	PL (%)	PI	
BH1	1.00～1.50	CHW Breccia	42.0	76.0	38.0	17	
	3.00～3.50	CHW Breccia	44.0	68.0	42.0	16	
BH3	1.00～1.50	Colluvium	59.0	90.0	37.0		
	2.50～3.00	Colluvium	63.0	95.0	33.0		
BH4	3.00～3.50	Colluvium	38.0	68.0	36.0		
	4.00～4.50	CHW Breccia	43.0	65.0	31.0		
	12.56～15.00	Alluvium	16.0	79.0	40.0		
BH5	3.00～3.50	Colluvium	59.2				16.24
	5.00～5.50	Colluvium	68.7				16.02
	5.50～6.00	Colluvium	58.0	94.0	32.0		
BH6	2.50～3.00	Colluvium	42.0	72.0	28.0	18	
	4.50～5.00	Colluvium	56.0	102.0	33.0	21	16.88

Table 3.3.6 Results of Physical Test (source: JET)

Trial Pit	Depth (m)	Geology	Natural Moisture content (%)	Atterberg Limits			Linear Shrinkage
				LL (%)	PL (%)	PI	
Tp1	1.40	C/HWB	46.6	96.1	37.0	22.5	59.1
Tp3	2.00	HWB	38.4	62.5	33.1	16.4	29.4
Tp4	1.50	Clay	49.2	91.8	47.4	20.7	44.4
Tp5	3.00	Clay/Colluvium	37.2	69.3	34.3	19.6	35.0
Tp6	1.00～1.50	Clay/Colluvium	56.1	75.0	46.2	18.6	28.8
	1.50～1.80	Clay/Colluvium	24.8	102.4	64.5	23.2	37.9

Table 3.3.7 Results of Triaxial Compression (source: JET)

Drilling No.	Depth (m)	Geology	Moisture content (%)		Before consolidation		Shear strength parameters	
			Before	After	Bulk.U. Wt (kN/m^3)	Dry.U. Wt (kN/m^3)	C_1 (kN/m^2)	φ_1 (°)
BH5	3.0～3.5	Colluvium	50.2	49.7	18.7	12.5	0.4	1.4

b. Results of the Laboratory Soil Test

b.1 Chitrakoot

Table 3.3.8 Results of Physical Test(1) (source: JET)

Borehole	Depth (m)	Geology	Particle size distribution (%)				Sample Type
			Fines	Sand	Gravel	Cobbles	
BH-C1	3.00～3.45	Colluvia	43.0	15.0	42.0	0	STP20
BH-C2	4.80～5.25	Colluvia	52.7	10.3	37.0	0	U2
BH-C3	6.60～7.05	Colluvia	70.0	29.0	1.0	0	U2
BH-C4	6.35～6.80	Colluvia	65.0	10.0	25.0	0	SPT28
BH-C5	4.25～4.70	Colluvia	97.0	4.0	3.0	0	SPT56
BH-C6	5.30～5.75	Colluvia	77.6	18.9	3.5	0	SPT25

Table 3.3.9 Results of Physical Test(2) (source: JET)

Borehole	Depth (m)	Particle density (g/cm^3)	Moisture content (%)	Atterberg Limits			Bulk density (g/m^3)
				LL (%)	PL (%)	PI	
BH-C1	3.00～3.45	1.94	50.0				
BH-C2	4.80～5.25	2.98	51.2	78.0	42.9	35.1	1.80
BH-C3	6.60～7.05	2.57	43.8	73.0	45.1	27.9	1.60
BH-C4	6.35～6.80	2.98	61.8	89.5	45.0	44.5	
BH-C5	4.25～4.70	2.67	47.7	110.5	41.7	68.8	
BH-C6	5.30～5.75	2.10	41.3				

b.2 Quatre Soeurs

Table 3.3.10 Results of Physical Test (1) (source: JET)

Borehole	Depth (m)	Geology	Particle size distribution (%)				Sample Type
			Fines	Sand	Gravel	Cobbles	
BH-Q1	1.00～1.45	Colluvia	70.0	10.0	20.0	0	STP10
BH-Q2	9.00～9.40	Silty Clay	35.5	8.5	52.0	0	U2

Table 3.3.11 Results of Physical Test (2) (source: JET)

Borehole	Depth (m)	Particle density (g/cm^3)	Moisture content (%)	Atterberg Limits			Bulk density (g/m^3)
				LL (%)	PL (%)	PI	
BH-Q1	1.00～1.45	2.98	55.8	88.0	34.17	53.83	—
BH-Q2	9.00～9.40	2.83	105.6	86.5	35.0	51.5	1.58

c. Ring Shear Test Result by this Project

Table 3.3.12 Ring shear test result（source：JET）

Location of sample	Sample name	Residual cohesion Cr'（kPa）	Residual shearing resistance angle Φr'(°)
Chitrakoot	S-1	18.7	11.8
Quatre Soeurs	S-2	5.7	12.2
Vallee Pitot	S-3	3.5	6.4

3.3.3 Water Quality Analysis

The purpose of the water quality analysis is to identify the distribution of groundwater in the survey area and to define the groundwater system (streaklines) as part of the landslide survey.

Chitrakoot

- The amounts of major dissolved components in the groundwater were low at all sites. The component composition in the groundwater is about the same as that in surface water. The water temperature in the groundwater was high more than 23 ºC at all sites.

Quatre Soeurs

- The amounts of major dissolved components in the groundwater were low at these sites except for BH-4. The component composition in the groundwater is about the same as that in surface water. The water temperature in the groundwater was high more than 28 ºC at all sites. The water quality at BH-4 was high with sodium and chloride ions. It was indicated that the groundwater was contaminated with the sea water.

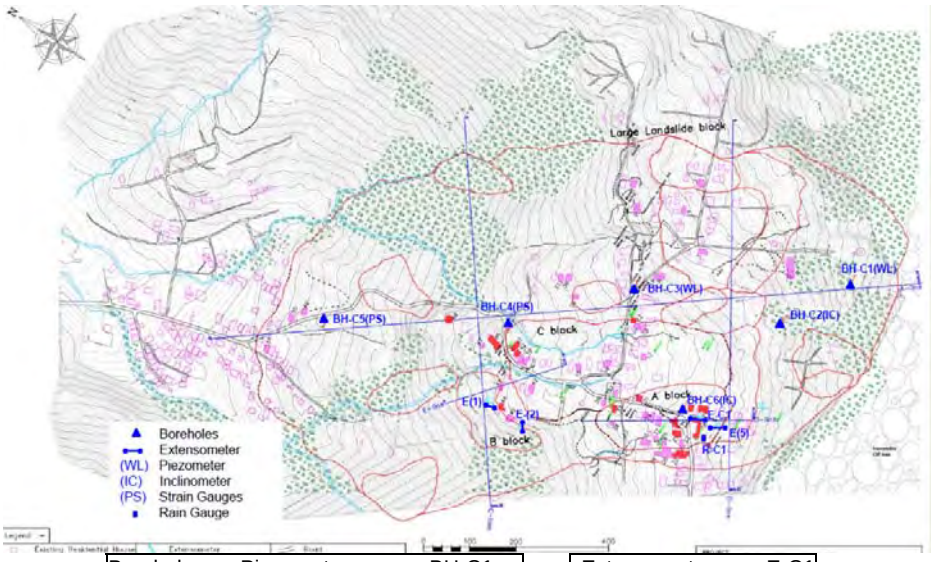
From these results, it was considered that the groundwater associated with the landslide action was the shallow groundwater and interlocked with rainfall.

3.4 Monitoring

3.4.1 Installation of Monitoring Devices

Table 3.4.1 Instruments for the Landslide Monitoring (source: JET)

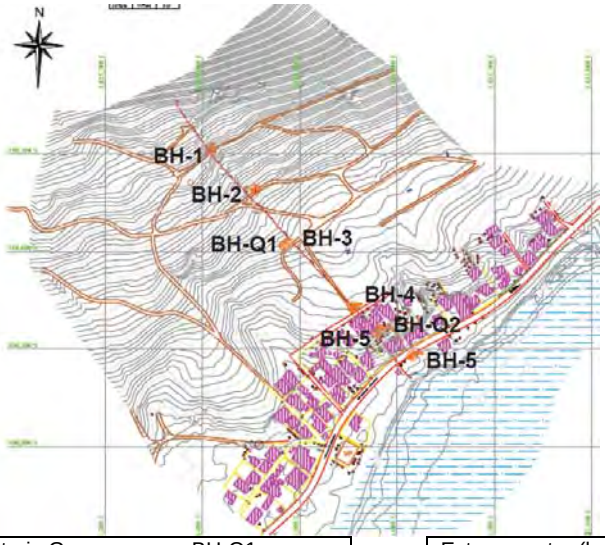
Instrument	Purpose	Sensor	Logger	Manufacturer	Location of installation
Extensometer	Displacement of the ground surface (distance between two points),	SLG-100	(Installed in the sensor, 1 hour interval)	Osashi Technos	Chitrakoot, Quatre Soeurs, Vallee Pitot
Laser distance meter	Displacement of the ground surface (distance between two points)	DIST D3aBT	(Manual operation, once a month)	Leica	Quatre Soeurs
Inclinometer	Displacement of the subsurface (lateral displacement from the deepest point)	KB-10HC	TC-32K (once a month)	Tokyo Sokki Kenkyujo	Chitrakoot
Strain gauge	Deformation of the earth (distortion in the ground)	SKF-6070	TCR-25 (once a month)	Tokyo Denki	Chitrakoot, Quatre Soeurs
Automatic Piezomete	Fluctuation of the groundwater level (variation of water pressure)	DS-1	WLG-01 (1 hour interval)	Osashi Technos	Chitrakoot, Quatre Soeurs
Water level meter	Groundwater level (distance between the surface and the ground water level)		(Manual Operation, once a month)		Quatre Soeurs
Rain gauge	Precipitation	RS-2	Net LG-201E (1 hour interval)	Osashi Technos	Chitrakoot, Quatre Soeurs



Boreholes		
	Piezometer	BH-C1
	Inclinometer	BH-C2
	Piezometer	BH-C3
	Strain Gauges	BH-C4
	Strain Gauges	BH-C5
	Inclinometer	BH-C6
	total	**6**

Extensometer	E-C1
Extensometer	E-1
Extensometer	E-2
Extensometer	E-5
total	**4**
Rain Gauge	R-C1
total	**1**

Figure 3.4.1 Plan of Instrument Installation – Chitrakoot (source: JET)

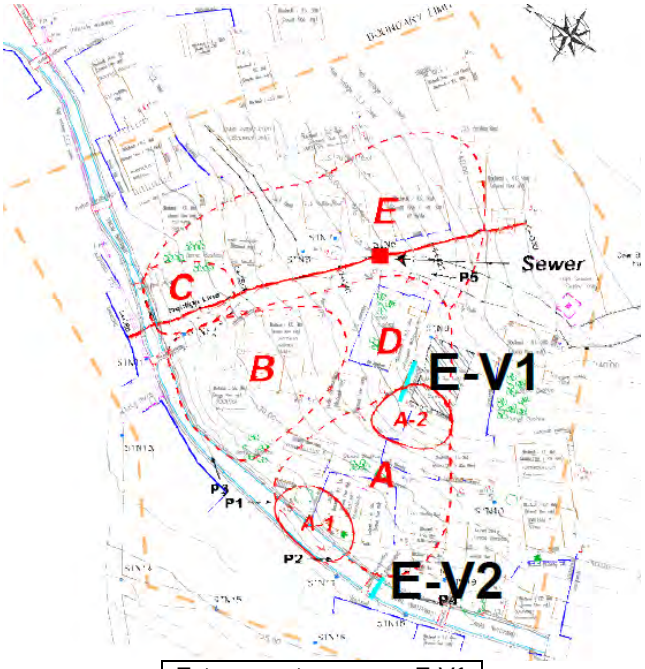


Boreholes	Strain Gauges	BH-Q1
	Strain Gauges	BH-Q2
	Piezometer	BH-5 (existing)
	Groundwater level	BH-2 (existing)
	Groundwater level	BH-3 (existing)
	Groundwater level	BH-4 (existing)
	total	**6**

Extensometer (laser)	E-Q1
Extensometer (laser)	E-Q2
Total	**2**
Rain Gauge	R-Q1
Total	**1**

- *One rain gauge is installed out of the map*

Figure 3.4.2 Plan of Instrument Installation – Quatre Soeurs (source: JET)



Extensometer	E-V1
Extensometer	E-V2
Total	**2**

Figure 3.4.3 Plan of instrument installation – Vallee Pitot (source: JET)

3.4.2 Monitoring Results

a. Chitrakoot

a.1 Rain gauge

During the monitoring period (26th February 2013 to 4th March 2015), much precipitation was recorded in rainy season (November to April). 450.0mm/month as the maximum monthly rainfall in the monitoring period was recorded in December 2014, and the minimum monthly rainfall in the monitoring period was 8.5mm/month recorded in September 2013. There were ten days when daily precipitation exceeded 50mm in the monitoring period.

There were three days when daily precipitation exceeded 100mm/day in the monitoring period, 30th March 2013, 21st March 2014 and 16th December 2014. On 16th December 2014, 133.0mm of rainfall within six hours and 77mm of maximum hourly precipitation were recorded. On 21st March 2014, 132.0mm/day and 50.0mm/hour were recorded. The daily precipitation on 20th March 2013 was 106.5mm, and total precipitation of 30th and 31st March was 152.5mm. The maximum hourly precipitation in 30th to 31st was 25.5mm.

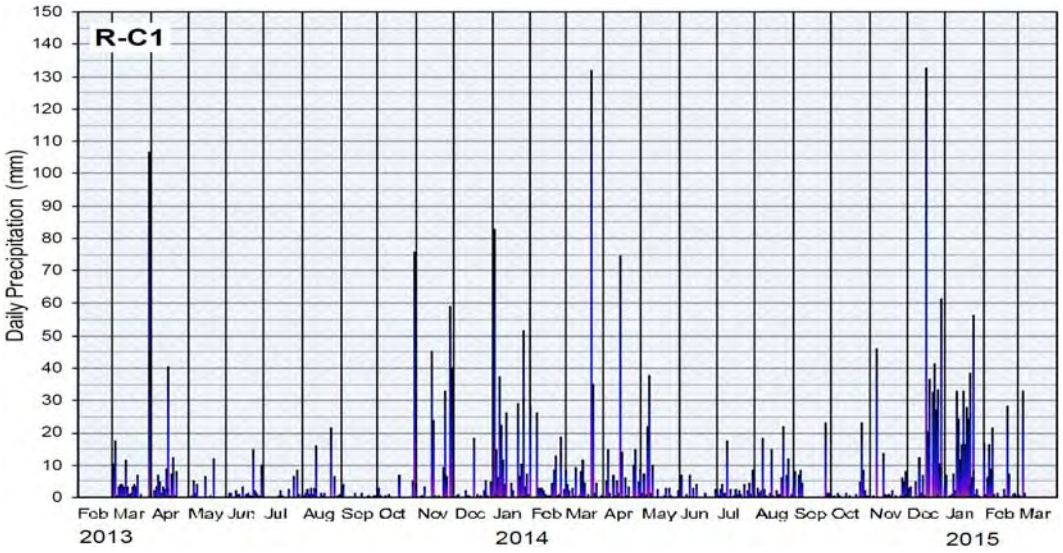


Figure 3.4.4 Result of Rain Gauge (source: JET)

Table 3.4.2 Monthly and Maximum Daily Precipitation and Maximum Hourly Precipitation (source: JET)

2013

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	-	-	244.5	115.0	35.0	47.5	23.5	65.5	8.5	97.0	233.5	41.0
Maximum daily precipitation	-	-	106.5	40.5	12.0	15.0	8.5	21.5	4.0	76.0	59.0	18.5
Maximum hourly precipitation	-	-	26.0	4.5	4.0	7.5	3.0	8.5	1.0	21.0	25.0	9.5

2014

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	422.5	115.0	234.5	175.5	95.0	26.0	69.0	102.0	57.0	46.5	88.5	450.0

Maximum daily precipitation	83.0	26.5	132.0	74.5	38.0	7.0	17.5	22.0	23.0	23.0	46.0	133.0
Maximum hourly precipitation	29.0	8.5	50.0	25.0	8.5	3.5	14.0	10.0	3.5	8.0	26.0	77.0

2015

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	367.0	116.0	-	-	-	-	-	-	-	-	-	-
Maximum daily precipitation	56.5	28.5	-	-	-	-	-	-	-	-	-	-
Maximum hourly precipitation	30.0	7.0	-	-	-	-	-	-	-	-	-	-

a.2 Extensometer

E(1) is installed at the foot of Chitrakoot landslide area. Compression displacement has continued. This may represent a shallow slide at the location.

Since no deformation on the ground and the house around the location can be found but only small deformation can be seen at the base of the protection cage, the extensometer shows surface creep.

E(2) is installed at the foot of Chitrakoot landslide area. The result shows small compression and small tension alternately.

Since no deformation on the ground can be found and the ground is almost level below the location of the extensometer, the extensometer does not show big landslide. The complicated movement may show two shallow ground movements which move separately. “A” may always move continuously and “B” may move with heavy rain.

E(5) is installed near Chitrakoot Government School in the head of the Chitrakoot landslide area. The result shows small displacement with heavy rain in February, March and April. After May, the displacement was slow. In January 2015, over 100mm of compression deformation was recorded. This was caused by human work during the data collection, not by landslide activities. In January 2015, about 20mm of tension deformation was recorded.

EC-1 is installed in the premises of Chitrakoot Government School. It shows 3mm tension displacement immediately after installation in February, however no deformation can be seen after March. In January 2015, about 15mm of tension are recorded.

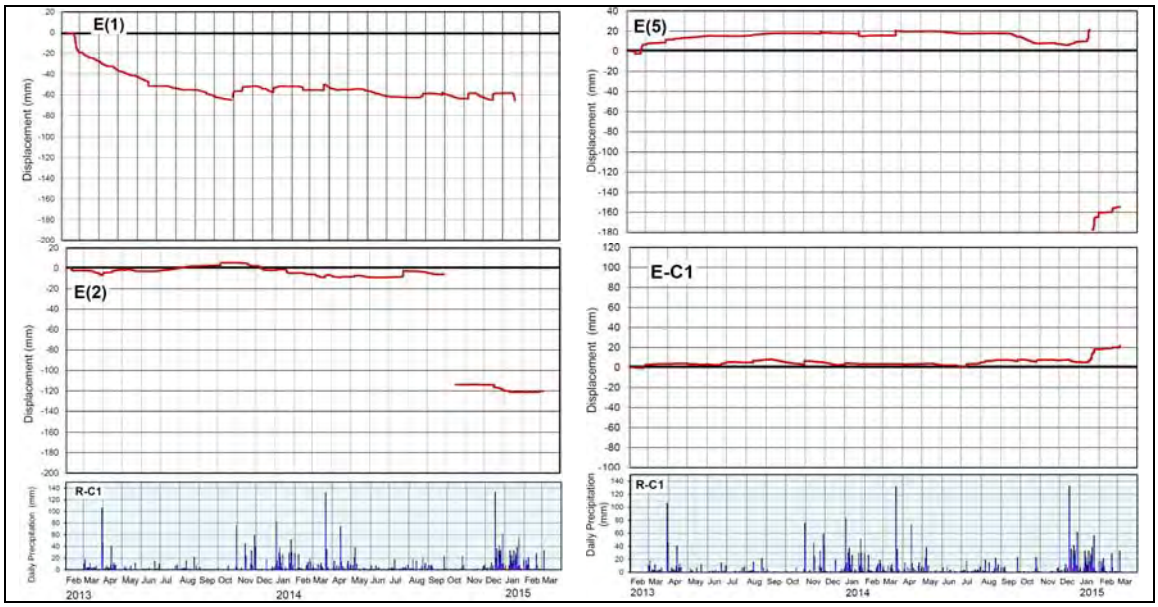


Figure 3.4.5 Results of extensometer (source: JET)

a.3 Inclinometer

BH-C2 is installed at the head of Chitrakoot landslide area. Some deviation can be seen below 13m on the inclinometer graph below. This may be caused by axial compressive stress. This axial compressive stress may show vertical stress in the ground. This phenomenon is often seen at the head of landslide where the vertical stress is distinguished. The graph variations (showing slope angle changes) may be large at the depths where grouting (sand fill) is not perfect. The slip surface of the landslide at BH-C2 may be at about 15m.

BH-C6 is installed near Chitrakoot Government School. The monitoring could be done only 2 times (January and February 2014), since the bend of the pipe at the depth of 6 m is in excess of permissive range for the sensor to pass through. This shows that the landslide with a 7m deep slip surface is very active.

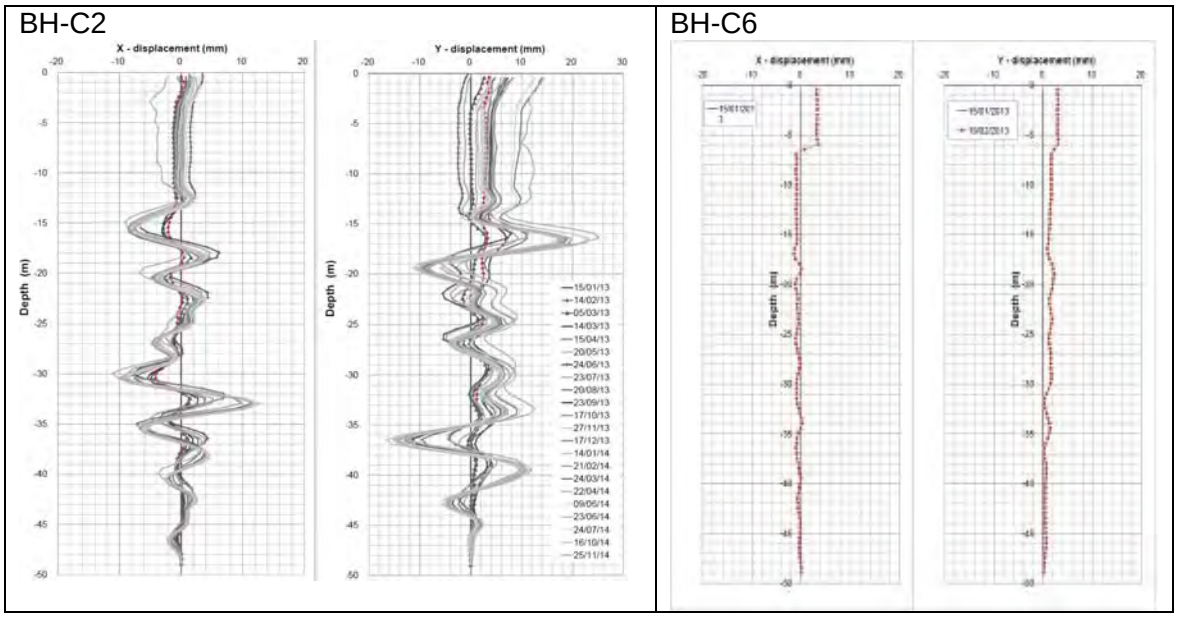


Figure 3.4.6 Results of Inclinometer (source: JET)

a.4 Strain gauges

BH-C4 is installed at left of center of Chitrakoot landslide area. Small deformations can be seen at 13m, 21m and above 6m deep. These small deformations may not be caused by landslide movement. It must be continued to be watched carefully.

BH-C5 is installed at the foot of Chitrakoot landslide area. There is nothing worthy of special mention in this monitoring.

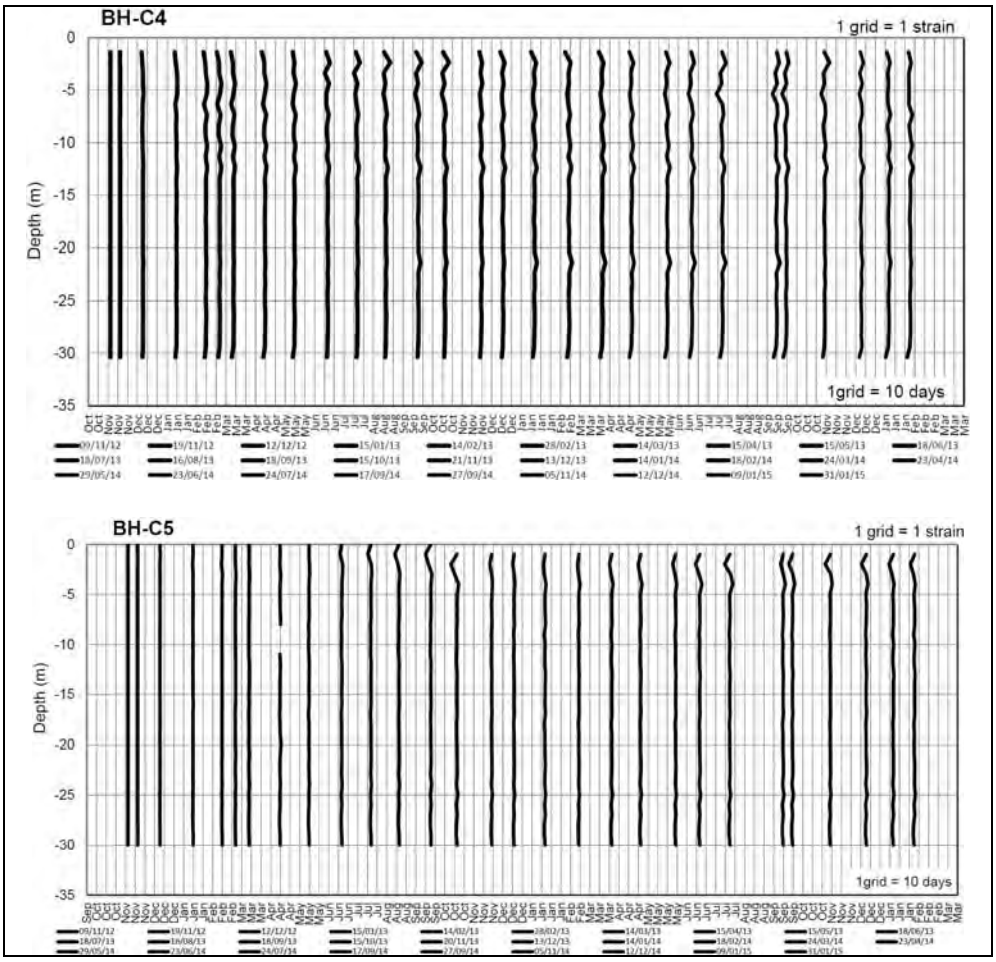


Figure 3.4.7 Results of Strain Gauges (source: JET)

a.5 Piezometer

Piezometers were installed at BH-C1 and BH-C3. Piezometer at BH-C3 which is the center of Chitrakoot landslide area was shifted to BPP(11) since over 40 m deep of groundwater level at BH-C3 cannot affect a landslide in Chitrakoot.

BH-C1 is located at the head of Chitrakoot landslide. The groundwater level at BH-C1shows a clear tendency to rise in January and to drop in June. This seasonal variation in the groundwater level is 2 month behind the rainy season which is around from November to April. This may be because of slow movement of the groundwater in low permeable ground in the area.

The data lost from August to November in 2013 is due to malfunction of the piezometer controller.

BH-(11) is located near Chitrakoot Government School. The groundwater level data were not obtained from the middle of February 2013 to February 2014 because of malfunction of the piezometer sensor which was soaked in the high level groundwater. In February 2013, the groundwater level at BH-(11) rose above the ground surface. After resumption of the monitoring in February 2014, the groundwater level was almost the same level as the ground surface until June 2014. The groundwater level was dropping gradually after June 2014 until November 2014. The groundwater at BH-(11) would have been under enough pressure to force it to the surface in rainy season, since the groundwater was seen gushing out from the mouth of the observation hole. The artesian pressure of the groundwater was not able to be confirmed by the piezometer since the water flows out from the mouth of the observation pipe. The groundwater level was probably higher than the ground surface between February to June 2014.

Similarly, there are some other boreholes of which the groundwater level is very high in rainy season in Chitrakoot landslide area.

The groundwater level at BH-C3 was confirmed at about 40m deep in November 2012.

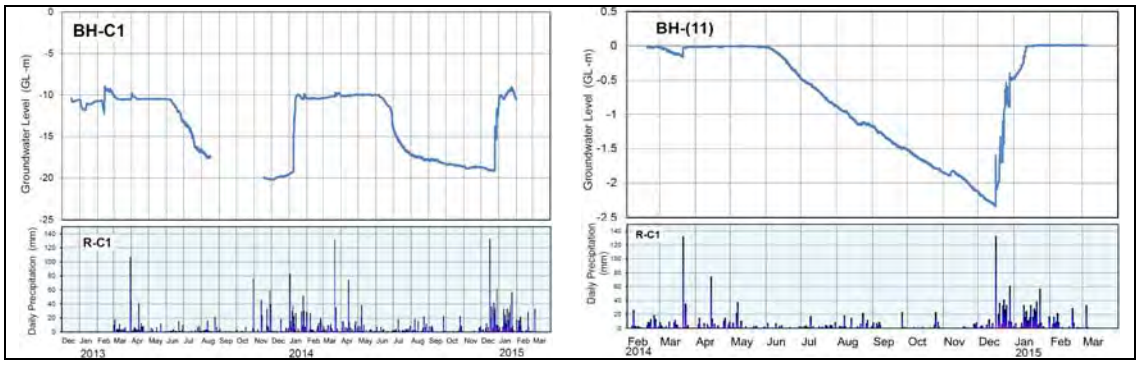


Figure 3.4.8 Results of Piezometer (source: JET)

b. Quatre Soeurs

b.1 Rain gauges

A rain gauge is installed at about 0.5km to the south of Quatre Soeurs landslide.

During the monitoring period (2nd April 2013 to 4th March 2015), much precipitation was recorded in rainy season (November to April). A maximum monthly rainfall of 392.0mm/month in the monitoring period was recorded in January 2015, and the minimum monthly rainfall in the monitoring period was 13.5mm/month recorded in May 2013.

There were seven days when the daily precipitation exceeded 50mm/day in the monitoring period. Daily precipitation exceeding 100mm/day was recorded on only 17th December 2014.

118.5mm of daily precipitation and 58.0mm of hourly precipitation were recorded on 17th December 2014.

98.0mm of daily precipitation was recorded on 21st March 2014, and total continuous

precipitation was 117.5mm including the precipitation on 22nd March. It was high intensity rainfall recoding 39.0mm of hourly precipitation.

94.5mm of daily precipitation were recorded on 14th November 2013. It is second heaviest precipitation in the monitoring period. The rainfall was started on 13th November, and total continuous precipitation was 121.5mm. However it was not so high intensity rainfall recoding an hourly precipitation of 19.0mm.

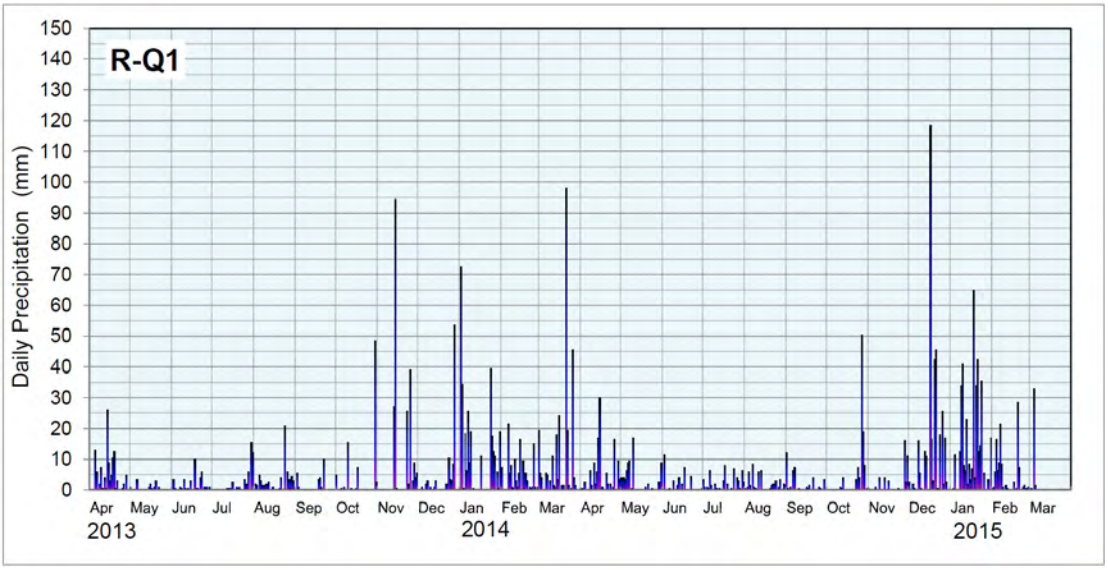


Figure 3.4.9 Result of Rain Gauge (source: JET)

Table 3.4.3 Monthly Precipitation, Maximum Daily Precipitation and Maximum Hourly Precipitation (source: JET)

2013

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	-	-	-	111.0	13.0	38.0	47.5	67.0	25.0	81.5	210.0	92.0
Maximum daily precipitation	-	-	-	26.0	3.5	10.0	15.5	21.0	10.0	48.5	94.5	53.5
Maximum hourly precipitation	-	-	-	7.5	1.5	5.5	6.0	6.0	6.5	12.0	19.0	23.0

2014

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	304.0	118.0	275.0	116.5	72.0	35.0	54.0	43.0	40.0	98.5	42.5	342.5
Maximum daily precipitation	72.5	21.5	98.0	30.0	17.0	11.0	8.0	8.5	12.0	50.5	16.0	118.5
Maximum hourly precipitation	18.0	4.5	39.0	8.0	9.0	5.0	4.5	4.5	5.0	37.0	10.0	58.0

2015

Month	1	2	3	4	5	6	7	8	9	10	11	12
Monthly precipitation	392.0	116.0	-	-	-	-	-	-	-	-	-	-
Maximum daily precipitation	65.0	28.5	-	-	-	-	-	-	-	-	-	-

Maximum hourly precipitation	12.0	7.0	-	-	-	-	-	-	-	-	-	-

b.2 Extensometer (laser distance meter)

Both E-Q1 and E-Q2 of which variations were within 10mm do not show remarkable movement. E-Q1 shows tendency of tension in winter and compression in summer. E-Q2 shows similar tendencies but behind E-Q1. These tendencies may be due to deformation of the ground or structures by the variation in temperature.

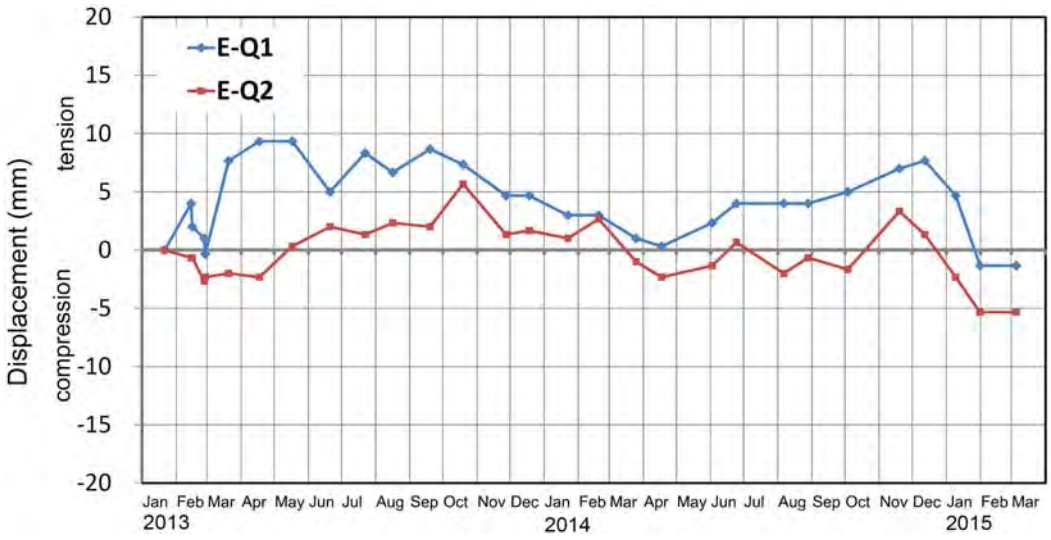
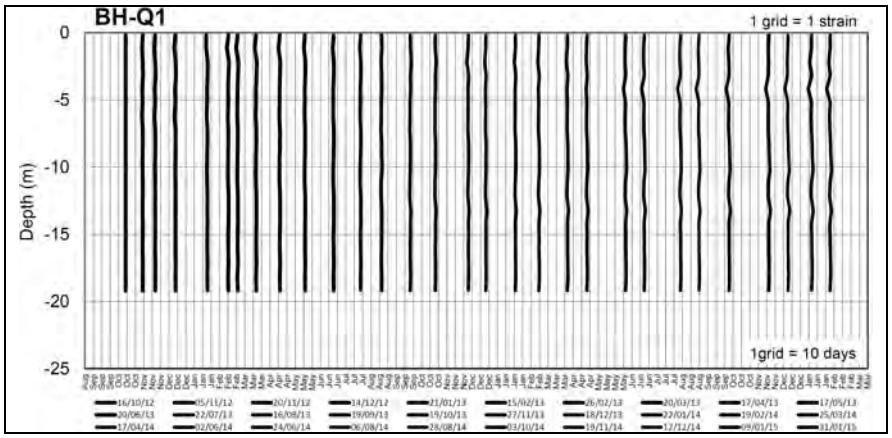


Figure 3.4.10 Result of Laser Distance Meter (source: JET)

b.3 Strain gauges

BH-Q1 is installed in upper landslide block (Block B). There is nothing worthy of special mention on this monitoring.

BH-Q2 is installed in upper landslide block (Block A). Small deformation can be seen at 2m, 7m and 11m deep. These deformations are not big enough to be determined to be due to landslide activities.



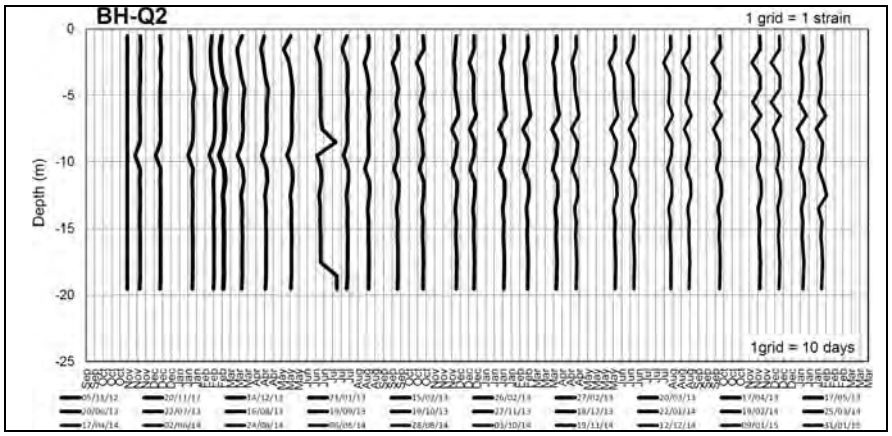


Figure 3.4.11 Results of Strain Gauges (source: JET)

b.4 Piezometers

Piezometer at BH-Q2 which is the center of Block A was shifted to BH5 since the groundwater level is almost equal to the sea level following the tide level and over 13 m deep of the groundwater level at BH-Q2 cannot affect the landslide.

8m deep BH5 which was drilled before the project is located beside BH-Q2 (3m away from BH-Q2). The groundwater level follows the amount of the precipitation. In a day with much precipitation, the groundwater level rises to 0.5m below the ground surface. The base level of the groundwater was around 3.5m deep in rainy season, around 4.0m deep in non-rainy season. The groundwater level recorded by the piezometer at BH-Q2 must be shallow groundwater flowing in shallow permeable layer.

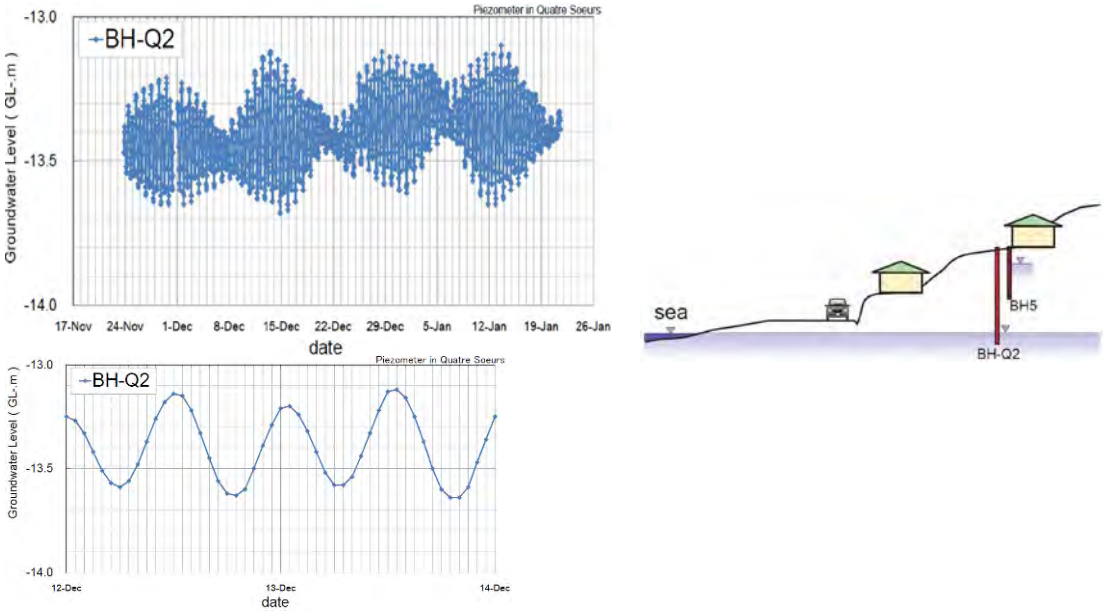


Figure 3.4.12 Groundwater at BH-Q2 (source: JET)

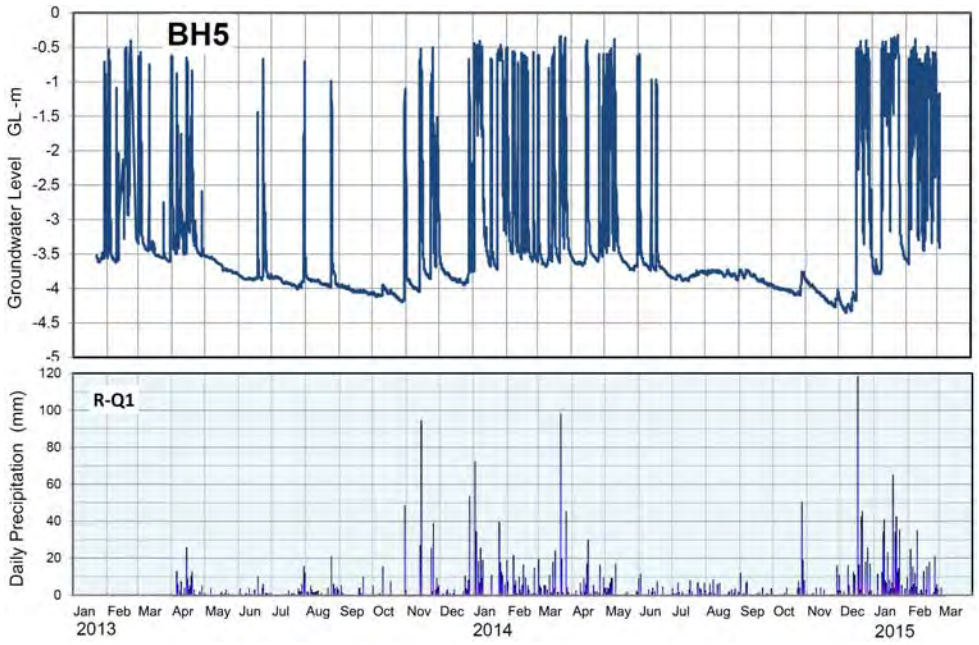


Figure 3.4.13 Results of Piezometer (source: JET)

b.5 Groundwater monitoring (manual operation)

The groundwater levels are stable at all boreholes except BH-Q1 and BH-3. The water in the boreholes except BH-Q1 and BH3 may be isolated from the groundwater because strainers in the boreholes might be choked with soil. The water level in the borehole of BH-Q1 which may follows actual groundwater level, rose to about 1m deep in February 2013 from 14m deep in dry season.

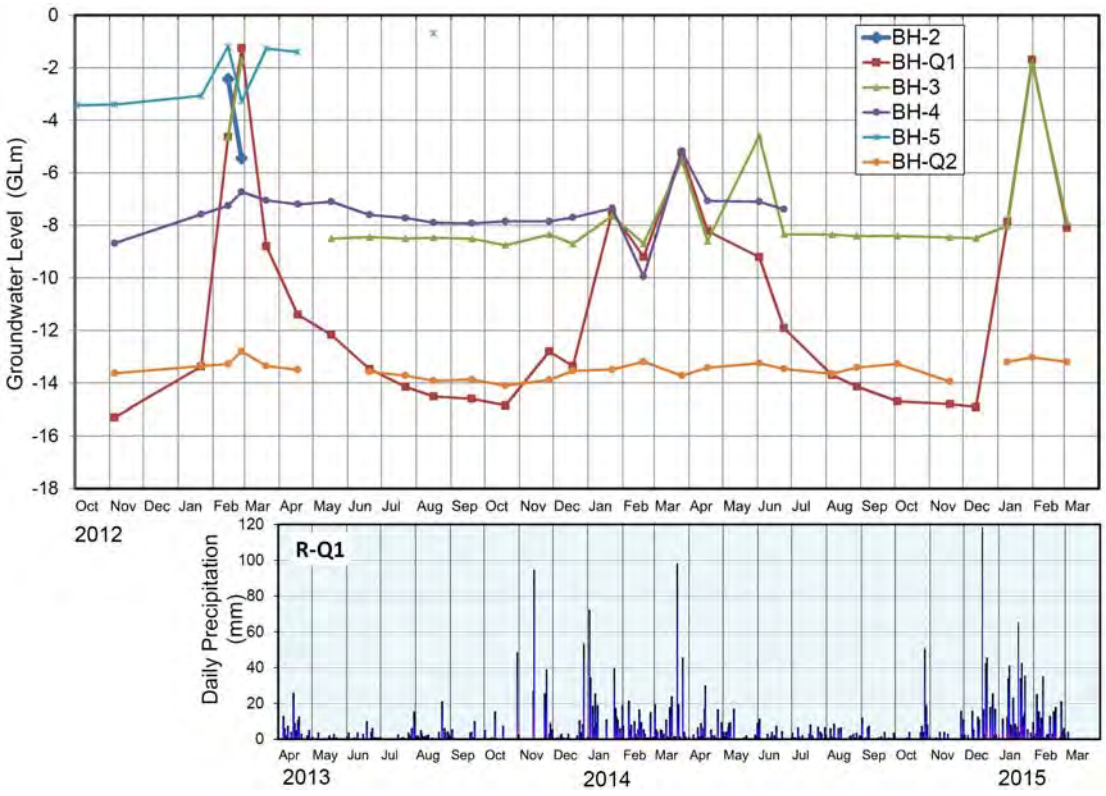
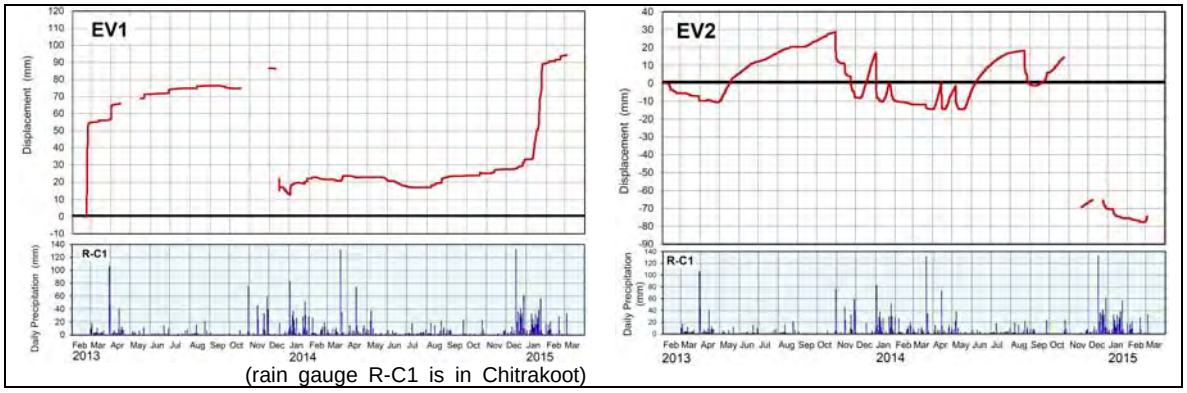


Figure 3.4.14 Water Level in the Boreholes (source: JET)

c. Vallee Pitot

EV1 which is installed at the head of the landslide area shows 55 mm of tension movement immediately after the installation. After that, some small tension movements are seen with over 10mm continuous precipitation. After January 2014, the variation in displacement became small within 10mm. The large displacement in December 2013 was because an operator who touched the wire of the extensometer. In January 2015, 60mm of big tension deformation was recorded. This deformation showed the landslide activities which affected on the surrounding houses.

EV2 which is installed at the toe of the landslide area shows compression movement immediately after the installation. However, it changes to tension movement in May and the tension movement continues all the time until September. The tension movement may be caused by partial deformation of the canal which EV2 straddles as shown in Figure 3.4.19. Even a big deformation was recorded at EV1 in January 2015, EV2 did not record big deformation.



(rain gauge R-C1 is in Chitrakoot)

Figure 3.4.15 Results of Extensometer (source: JET)

3.5 Geophysical Exploration

3.5.1 Elastic Wave Exploration

Elastic wave exploration is generally referred to as seismic exploration. Through generation of elastic wave into the ground and measurement of the propagation velocity at the surface, it helps understand properties of geological layers close to the surface. In the landslide investigation, this method is used to estimate the locations of weathered rock layer and the weathering degree, and to obtain the information about strata sequence and the distribution of fault and fracture zone. The exploration results can also be used as the fundamental information for groundwater draining work design.

Table 3.5.1 Extent & Specifications of the Seismic Exploration (source: JET)

Traverse line	Description Methodology	Traverse line length (m)
A1-line	8 consecutive seismic lines of 115m each (lines A1-1 to A1-8) The seismic profile crosses next to boreholes BH C1&BH C4	920
A2-line	2 overlapping seismic lines of 115m each (lines A2-1 & A2-2) The seismic profile crosses next to borehole BH C5	230
B1-line	2 consecutive seismic lines of 115m each (lines B1-1 & B1-2)	230
B2A-line	2 overlapping seismic lines of 115m each (lines B2A-1 & B2A-2)	230
B2B-line	1 seismic line of 115m (line B2B)	115
C-line	2 consecutive seismic lines of 115m each (lines C-1 & C-2)	230
Total		1,955

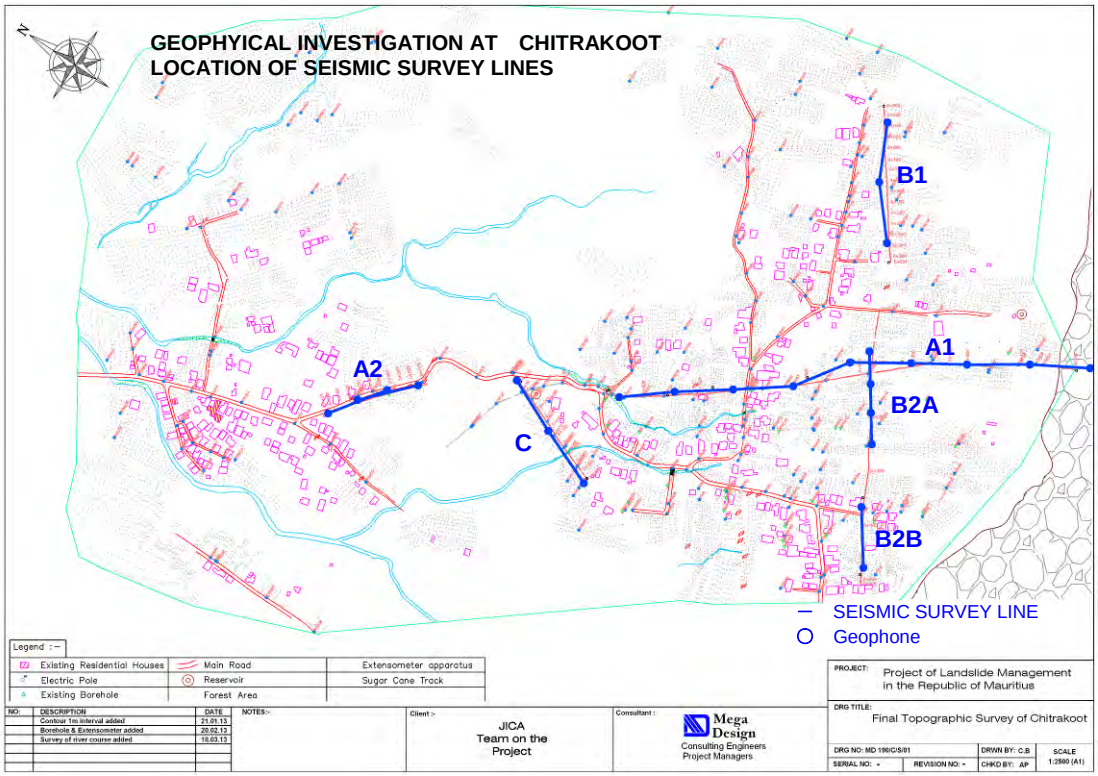


Figure 3.5.1 Location of Seismic Survey Lines at Chitrakoot (source: JET)

The velocity structure is generally categorized into 2～3 strata, and the surface stratum is presumed to be colluvium with an elastic wave velocity of less than about 500m/s. The

stratum thickness is less than about 20m and distributed uniformly throughout the entire survey area.

The elastic wave velocity of the base rock shows a value of 1700m/s～3900m/s, more than three times the surface stratum velocity. The variation in velocity in hard base rock composed of basalt is attributed to the prevalence of fractures and cracks inherent in basalt.

The state and hardness of the core of the colluvium and basalt clearly differ, resulting in a difference between the elastic wave velocities for the two.

Table 3.5.2 Summary Table of the Various Strata Identified (source: JET)

Traverse line	Thickness (m)	Seismic velocity (m/s)
A1-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 3 to 15m	310 to 790
	-Moderately to slightly weathered basalt/ agglomerate: from 12m deep	1742 to 2343
A2-line	-Gravelly silty clay/ colluvium:0 to 7m	346 to 463
	-Highly to moderate weathered basalt/ agglomerate: 4 to 12m	878 to 1320
	-Slightly weathered basalt/ agglomerate: 7 to 10m	3722 to 3843
B1-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 5 to 15m	442 to 484
	-Slightly weathered basalt/ agglomerate: from 15m deep	2283 to 2285
B2A-line	-Gravelly silty clay/ colluvium: 5 to 8m	389 to 393
	-Highly to moderate weathered basalt/ agglomerate: 7 to 20m	1033 to 1201
	-Slightly weathered basalt/ agglomerate: from 20m deep,	2568 to 3630
B2B-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 9 to 19m	472
	-Moderately to slightly weathered basalt/ agglomerate: from 15m deep	1998
C-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 4 to 15m	443 to 492
	-Moderately to slightly weathered basalt/ agglomerate: 10 to 15m	2154 to 2174

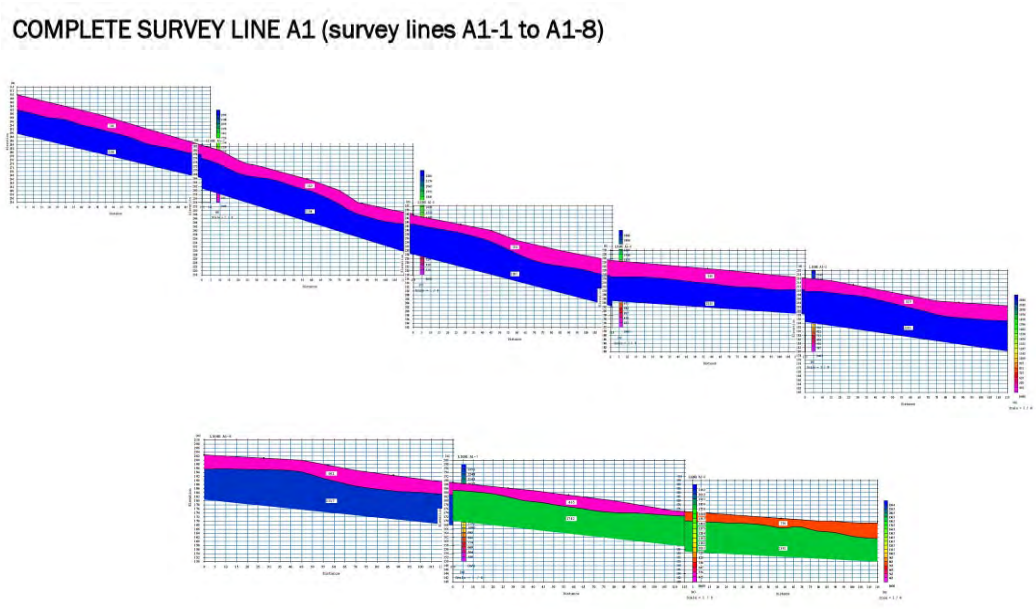


Figure 3.5.2 Seismic Velocity Section (A1-line) (source: JET)

3.5.2 Two-Dimensional Resistivity Exploration

a. Purpose of Investigation

During landslide investigation, based on the two dimensional distribution of the electrical resistivity, the weathered layer, bedrock, permeable layers and their continuity, existing situation of the faults and their continuity under the landslide slope can be estimated. The results can be used as fundamental information for the design of groundwater drainage.

In the two dimensional resistivity exploration, high density electrical potential is measured by placing electrodes at 5m intervals. Then through inverse analysis on a computer using the obtained electrical potential data, resistivity distribution is determined.

Table 3.5.3 Extent & Specifications of the Resistivity Exploration (source: JET)

Traverse line	Description Methodology	Traverse line length (m)
A1-line	Strings of 72 electrodes, spaged5m+6roll-along of 18 electrodes. Sequence of measurement of 3,598 quadripoles Typical depth of investigation: 40m	900
A2-line	Strings of 36 electrodes, spaced 5m Sequence of measurement of 306 quadripoles Typical depth of investigation: 30m	175
B1-line	Strings of 60 electrodes, spaced 5m Sequence of measurement of 8,528 quadripoles Typical depth of investigation: 40m	295
B2A-line	Strings of 36 electrodes, spaced 5m Sequence of measurement of 306 quadripoles Typical depth of investigation: 35m	175
B2B-line	Strings of 30 electrodes, spaced 5m Sequence of measure of 207 quadripoles Typical depth of investigation: 30m	145
C-line	Strings of 48 electrodes, spaced 5m Sequence of measurement of 562 quadripoles Typical depth of investigation: 40m	235
Total		1,925

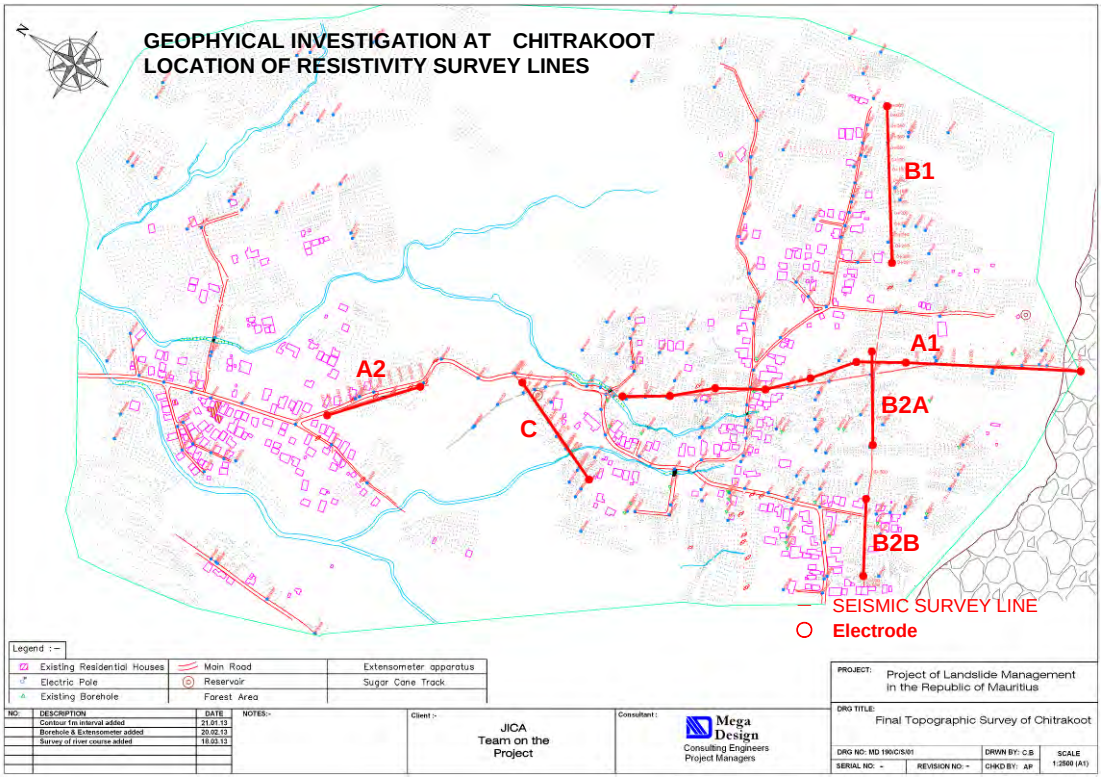


Figure 3.5.3 Location of Resistivity Survey Lines in Chitrakoot (source: JET)

The resistivity distribution is generally divided over 2～3 strata, and the surface layer is estimated to be colluvium of less than about 50ohm.m. The stratum thickness is less than about 20m and distributed uniformly over the entire survey area. Also, a fall in resistivity is observed in 3 places on the A1-line, indicating a weathered zone or groundwater flow.

Compared to the resistivity of the surface layer, that of the base rock was high at a value of 50～1000ohm.m or more than 1000ohm.m. The hard rock base is made up of basalt, and the basalt is presumed to have an effect on the resistivity value.

Table 3.5.4 Summary Table of the Various Strata Identified (source: JET)

Traverse line	Thickness (m)	Resistivity (ohm.m)
A1-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 3 to 15m	0 to 50
	-Moderately to slightly weathered basalt/ agglomerate: from 12m deep, encountered on a depth of 35m	50 to 1000
A2-line	-Gravelly silty clay/ colluvium:0 to 7m with pockets at 15m at the end of the survey line	0 to 10
	-Highly to moderate weathered basalt/ agglomerate: 4 to 12m	10 to 150
	-Slightly weathered basalt/ agglomerate: 7 to 10m	150 to 1000
	-Fractured basalt: from 22m deep, encountered on a depth of 15m	>1000
B1-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 5 to 15m	0 to 50
	-Slightly weathered basalt/ agglomerate: from 15m deep, encountered on a depth of 15m	150 to 1000
B2A-line	-Gravelly silty clay/ colluvium: 5 to 8m	0 to 10

	-Highly to moderate weathered basalt/ agglomerate: 7 to 20m	10 to 50
	-Slightly weathered basalt/ agglomerate: from 20m deep, encountered on a depth of 17m	150 to 1000
B2B-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 9 to 19m	0 to 50
	-Moderately to slightly weathered basalt/ agglomerate: from 15m deep, encountered on a depth of 15m	50 to 1000
C-line	-Gravelly silty clay/ colluvium & Highly to completely weathered basalt/ agglomerate: 4 to 15m	0 to 50
	-Moderately to slightly weathered basalt/ agglomerate: 10 to 15m	50 to 1000
	-Fractured basalt: from 27m deep, encountered on a depth of 15m to 20m	>1000

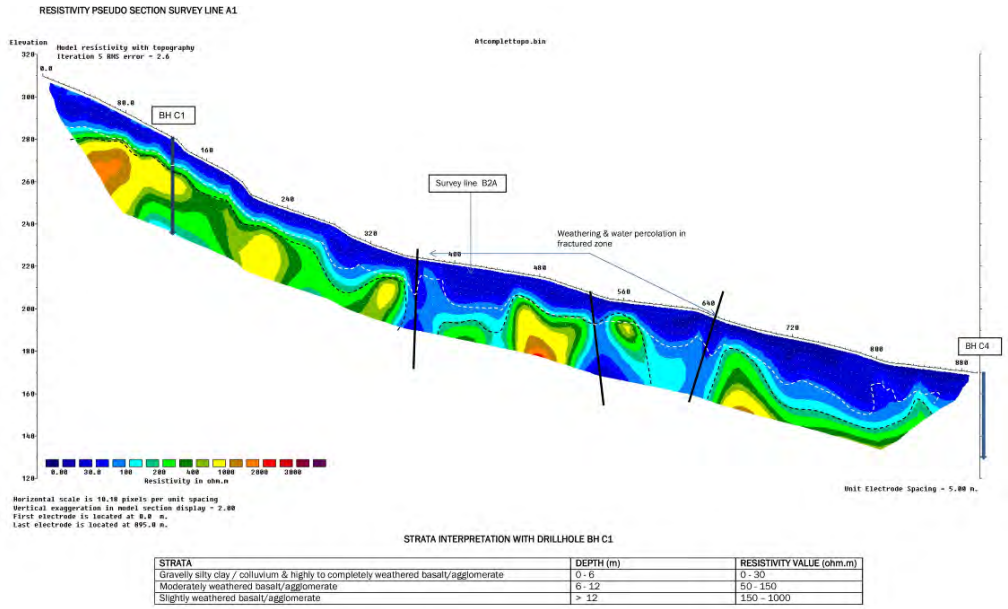


Figure 3.5.4 Resistivity Pseudosection (A1-line) according to Inverse Analysis (source: JET)

3.6 Drilling Survey

3.6.1 Drilling Plan

A drilling survey is conducted by extracting direct core from the ground in order to ascertain the slip plane surface, geological features, and geological structure. For this project all core sampling was conducted with a core diameter of 76～101mm.

Table 3.6.1 Borehole Details (source: JET)

Borehole Location	Borehole	Borehole Diameter (mm)	Depth (m)	In Situ Test	Installation
Chitrakoot	BH-C1	76	48.86	SPT	Piezometer
	BH-C2	101	50.0	SPT	Inclinometer
	BH-C3	76	50.0	SPT	—
	BH-C4	76	30.0	SPT	Pipe strain gauge
	BH-C5	76	30.0	SPT	Pipe strain gauge
	BH-C6	101	50.0	SPT	Inclinometer

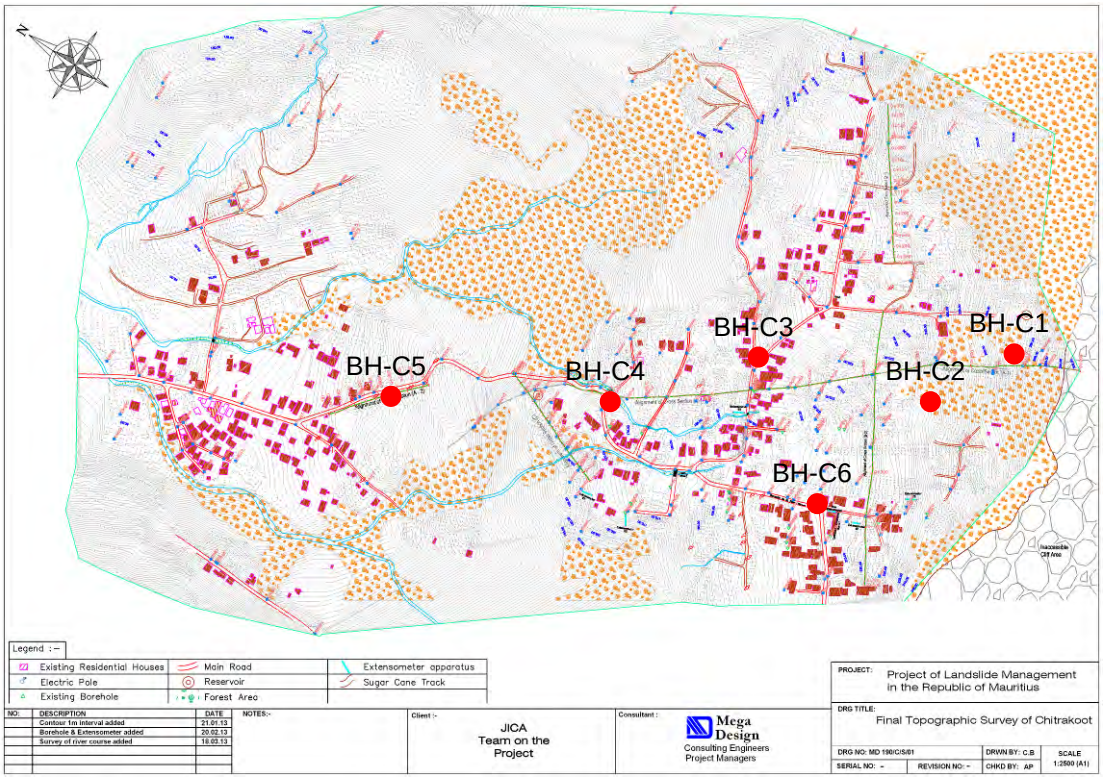


Figure 3.6.1 Survey locations in Chitrakoot (source: JET)

Table 3.6.2 Borehole Details (source: JET)

Borehole Location	Borehole	Borehole Diameter (mm)	Depth (m)	In Situ Test	Installation
Quatre Soeurs	BH-Q1	76	21.0	SPT	Pipe strain gauge
	BH-Q2	76	21.0	SPT	Pipe strain gauge
	BH-5(existing)	76	NA	NA	Piezometer

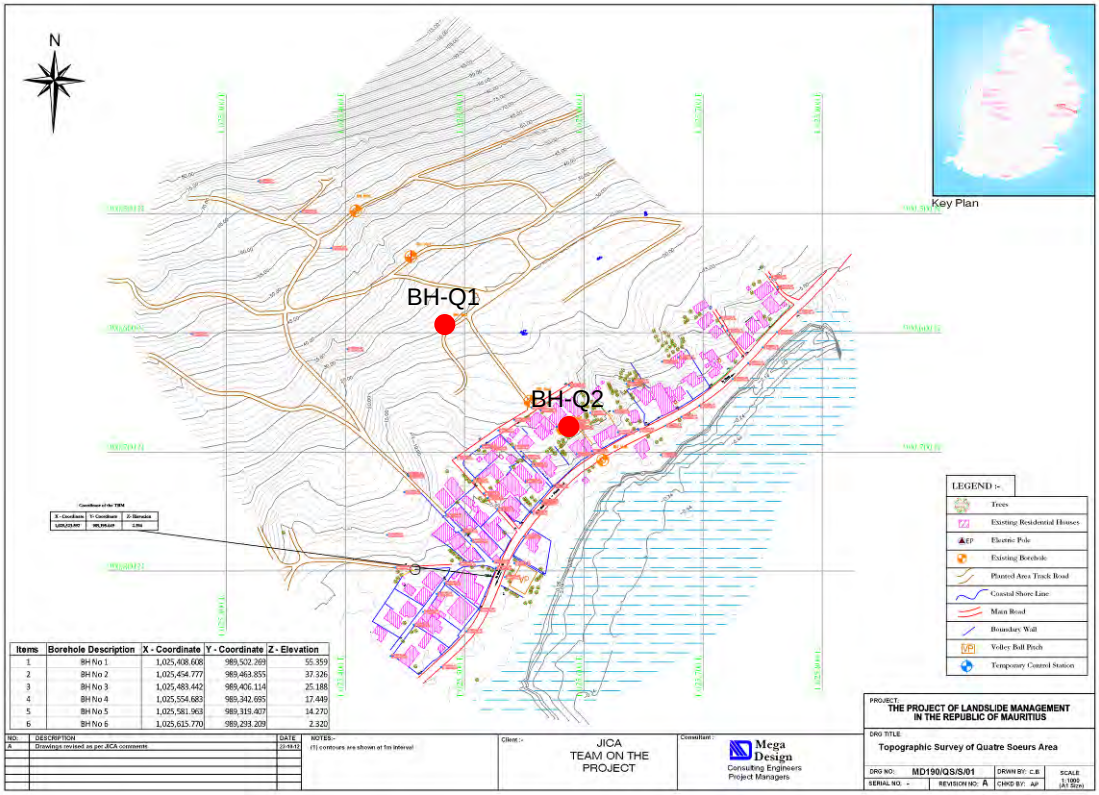


Figure 3.6.2 Survey Locations in Quatre Soeurs (source:JET)

3.6.2 Core Drilling

a. Specifications

The specifications of the drilling machines and materials are as follows.

Table 3.6.3 Specifications of the Drilling Machines and Materials (source: JET)

Drilling equipment	APAFOR38 and APAFOR48
Drilling method	Rotary coring-T2-101
Core Barrel	NMCL Triple Tube
Casing	89mm and 114mm

	
Drilling machine	Tank/ Tank car
	
Lorry	Material storage
	
Standard penetration test materials	Core tube/ Rod

Photo 3.6.1 The Drilling Machines and Materials (source: JET)

3.6.3 Installation of Observation Equipment

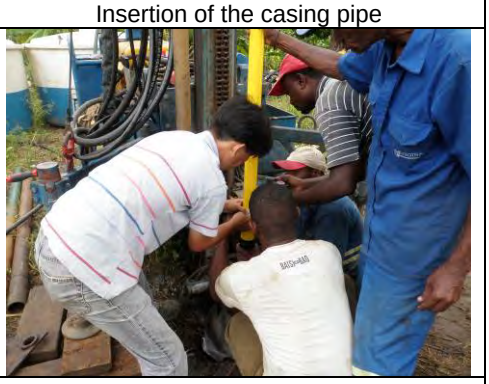
a. Installation of Pipe Strain Gauge

	
Installation of the pipe strain gauge	Setting of the pipe strain gauge complete

	
Connection of the data logger	Connection of the data logger complete
	
Setting of the data logger	Setting of the protection box

Photo 3.6.2 Installation of the Pipe Strain Gauge (source: JET)

b. Installation of Borehole Inclinometer

	
Special casing pipe (guide pipe)	Insertion of the casing pipe
	
Positioning of the casing pipe	Connection of the casing pipe

	
Setting of the casing pipe completed	Setting of the protection box

Photo 3.6.3 Installation of the Casing Pipe (Guide Pipe) (source: JET)

c. Installation of Water Level Meters

	
PVC pipe	Installation of PVC pipe completed
	
Installation of water level meter	Setting of the data logger

Photo 3.6.4 Installation of Water Level Meter (source: JET)

3.6.4 Drilling Results

a. Chitrakoot

Drilling results are summarized in the boring logs and core sample photographs and included in the Supporting Report.

The chart below shows the core recovery, solid core recovery and RQD obtained by means of drilling. The strata can be broadly classified into 3 types.

Table 3.6.4 Standard Penetration Test (source: JET)

Borehole	Depth (m)	Type	Depth (m)	Thickness (m)	Total core Recovery (%)	Solid core Recovery (%)	RQD (%)
BH-C1	48.86	1	5.00	5.00	100	0	0
		2	10.15	5.15	100	0-50	0-45
		3	48.86	38.71	100	45-100	12-100
BH-C2	50.00	1	8.00	8.00	100	0	0
		2	9.70	1.70	100	0	0
		3	50.00	40.30	100	14-100	0-100
BH-C3	50.00	1	6.00	6.00	100	0	0
		2	15.00	9.00	100	0-43	0-30
		3	50.00	35.00	100	80-100	65-100
BH-C4	30.00	1	7.55	7.55	100	0	0
		2	15.00	7.45	100	0-77	0-77
		3	30.00	15.00	100	82-100	60-100
BH-C5	30.00	1	5.75	5.75	100	0	0
		2	16.00	10.25	100	0-56	0-35
		3	30.00	14.00	100	65-100	60-100
BH-C	50.00	1	7.00	7.00	100	0	0
		2	13.00	6.00	100	0	0
		3	50.00	37.00	100	10-100	0-100

b. Quatre Soeurs

Table 3.6.5 Standard Penetration Test (source: JET)

Borehole	Depth (m)	Type	Depth (m)	Thickness (m)	Total core Recovery (%)	Solid core Recovery (%)	RQD (%)
BH-Q1	21.00	2	2.00	2.00	100	0	0
		3	7.80	5.80	100	0-33	0-33
		5	21.00	13.20	100	44-100	30-100
BH-Q2	21.00	2	18.75	18.75	100	0	0
		3	21.00	2.25	100	0-18	0

3.6.5 Standard Penetration Test

The standard penetration test is conducted to seek the N value in order to determine the hardness, firmness, and soil layer structure of the ground in situ. Test methods are carried out in accordance with BS 1377.

Standards for soil stiffness and consistency are as follows.

Table 3.6.6 Soil strength description (source: JET)

Consistency	Identification
Very soft	Easily molded fingers
Soft	Easily penetrated with thumb
Firm	Indent by thumb/molded with strong pressure
Stiff	Indent by thumb
Very Stiff	Penetrated by thumbnail
Hard	Penetration by thumbnail difficult

a. Chitrakoot

The N value of the surface layer of boreholes BH-C3 and BH-C6 is relatively soft at less than 10. The mixture of gravel is irregular, but shows a tendency to become more prevalent in the deeper parts of the colluvium. Based on the soil test results, the matrix of this stratum is mainly composed of fines, and therefore the N value is expected to decline in regard to cohesive soil containing no gravel.

Table 3.6.7 Standard Penetration Test (source: JET)

Borehole	Depth (m)	SPT level	SPT N value	Estimated UCS,kpa (Jennings and Al,1973)	Estimated Cu,kpa	Consistency
BH-C1	48.86	3.00	20	150-300	75-150	Very stiff
BH-C2	50.00	2.20	33	150-300	75-150	Very stiff
		3.35	23	150-300	75-150	Very stiff
		6.55	21	150-300	75-150	Very stiff
		8.00	19	150-300	75-150	Very stiff
BH-C3	50.00	1.00	8	40-80	20-40	Firm
		2.55	14	75-150	37-75	Stiff
		4.10	16	150-300	75-150	Very stiff
		5.45	19	150-300	75-150	Very stiff
		8.10	33	150-300	75-150	Very stiff
		9.65	41	150-300	75-150	Very stiff
		11.51	>51	Possibly cobbles/boulders		
BH-C4	30.00	2.55	26	150-300	75-150	Very stiff
		5.00	10	75-150	37-75	Stiff
		6.35	28	150-300	75-150	Very stiff
		8.00	36	150-300	75-150	Very stiff
		9.35	34	150-300	75-150	Very stiff
BH-C5	30.00	1.25	>51	Possibly cobbles/boulders		
		2.80	31	150-300	75-150	Very stiff

		4.25	>51	150-300	75-150	Very stiff
		5.75	Penetration not possible	Possibly cobbles/boulders		
BH-C6	50.00	2.00	8	40-80	20-40	Firm
		3.85	5	40-80	20-40	Firm
		5.30	23	150-300	75-150	Very stiff
		7.00	14	75-150	37-75	Stiff
		8.80	32	150-300	75-150	Very stiff
		10.65	26	150-300	75-150	Very stiff

b. Quatre Soeurs

The geology tested was colluvium and the consistency was “stiff” or “firm”. Excluding borehole BH-Q1, the N values were almost uniform for the boreholes at a range of 10-20. As in Chitrakoot, the colluvium contained an abundance of gravel, which affected the N value. In addition, because the matrix is composed mainly of fines, the N value is expected to decline in regard to cohesive soil containing no gravel.

Table 3.6.8 Standard Penetration Test (source: JET)

Borehole	Depth (m)	SPT level	SPT N value	Estimated UCS,kpa (Jennings and Al,1973)	Estimated Cu,kpa	Consistency
BH-Q1	21.00	1.00	6	40-80	20-40	Firm
BH-Q2	21.00	1.13	12	75-150	37-75	Stiff
		2.20	17	75-150	37-75	Stiff
		3.55	15	75-150	37-75	Stiff
		5.00	15	75-150	37-75	Stiff
		6.75	14	75-150	37-75	Stiff
		10.35	16	75-150	37-75	Stiff
		13.45	Penetration not possible	Possibly cobbles/boulders		

3.7 Field Reconnaissance

3.7.1 Damage to Houses

a. Chitrakoot

A survey on damage to houses was conducted in conjunction with MPI, with the aim of understanding the extent of landslide damage in the relevant areas. The houses determined to have suffered damage are shaded in pink, with heavily damaged houses shaded in red. The locations of damaged houses generally correspond to the locations that suffered deformation in the 2005 landslide.

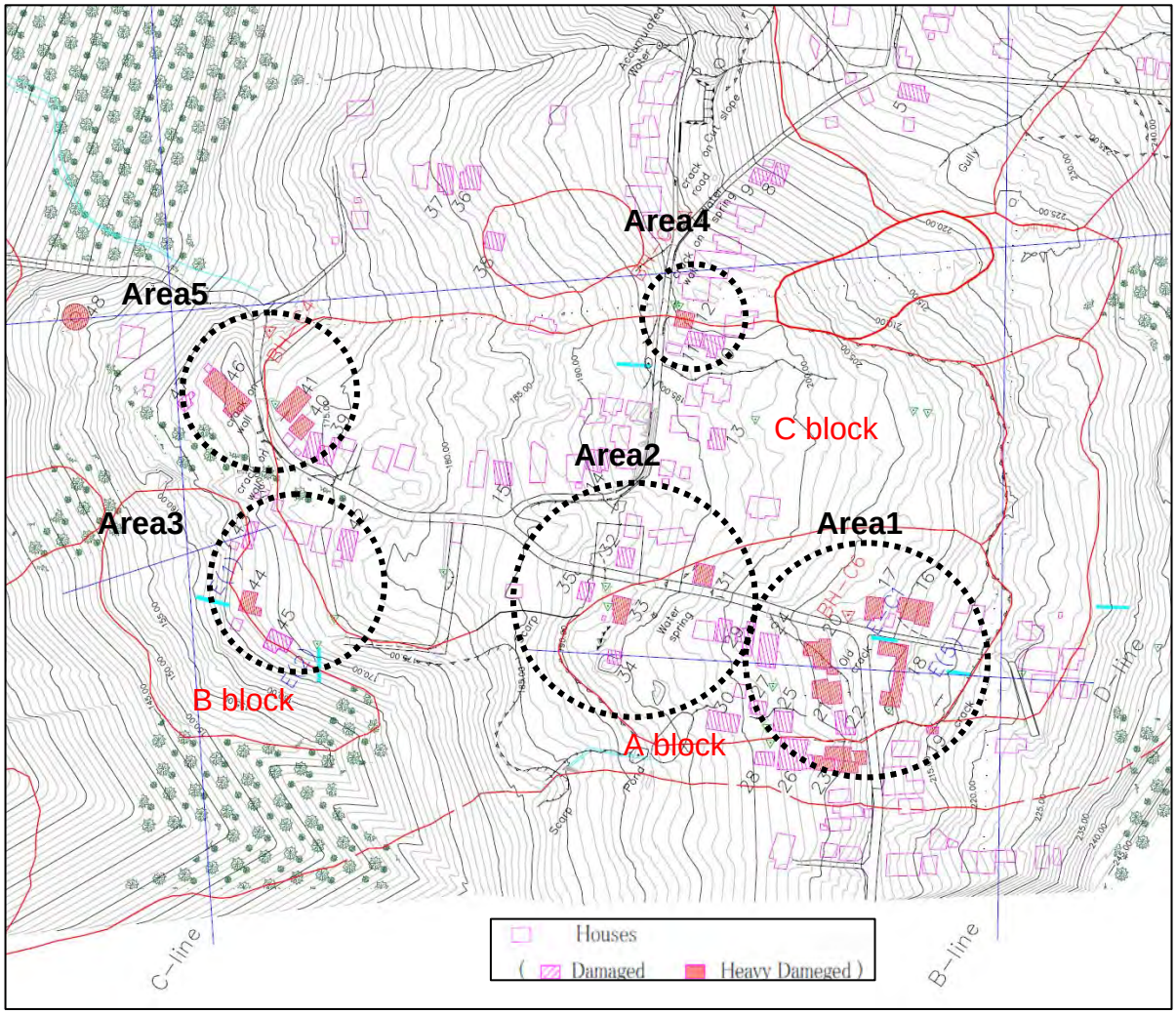


Figure 3.7.1 Results of Survey on Damage to Houses, Chitrakoot (source: JET)

b. Quatre Soeurs

A house deformation survey was carried out in December 2010. In addition, a crack monitoring survey is being conducted on 6 houses with heavy damage.

Table 3.7.1 Monitoring of Damaged Houses (source: JET)

House.No	Owner	Location of control points	House.No	Owner	Location of control points
1	JHURRY JUGNUNUN	C1,C2,C3,C14	4	JHOOMAH RAJEN	C8,C9
2	JHOOMAH ROOPCHAND	C4,C5	5	JHOOMAH DHANANJAY	C10
3	JOOMAH NEERMAL	C6,C7	19	MURACHPERSAD TETREE	C11,C12,C13,C15

Figure 3.7.2 Monitoring Locations of the Damaged Houses (From Past Material, C1～C15: Monitoring Locations)[1]

c. Vallee Pitot

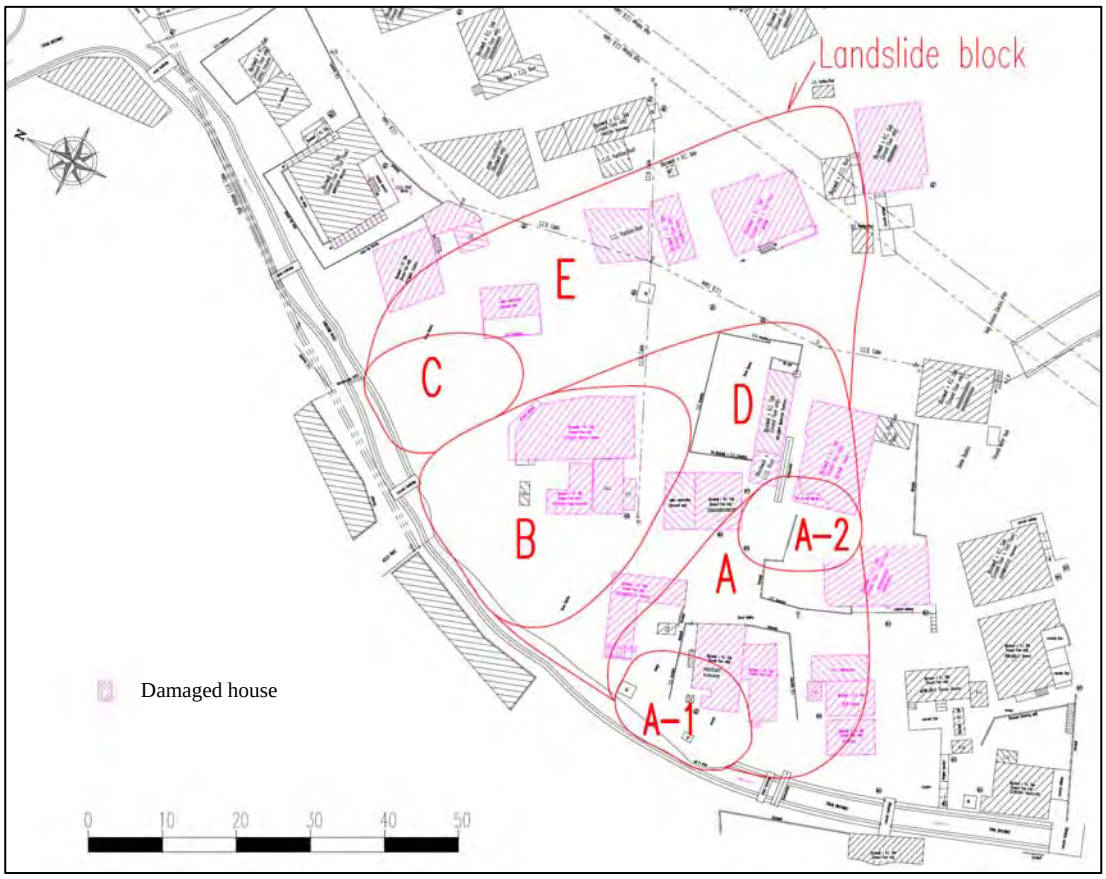


Figure 3.7.3 Results of Survey on Damage to Houses, Vallee Pitot (source: JET)

3.7.2 Results of Field Reconnaissance

a. Chitrakoot

Field reconnaissance was conducted with a focus on crack occurrence in houses with deformation and as indicated in past reports, and the results sorted.

Table 3.7.2 Areas with Extensive Damage and Its Characteristics (source: JET)

Area	Location	Characteristics	Past investigation
1	Around School	Cracks occurred in the elementary school building and the slope in back, and part of the school building was removed. The damaged school building is currently under restricted use. Major deformation was seen in houses by the side of the school building. This area suffered the most damage in the 2005 landslide.	Extensometer E(5) Drilling BPI(7),BPP(16),BPP(11) BPX(1),BPP(19), BPI(1),BPP(5)
2	Around Upper Main Road	Damage has occurred in the main road near the elementary school and houses close to the main road. Damage to houses is varied, including inclination of houses, subsidence, and cracks in walls and floors, and first became apparent after the 2005 cyclone.	Drilling BPX(3),BPP(9)

3	Downward Slope	Intermittent cracking is occurring in the slope north of Area 2. Damage to houses is also evident, and a crack passing through the wall of a house beside extensometer E(1) has developed.	Extensometer E(1),E(2) Drilling BPX(2),BPI(3)
4	Roadside and Houses	Cracking has occurred in the road and houses located on the east side of the stream (waterway) that cuts across the land, but the scale of damage is comparatively small. Below the road is an expanse of sugarcane fields.	Extensometer E(4) Drilling BPP(6),BPI(6)
5	Around Lower Main Road	There is damage to the houses and concrete-block walls near the main road. Damage to houses includes inclination of houses, subsidence, and cracks in walls, becoming evident after the 2005 cyclone. Whether damage is due to landslide cannot be determined.	Extensometer E(3) Drilling BPX(4),BPI(13)

House17

Photo 3.7.1 Heavily Damaged House

House16

Photo 3.7.2 Heavily Damaged House

(source: JET)

As the houses are somewhat old, there is a possibility that there were deformations even before the 2005 cyclone. However, given their proximity to the school, it is conceivable that the deformations were caused by the landslide.

b. Quatre Soeurs

Table 3.7.3 The Characteristics of Slope Classification (source:JET)

Slope classification	Gradient	Characteristics
Upper Slope	16～20°	The slope above elevation 25m. The slope type is one in which the contour lines correspond to an almost parallel linear slope. Topsoil and cultivated soil are distributed thinly, and many blocks such as basalt and breccia can be seen. One side of the slope, particularly above about elevation 40m, is comprised of unstable blocks.
Middle Slope	5°	A gentle slope from the road above the houses to an elevation of around 25m, it is a flat terrain with a slope gradient of 5°. The ground surface is composed of topsoil and cultivated soil, but unlike the upper slope the distribution of blocks is relatively small. It is a stable slope with few deformations such as cracks.

Lower Slope	15～17°	Spanning from the road above the houses to the main road on the coast, it is a steep slope crowded with houses. Because there are houses and a main road along the coast subject to preservation, whenever a landslide or slope failure occurs the damage is extensive and it is an area with an urgent need for countermeasure works.

Photo 3.7.3 Horizontal Open Cracks in the Wall

Photo 3.7.4 Open Cracks in the Foundation

(source: JET)

c. Vallee Pitot

1st Reconnaissance in 2012

The first reconnaissance was carried out by JET (JICA expert team) on the 22nd June 2012. House (1) had been damaged, and main scalp of landslide was observed.

2nd Reconnaissance on 22nd February 2013

A resident of Vallee Pitot informed JET office by telephone that a house had been heavily damaged on the afternoon of 21st February. JET soon after informed MPI, and MPI went to the site on 22nd February with JET and the police to carry out site reconnaissance.

3rd Reconnaissance on 26th February 2013

News that a part of House (1) had broken reached MPI on 25th February 2013. MPI and JET went to the site on 26th February, and 3rd reconnaissance was carried out. The outside wall of house (1) was completely broken, and the main scalp had increased in size since the 2nd reconnaissance. In addition, new open cracks were found in the upper part of this house. The 3rd reconnaissance confirmed that the landslide area of Vallee Pitot was much larger than previously thought (indicated by the yellow dotted line in the figure below).

Figure 3.7.4 Landslide Plan Map (3rd Reconnaissance on 26th February 2013) (source: JET)

3.8 Disaster Inspection

Thirty-seven (37) slope disaster hazard areas are defined in the Disaster Scheme, which means that the 37 areas are officially identified by the Mauritius Government as “high hazard areas for slope disasters”. Therefore countermeasures which mitigate the risk of disasters are necessary to protect the citizens and the infrastructures in Mauritius

A regular disaster inspection is a better risk management method to identify ominous signs that may cause a serious disaster before a slope disaster happens, which should last until the completion of countermeasure construction and the confirmation of effectiveness of the countermeasures. The disaster inspection procedures JET has proposed to MPI will be conducted continuously in the Project.

3.8.1 Significance and Objectives of Disaster Inspection

The overall goal of the inspection is to implement the management of slopes disaster effectively and efficiently. The specific objectives are as follows;

- To find out early the anomalies related to potential disasters
- To systematically understand the disaster risk area along roads
- To organize records of disasters along roads and potential disasters
- To decide the mitigation methods/countermeasures

3.8.2 Method of Disaster Inspection

The disaster inspection is conducted with a regular check sheet and photo sheets. In the regular check sheet, new failures, cracks, small rock falls/failures, spring water, clogged culverts etc. should be checked and the inspector should describe the current condition and the proposed action. In the photo sheet, the overview, the checkpoints and the abnomaly etc. should be taken and the inspector should take the photos from fixed points to compare the situation with previous photos.

3.8.3 Results of Disaster Inspection

The JET and C/P have conducted the disaster inspection for the 37 slope disaster hazard areas after the rainy season from April to May in 2013, and have discussed the stability and the priority.

The 37 slope disaster hazard areas are divided into three (3) ranks as follows based on the emergency and priority as judged by the disaster inspection.

A: Need for emergency countermeasures

B: Need for continuous inspections

C: Removal from a list

Table 3.8.1 The Results of Disaster Inspection for 37 Slope Disaster Areas (source: JET)

No.	Area name	Classification of disaster	Striking condition	Evaluation	Proposed action
1	Temple Road, Creve Coeur	Damage of wall		B	
2	Congomah Village Council (Ramlakhan)	Stream erosion		B	
3	Congomah Village Council (Leekraj)	Damage of wall		B	
4	Congomah Village Council (Frederick)	Damage of wall		B	
5	Congomah Village Council (Blackburn Lanes)	Damage of Embankment		B	
6	Les Mariannes Community Centre (Road area)	Slope failure		B	
7	Les Mariannes Community Centre (Resident area)	Stream erosion		B	
8	L'Eau Bouillie	Damage of embankment	The road was paved and repaired. There are no ditches in the area. But new cracks and deformation happened by erosion of the roadside because of the heavy rainfall in the middle February and the end of March.	A	Concrete ditched should be constructed along the road to prevent further erosion of the road foundation.
9	Chitrakoot, Vallee des Pretres	Landslide	As a pilot project site, monitoring is being conducted.	A	Until the completion of countermeasures, monitoring and early warning system should be continuously implemented.
10	Vallee Pitot (near Eidgah)	Landslide	As a pilot project site, monitoring is being conducted.	A	Until the completion of countermeasures, monitoring and early warning system should be continuously implemented.
11	LePouce Street	Stream erosion	No significant progress.	B	It is necessary to construct the ditch of an appropriate scale.
12	Justice Street (near Kalimata Mandir)	Damage of wall	No significant progress. However, the mud flow is generated after the heavy rain, and the drain system is not enough.	B	Artificial structures (drainage, culvert, etc.) should be constructed in the future. The fill removal in the back of the ditch is also effective. It is preferable to construct the channel on the slope.
13	Mgr. Leen Street and nearby vicinity, La Butte	Landslide		B	
14	Pouce Stream	Stream erosion	Damage is confirmed to the gabion. However, the function of the erosion prevention is secured.	B	
15	Old Moka Road, Camp Chapelon	Landslide	No significant progress. However, the groundwater level is high in this area. Pushing the ditch out and cracks of house are confirmed. A detail investigation shall be carried out.	B	Artificial structures (drainage, horizontal drainage etc.) should be constructed on the house side along the road to decrease the water level.
16	Boulevard Victria, Montague Coupe	Damage of wall	No significant progress. However, the gabion has become unstable recently.	A	It will be necessary to reinforce the gabion in the future. The fill removal in the back of the gabion is also effective.
17	Pailles: (i) access road to Les Guibies and along motorway, near flyover bridge	Slope failure	The slope around the bridge has small collapsed and sediment discharge was confirmed in the ditch.	A	Artificial structures (drainage, ditch etc.) should be constructed on the slope. It is necessary to green the slope to prevent further erosion of the slope.
18	Pailles: (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	No significant progress.	B	
19	Pailles: (iii) soreze regin	Slope failure	A lot of damages of the ditch are confirmed. The rockfall and the small collapse are confirmed.	A	It is necessary to repair the ditch. In the future rockfall countermeasures should be constructed along the road.
20	Plaine Champagne	Slope failure		B	

	Road, opposite "Musee Touche Dubois"				
21	Chamarel: (i) near Reataurant Le Chamarel	Damage of embankment		B	
22	Chamarel: (ii) Roadside	Damage of embankment		B	
23	Gremde Riviere Noire Village Hall	Damage of house	No significant progress. The cracks are caused by not landslide but lack of bearing capacity of the ground.	C	This area can be removed from the inspection sites after the discussion with related organization.
24	Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	No significant progress. Small debris and garbage are stacked at the inlet of culvert	B	Regular maintenance (excavation of debris and garbage) should be conducted after rainy season to prevent the clog of culvert and overflow.
25	Baie du Cap: (ii) Maconde Region	Rock fall		B	
26	Riviere des Anguilles, near the bridge	Stream erosion	No significant progress. However, over the past several years, the erosion is slightly progressing so that the edge of the cliff has been approaching the houses.	A	Artificial structures (gabion, concrete walls etc.) should be constructed on the house side along the river to prevent further erosion of the cliff.
27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	As a pilot project site, monitoring is being conducted.	A	Until the completion of countermeasures, monitoring and early warning system should be continuously implemented.
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure		B	
29	Cave in at Union Park, Rose Belle	Cavern	No significant progress. The cave was already filled. There is no movement or erosion.	C	This area can be removed from the inspection sites after the discussion by related organization.
30	Trou-AUX-Cerfs	Slope failure	Vegetation is getting recovery	B	
31	River Bank at Cite L'Oiseau	Stream erosion		B	
32	Louis de Rochecouste (Riviere Seche)	Stream erosion		B	
33	Piper Morcellement Piat	Stream erosion	Stone masonry wall was collapsed due to the heavy rain in Middle February. The collapse cause further erosion on house side.	A	The retaining wall should be repaired to avoid further collapse.
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	The cracks are in the retaining wall, and spring water is observed though there is no damage in the house. No significant progress.	B	It is preferable to observe the crack of the retaining wall continuously.
35	Cavernous Area at Mgr Leen Avenue and Bassin	Cavern	No significant progress. The cave was already filled. There is no movement or erosion.	C	This area can be removed from the inspection sites after the discussion by related organization.
36	Morcellement Hermitage, Coromandel	Slope failure		B	
37	Montee S, GRNW	Stream erosion	No significant progress. However, the erosion is slightly in progress.	B	It will be necessary to construct a bank protection in the future.

3.8.4 Recommendation on Disaster Inspection

a. Rank A Area

Prompt implementation for countermeasures is necessary for the selected nine (9) Rank A areas. The countermeasures should be discussed by MPI with cooperation of each district office. After the completion of countermeasure construction and the confirmation of

effectiveness of the countermeasures, the area can be removed from the list of the Disaster Scheme after discussions with related organizations.

b. Rank B Area

For the selected 25 Rank B areas, the regular inspection should be continuously implemented after every rainy season until the countermeasures have would be been completed. After the completion of countermeasure construction and the confirmation of effectiveness of the countermeasures, the area can be removed from the list of the Disaster Scheme after the discussions with related organization.

c. Rank C Area

The following three (3) areas on Rank C areas can be removed from the list of the Disaster Scheme after the discussions with related organization.

3.9 Review and Recommendations for the Disaster Scheme

3.9.1 Review of the Existing Warning System of Landslides in Mauritius

The schemes of emergency response for cyclones, torrential rain, tsunamis, high waves and landslides are indicated in Cyclone and Other Natural Disasters Scheme (CONDS) in Mauritius.

The chapter on landslides in the scheme contains monitoring, actions by Local Authorities, responsibility of the Central Cyclone and Other Natural Disasters Committee, warning/evacuation system, and distribution of landslide bulletins.

Table 3.9.1 The Warning Stages, Standards for Issuing Warnings and Responses[2]

Stage	Standards for issuing warnings and responses
Stage 1 (Preparatory Stage)	・ Rainfall will be measured by the representatives of Local Authorities/ inhabitants. As soon as 30mm rainfall per 12 hours is recorded, the information will be communicated to the Director, Meteorological Services. ・ The Meteorological Services (MS) will confirm the recording and transmit it to the National Disaster and Operations Coordination Centre (NDOCC) which in turn will communicate it to the Prime Minister's Office (PMO) and to the Ministry of Public Infrastructure, National Development Unit, Land Transport and Shipping (MPI). ・ On being informed that 30mm of rainfall in 12 hours has been recorded, the MPI will start taking daily readings of extensometers to measure ground displacement. ・ Upon 2mm a day or more displacement being recorded, the MPI will communicate the reading to the MS, NDOCC and the appropriate Local Authorities. (At sites where no extensometers are available, the MPI will arrange for a site inspection on being informed that there has been some land movement.) ・ Stage I warning is communicated by the Chairperson of the Coordinating Committee (PMO), to MPI. The latter will communicate same to the NDOCC and the MS. ・ The NDOCC will then inform the residents of the affected areas. The warning will also be communicated by the NDOCC to related ministries and organizations which make up the Coordinating Committee of NDOCC. ・ The Police will advise the inhabitants of landslide-prone areas through their representatives, to start preparing themselves to move out of their houses in accordance with instructions already issued to them.
Stage 2 (Warning Stage)	・ The MPI will constantly monitor ground movement and will inform the MS and the NDOCC as soon as displacement of 1cm per day is recorded or if visual displacement of ground is noted. ・ The NDOCC will inform the PMO and the Chairperson of the Coordinating Committee who will convene a meeting to issue the Stage 2 Warning. ・ The warning will be broadcast by the Mauritius Broadcasting Corporation (MBC) and private radio stations. ・ Communication to the affected residents will be done by the Police Department by loudspeakers or other means. ・ The Police Department shall, when issuing a Stage 2 Warning, advise the residents to complete all preparations for eventual evacuation and stand by ready to vacate their houses once the order is issued. Arrangements should be made by the Ministry of Health and Quality of Life (MHQL) and the Police Department for the transfer to hospitals of disabled people who elect to do so. First Aid Service (FAS) providers may be invited to extend their assistance. ・ The Crisis Committee (CC) will review the situation in the light of all available information pertaining to rainfall recording and ground displacement. ・ The Stage 2 Warning will also be communicated by the NDOCC to the following Ministries/Departments/Organizations which will be responsible for the following: ➢ MHQL: (i) to prepare special ward for any casualty that may arise out of an eventual evacuation; (ii) to provide an adequate number of medical and para-medical personnel intended to receive casualties; and (iii) to be ready to dispatch ambulances adequately staffed and equipped.

	➢ The Ministry of Social Security, National Solidarity and Reform Institutions (MSS) and the Ministry of Gender Equality, Child Development and Family Welfare (MGCW) will ensure that all Refugee Centres under their respective control are opened and made ready for use. ➢ The Central Water Authority (CWA) will stand by ready to close the shut-off valves on the pipes going through the region as soon as the evacuation order is issued. ➢ The Central Electricity Board (CEB) will be ready to switch off electricity supply in the affected area as and when instructed by the Crisis Committee or the most senior gazetted Police Officer. CEB will ensure as far as possible that power cuts are restricted to the affected areas only so as to avoid unnecessary deprivation of electricity to unaffected areas. ➢ MPI will take readings of extensometers as frequently as may be appropriate to determine whether the ground displacement progresses beyond 1cm a day and ensure that the information is communicated to the NDOCC and the MS. ➢ The Fire Services and the Non-Governmental Organizations (Red Cross Society, St. John Ambulance, etc.) will be informed by the NDOCC of the possibility of an evacuation order being issued and to enlist their assistance.
Stage 3 (Evacuation Stage)	・ Stage 3 is reached when ground displacement is equal to or is greater than 2mm in an hour. ・ As in the case of the two previous stages, the recording will be continually monitored by the MPI and the data communicated to the NDOCC and the MS. The NDOCC will then pass on the information to the CC which will meet to approve the evacuation order. The evacuation order will be broadcast and/or communicated to the appropriate residents in the same manner as in Stage 2. ・ If, on information being obtained from the MPI and the MS, the NDOCC considers that an urgent and immediate evacuation is required and that there might not be enough time to convene the CC, then the most senior gazetted officer present in Line Barracks will give the order for evacuation after consultation with the Chairperson of the CC, if possible. ・ As Stage 3 is reached and evacuation is in progress, the various Ministries/Departments/Organizations involved should actively set in motion arrangements for which they are responsible. In particular, the following measures should be implemented: ➢ Ministry of Education and Human Resources (MEHR) and Ministry of Tertiary Education, Science, Research and Technology (MTSRT): Educational Institutions in affected areas should be closed. ➢ MSS and MGCW will ensure that all Refugee Centres under their respective control are opened and made ready for use. ➢ MHQL: Ambulances should be dispatched on site for the conveyance of handicapped, old and sick people, and any casualty cases to hospital. Arrangements will also be made for Health Inspectors to visit regularly the refugee centres to ensure acceptable sanitary conditions there. ➢ CWA will close the valves on the pipelines within the affected area and will arrange for water to be supplied regularly to the refugee centres. ➢ CEB will proceed with the interruption of the power supply in the affected areas. ➢ Police Department will cordon off the affected area and ensure the protection of property of the residents. An Incident Officer will be responsible and will have full authority for the control and coordination of the operation on site. Access to the cordoned off area will only be permitted by the Incident Officer.
Stage 4 (Emergency Stage)	・ When there is sudden landslide and the CC cannot for practical reasons be convened, the Emergency Warning is issued by the NDOCC after consultation with the Chairperson of the CC, if possible. ・ Action will be triggered off as provided for under Stage 3. ・ The prevalence of cyclonic conditions over and around Mauritius will entail the adoption of special arrangements with regard to the inhabitants of landslide-prone areas. ・ The issue of a Cyclone Warning Class II or a Torrential Rain Warning may constitute for the inhabitants a Landslide Stage 2 Warning. Being given that the issue of a Cyclone Warning Class III entails the cessation of all normal activities, the inhabitants of the landslide prone areas may be evacuated if there exists a strong likelihood of a Cyclone Warning Class III being issued and the possibility of landslide to occur.

	・ As soon as a Cyclone Warning II or a Torrential Rain Warning is issued by the MS, the CC will, in consultation with the Chairperson of the Coordinating Committee, convene a meeting to consider the advisability of issuing an evacuation order. Action as provided for in Stage 3 will be triggered off.
Stage 5 (Termination)	・ A close monitoring and stocktaking exercise will be undertaken by relevant authorities after stabilization of ground movement has been noted. ・ The all-clear signal will be given after a meeting of the CC.

3.9.2 Recommendation for the Disaster Scheme

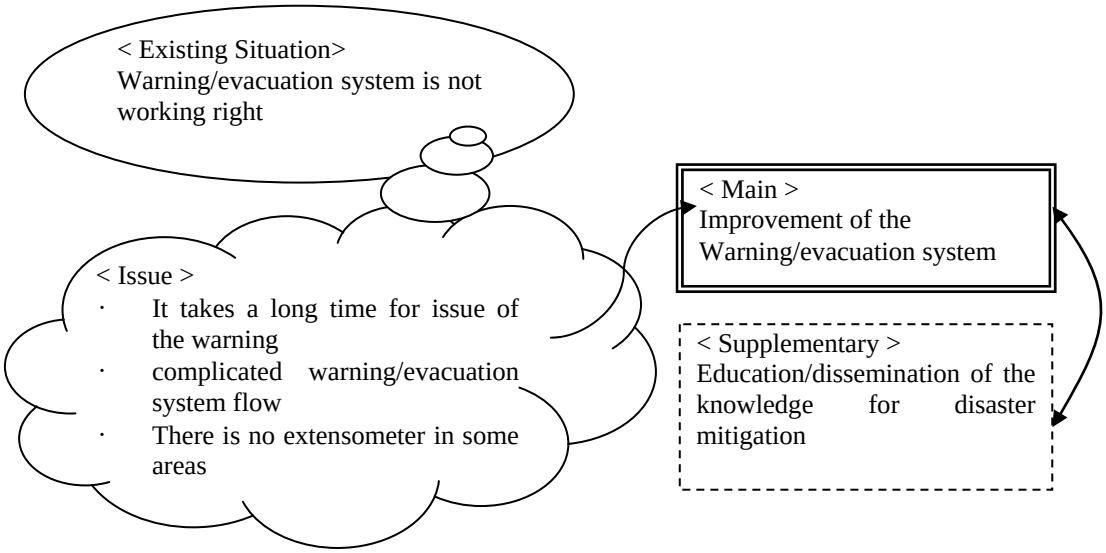


Figure 3.9.1 Outline Image of the Draft Recommendation for Disaster Scheme (source: JET)

The existing situation, issues and basic policy for countermeasure regarding the warning/evacuation system in the Disaster Scheme is shown below.

Table 3.9.2 Existing Situation, Issues and Basic Policy for Countermeasure Regarding the Warning/Evacuation System in the Disaster Scheme (source: JET)

Existing situation	Issues	Basic policy for countermeasure
MPI is responsible for the monitoring of landslides all over the Island.	It is difficult to take responsibility for landslide monitoring all over the island due to limited human resources/systems and budget of MPI	Change concentration of the responsible area from all of Mauritius to high risk area.[1]
Warning/evacuation order will be issued by decision of the Crisis Committee based on the information from the site through NDOCC[2]	The landslide disaster might occur before the decision of evacuation notice when an emergency situation occurs (cyclone, torrential rain, etc.)	Introduction of the voluntary evacuation of the site in response to the emergency (torrential rain, cyclone, etc). Separating the warning/evacuation system flow between site and government response. And introduction of issue of the evacuation notice by decision on the site. (The information sharing between site and government will be required through the Police, Special Mobile Force and NDOCC)
The warning/evacuation system flow has too many processes and is complicated.	The response might be delayed.	Change the warning/evacuation stages from five to three and simplify the warning/evacuation system flow.
The warning/evacuation notice is issued using data from rain gauges and extensometers.	There is no rain gauge/extensometer in some areas.	Multiple triggers which include not only the rain gauge/extensometer data, but also residents' information (deformation, signs of movement) should be utilized to avoid the situation of non-functional warning/evacuation system not turning the triggers into action.
The monitoring data of the extensometer is the trigger for the warning/evacuation in the existing disaster scheme. The recording will be continually monitored by the MPI.	MPI may not be able to access the site during an emergency (cyclone, torrential rain, etc.) because of flooded roads, traffic restriction by government, etc.	The trigger for evacuation notice should not rely only on the MPI's monitoring data. (The multiple trigger is required.) Separating the warning/evacuation system flow between site and government response, and introduction of issue of the evacuation notice by decision on the site.
The communication between NDOCC and MMS[3]/MPI is required for issue of evacuation notice and sharing the information (data of rain gauge/extensometer).	It might not be possible to communicate with each other because of electrical power outage/ disconnection during an emergency.	Introduction of the voluntary evacuation of the site to respond to the emergency (torrential rain, cyclone, etc). Separating the warning/evacuation system flow between site and government response, and introduction of issue of the evacuation notice by decision on the site.

Based on the above, the existing disaster scheme article, draft proposal of addition/modification, reason of addition/modification and necessity as a recommendation for the disaster scheme were summarize in the Final Report.

Education/dissemination of knowledge for disaster mitigation is proposed as a supplementary

[1] The technical transfer about the designation of the warning zone will be implemented by this project. The designation, warning/evacuation system development and education/dissemination by MPI with related ministries/agencies will be required in the future. The survey and designation will be required not only in the warning zone, but also in the landslide-prone areas in Mauritius of the Disaster Scheme in the future on an as needed basis.

[2] NDOCC: National Disaster and Operations Coordination Centre: Police Information and Operations Room will be changed to the core of the NDOCC. The NDOCC has experience of the implementation of the disaster drill and education on a nationwide basis.

[3] MMS: Mauritius Meteorological Services

recommendation.

<Knowledge dissemination/education for disaster mitigation>

Dissemination of disaster mitigation knowledge, and publicity activities to promote knowledge during a disaster, relating to a warning/evacuation system, should be implemented.

<Disaster drill>

MPI will conduct periodical disaster drills with community participation/involvement (including enhancement of awareness, confirmation of the warning/evacuation system) along with the cooperation of local authorities, Police, NDRRMC and related organizations in the Warning Zone.

3.10 Review and Recommendations for the Planning Policy Guidance

In this section, recommendations for Planning Policy Guidance (PPG) are examined through the clarification of legal system issues for landslide disaster risk management (LDRM: Landslide Disaster Risk Management) and consideration of the solution for the issues based on the review of the existing Mauritian legal systems/schemes about LDRM, analysis of the present situation concerning the landslide prone area and review of Japanese legal systems. The process of making the recommendation is shown in the following figure.

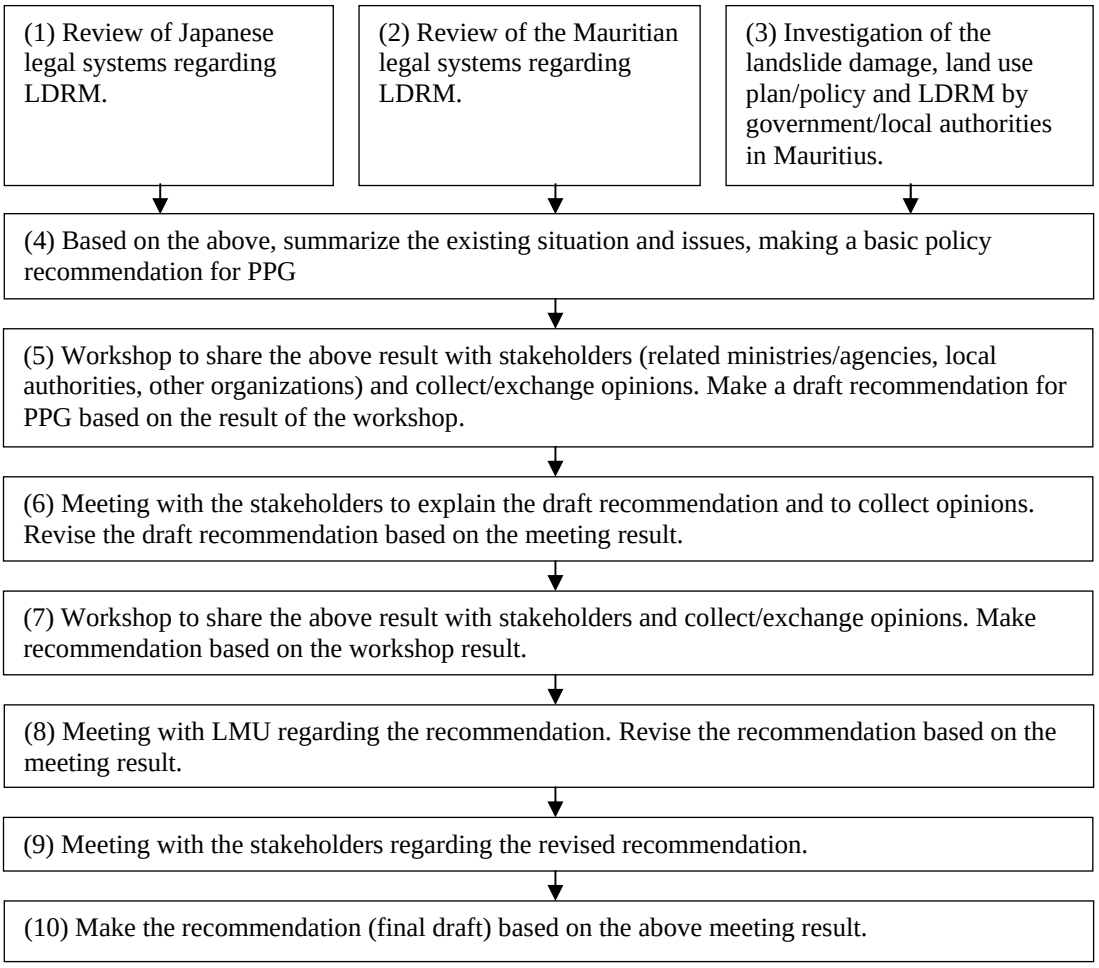


Figure 3.10.1 Process for Making Recommendation for PPG (source: JET)

3.10.1 Review of Japanese Legal Systems for Landslide Countermeasures

There are four main Acts for countermeasure of landslide damage in Japan:

(a) Sabo Act; Erosion Control Act (legislation 1887)
(b) Landslide Prevention Act (legislation 1958)
(c) Act for Prevention of Disasters Due to Collapse of Steep Slopes (legislation 1969)
(d) Landslide Disasters Prevention Act (legislation 2000)

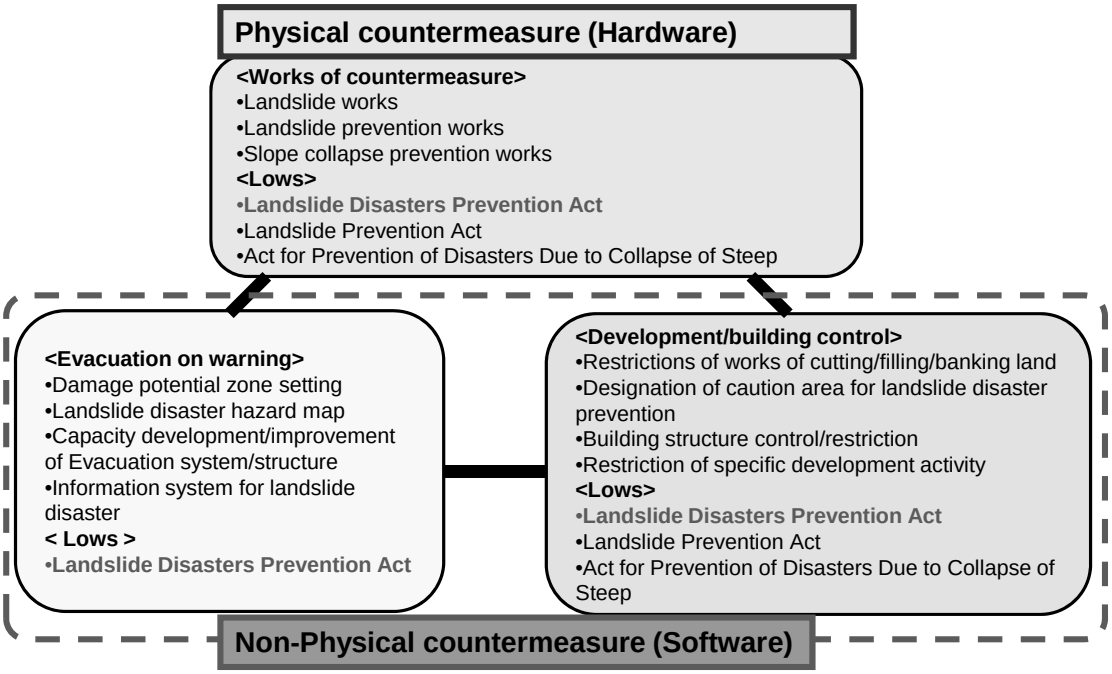


Figure 3.10.2 Japanese Legal Systems for Landslide Countermeasures[3]

Table 3.10.1 Related Acts regarding Landslide Disaster Prevention (source:JET)

Name	Contents related with landslide disaster prevention
Disaster Countermeasure Basic Act	・ Responsibilities of municipalities ・ Disaster prevention council of municipality ・ Regional disaster prevention plan of municipality ・ Precaution/alert system by municipality mayor ・ Proactive steps by municipality mayor ・ Evacuation instructions by municipality mayor ・ Rights for designation of caution zone by municipality mayor
Building Standards Act	・ Building certification ・ Health and safety: Appropriate countermeasures such as construction of retaining walls should be taken to avoid landslide disaster damage ・ Standards of structural strength ・ Disaster dangerous zone ・ Addition of restriction by municipal ordinance
Act on Regulation of Residential Land Development	・ Restriction zone for housing land development ・ Permission for housing land development ・ Disaster prevention obligations for housing land development ・ Order for improvement
Housing Loan Corporation Act	・ Provision of loans to persons who relocate their own buildings
City Planning Act	・ Permission for development

	・ Standards for development permission
Building Lots and Buildings Transaction Business Act	・ Explanation of important matters in the agreement
National Government Defrayment Act for Reconstruction of Disaster Stricken Public Facilities	・ Regulation of cost burden to government, including what can be taken on by national government dependant on the financial capability of local authorities to cover costs for disaster recovery of public infrastructure ・ Public infrastructure facilities include: rivers, coast, erosion control, restoration of degraded forest land, landslide prevention, steep slope collapse prevention, roads, ports, fishery ports, sewerage, parks.

3.10.2 The Existing Legal Systems/schemes for LDRM in Mauritius

Table 3.10.2 The Existing Mauritian Legal Systems/Schemes for LDRM (source:JET)

Legal system/scheme	Content
Town and Country Planning Act (TCPA), 1954	・ Town and Country Planning Act (TCPA) make provisions for social appeals about development restrictions/regulations to Local Authorities. ・ Local Authorities make Outline Planning Schemes (OPS) which contain the actual development area/boundary and its contents. The developer has to submit an application to the Local Authority about the development including information such as building/construction works, changes of the land/building use, subdivision of a land lot. ・ Local Authorities have the right to stop a development which does not follow the OPS and other related legal systems/schemes.
Planning and Development Act (PDA), 2004	・ The Planning and Development Act (PDA) is a new and modern piece of legislation enacted to bring the planning exercise more in line with the requirements of today's changes and challenges (globalization, structural changes in the economy, the need to provide for new sectors of activities). ・ It gives legal status to the National Development Strategy which had remained as a vision document only. ・ However, only a few sections of the PDA 2004 have been proclaimed to date. ・ The objectives of PDA: Sustainable development considering ecological systems; to provide for the appropriate sharing of responsibility for planning and development between the different levels of government; to establish appropriate institutions, structures and processes to achieve effective planning and development; to encourage appropriate private sector participation in planning and development, etc. ・ The Minister of the Ministry of Housing and Lands (MHL) is able to issue Planning Policy Guidance (PPG) regarding development and land use planning to the Local Authorities based on this Act (Article 13 of PDA).
Building Act (BA)	・ Application for a building permits (including new construction, extension or reconstruction); responsibilities around dangerous building and legal proceedings are defined by this Act.
Local Government Act (LGA), 2003	・ The Local Government Act (LGA) is very closely related to the Local Authorities' jurisdiction over development plans. In particular, it covers decentralization, appropriate financial and administrative operation, procedures for development permission, property taxation etc. ・ The LGA also contains the powers and functions of the Permits and Licences Committee, applications for permits, examination of applications for permits and licences by the committee, application to Judge in Chambers, etc.
National Development Strategy (NDS), 2005	・ National Development Strategy (NDS) aims to adopt strategic guidance for the economic infrastructure development of government and local authorities with the goal of achieving development in a planned manner. ・ NDS is made up of two volumes: Volume 1, National Development Strategy & Policies, and Volume 2, Institutional and Legislative Aspects. ・ Volume 1 contains the introduction, context, vision and key development principles, core strategy for conurbation, countryside and coast, housing, social and community facilities, industry and commerce, tourism, agriculture, forestry, natural resources, environment and fisheries, transport, physical infrastructure. In the contents of the core strategy for conurbation, countryside and coast, the PPG is defined as a translated national strategy, namely, made

	easier to understand, for Local Authorities to actually achieve NDS implementation. ➢ Guidance notes are intended for use by officers involved in development control activities at central and local levels. ➢ It is expected that PPG will be an important element in preparing Local Councils' revised Local Plans and Action Area Plans by translating the NDS policies and principles for application at the local level. ➢ To provide this bridge between policy and implementation, a series of PPG notes has been prepared consistent with the NDS and policies and relevant Local Development Plans (Outline Planning Schemes) as revised.
Planning Policy Guidance (PPG), 2004	・ PPG is a scheme which has legal binding force for land use policy/planning and can contribute to LDRM in Mauritius. ・ The objective is to create a set of performance criteria and design standards that are applicable to most forms and scales of development for use by individual site owners, developers of large schemes, and assist Government and Local Authorities when considering permit applications. ・ This guidance should be considered with the NDS, Outline Planning Schemes/Local Plans, Action Area Plans and Subject Plans. ・ PPG was established in 2004 and it is revised for commercial development, cultural landscape, place of worship, industrial commercial development and small firms, urban heritage areas, radio telecommunication equipment, hotel/resort development and petrol filling stations, etc. ・ PPG has a total of six hundred pages composed of A) introduction and design principles, B) design sheets and C) technical sheets. The design sheets contain commercial development, hotels and resort development, industrial development and residential development. The section on residential development covers design for sloping sites. The design for sloping sites has the following design standards: ➢ Development will not normally be permitted on slopes steeper than 1:5 (20%). ➢ Above slopes of 1:10 (10%), and in areas of poor load-bearing capacity, the ground conditions should be checked and proposed structures certified by a qualified engineer. A Site Constraint Analysis and written statement detailing all proposed mitigation measures should be submitted to and approved by the Permit Authority prior to the commencement of any on-site works. ➢ As a general guide, development should not be any higher than 45 meters above the mountain base or, in the case of slopes facing the sea, 45 meters above Mean Sea Level.
Outline Planning Schemes (OPS)	Outline Planning Schemes (OPS) were legally established based on the TCPA. They are planned for each Local Authority. OPS have three functions: ・ To provide guidance to scheme promoters, developers and individuals contemplating a development project and the subsequent submission of a building and land use permit application; ・ To assist Government officers at Ministry and Local Authority levels when offering advice to developers and when subsequently assessing permit applications; and ・ To provide the physical development focus for programmes and projects for the variety of Ministries and agencies, as well as the private and non-governmental sectors which have an interest in land development. The Outline Planning Schemes are in two parts: ➢ The Text section which includes: ✧ the Development Context for the Scheme which outlines key development trends, constraints, issues and objectives, and ✧ the Policies and Proposals, which are written in bold, followed by their reasoned justification. The policies are grouped together according to particular subject matter or by land use type. ➢ The Map section which includes: ✧ the Development Strategy Map, covering major proposals for the whole of the District, and ✧ the Development Management Map, which shows settlements and zones where development is likely to be permitted and other areas where there are various constraints to development.
The Building and	・ The Building and Land Use Permit Guide (BLUPG) explains how to prepare,

Land Use Permit Guide (BLUPG)	submit and process an application. ・ BLUPG provides a simple, step by step guide for applicants, persons involved in preparation of plans, officers of Local Authorities, and for the public at large. ・ BLUPG can be used as a checklist for completing plans and other supporting documentation. ・ BLUPG includes the simplified contents of TCPA, PDA, BA, LGA, PPG and OPS.

3.10.3 Existing Situation of Landslide Prone Areas in Mauritius

a. Emerging Landslide Risk in the Existing Developed Area (example: Chitrakoot)

The risk of large scale landslide has existed for a long time in Chitrakoot. The housing land was developed because the risk had not been identified. The following figure shows the topographic map of Chitrakoot around 1989. The settlement of about one hundred households is confirmed by the map.

b. Disaster Damage due to Inadequate Construction Works in a Slope Area (example: Quatre Soeurs)

According to the interview survey of residents of damaged houses, they cut land and set retaining walls for house building in 2003 and then they had landslide damage due to torrential rain in 2005. Based on the above, it is considered that the cut land to the slope of soft cohesive geology caused the destabilization, the groundwater level rose rapidly, and then the landslide occurred (source: JET).

c. Sprawl in the Slope Area of Suburb under the Pressure of Development (example: Vallée Pitot)

The sprawl is confirmed from Port Louis city center to the slope of Vallée Pitot. It is considered that the landslide occurred because of haphazard development expansion that did not have drainage planning. According to the information from MPI, the population of this area is about 45,000, and 80% of the population occupies the land illegally.

3.10.4 Recommendation of PPG

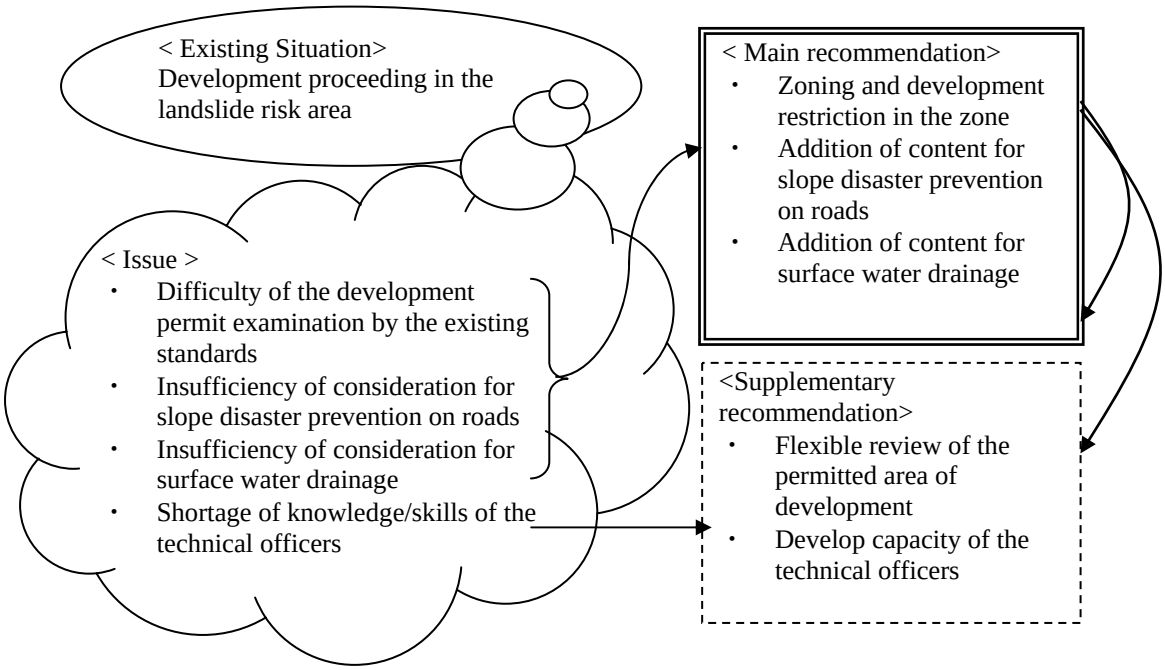


Figure 3.10.3 Outline Image of the Draft Recommendation for PPG (source: JET)

The following solutions are proposed as a main recommendation to the above issues:

- Designate the hazard zone for a slope disaster
- Restrict development in the hazard zone.

Draft proposal of addition/modification, Reason of addition/modification and necessity as recommendations for PPG are summarize in the Main Report.

3.11 Technical Guideline for Initial Survey

The Guideline covers what and how landslide disasters should be dealt with, and includes the procedures MPI should implement on landslide disasters. The procedures are composed of literature survey, initial site survey, emergency response, detailed survey plan, etc. The detailed survey/analysis/monitoring and the design/construction after the discussion of the survey plan are described in "Procedure Manual for Landslide" which is elaborated in the next section.

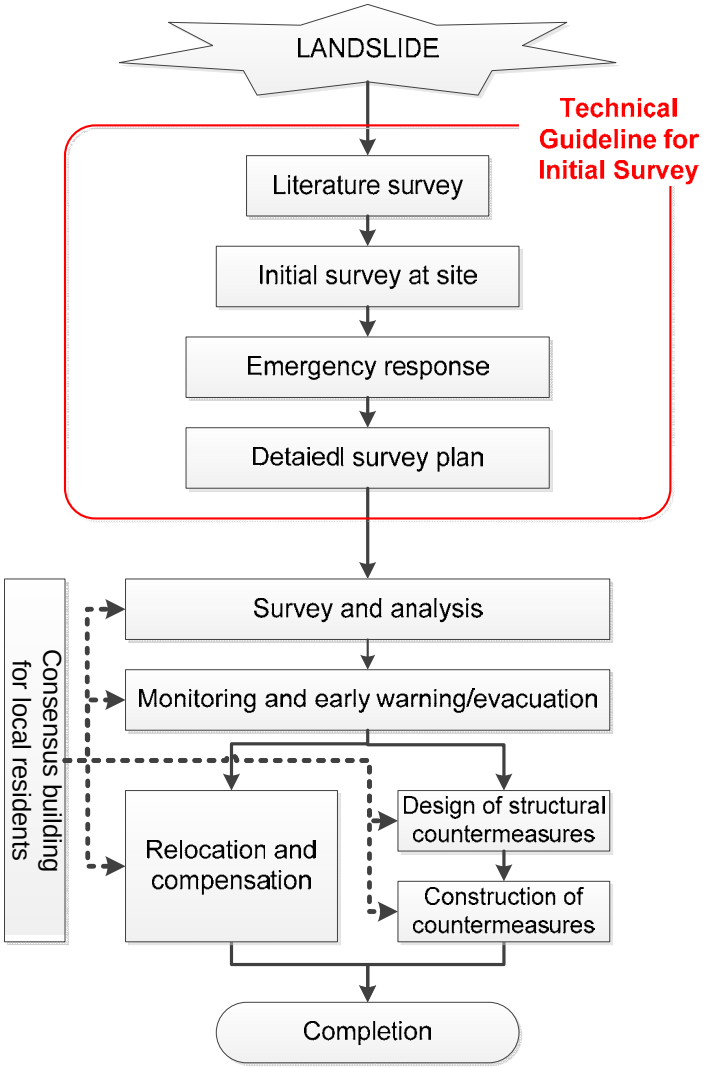


Figure 3.11.1 The scope of application of the Technical Guideline for Initial Survey (source: JET)

Table 3.11.1 The Contents of the Technical Guideline for Initial Survey (source: JET)

Cp.	Title	Contents
1	Introduction	- Contents, purpose, flow of the guideline - Outline of landslides in Mauritius - Workflow of initial survey
2	Literature survey	- Data to be collected ant their utilization - Regulation of law and land-use
3	Initial site survey	- Setting of target areas - Site survey and analysis - Monitoring for initial survey
4	Emergency response	- Structure measure - Evacuation and relocation - Early warning system
5	Detailed survey plan	- Outline of detailed survey - Outline of countermeasure policy

3.12 Procedure Manual for Landslide

The Manual covers what and how to undertake countermeasures to mitigate the disaster risk of landslides, and how to support MPI in conducting surveys/analysis and planning/design/construction of countermeasures for landslides by themselves. It is also formulated based on the review of the early warning/evacuation procedures and PPG. The manual includes strategic methods to induce development and important points to remember, as well as problems found in the F/S and the pilot project and solutions, and how the solutions were reached.

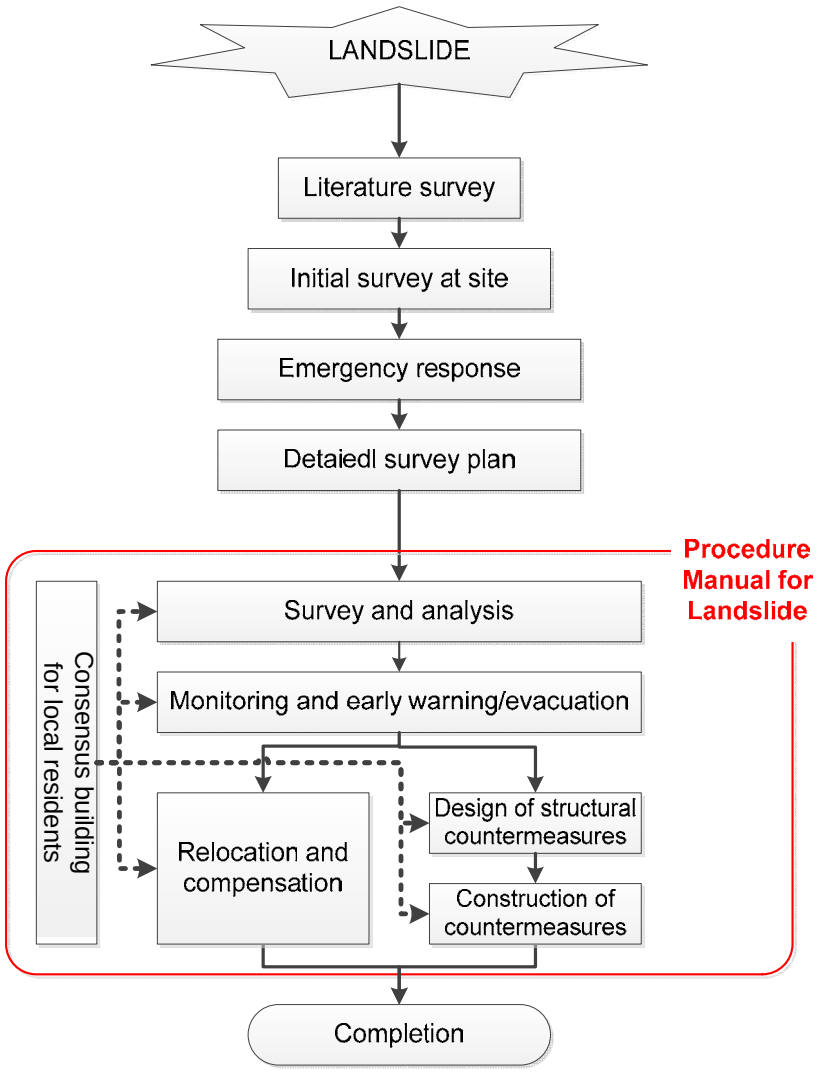


Figure 3.12.1 The Scope of Application of the Procedure Manual for Landslides (source: JET)

Table 3.12.1 The Contents of the Procedure Manual for Landslides (source: JET)

Cp.	Title	Contents
1	Introduction	- Outline of landslides in Mauritius - Contents, purpose, flow of the Manual - Application, composition of the Manual
2	Survey and analysis	- Topographic survey, aerial photo identification, field reconnaissance, drilling, geophysical exploration, laboratory test, water analysis

		- Installation of monitoring devices - Cross section, active areas/blocks, direction of movement, volume, discussion of slip surface - Basic factor and trigger - Stability analysis and safety factor
3	Monitoring and early warning/evacuation	- Monitoring system and information transmission - Setting of threshold for warning and evacuation - Responsibility and role of related organizations - Evacuation procedure
4	Relocation and compensation	- Existing law (PPG etc.) and planning scheme - Caution area and special caution area - Area setting for relocation/compensation - Implementation of relocation - Implementation of compensation
5	Consensus building for local residents	- Significance of consensus building - Flow of consensus building - When and what to be built for local residents - How to deal opinions and comments from residents
6	Design of structural countermeasures	- Basics of design of landslide countermeasures - Design of restraint works and control works - Environmental and social considerations
7	Construction of structural countermeasures	- Construction plan - Checkpoints for construction - Construction and supervision
8	Initial survey and emergency response	[Excerpt of “Technical Guideline for Initial Survey”]

Reference for Chapter 3

[1] MPI

[2] Prime Minister’s Office(2011): Cyclone and Other Natural Disasters Scheme (2011-2012), Japan International Cooperation Agency (2012): A preliminary Study on The Project for Capacity Development on Coastal Protection and Rehabilitation and the Project for Landslide Management in the Republic of Mauritius

[3] Ministry of Land, Infrastructure, Transport and Tourism (2012): Policy review report 2011 of Landslide Disasters Prevention Act (Draft)

Chapter 4

Landslide Management Plan 2
(Analysis and Interpretation)

4 Landslide Management Plan 2 (Analysis and Interpretation)

4.1 Geological Interpretation

4.1.1 Chitrakoot

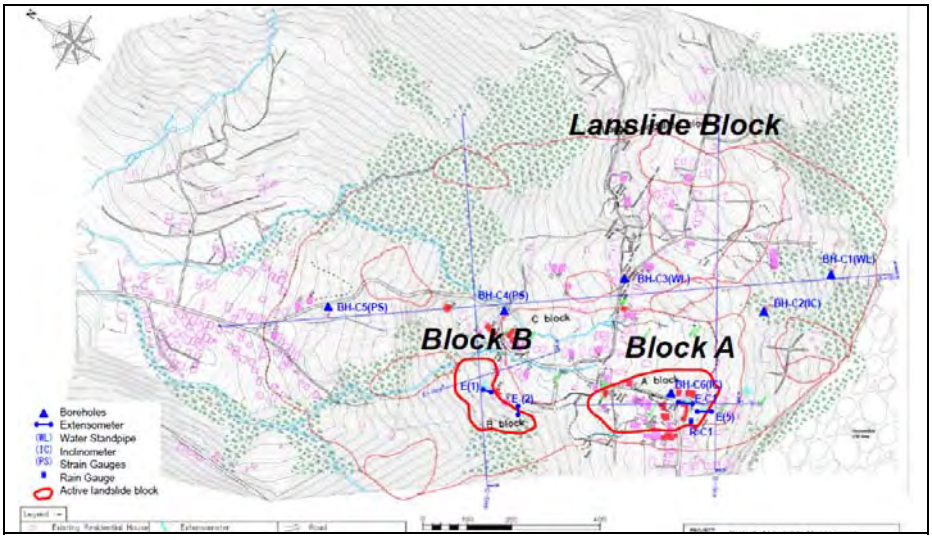


Figure 4.1.1 Landslide Blocks in Chitrakoot (source: JET)

Block A

There is the Chitrakoot Government School and many residential houses in Block A which is 300 m long and 150 m wide landslide block. The school and some houses in the block have deformations and many cracks on their structures. The landslide slip surface is confirmed by inclinometer BH-C2 in Block A at the depth of 7 m.

Block B

The most of the area of B Block, which is a 100 m long and 200 m wide landslide block, is wasteland and there are only three residential houses in Block B. All of three houses have some cracks and deformations.

Whole area of Chitrakoot

Deformations and cracks can be seen on the houses in the center and west of the whole area of Chitrakoot. These deformations and cracks indicate that the whole area was active in the past, but now there is no evidence of activity of the whole area.

There are some small blocks such as Block A and Block B within the whole area. These small blocks might have moved separately to the whole area in the past.

4.1.2 Quatre Soeurs

Two blocks can be found in Quatre Soeurs by aerial photo analysis and site survey. Block A, which is located at the toe of the slope in Quatre Soeurs, and Block B, which is located on the upper slope of Quatre Soeurs, can be distinguished as active blocks. Other blocks are not clear in Quatre Soeurs area because there is no deformation on the ground surface and

structures.

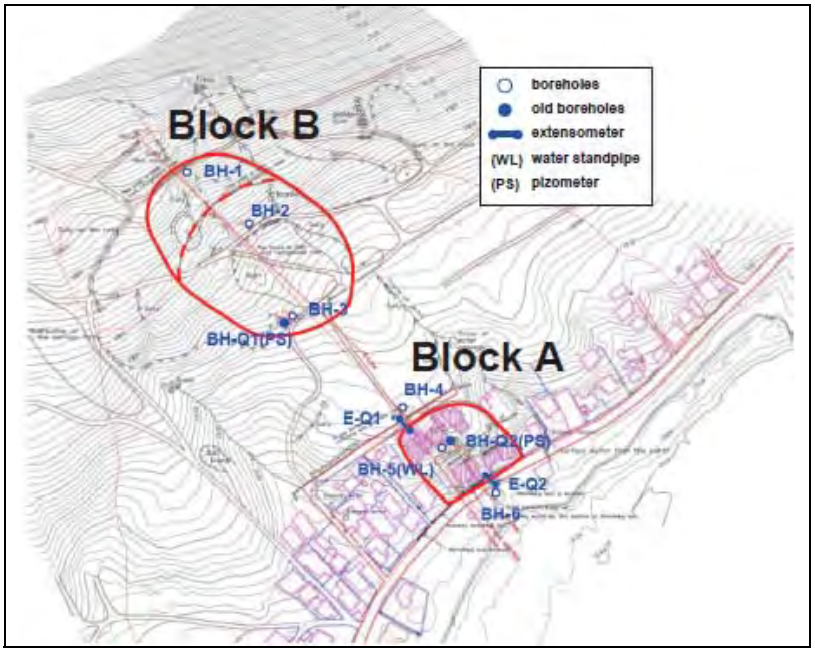


Figure 4.1.2 Landslide Blocks in Quatre Soeurs (source: JET)

Block A

Block A, which is a 60 m long and 50 m wide landslide block on a steep slope, is located in lower part of the slopes of Quatre Soeurs. Bottom of the block adjoins the coastal road. There are many residential houses in the block. The houses in the block have deformations and many cracks on their structures. Most of the deformations and cracks are caused by the landslide activities in the years of 2005 and 2008.

B Block

The surface of Block B, which is a 150 m long and 100 m wide landslide block in a gentle slope, is used for agricultural land without structures such as houses. The activity of Block B may have stopped because there are no observable deformations such as cracks or sinks in the block. And also, the strain gauges in Block B do not show any deformation.

4.1.3 Vallee Pitot

Vallee Pitot landslide area, which is about 80 m long and 100 m wide, can be divided into five small landslide blocks (A, B, C, D, E), as shown in Figure 4.1.7, according to deformations to the structures in the area. The landslide blocks A, B and C in Vallee Pitot are along the canal.

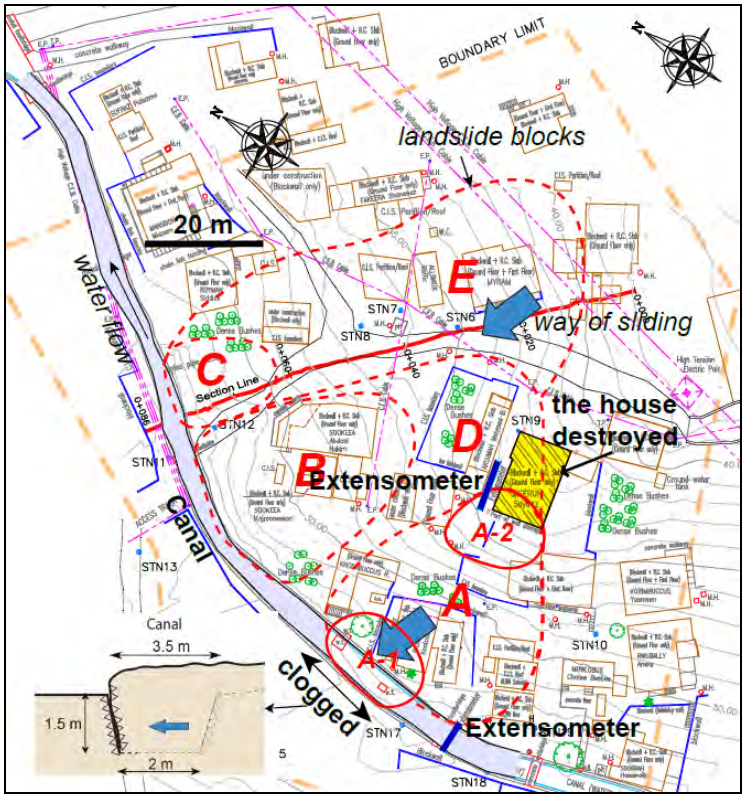


Figure 4.1.3 Landslide Blocks in Vallee Pitot (source: JET)

Details of geological conditions have not been obtained in Vallee Pitot because no geological investigations have been executed. The slip surface is estimated to be at a maximum depth of around 5-6 m according to the size of the blocks and the topographic features.

4.2 Interpretation of Monitoring

4.2.1 Chitrakoot

Block A

Activity of the landslide

Two extensometers, E(5) and E-C1, are installed in Block A.

E(5) shows small displacement about 15mm in the rainy season in 2013. Displacement at E-C1 has been within 10 mm, and large displacement has not been seen through the monitoring period. According to two extensometers in Block A, landslide activity of Block A has been presumably stopped after February 2013.

Inclinometer at BH-C6 detected activity of the landslide.

Depth of the slip surface of the landslide

Inclinometer BH-C6 in Block A shows clear bend of the pipe at the depth of 7 m. The bend must be slip surface of the landslide. The slip surface has been confirmed at BH-C6 only.

Groundwater

The groundwater level at BH-11 is above the ground surface in rainy season, and below the ground surface in non-rainy season. At BH-C1within Block A, the groundwater level was high in rainy season and low in non-rainy season. Both BH-11 and BH-C1, seasonal variation in the groundwater level is distinct, however the groundwater levels have not followed the daily precipitation or the hourly precipitation.

The groundwater in areas besides Block A record significant level changes according to season, however, groundwater level does not change after heavy rain.

Block B

Activity of the landslide

Two extensometers, E(1) and E(2), are installed in B block. Both E(1) and E(2) shows deformations from installation. However, as mentioned in Section 3.4, the deformations of E(1) and E(2) are not a result of a big landslide. The activity of Block B may not be so active, since there are no new cracks or new deformations on the houses and structures around the extensometers,

Depth of the slip surface

The depth of the slip surface is not confirmed since instrument which can detect the slip surface is not installed in Block B.

Groundwater

The groundwater level has not been monitored in Block B and the exact groundwater level has not been obtained. The groundwater level in Block B in rainy season seems very high, because the ground surface in Block B is very wet in rainy season and the water levels in boreholes around Block B are shallow around 1 – 2m deep.

Whole Area in Chitrakoot

Activity of the landslide

The instruments which can detect the landslide activities in Chitrakoot are extensometers, inclinometers and strain gauges. The extensometers can monitor the landslide movement automatically.

Only the inclinometer at BH-C6 in Block A detected landslide activities clearly among them. Extensometers and strain gauges did not detect the landslide activities. The inclinometer at BH-C2 shows displacement which may be caused by landslide, but it is not clear.

Activity of the landslide Block A is confirmed by BH-C6, however two extensometers did not show landslide activities clearly. Therefore Block A might be divided into small blocks.

Only limited instruments have been installed in large Chitrakoot landslide area, there may be active landslide blocks other than blocks A and B.

4.2.2 Quatre Soeurs

Block A

Activity of the landslide

The distance monitoring at 2 locations at the head and the toe of Block A using the laser distance meter do not show distinct activity of Block A. The strain gauges at BH-Q2 shows some small deformations.

Block A may have moved slightly in the last 2 years, however there has been no sign of the landslide activities observable on the ground surface in last 2 years.

Depth of the slip surface

Strain gauges at BH-Q2 are installed in residential area in order to know the depth of the slip surface. According to the result of the strain gauge monitoring, small deformation which could be slip surface is seen at about 10m deep, but it is not clear.

Groundwater

Piezometer at BH5 at the center of Block A shows large fluctuation of the groundwater level.

The level is about 3.5m to 4.0m deep usually and rises to the ground surface abruptly in heavy rain. The groundwater level in Block A and precipitation is related closely. This groundwater would flow in shallow permeable soil layer.

The groundwater did not affect the landslide activities since the clear landslide activity has not been seen in Block A even though the groundwater level rose to ground surface many times.

Block B

Activity of the landslide

The activity of Block B is not confirmed since instruments to monitor the activity of the landslide are not installed in Block B. However Block B is considered to be stable since the strain gauges installed in Block B do not show any deformation of the ground.

No signs of the landslide activities have been found on the ground surface in last 2 years.

4.2.3 Vallee Pitot

Only two extensometers (EV-1 and EV-2) at the head and the toe of the landslide have been installed in Vallee Pitot. EV1 which is installed at the head of the landslide area shows big tension displacement in rainy season of 2013, however the displacement became small within 10mm after January 2014. EV2 which is installed at the toe of the landslide area shows alternation of slow tension displacement and rapid compression displacement. Compression displacement must show the landslide movement.

Typical landslide movements such as tension on top and compression on toe can be seen ion the results of two extensometers. However, the displacements are small after February 2013, and no significant displacement was monitored even in heavy rain on 21st March 2014.

4.3 Consideration of Threshold for Soil Water Index

SWI is an indicator to ascertain the amount of moisture within the soil during or after the rainfall. Unlike the extensometer and rain gauge which takes into account only the hydrological condition on the surface, SWI considers the amount of groundwater, in which the landslide activities can be estimated more accurately. Therefore, a higher accuracy threshold can be set for early warning and evacuation. SWI is also being introduced by Japan Meteorological Agency for each 5km grid in Japan.

The existing threshold for early warning and evacuation has been considered by this project using the monitoring results of extensometers and rain gauges, however SWI was also taken into consideration as a new parameter.

4.3.1 Method of Analysis

Generally the 3-Step Tank Model is used for calculation of the soil water index. The first tank indicates surface outflow, the second tank indicates surface infiltration and outflow, and the third tank indicates groundwater outflow. The rainwater flows towards the lower tank as time elapses, and the hourly shifted volume is proportional to the water volume inside the tank.

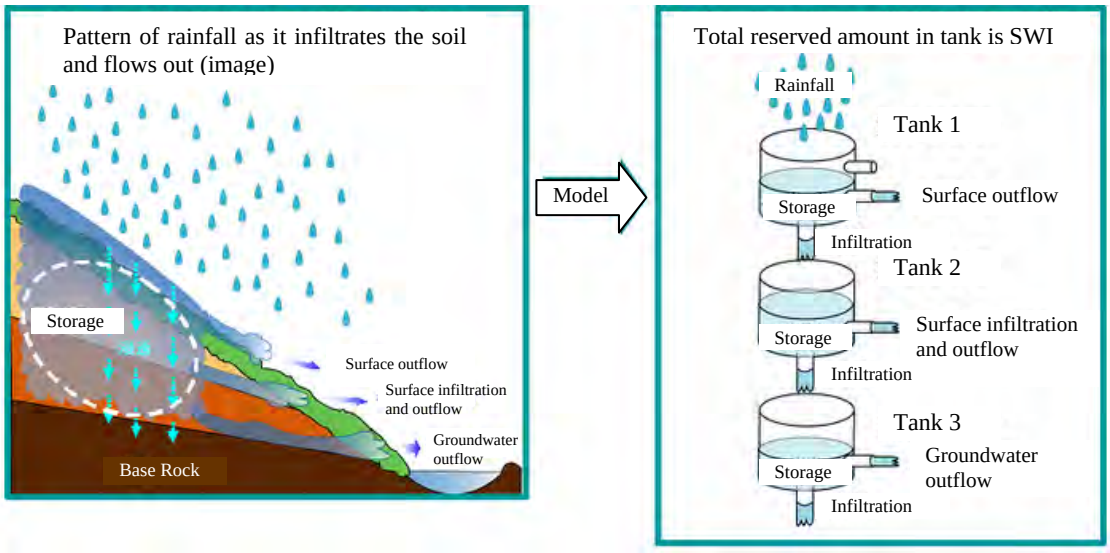


Figure 4.3.1 Image of SWI Model[1]

4.3.2 Data

a. Rainfall Data

The hourly rainfall data for the target area are needed to calculate the SWI. In this project, 2 types of rainfall data of the past (MMS and GSMaP) were obtained.

b. Disaster Record

The necessary information on sediment disaster record at Chitrakoot and Quatre Soeurs were obtained mostly in the feasibility report of this project.

c. Cumulative Precipitation

In Japan, the reference reset time is mostly around three to six hours though it could not be applied in this SWI calculation because the daily rainfall data of MMS has to be divided into 24 hours. Therefore, the reset value will be 24 hours in this SWI calculation which means that the cumulative precipitation will be reset to 0mm if it does not rain for 24 hours.

4.3.3 Result of SWI Calculation

a. Chitrakoot Area

From the consideration of MMS data, there is a potential of landslide disaster risk in Chitrakoot when the SWI exceeds 102.

From the consideration by GSMaP data, there is a potential of landslide disaster risk in Chitrakoot when the SWI exceeds 102.

b. Quatre Soeurs Area

From the consideration by MMS data, there is a potential of landslide disaster risk in Quatre Soeurs when the SWI exceeds 146.

From the consideration by GSMaP data, there is a potential of landslide disaster risk in Quatre Soeurs when the SWI exceeds 147.

4.3.4 Introduction of SWI in Mauritius

a. The Threshold of Early Warning and Evacuation using SWI

- Chitrakoot：SWI more than 102
- Quatre Soeurs：SWI more than 146

b. Improvement of Accuracy in Future

The thresholds using SWI in this calculation were based on the MMS data (daily rainfall data divided in to 24 hours) and GSMaP data which originally have to be calculated by the actual hourly rainfall data.

Also, the consideration of the threshold could not be done sufficiently because the disaster record is barely organized and the detailed information (date, movement, etc.) are unavailable in Mauritius.

- Introduction of the meteorological system which can measure hourly rainfall throughout Mauritius.

- The accumulation and management of sediment disaster record by NDRMMCC or MPI.

By solving these two tasks, the SWI can be calculated using actual rainfall data and the higher accuracy threshold could be set from the accumulated disaster record.

4.4 Stability Analysis

4.4.1 Factor of Safety

Stability of a landslide is evaluated based on its factor of safety. The factor of safety is obtained by stability analysis of landslide using result of monitoring and geotechnical investigations. Then a current stability of the landslide, whether it is active (factor of safety Fs<1.0) or it is dormant (factor of safety Fs>1.0) is determined.

Table 4.4.1 Definition of Safety Factor for Landslide[2]

Safety factor	Landslide condition
Fs = 0.95	Case inmoving continuously anytime
Fs = 0.98	Case in moving continuously for corresponding to rainfall etc.
Fs = 1.00	Case in settling down of the landslide

4.4.2 Setting Parameters

4.4.3 Method of Stability Analysis

4.4.4 Stability Analysis

a. Chitrakoot Area

The stability analysis of the active landslide blocks (Block A and Block B) was carried out in the Chitrakoot area as follows.

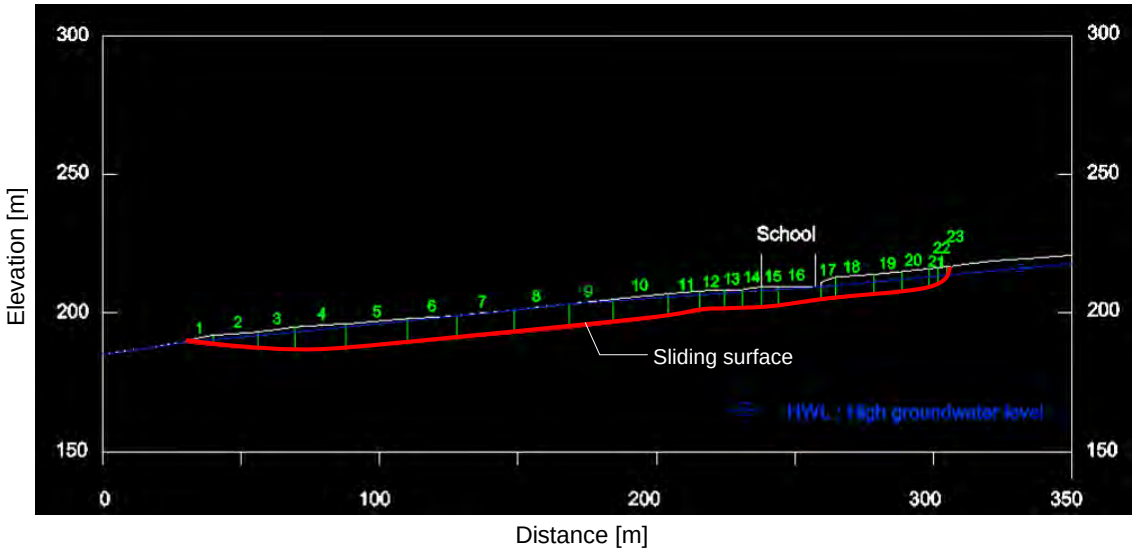


Figure 4.4.1 Longitudinal Section for Stability Analysis, Block A in Chitrakoot (source:JET)

Table 4.4.2 Result of the Stability Analysis, Chitrakoot Area (source:JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A	0.98	18.0	5.0	5.37
Block B	0.98	18.0	5.0	7.67

b. Quatre Soeurs Area

The stability analysis of the two landslide blocks (Block A and Block B) which moved in 2005 was carried out in the Quatre Soeurs area as shown below

Figure 4.4.2 Longitudinal Section for Stability Analysis, Block A in Quatre Soeurs (source: JET)

Table 4.4.3 Result of the Stability Analysis, Quatre Soeurs Area (source:JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A	1.00	16.0	8.0	16.08
Block B	1.00	16.0	8.0	13.00

c. Vallee Pitot Area

The stability analysis of the two landslide blocks (Block A-1 and Block E) was carried out as shown below.

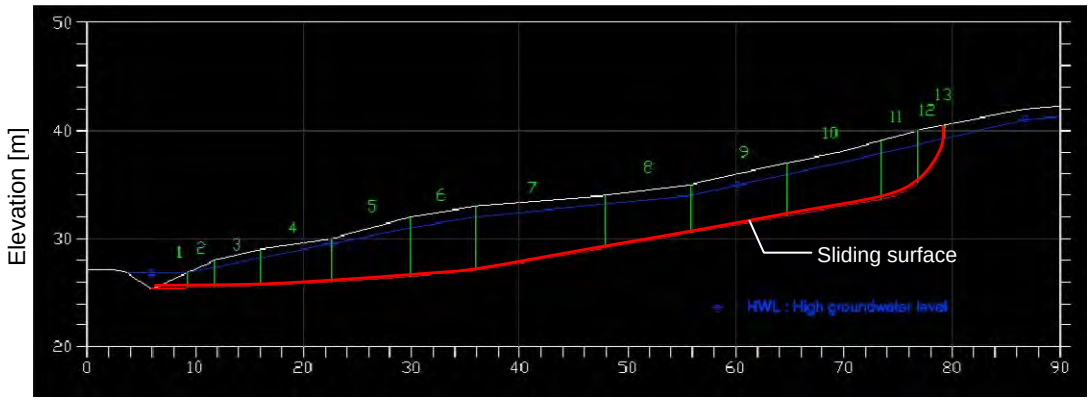


Figure 4.4.3 Longitudinal Section for Stability Analysis, Block E in Vallee Pitot (source:JET)

Table 4.4.4 Result of the Stability Analysis, Vallee Pitot Area (source: JET)

Landslide block	Current factor of safety Fs_0	Unit weight γt [kN/m^3]	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Block A-2	0.98	18.0	1.5	12.21
Block E	0.98	18.0	5.0	9.88

4.4.5 Evaluation of the Soil Strength

The residual strength of the landslide clay is provided by the ring shear test that is one of the laboratory soil tests. The validity of strength C (cohesion) and φ (shear resistance angle) of soil used in landslide stability analysis is inspected through a comparison with the residual strength.

Table 4.4.5 Results of Ring Shear Test, Cohesion C and Shear Resistance Angle φ (source: JET)

Landslide	Setting method of the soil strength	Cohesion C [kN/m^2]	Shear resistance angle φ [deg]
Chitrakoot Block A	**Result of ring shear test**	**8.7**	**11.8**
	Soil strength used in landslide stability analysis	5	5.37
	Estimate from plasticity index PI	-	4-22
Quatre Soeurs Block A	**Result of ring shear test**	**5.7**	**12.2**
	Soil strength used in landslide stability analysis	8	16.08
	Estimate from plasticity index PI	-	4.5-24.5
Vallee Pitot Block A-2	**Result of ring shear test**	**1.5**	**12.21**
	Soil strength used in landslide stability analysis	5	9.88

[Chitrakoot, Block-A]

It is judged that the result of ring shear test does not accord with the present conditions of the landslide activity. It is thought that this is because the collected soil samples have different characteristics to that of the landslide clay, and the result of the ring shear test is not suitable for stability analysis.

[Quatre Soeurs, Block-A]

The result of the ring shear test is slightly smaller than C and φ of the stability analysis but is very near to these values, and it is distributed within the estimate from plasticity index PI. From this, it is judged that the strength of soil used for stability analysis relatively accurate.

[Vallee Pitot, Block-A2]

The results of the ring shear test are distributed extremely close to the C-φ line, and are distributed within the estimate from plasticity index PI. From this, it is judged that the strength of soil used for stability analysis was appropriate.

In Vallee Pitot, a detailed landslide investigation and monitoring will be carried out from 2015 by C/P (MPI). When the detailed design of the landslide countermeasure is carried out in future here, all the results such as results of C-φ diagram, ring shear test and the detailed landslide investigation should be considered, and the strength of the soil should be set again.

[Summary]

In the case of Chitrakoot, because the slip surface is located in the border of colluvium and weathered basalt, it is assumed that the strength of the slip surface was different from the strength of provided colluvium in a ring shear test.

On the other hand, in Quatre Soeurs and Vallee Pitot, because there is a slip surface in colluvium, it is thought that the strength of the ring shear test was about the same as the strength of the slip surface.

4.5 Susceptibility Assessment

Chitrakoot area

The susceptibility of the big landslide block and the small active landslide blocks (Block A and Block B) were assessed in the Chitrakoot area as follows:

Table 4.5.1 Results of Susceptibility Assessment in Chitrakoot Area (source: JET)

Item	Description	
	Block A	Block B
Landslide movement And Groundwater level, Rainfall	➢ The groundwater level rose to near the ground surface in the wet season from January to March, 2013. ➢ There was naturally occurring flow from the borehole. ➢ Landslide movement was confirmed after rain. ➢ The occurrence of landslide movement in times of rain was confirmed in the extensometer and inclinometer.	➢ Spring water was confirmed on the ground surface in the wet season from January to March, 2013. ➢ It is estimated that the groundwater level rises to near the ground surface. ➢ The occurrence of landslide movement in times of rain was confirmed in the extensometer.
Change in ground surface/structure	There was damage to sixteen (16) houses and roads in the landslide block	There was damage to three (3) houses in the landslide block
Stability analysis result	Fs_0＝0.98	Fs0＝0.98
Result of Susceptibility Assessment	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of countermeasures	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of countermeasures

Quatre Soeurs area

The susceptibility of the active landslide blocks (Block A and Block B) was assessed in the Quatre Soeurs area as follows:

Table 4.5.2 Results of Susceptibility Assessment in Quatre Soeurs Area (source: JET)

Item	Description	
	Block A	Block B
Landslide movement And Groundwater level, Rainfall	➢ The groundwater level rose in the wet season from January to March, 2013. ➢ Spring water was confirmed after the rain. ➢ However, landslide movement was not confirmed during the monitoring period in 2013.	➢ The groundwater level rose in the wet season from January to March, 2013. ➢ Spring water was confirmed after the rain. ➢ However, landslide movement was not confirmed during the monitoring period in 2013.
Change in ground surface/sturacture	➢ In 2005, eleven (11) houses and roads were damaged in the landslide block ➢ However, in the wet season from	➢ The land in the block is used as farmland, and there are no houses. ➢ Since 2006, damage to the land has not been not confirmed

	January to March, 2013, the progress of the damage was not confirmed	
Stability analysis result	Fs_0＝1.00	Fs0＝1.00
Result of Susceptibility Assessment	**Medium-Risk** ➢ Continuation of monitoring ➢ It is necessary to investigate countermeasures	**Medium-Risk** ➢ Continuation of monitoring ➢ It is necessary to investigate countermeasures

Vallee Pitot area

The susceptibility of the active landslide blocks (Block A-2 and Block E) were assessed in the Vallee Pitot area as follows:

Table 4.5.3 Results of Susceptibility Assessment in Vallee Pitot Area (source: JET)

Item	Description	
	Block A-2	Block E
Landslide movement And Groundwater level, Rainfall	➢ Spring water was confirmed in the wet season from January to March, 2013. ➢ The occurrence of sudden landslide movement in times of rain was confirmed in the extensometer.	➢ Spring water was confirmed on the ground surface the in wet season from January to March, 2013. ➢ In times of heavy rain,new cracks formed, and landslide movement was confirmed..
Change in ground surface/sturacture	➢ In January 2013, two (2) houses were damaged in the landslide block, for a landslide movement, inhabitants relocated ➢ The main scarp and neighboring cracks suddenly spread.	➢ In January 2013, three (3) houses were damaged in the landslide block ➢ The main scarp and neighboring cracks suddenly spread.
Stability analysis result	Fs_0＝0.98	Fs0＝0.98
Result of Susceptibility Assessment	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of the countermeasures	**High-Risk** ➢ Continuation of monitoring ➢ Immediate implementation of the countermeasures

Reference for Chapter 4

[1] Meteorological HP
[2] Japan Construction Engineer's Association (2010)

Chapter 5

Feasibility Study

5 Feasibility Study

5.1 Priority Site and Pilot Project site

5.1.1 Selection of Priority Site

Chitrakoot is one of the largest and most active landslides in Mauritius. Its volume and disaster scale are so large that many countermeasures which are model cases in Mauritius would be adopted. In addition, due to the strong request from the Mauritian government. Therefore, Chitrakoot is selected as the priority site.

For Vallee Pitot area, because MPI requested that they would work on the landslide measures by themselves for improvement of their sustainability it is not chosen in the priority area. MPI is going to start a detailed landslide investigation and monitoring in the Vallee Pitot area after October, 2013.

For Quatre Soeurs area, because the relocation of inhabitants by MPI has made progress, it is not chosen in the priority area.

Priority Site (One sites): Chitrakoot / the Municipality of Port Louis

5.1.2 Selection of Pilot Project Site

In this project, a feasibility study (F/S) was carried out for Chitrakoot, the area chosen as the priority site. The pilot project site was selected based on the results of the (F/S). The results of the F/S are summarized below (The details of the F/S are shown in Chapter 5.6.).

- **Plan for pilot project** : The landslide countermeasures in the pilot project area will be one of the first construction works and will serve as a very important model project in Mauritius, which has many landslides.

- **Pilot project evaluation :** MPI has sufficient organization and budget to carry out the countermeasures, and there is high awareness and cooperative structure among the local government, other related organizations and the local residents. The project was highly evaluated on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) of the DAC (Development Assistance Committee). The pilot project is judged to be reasonable and effective in terms of technical, economic and social aspects.

- **EIA (Environmental Impact Assessment) :** Based on the JICA Guidelines for Environmental and Social Considerations and the contents of the MoEED's initial environmental impact assessment, land reclamation and backfilling survey, A plan that would avoid or minimize the impact on the ecosystem and relocation of residents were presented.

- **Promotion of fund raising** : The Mauritius Government, including MPI, are extremely positive and have sufficuent budget for the landslide countermeasures. Therefore, it is determined that the Mauritius Government will be able to sustain the landslide disaster management project.

- **Organizational reinforcement plan** : The Landslide Management Unit (LMU) has

effectively implemented the capacity development plan on its own initiative. The LMU has accepted the capacity development plan proposed by the Japanese Expert Team (JET) and has been actively working on its capacity development.

Based on above the results of the F/S, the Chitrakoot area is judged to be suitable as the pilot project site.

Pilot Project Site (One site): Chitrakoot / The Municipality of Port Louis

5.1.3 Disaster Scenario at the Pilot Project Site

The disaster scenario should be discussed for consideration of countermeasures in the Pilot Project site.

As mentioned before, the areas where active movement is recognized in the Pilot Project site, Chitrakoot, are following small blocks. The disaster scenario is described for each block.

- Block A: Landslide: length 250m * width 100m * depth 6m
- Block B: Slope failure (creep deformation): length 100m * width 150m

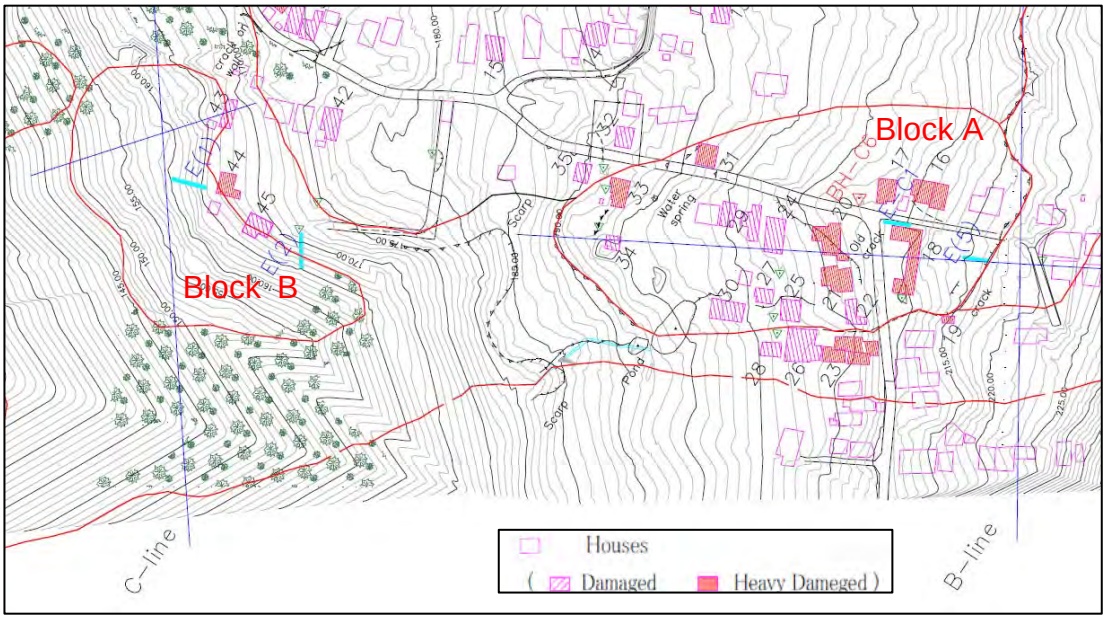


Figure 5.1.1 Location of the block A and B (source: JET)

5.2 Policy of Countermeasures

5.2.1 Plan for Countermeasures Works in Chitrakoot

a. Target Landslide Block

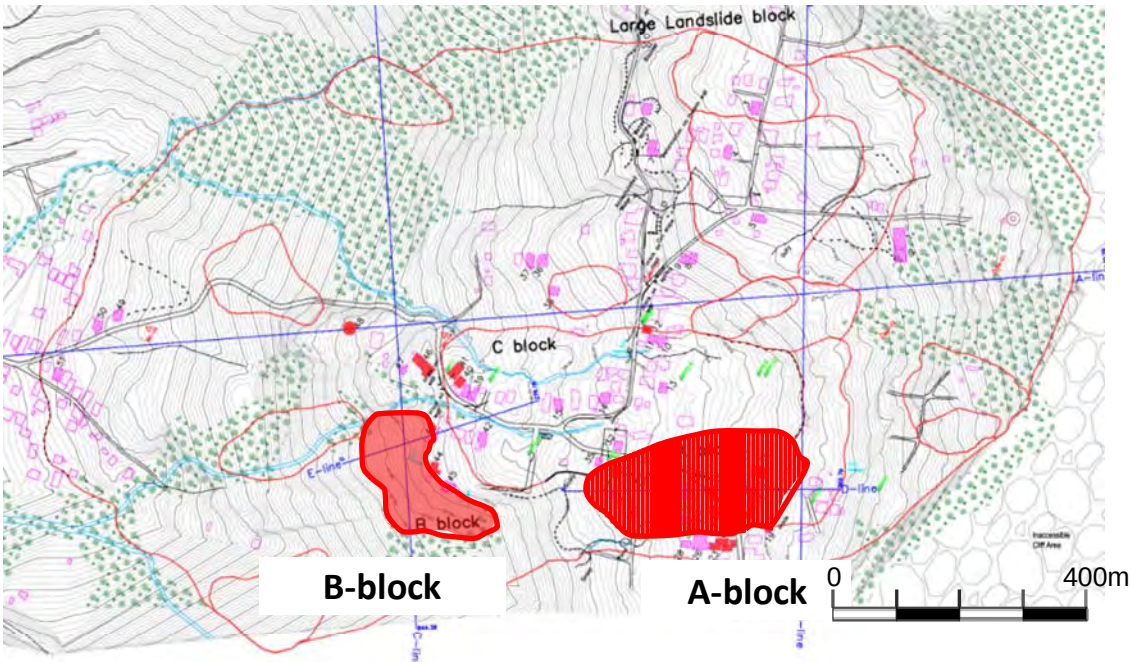


Figure 5.2.1 Target Landslide Blocks in Chitrakoot Area (source: JET)

b. Planned Factor of Safety

The planned factor of safety (hereinafter planned FoS) is to be achieved by conducting additional countermeasures to those that contributed to attaining the current factor of safety, which is defined in Chapter 4.3 above. The planned FoS can be set depending on importance of the target for protection. Since target for protection in Block A landslide is a residential area that includes a government school, the planned FoS of the Block A was set as **1.20**. Since target for protection in Block B is three houses, the planned FoS of the Block B also was set as **1.20**.

c. Basic Policy of the Landslide Countermeasure Works in Chitrakoot Area

c.1 Feature of landslide Block-A and Block-B in Chitrakoot area

- Since activity of these landslides has been detected in 2005, those landslides can be categorized as Re-activation type landslide.
- Since the landslide activity is detected in the rainy season only, it can be considered that rainfall and rising up of groundwater level is the main cause of landslide activation.
- Sudden rising up of groundwater level is occurred due to large volume of runoff water from mountain side in rain time.
- Since slip surfaces of the landslides exist at shallow depths, it can be considered that shallow groundwater influences gets involve landslide activity.
- The landslide blocks exist under the residential area.

c.2 Basic policy of countermeasure

- Since the landslide blocks will reactivate due to rises in groundwater level, groundwater drainage work is the most effect countermeasure work.
- Drainage work shall be given priority to install to avoid rising groundwater level
- Drainage work with blind ditch shall be installed to collect shallow groundwater
- From sustainability point of view, countermeasure work which can be conducted through a technical transfer in Mauritius shall be selected.
- The selected countermeasure work shall be easy to maintenance after installation.
- The impact of countermeasure works on stability and environment of neighboring slopes shall be kept to a minimum
- Existing hydraulic environment shall not be impacted by discharged water from the drainages

d. Consideration and Selection of Countermeasure Works

A factor of safety of 1.10 shall be secured by the control works.

Block A

Planned countermeasure works
Control work: Groundwater drainage work (Horizontal drainage, Open-blind ditch)
Surface drainage work
Restraint work: Pile work

Block B

Planned countermeasure works
Control work: Groundwater drainage work (Horizontal drainage, Open-blind ditch)
Surface drainage work
Restraint work: Pile work

e. Verification of Effectiveness of Planned Countermeasure Works

Block A

A factor of safety of 1.10 shall be secured by reducing the groundwater level in the landslide block by implementing control works. Planned reduction depth of groundwater level by the horizontal drainage work and open-blind ditch is -2m from High Water Level (H.W.L.)*[3]. According to the stability analysis based on the condition after implementation of the works, the factor of safety of Block A will be **1.13**.

The effectiveness of the works was verified by stability analysis using the modified Fellenius Method with calculation model, which was applied in the stability analysis for the current factor of safety (refer to Chapter 4.2). The parameters for the analysis were the same as those applied in the current factor of safety analysis. The results of the calculation are attached in theSupporting Report.

The effectiveness of the large scale channel which is planned to be installed in the upper slope of the Block A is difficult to be checked in the design phase. The effect of the channel w

According to the conditions after installation of the control works, shear force: **T** is 3293.95kN/m^2, share resistant force: **S** is 3721.18kN/m^2 and planned FoS is 1.20 (refer to Result of Calculation for verification of the effectiveness of the control works in Supporting Report).

Pr = 1.20 × 3293.95 - 3721.18 = 232

Therefore, required prevention force is **232** kN/m to achieve a planned FoS of 1.20 from 1.13.

Block B

A factor of safety of 1.10 shall be secured by reducing the groundwater level in the landslide block by implementing the same type of control works as in Block A. Planned reduction depth of groundwater level by the horizontal drainage work and open-blind ditch is -2m from High Water Level (H.W.L.)*[3]. According to the stability analysis based on the condition after installation of the works, the factor of safety of Block A will be **1.17**.

The effectiveness of the works was verified by stability analysis using the modified Fellenius Method with calculation model, which was applied in the stability analysis for the current factor of safety (refer to Chapter 4.2). The parameters for the analysis were the same as those applied in the current factor of safety analysis.. The results of the calculation are attached in Supporting Report.

For the calculation, effectiveness of countermeasure works of Block A is not considered even though these works can be expected to reduce the groundwater level in Block B also. The effect of the works of Block A can be verified by groundwater level monitoring after installation of the works.

Required prevention force for the pile work to achieve the planned FoS can be obtained by the following formula (Formula 5-1). This formula is derived from Formula 5-2 in which the required prevention force adds to the shear resistance force of Formula 5-1.

According to the conditions after installation of the control works, shear force: **T** is 1058.91 kN/m^2, share resistant force: **S** is 1244.09 kN/m^2 and planned FoS is 1.20 (refer to Result of Calculation for verification of the effectiveness of the control works in Supporting Report).

Pr = 1.20 × 1058.91 - 1244.09 = 27

Therefore, required prevention force is 27 kN/m to achieve a planned FoS of 1.20 from 1.17.

Conditions and results of the calculation of blocks A and B are shown in the table below.

f. Plan of Countermeasure Works

As a result of selection and consideration of countermeasure work described above, control works shall be arranged as follows,

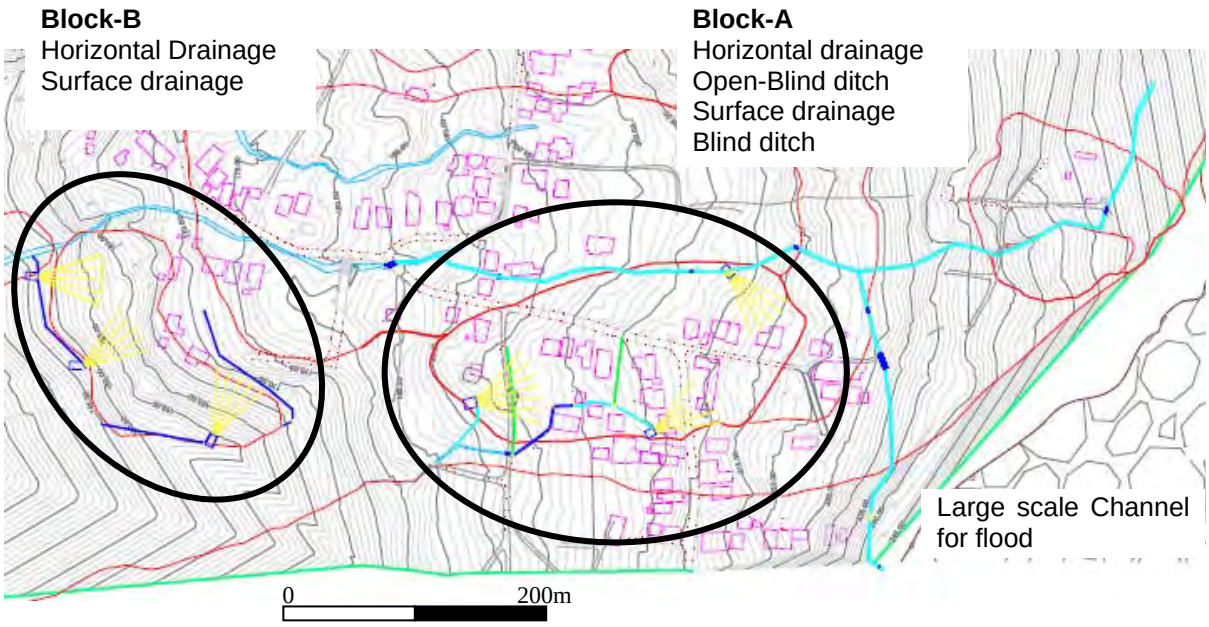


Figure 5.2.2 Plan of Countermeasure Works in Chitrakoot Area (source: JET)

5.2.2 Emergency Works in Vallee Pitot

During/after rainy season in 2013 (March - May in 2013), a soil mass slid from the mountain area and was stacked by a drainage canal in the Vallee Pitot area. The soil mass has destroyed the canal over the length of some 20 meters and totally blocked the water flow therein.

a. Issues

As mentioned in the previous section, the landslide movement has been active in Vallee Pitot since February 2013 so that the bottom of the canal in the area has been buried with sediment from the landslide. The problems and issues in the area are as follows:

- During the next rainy season (January - March 2014), rainfall water will overflow from the blocked canal with landslide debris and will flood lower parts of Vallee Pitot.
- If the rainwater is allowed to overflow in an uncontrolled manner, there is a high risk of provoking soil mass slides

Longitudinal condition of the canal", the water in the canal flows from south to north at Vallee Pitot, however at about 100m upper stream, the gradient of the canal is changed toward to south. Therefore, volume of the water flowing in the canal at Vallee Pitot is the total volume of rain water and sewerage water which are flowing into this 100m length of the canal. This canal may be expected as a role of gutter in this area.

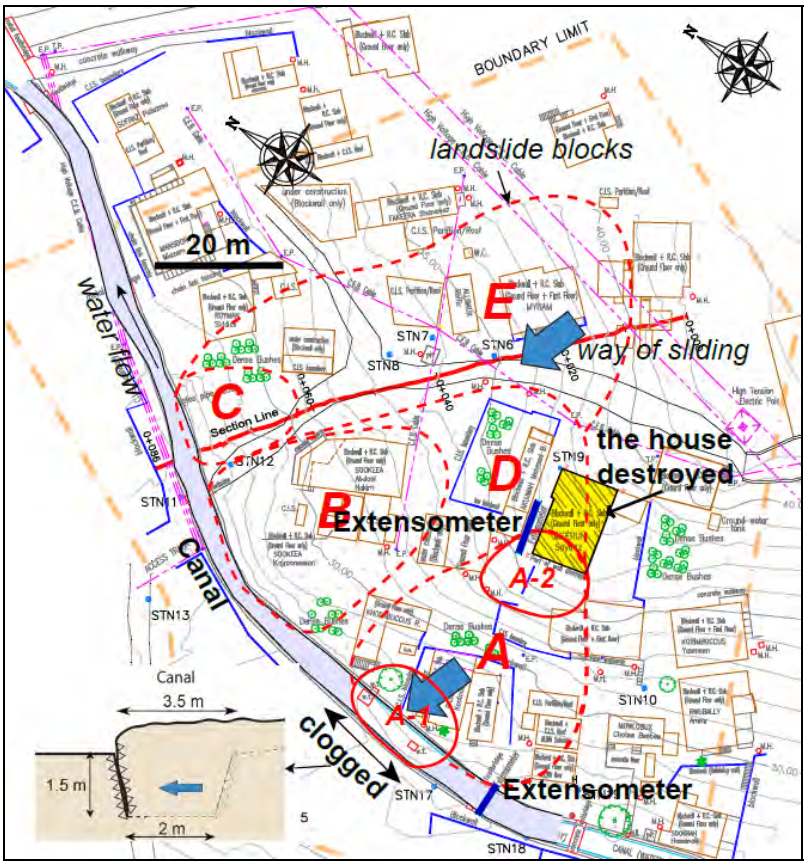


Figure 5.2.3 Location Map with Houses of the Landslides (source: JET)

b. Proposed Countermeasures

For prevention of floods and subsequent potential landslides, countermeasures should be implemented. The countermeasures in this area are divided into two (2) types as follows;

1) Emergency works for the flood problem: the emergency works must be implemented immediately and completed prior to the next rainy season (January –March 2014) and also should always remain functional until the completion of permanent countermeasure works.

2) Permanent works for the flood problem and the landslide problem: the permanent works should be conducted after detailed investigations (drilling survey/monitoring/analysis/plan) of countermeasures. The canal should be repaired after the countermeasures have been constructed and the site has been stabilized. The countermeasures may include permanent relocation of some local residents probably in the area denoted as a most active “Landslide A”.

b.1 Emergency Works

Based on the discussions on the workability/effectiveness/economic efficiency with JET and MPI out of these possible alternative solutions, “Modification of the canal gradient” is more realistic and suitable as emergency works.

However, cutting and filling must be undertaken with the construction in case of the modification of the canal gradient. Cutting and filling in landslide area may cause landslide

movement so prudent construction is needed as follows:

- Cutting and filling shall be minimized.
- Drains shall always be functional during the construction.
- Construction shall be implemented on a span by span basis (continuous excavation may trigger landslide, so that the excavation shall be conducted on sections of a few meters at a time).
- Counterweights such as sand bags shall be utilized during excavation of the canal to prevent triggering landslides.

MPI has completed the topographic survey in the area and is conducting the cutting and filling in the canal at present.

b.2 Permanent Works

Detailed investigation and continuous monitoring is indispensable for planning of the permanent countermeasures. The flow of permanent works in the area is as follows;

1) Detailed investigation
2) Monitoring
3) Analysis
4) Planning of countermeasures
5) Construction of countermeasures
6) Repair of the canal

5.2.3 Relocation in Quatre Soeurs

The following table shows the background and progress of the relocation of the inhabitants of Quatre Soeurs according to the interview survey from MPI and MHL.

Table 5.2.1 Background and Progress of the Relocation of the Inhabitants of Quatre Soeurs (source: JET)

Date	Content
Mar 2005	・ Inhabitants of Quatre Soeurs informed the landslide disaster damage to MPI. ・ MPI conducted the site survey based on the information above.
Nov 2010	・ MPI conducted the detailed survey by a consulting company. ・ The relocation of the inhabitants of Quatre Soeurs was proposed as a countermeasure in the report of the detailed survey ・ In the response of the proposal in the report above, the government has started the negotiation for relocation with the inhabitants.
Dec 2010	・ Ministry of Finance and Economic Development (MoFED) tried to evaluate the asset of the inhabitant's lands/buildings based on the survey by MHL and MPI. However, they could not obtain the results evaluation due to it is difficult to evaluate them.
Mar–May 2011	・ The government side and inhabitants have visited two times the relocation candidate site. ・ The government could not gain consensus about the relocation.
Dec 2011	・ MHL proposed the "Camp Ithier", residential development in progress, where has been developed by National Housing Development Company (NHDC) as a candidate site of relocation.

	・ The government could not gain consensus due to the difference between government's proposal and inhabitant's request regarding the area of site and buildings. ・ NHDC proposed a standard type of house which has one kitchen and two bedrooms. ・ The inhabitants have been lived in a house which has the same or more rooms/equipment/parking spaces than the NHDC's proposal. Therefore the inhabitants require the same size or larger size than their existing residential.
Jul-Sep 2012	・ The government side (MPI, MHL and Local Authority) proposed houses/lands wider than the previous meeting (candidate site of relocation: Camp Ithier). ・ The government could not gain consensus due to the difference between government's proposal and inhabitant's request.
Feb 2013	・ Deputy Prime Minister, MPI, MHL, Ministry of Education and Human Resources, Ministry of Foreign Affairs and the inhabitants (10 households) had a meeting in the Deputy Prime Minister's Office of Port Louis. ・ The government side proposed a land (460㎡) and one-story house (total floor area: 110㎡) in Camp Ithier as a compensation. ・ Nine out of ten households agreed to the proposal above.
Mar 2013	・ The negotiation is continued for one household who did not agree to the government's last proposal. ・ The government side has collected detailed request of one-story house floor plans, equipment, etc. from the inhabitants who agreed with the government's last proposal with the accompany of Building Department Staff of MPI.
May 2013	・ The government side and the inhabitants carried out a meeting in Camp Ithier. ・ The house and site drawings were shown to the inhabitants. ・ Several inhabitants signed the agreement. However, two inhabitants did not sign the agreement (because the plot land area is smaller than their existing residential). ・ The agreement of relocation has only basic outline and it does not have detailed information such as compensation payment/contents, etc. ・ The location of the plot lands was discussed with the government side with the inhabitants (location between houses and roads, kindergartens, parks, public facilities, etc.)

5.3 Environmental Impact Assessment (EIA)

5.3.1 EIA Related to Pilot Project

This pilot project falls under one of the project categories that require EIA survey, No. 24, "Land clearing and development, including installation of high tension lines in environmentally sensitive areas such as water catchment areas, waterlogged areas, wetlands, mountain slopes and islets." Therefore, an EIA survey must be conducted.

Additionally, the project implementing body for the EIA survey is the JICA Study Team. Therefore, the project is promoted according to the JICA guidelines as a policy but care was taken to meet the requirements for the EIA survey by Mauritius. The EIA survey started in mid-September 2013 and, at present, mainly the collection and analysis of existing data are being promoted.

5.3.2 Main Environmental and Social Impacts and Mitigation Measures

At present, the Study Team is creating an environmental checklist and examining possible mitigation measures based on the JICA Guidelines for Environmental and Social Considerations. This section describes the main environmental and social impact items expected for the implementation of the pilot project, degrees of these impacts, and proposals of mitigation measures, which are summarized in the table below. The environmental checklist (proposal) as of this moment is provided at the end of this document.

Table 5.3.1 Expected Environmental and Social Consideration and Impact Items and Mitigation Measures (source: JET)

Category	Environmental Item	Assessment	Expected environmental causes and mitigation measures
Pollution Control	Air Quality	C	Exhaust gas from construction machinery during construction Use well maintained heavy machinery
	Water Quality	B	Turbid water from embankment or excavated ground during construction Install stockpiles and silt traps.
	Waste	B	Solid waste, used oil, etc. generated in construction Establish a management plan for waste during construction or carry it to a waste disposal and treatment facility.
	Noise and Vibration	C	Noise and vibration from construction machinery during construction Use noise-controlled construction machinery.
Natural Environment	Ecosystem	C	Obstruction of wildlife movements by construction of surface drainage ditches Install covers in some areas because wildlife movements may be influenced a little in the rainy season.
	Hydrology	C	Although the groundwater level and surface water flow may be changed from now, measures against landslides are required.

	Topography and Geology	B	Soil erosion from excavated ground or embankment during rainfall Provide proper seepage control or dispose of surplus soil properly.
Social Considerations	Resettlement	C	There is no problem of resettlement. Land negotiations are conducted on the responsibility of MPI.
	Living and Livelihood	B	Traffic hindrance by the construction vehicles during construction The contractor conducts traffic control during construction.
	Heritage	C	No problems in particular
	Landscape	C	Take care so that the surface drainage ditches harmonize with the mountain area.

Note: A: Serious impact is expected.
B: Some impact is expected.
C: Unknown (Must be examined.)
D: Little impact is expected. (Not covered by FA/EIA)

5.4 Pilot Project Evaluation

5.4.1 Pre-Evaluation

The pre evaluation is to confirm the necessity and benefit of the project with five (5) items (relevance, effectiveness, efficiency, impact and sustainability) based on the DAC (Development Assistance Committee) criteria. It is important that the purpose of the evaluation should be set by a quantitative index and that the evaluation plan in future should be clear. The purpose and the check points of the pilot project in the Project and the check sheet in the pre evaluation are indicated as follows;

Table 5.4.1 Check Sheet of Pre Evaluation in the Pilot Project (source: JET)

Overall evaluation
It is virtually the first time landslide countermeasures such as those in the Project pilot area have been implemented in Mauritius; therefore this is a very important model case for Mauritius, which is very prone to landslides. The organization and budget in MPI are enough for countermeasures, and the local government/other related organizations/local residents have high awareness and cooperative structure. As mentioned before, high evaluations are marked on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) on the DAC. It is judged that the pilot project is reasonable and effective from technical, economic and social aspects.

5.4.2 Interim Review

The interim review is to verify the pilot project is achieving its full potential and to review and improve the plan and operational framework of the project. In general, relevance, effectiveness and efficiency are reviewed at the interim stage. The purpose and the check points of the pilot project in the Project and the check sheet in the interim review are indicated as follows;

Table 5.4.2 Check Sheet of Interim Review in the Pilot Project (source: JET)

Overall evaluation (amendment of plan/schedule/cost, compatibility with original policy, improvement/alternative plan)
There is no need of amendment of plan/schedule/cost. The relevance, the effectiveness and the efficiency for the project has been evaluated as “very high” because the project has been successfully progressed without any obstacles. Therefore it is reasonable and effective that the pilot project should be continued in accordance with the original policy.

5.4.3 Post Evaluation

The post evaluation is to improve future projects effectively and efficiently, and to fulfill the accountability of the project. In general, the five (5) items on the DAC are evaluated after the project. The purpose and the check points of the pilot project in the Project and the check sheet in the post evaluation are indicated as follows;

Table 5.4.3 Check Sheet of Post Evaluation in the Pilot Project (source: JET)

Overall evaluation
Although It was virtually the first time landslide countermeasures such as those in the Project pilot area have been implemented in Mauritius; the Mauritius government as well as the local municipality, the forest agency, the water resource agency and the local residents are cooperative with the pilot project so that MPI and JET have completed the countermeasures as scheduled. MPI allocated the enough budgets for landslide countermeasures after 2015. The works are applicable to other areas in Mauritius in the future. However the monitoring is needed to confirm the appearance of effectiveness. As mentioned before, high evaluations are marked on the five (5) items (relevance, effectiveness, efficiency, impact and sustainability) on the DAC. It is judged that the pilot project was reasonable and effective from technical, economic and social aspects.

5.5 Promotion of Fund Raising

In 2015 fiscal year and after, countermeasures are supposed to be conducted in the 37 designated areas in the Disaster Scheme. Detailed investigation and installation of monitoring devices will be implemented in 2015 fiscal year and the construction of countermeasures in 2016 fiscal year and after. MPI will reconsider the priority of countermeasures based on the results of the detailed invastigation and analysis in 2015 so that they will start the construction of countermeasures form the high priority areas.

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1.0 million Rs, 2) overtime and allowance: 0.5 million Rs, 3) preparation of hazard maps: 1.5-2.0 million Rs and 4) expert on retainer basis: 1.0-2.5 million Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2015 – 2017 are indicated as follows;

- 2015 FY: 55,650,000 Rs
- 2016 FY: 40,100,000 Rs
- 2017 FY: 44,700,000 Rs

Table 5.5.1 List of Countermeasures and Budgets in 2015-2017[1]

No.	Area name	Disaster	2015 (Rs)	2016 (Rs)	2017 (Rs)
1	Construction Works in Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block A) - Section 2	Landslide	400,000		
	Construction Works in Chitrakoot (Block A) - Section 2	Landslide	8,000,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block B)	Landslide		400,000	
	Construction Works in Chitrakoot (Block B)	Landslide		6,000,000	
2	Consultancy Services for Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	450,000		
	Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	9,000,000		
3	Remote Monitoring System in Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
4	Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
5	Morcellement Hermitage, Coromandel	Slope failure	250,000		
6	L'Eau Bouillie	Damage of embankment	250,000	5,000,000	
7	Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
8	Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000	7,000,000	
9	Pailles Soreze region	Slope failure	500,000	3,000,000	
10	Riviere des Anguilles, near the bridge	Stream erosion	450,000	9,000,000	
11	Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	250,000		
12	Piper Morcellement Piat	Stream	150,000	3,000,000	

		erosion			
13	Temple Road, Creve Coeur	Damage of wall	100,000		
14	Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
15	Congomah Village Council (Leekraj)	Damage of wall	100,000		
16	Congomah Village Council (Frederick)	Damage of wall	100,000		
17	Congomah Village Council (Blackburn Lanes)	Damage of Embankment	100,000		
18	Les Mariannes Community Centre (Road area)	Slope failure	100,000		
19	Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
20	Le Pouce Street	Stream erosion	100,000		Budget will depend on results of detailed investigations and expert recommendations. Around 40 million Rs is forecasted
21	Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
22	Pouce Stream	Stream erosion	300,000		
23	Old Moka Road, Camp Chapelon	Landslide	575,000		
24	Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
25	Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
26	Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
27	Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
29	Trou-Aux-Cerfs	Slope failure	100,000		
30	River Bank at Cite L'Oiseau	Stream erosion	100,000		
31	Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
32	Candos Hill, LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	125,000		
33	Montee S, GRNW	Stream erosion	100,000		
34	Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000
35	Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
36	Overtime Work by Landslide Management Counterparts		1,200,000	1,200,000	1,200,000
37	Maintenance and Repairs of Equipment		1,000,000	1,000,000	1,000,000
Budgetary Forecast for Financial Years 2015 to 2017					44,700,000

It is judged that the Mauritius Government including MPI is so positive towards and allocates ample budget for the landlside countermeasures that they have enough sustainability for future landslide disaster management projects.

5.6 Organizational Reinforcement Plan

5.6.1 Landslide Management Unit (LMU) in MPI

Landslide monitoring, which was previously undertaken by the National Development Unit (NDU), has been transferred to the Landslide Management Unit (LMU) since September 2009. LMU is attached to Repair and Rehabilitation Unit (RRU) in the Civil Engineering Section in order to enhance landslide monitoring.

5.6.2 Issues, Goals and Activities in Capacity Development for Medium and Long Term Plan

Issues, goals and action plans were discussed with the director of the Civil Engineering Department and the LMU engineers in 2013. The discussion details are summarized in the table below.

Table 5.6.1 Issues, Goals and Activities in Capacity Development Plan (source: JET)

Issues	Aims	Activities to achieve the aims	Outcomes
Not enough knowledge and experience of the LMU	Enhancing technical knowledge and experience	• Strengthening on site knowledge and experience by technical transfer by JET	• Technical transfer on landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and trainings in Japan.
		• Introducing a programme to study geotechnical engineering at MA level	• One LMU technical officer has applied for JICA's ABE initiative to study for a Master's degree in Japan as of November 2014.
		• Attending international seminars and conferences on landslides	• Will be considered in the future. The technical knowledge and experience will also be enhanced through equipment training from the suppliers when purchasing the equipment.
		• Exchanging skills and knowledge with the other countries	
		• Dispatching expert(s)	• MPI requested JICA to dispatch a landslide adviser in August 2014.
Not enough staff in the LMU	Securing enough and appropriate staff	• Shifting from part-time to full-time LMU staff	• Six Engineers/Senior Engineers, three Technical Officers and one Public Relations Officer/Intern will be posted to the LMU according to the official letter from Supervising Officer of the MPI. One engineer has been already posted to the LMU since October 2014.
		• Employing experienced and pre-registration trainee engineers with geology background	
		• Employing public relation officer(s) who is (are) in charge of landslide education	
		• Introducing a retainer system for specialists in order to cooperate with private and academic sectors	• The first priority of the MPI is that JICA's landslide adviser will be dispatched, however, MPI is considering employing a landslide expert on a retainer basis in case JICA's adviser is not dispatched.
Weak coordination with the other stakeholders	Improving the LMU's management capacity for landslide sector	• Defining LMU's tasks and responsibilities and producing official documents	• MPI organised several stakeholder meetings to propose and discuss tasks and responsibilities of LMU and the other stakeholders. Additionally, MPI organised one day seminar in which LMU engineers explained and finalised the tasks and responsibilities of all stakeholders in terms of responses to 37
		• Consulting with the other stakeholders in order to define their own tasks and responsibilities	

			classified sites, emergency responses and possible risk areas. Other stakeholders also presented their tasks and responsibilities for landslide management.
Little popularity of the LMU	Improving LMU's popularity	• Informing LMU's tasks, responsibilities and activities to all stakeholders by an official letter	• The tasks and responsibilities of the LMU were defined and finalised through several stakeholder meetings and hand outs distributed in the one day seminar. Regular stakeholder meetings will be organised in the future where LMU's activities and achievements will be shared with the stakeholders.
		• Issuing and distributing newsletter to introduce LMU's activities	
		• Explaining the LMU's activities on occasions such as NDRRMC	
		• Sensitising the LMU through the NDRRMC	
Not enough knowledge on landslides among the stakeholders	Improving knowledge among the other stakeholders	• Organising landslide seminars for the relevant ministries and local municipalities	• Landslide knowledge among stakeholders has been enhanced by distributing the reports issued under the project, stakeholder meetings and one day seminar organised in November 2014.
		• Issuing and distributing newsletter of landslide management which is a supplementary material for the seminars	
		• Employing temporary assigned staff from private companies in order to train and strengthen private sector personnel	• Will be considered in the future when LMU engineers obtain knowledge and experience on landslide management.
		• Establishing methodology of landslide education along with the other disasters	• Awareness of landslides among public has been strengthened through the meetings with inhabitants. Regular meetings with inhabitants will be conducted to enhance awareness further.
		• Raising awareness on land-use and development regulations	• The Ministry of Housing and Lands (MHL) updates the Planning Policy Guidance (PPG) based on the results of the landslide investigation reported by the MPI.
Evacuation plan and emergency communication network are not fully developed	Taking prompt response in emergency situations	• Strengthening evacuation system of local residents by establishing effective information and communication system	• According to the National Disasters Scheme 2014, the Ministry of Information and Communication Technology with the NDRRMC consider the methodology of disseminating disaster information to the public by Mauritius Telecom and other mobile operators.
		• Creating a hotline for all kinds of disasters for local residents	• Hotline for all kinds of disasters has been established in the NDRRMC. NDRRMC contacts MPI in case a landslide disaster

			occurs.
Emergency operation system of the LMU has not fully established yet	Establishing LMU's emergency operational system	• Creating emergency communication network within LMU	• The emergency operational system within the LMU has been established (see 5.6 d.4)
		• Establishing a dispatch system for night time, holidays and rainy season	
		• Implementing emergency communication drill within the LMU based on the above mentioned network system	• Will be implemented in the future.
		• Implementing emergency reconnaissance exercises at sites	
		• Updating the emergency communication network in order to respond to landslides anytime	• The emergency communications network within the LMU has been established. It will be amended/updated with the review of emergency responses.
Working arrangement with private sector has not been fully established yet	Establishing public/private cooperation system	• Summarising the works of survey, design, cost estimation and construction works which are allocated to the private sector	• Employing experts on a retainer basis is considered to gain the expertise of local or international geotechnical engineers. MPI/LMU will conduct the landslide management with the experts.
		• Summarising the issues in construction management system and proposing a workable arrangement	
		• Summarising the issues in completion confirmation system and proposing a workable arrangement	
		• Strengthening cooperation system with private construction companies and consulting engineers	

5.6.3 Outcomes Achieved and Future Capacity Development Plan

a. Technical Knowledge

Technical transfer regarding landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and training in Japan. The LMU engineers understand and obtain knowledge on landslide investigation and countermeasure works. One of the LMU technical engineers is currently applying for JICA's ABE initiative in order to study geotechnical engineering in master's degree and obtain academic knowledge on landslides. Moreover, MPI has applied JICA's landslide adviser in which MPI aims at enhancing technical experience adding to the abilities obtained through this project. LMU will be the main and lead organization for landslide management with academic knowledge and technical experience.

b. Organizational Establishment

As full-time staffs have not been posted to the LMU since its establishment in September 2009, engineers of the other sections in Civil Engineering Department have been assigned. Engineers have taken additional duties and responsibilities over their normal work. However, posting six Engineers/Senior Engineers was decided in March 2014. Following its decision, one engineer has been posted to the LMU since October 2014. The rest of Engineers/Senior Engineers will be posted after the selection is completed.

Together with six Engineers/Senior Engineers, posting three Technical Officers and one Public Relations Officer was decided at the same time. However, creation of a Public Relations Officer position is pending and one Intern under the Service to Mauritius (STM) programme will be recruited instead.

c. Coordination with the Other Stakeholders

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalized with the procedure below:

1) The tasks and responsible stakeholders in the ordinary and emergency situations were discussed among LMU engineers and technical officers;

2) Based on the discussions above, the responsible organizations and their tasks were summarized in the task flow;

3) The draft task flow was explained to MPI headquarters and the flow was approved by the permanent secretary of the MPI;

4) MPI organized several meetings and invited all main stakeholders such as NDRRMC, police, NDU, RDA, Mauritius Meteorological Services and local authorities to discuss the tasks and responsibilities of each organisation; and

5) The tasks and responsibilities of LMU and the other stakeholders were defined and finalized.

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

d. Emergency Operational System within the LMU

The LMU reviewed the operations in the past emergency situations and considered the emergency operational system to allocate the engineers and technical officers. Several options such as a monthly roster system were discussed, and the LMU has decided to allocate two responsible engineers and technical officers to each region of Rivière du Rempart, Pamplemousses, Port Louis, Black River, Plaines Wilhems, Moka, Flacq, Grand Port and Savanne (three engineers and technical officers are allocated to Port Louis). The emergency operational system will be revised and updated if necessary.

Reference for Chapter 5

[1] MPI

Chapter 6

Pilot Project
(Landslide Countermeasure)

6 Pilot Project (Landslide Countermeasures)

6.1 Structural Countermeasures

Table 6.1.1 Classification of Landslide Countermeasure Works[1]

Control Work ・ Surface drainage work (Drainage work, Infiltration prevention work) ・ Groundwater Drainage work Shallow groundwater drainage work (Conduit work, Open-blind ditch, Horizontal drainage work) ・ Deep groundwater drainage work (Infiltration well, Drainage tunnel work, Horizontal drainage work) ・ Soil removal work ・ Counterweight work ・ River structural facility (Dam, Consolidation work, Water control work, Revetment work)
Restraint Work ・ Pile work Pile work (Steal pipe pile work) Shaft work ・ Ground anchor work

6.1.1 Basic Design of Countermeasure Works

a. Channel for Flood Water

It has been recognized that the flow of surface water from the mountainous slope contributes to activity of the target landslides and causes flooding in the area. The channel to divert flood water shall be installed behind the landslide area to mitigate landslide activity and flooding in the residential area. It is expected to reduce runoff water into the residential area and to mitigate rising groundwater level in the target landslide area.

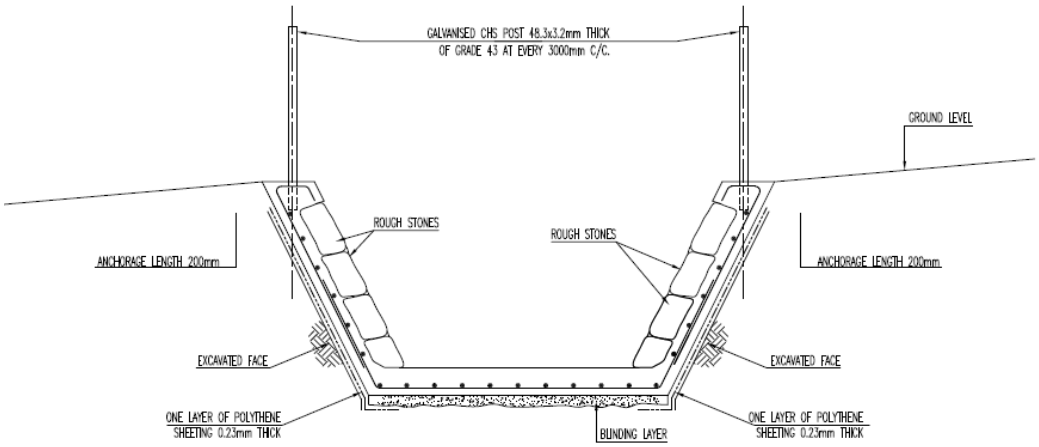


Figure 6.1.1 Typical Cross Section of Channel for Flood Water (source: JET)

b. Horizontal Drainage

The drainage pipe shall be perforated PVC pipe with 5 mm diameter holes. The internal diameter of the pipe is 40 mm.

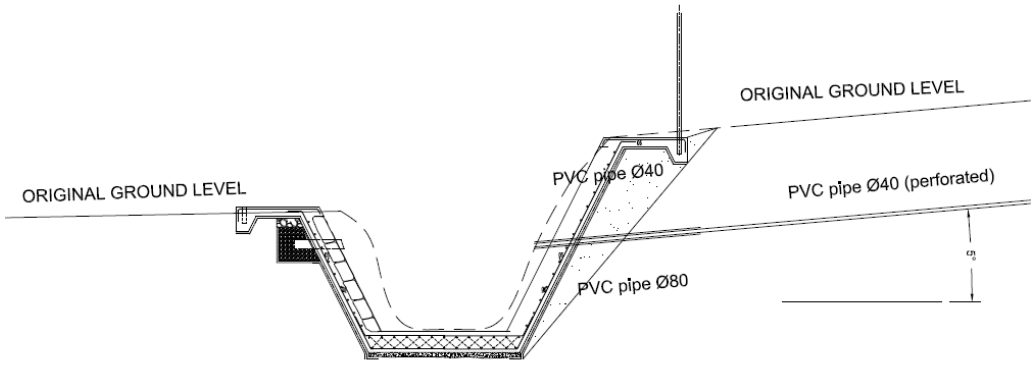


Figure 6.1.2 Typical Cross Section of Horizontal Drainage (source: JET)

c. Open - Blind Ditch

Conduit in the blind ditch part is set 1 to 1.5 m below the ground surface. Conduit pipe is perforated PVC pipe with 200 mm internal diameter. Waterproof sheet shall be laid on bottom of the blind ditch. In the blind ditch part shall be filled with crush run stone to secure permeability.

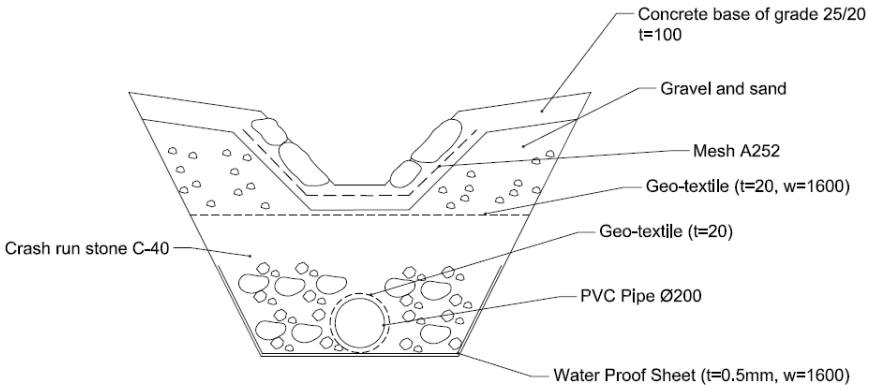


Figure 6.1.3 Typical Cross Section of Open-blind Ditch (source: JET)

d. Surface Drainage

Dimension of the open ditch part is trapezoidal with a wider top than bottom for ease of maintenance of the ditch. The surface of the ditch shall be paved by concrete to avoid infiltration of the water to the ground.

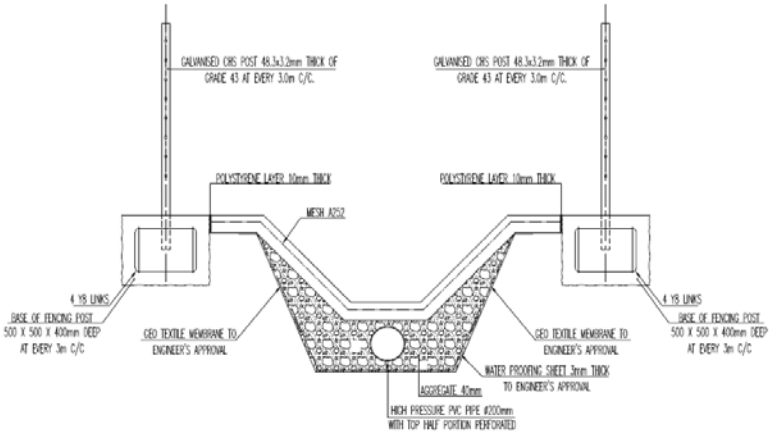


Figure 6.1.4 Typical Cross Section of Surface Drainage (source: JET)

e. Upgrade of Existing Water Course

Collected surface water collected by the channel for flood water is discharged to the existing water course (river). However, some part of the existing water course does not have sufficient capacity for the designed volume of discharge water. Therefore, there is a possibility that the existing water course cannot discharge the water properly in the heavy rain time. Upgrade work such as extension of the river dimension and protection of the river bank will be applied to the section of the water course. The river bank shall be protected by installation of boulder to avoid erosion by water flow. The section of the water course which is located on the landslide boundary will be protected by reinforced concrete structure to resist deformation by the landslide activity.

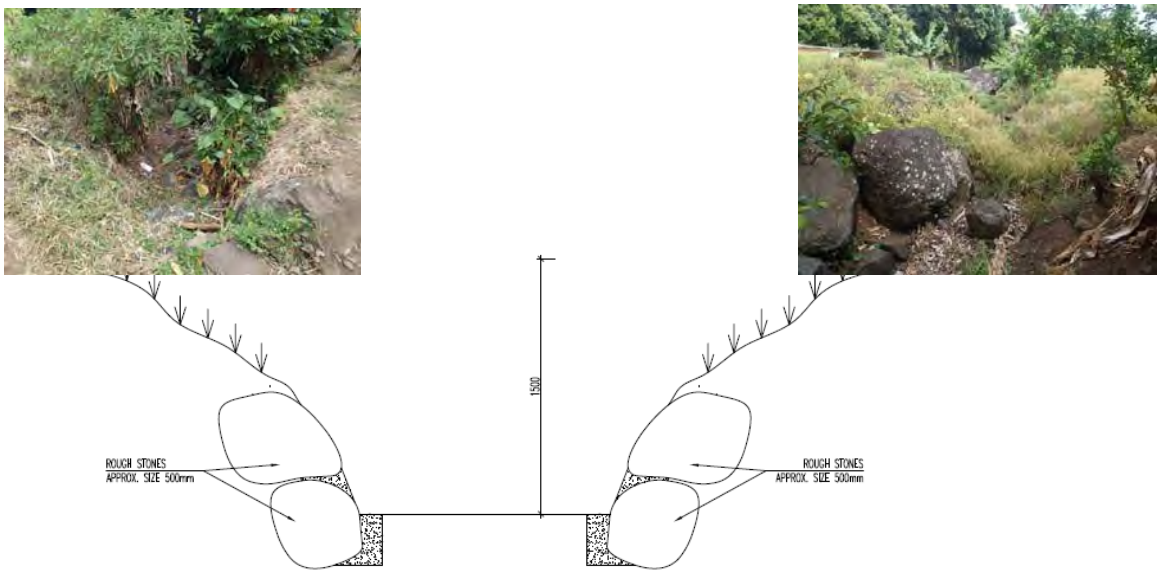


Figure 6.1.5 Typical Cross Section of Upgrade of Existing Water Course (source: JET)

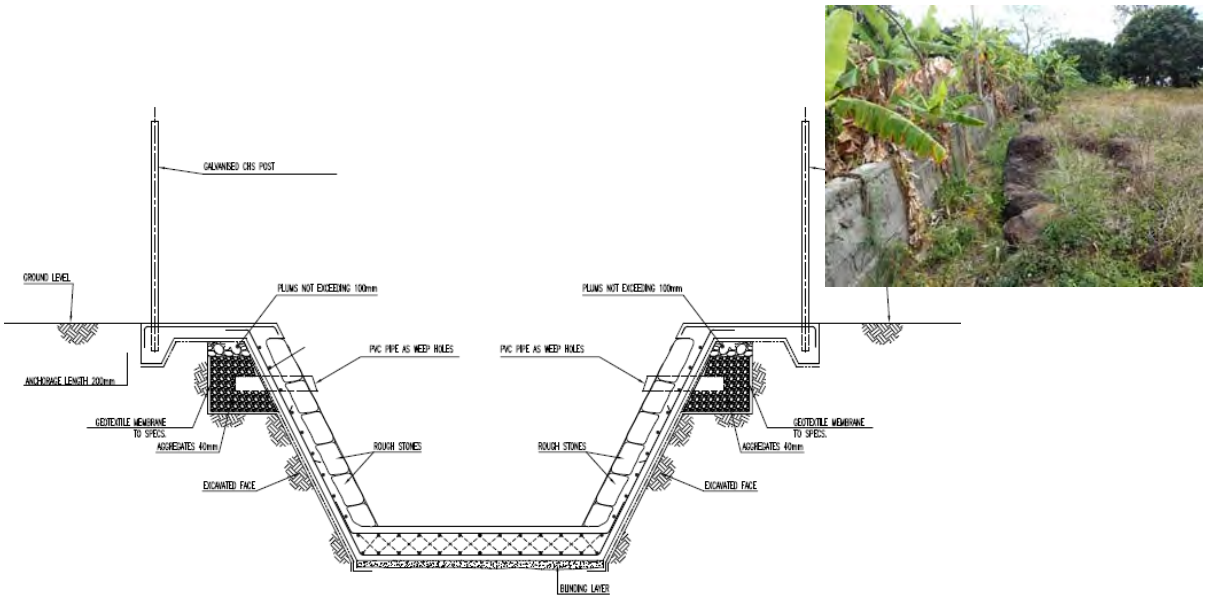


Figure 6.1.6 Typical Cross section of Protection of the Existing Water Course (source: JET)

f. Ancillary Works

f.1 Bridge

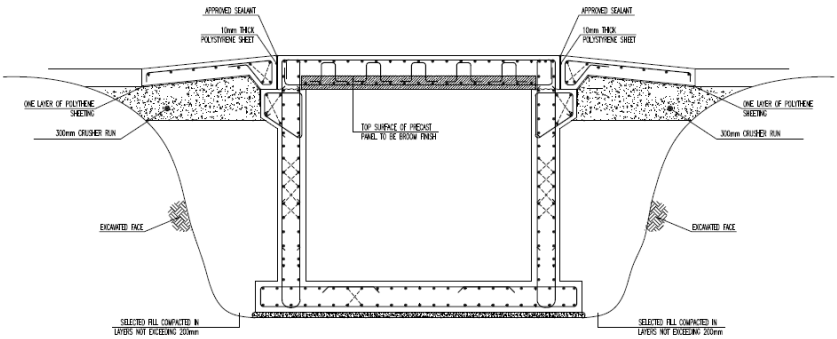


Figure 6.1.7 Typical Cross Section of the Bridge (source: JET)

f.2 Water Catch Basin

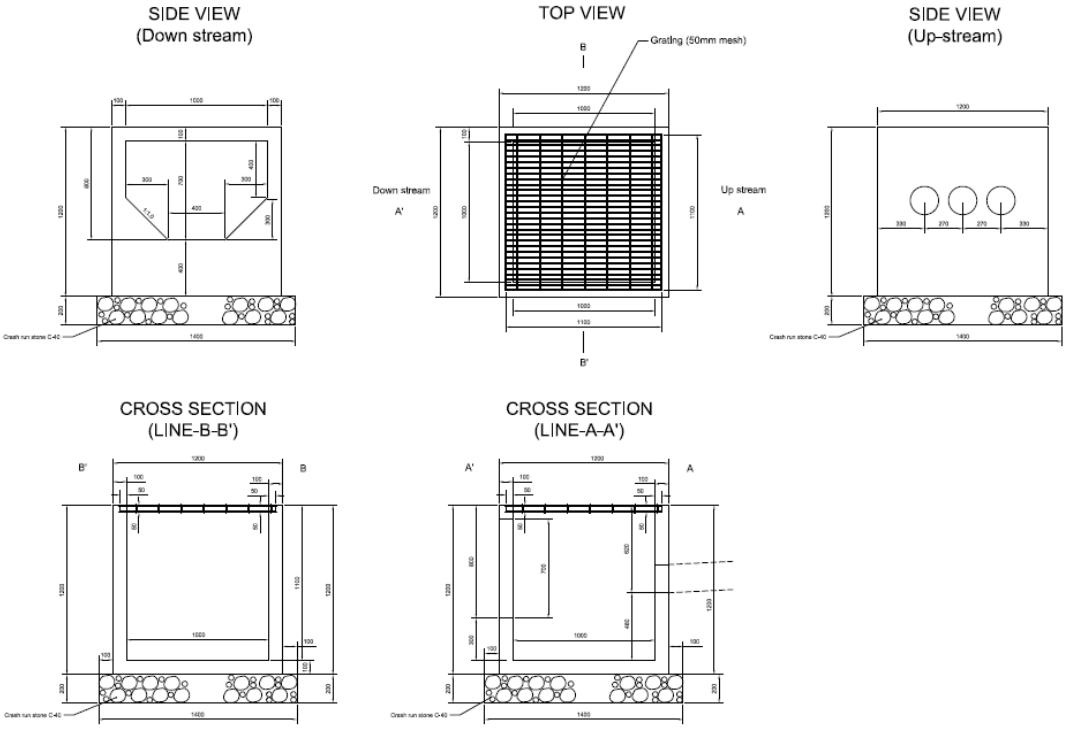


Figure 6.1.8 Typical Drawings of Water Catch Basin (source: JET)

6.1.2 Detailed Design of Countermeasure Works in Chitrakoot

a. Detail Design

Detailed design for countermeasure works in Chitrakoot area as the pilot site was carried out. A detailed specification for the structural countermeasure works was considered.

The following structural works were selected.

- Channel for flood water
- Horizontal drainage work
- Open-blind ditch work
- Surface drainage work
- Blind ditch
- Upgrade of existing water course
- Ancillary work (bridge, water catch basin)

The alignment of the countermeasure works above are shown in Figure 6.1.9.

The quantity of the countermeasure work for the Block-A landslide and the channel for the flood shall be as follows,

Table 6.1.2 Countermeasure Works (Control Work) for the Block-A Landslide (source: JET)

Work item		Quantity	Remarks
Channel for the Flood	CH-1	L=215m	
	CH-2	L=130m	
Horizontal Drainage work	HD-1	L=250m	50m*5
	HD-2	L=210m	50m*3＋30m*2
	HD-3	L=350m	50m*7
Open-blind ditch	OB-1	L=55m	
	OB-2	L=85m	
Surface drainage	SD-1	L=75m	
Blind ditch	BD-1	L=35m	Φ200*1
	BD-2	L=32m	Φ200*3
	BD-3	L=40m	Φ200*1
Upgrade of existing water course	UD-1	L=5m	Widening and protection
	UD-2	L=10m	Widening and protection
	UD-3	L=47m	Widening and protection
	RUD-1	L=175m	Widening and protection
	RUD-2	L=55m	Widening, protection and drop structure
Ancillary work	Br (for pedestrian)	2	Br-4, Br-5
	Br(for vehicle)	5	Br-1, Br-2, Br-3, Br-6, Br-7
	Water catch basin	3	

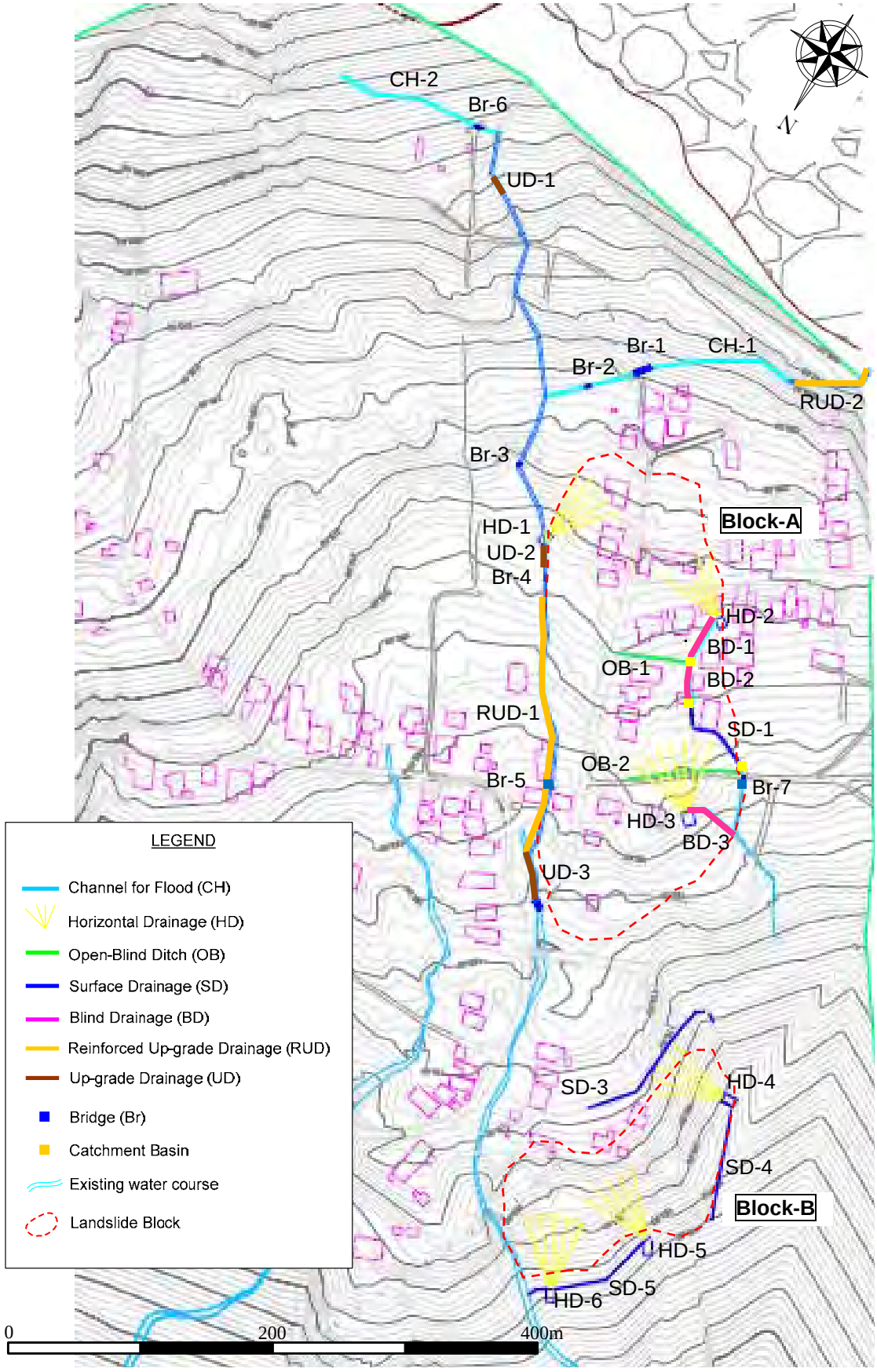


Figure 6.1.9 Location Map of Planned Countermeasure Works in Block A (source: JET)

a.1 Consideration for design of drainage dimension

Main purpose of the planning drainage works is to discharge properly the runoff and surface water at heavy rain. In a heavy rain time, large amount of water flows down with many soil, mud and fallen trees. Thus, designed cross sectional area of flow of the drainage shall be 80% of whole dimension of the drainage due to consideration of flowing down of sediments and trees. And there are many cases of sediment disaster that damage of disaster extended due to clogging of the bridge by flooding woods and changing of flowing course of water with debris. Thus dimension of flow of bridge shall be extended 20% from the dimension of the drainages.

a.2 Calculation of flow in each drainage

The required dimension of drainages was decided based on designed volume of runoff volume. The result of the calculation of the designed runoff volume and required dimension of each drainage is attached on the Supporting Report.

Runoff volume of surface water can be calculated by using the Rational formula.

$Q = 1 / 3.6 \times f \times r \times A$ ---------- (Formula 6-1)

where,
Q : Runoff volume (m^3/sec)
f : Flow coefficient
r : Intensity of rainfall (mm/hour)
A : Catchment area (km^2)

The result of the calculation of runoff volume of each drainage is shown in the table below. The detail calculation sheets are attached in the Supporting Report.

Table 6.1.3 Condition and Result of the Calculation of Runoff Volume (source: JET)

Drainage	Runoff Coefficient (f:)	Rainfall Intensity (r: mm/h)	Water catchment area (A:km^2)	Runoff Volume (Q:m^3/sec)
Channel for the flood （CH-1,CH-2)	0.4	126	0.380	5.320
Existing water course（UD-3)	0.22	126	0.017	0.131
Open-blind ditch（OB-1)	0.22	126	0.015	0.116
Open-blind ditch（OB-1)	0.22	126	0.006	0.046

Appropriate dimension of each drainage were studied in reference to the above runoff volumes.

a.3 Discharge Capacity of Drainage

The designed dimension of the channel is verified to check whether the channel has enough capacity to drain a sufficient volume of surface water.

Capacity of drainage of drains can be calculated using the following formula.

$Qa = A \times v$ ---------- (Formula 6-2)

where,
Qa: Discharge Capacity (m^3/sec)
A: Cross section area of flow (m^2)
v: Mean flow velocity (m/sec)

a.3.1 Discharge volume from the groundwater drainage work

Table 6.1.4 Condition and Result of Calculation of Discharge Volume of Each Horizontal Drainage Pipe (source: JET)

Condition	Area (A:m^2)	Mean flow velocity (v:m/sec)	Roughness coefficient (n)	Hydraulic mean depth (R:m)	Wetted perimeter (P:m)	Water slope (i:%)	Discharge volume (Q:m^3/sec)
Φ40mm, PVC	0.001	1.31	0.010	0.380	0.1005	0.08	0.00132

As the result of the calculation, designed discharge volume of the horizontal drainage work shall be as follows,

Table 6.1.5 Design Discharge Volume of Each Horizontal Drainage Work(source: JET)

Horizontal Drainage Work	Number of drainage pipe	Design Discharge Volume (Q:m^3/sec)
HD-1	5	0.0066
HD-2	5	0.0066
HD-3	7	0.0092

a.3.2 Discharge Capacity of Each Drainage

Table 6.1.6 Condition and Result of the Calculation for the Discharge Capacity of Each Designed Drainage (source: JET)

Drainage	Area (A:m^2)	Mean flow velocity (v:m/sec)	Roughness coefficient (n)	Hydraulic mean depth (R:m)	Wetted perimeter (P:m)	Water slope (i:%)	Discharge Capacity (Qa:m^3/sec)
CH-1,	1.36	5.33	0.025	0.459	2.96	0.05	7.24
CH-2	1.20	5.34	0.025	0.462	2.60	0.05	6.41
OB-1	0.19	2.45	0.025	0.143	1.34	0.05	0.47
OB-2	0.12	2.24	0.025	0.125	0.96	0.05	0.27
UD-1	1.36	5.12	0.027	0.486	2.80	0.05	6.96
UD-2	1.36	5.12	0.027	0.486	2.80	0.05	6.96

UD-3	1.36	5.12	0.027	0.486	2.80	0.05	6.96
SD-1	0.36	3.62	0.025	0.257	1.40	0.05	1.30
BD-1	0.025	3.00	0.01	0.050	0.50	0.05	0.08
BD-2	0.075	3.00	0.01	0.050	0.50	0.05	0.23
BD-3	0.025	3.00	0.01	0.050	0.50	0.05	0.08
RUD-1	1.36	5.53	0.025	0.486	2.80	0.05	7.52
RUD-2	1.17	5.00	0.025	0.419	2.80	0.05	5.87

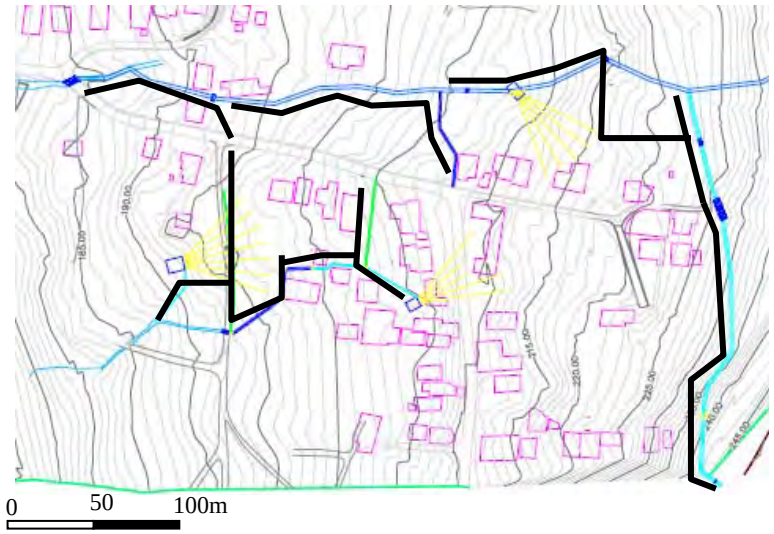
Table 6.1.7 Evaluation Result of the Availability of Designed Drainages (source: JET)

Drainage	Runoff water volume (Q:m^3/sec)	Inflow volume from the connected drainages (Q:m^3/sec)	Total inflow (Q:m^3/sec)	Discharge Capacity (Qa:m^3/sec)	Evaluation
CH-1,	5.32	-	5.32	7.24	OK
CH-2	5.32	-	5.32	6.41	OK
OB-1	0.12	-	0.12	0.47	OK
OB-2	0.05	-	0.05	0.27	OK
UD-1	-	5.32 CH	5.32	6.96	OK
UD-2	-	5.32 CH-1 0.001 HD-1	5.32	6.96	OK
UD-3	0.131	5.32 CH 0.001 HD-1	5.45	6.96	OK
SD-1	-	0.006 HD-2 0.12+0.23 OB-1	0.36	1.30	OK
BD-1	-	0.01 HD-2	0.01	0.08	OK
BD-2	-	0.01 HD-2 0.12+0.08 OB-1	0.20	0.23	OK
BD-3	-	0.01 HD-3	0.01	0.08	OK
RUD-1	-	5.32 CH 0.001 HD-1	5.32	7.52	OK
RUD-2	5.32	-	5.32	5.87	OK

a.4 Temporary work (Access road for the works)

The access roads shall be prepared for implementation of the work.

Table 6.1.8 Plan of Access Road for the Construction work (source: JET)



Total length：1,180m
Road width：2~3m

Land use
Private land, Cultivated field (Banana, Maze, Mango etc)

Since the target lands for the access road is flat/gentle, large scale excavation or fill work will not be required.

b. Quantity Survey

Table 6.1.9 Quantity Survey Result for Countermeasure Works for Block-A Landslide in Chitrakoot Area (source: JET)

Landslide	Countermeasure work	Work item	unit	quantity	Remarks
Common	Channel for the flood (Ch-1, Ch-2)	Excavation	m^3	1529.56	
		Blinding	m^2	552.34	
		Water proof sheet	m^2	849.75	
		Reinforcement	kg	13596.06	
		Rough stone	m^2	764.78	
		Safety fence	m^2	849.75	
		Frame work	m^2	329.31	
		Concrete	m^3	275.34	
Block-A	Horizontal drainage (HD-1, HD-2, HD-3)	Drilling work	m	810	>φ90mm, Installation of PVC pipe
		Excavation	m^3	633	Work space
		Concrete retaining wall	pc	3	Protection for outlet of drainage
	Open-blind ditch	Excavation	m^3	254	
		Stone wall with concrete	m^3	35	
		Mesh	m^2	280	
		Crush run filling	m^3	167	
		Geo-textile	m^2	351	
		Water proof sheet	m^2	224	
		PVC pipe installation	m	140	φ200
	Surface drainage	Excavation	m^3	87	
		Stone wall with concrete	m^3	24	
		Mesh	m^2	160	

Landslide	Countermeasure work	Work item	unit	quantity	Remarks
Block-A		Crush run filling	m^3	34	
		Geo-textile	m^2	104	
		Water proof sheet	m^2	128	
	Blind ditch	Excavation	m^3	251.1	
		Geo-textile	m^2	294.1	
		Water proof sheet	m^2	172.8	
		PVC pipe installation	m	188.0	
		Crush run filling	m^3	56.7	
		Back fill	m^3	108.0	
	Water catch basin	Concrete	m^3	41	
		Reinforcement	kg	2778	
		Excavation	m^3	42	
		Blinding	m^2	83	
		Framework	m^2	107	
	Bridge for vehicle	Excavation	m^3	50	per 1 bridge
		Blinding	m^2	15	per 1 bridge
		Reinforcement	kg	1380.4	per 1 bridge
		Framework	m^2	40.6	per 1 bridge
		Safety fence	m^2	4.8	per 1 bridge
		Back fill	m^3	8	per 1 bridge
		Concrete	m^3	28	per 1 bridge
	Bridge for pedestrian	Excavation	m^3	37	per 1 bridge
		Blinding	m^2	4.64	per 1 bridge
		Reinforcement	kg	149.9	per 1 bridge
		Framework	m^2	14.7	per 1 bridge
		Safety fence	m^2	4.8	per 1 bridge
		Back fill	m^3	2.8	per 1 bridge
		Concrete	m^3	3.04	per 1 bridge

Table 6.1.10 Quantity and Cost Estimation of Countermeasure Works in Chitrakoot Area (source: JET)[2]

Work Item		Quantity	Unit	Unit Cost	Cost of the Work (Rs)
Channel for the flood	CH-1	215	m	16,500	3,547,500
	CH-2	130	m	16,500	2,145,000
Horizontal drainage	HD-1	250	m	5,200	1,300,000
	HD-2	210	m	7,500	1,575,000
	HD-3	350	m	6,920	2,422,000
Open-blind ditch	OB-1	55	M	7,170	394,350
	OB-2	85	m	5,160	438,600
Surface drainage	SD-1	75	m	4,430	332,250
Blind ditch	BD-1	35	m	5,160	180,600

Work Item		Quantity	Unit	Unit Cost	Cost of the Work (Rs)
	BD-2	32	m	6,750	216,000
	BD-3	40	m	5,160	206,400
Upgrading of existing water course	UD-1	5	m	16,850	84,250
	UD-2	10	m	16,850	168,500
	UD-3	47	m	16,850	791,950
	RUD-1	175	m	18,200	3,185,000
	RUD-2	55	m	20,000	1,100,000
Ancillary works	Br (pedestrian)	2	pc	83,000	415,000
	Br (vehicle)	5	pc	300,000	600,000
	Water catch basin	5	pc	93,000	465,000

Rs: Mauritius Rupee

6.1.3 Plan for Construction

a. Work Plan and Schedule

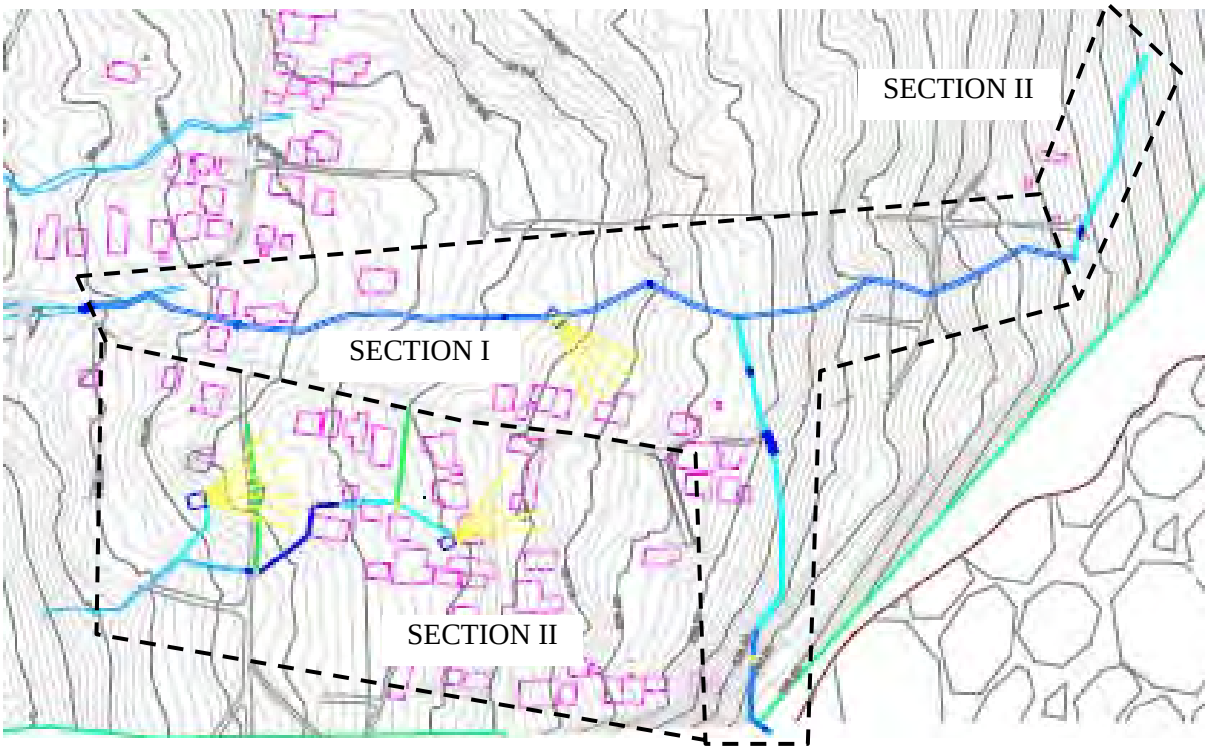


Figure 6.1.10 Work Section in Block-A Landslide (source: JET)

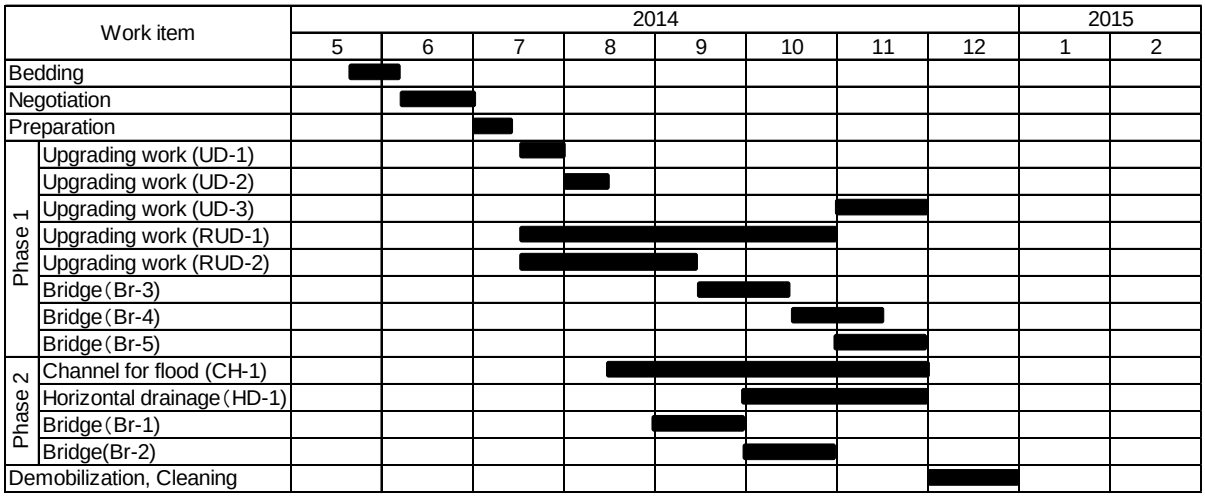


Figure 6.1.11 Work Schedule of Work Section I (source: JET)

b. Major Machinery and Materials for the Works

Table 6.1.11 Major Machinery and Materials for the Works (source: JET)

Category	Item	Specification/Capability	Applied work
Material	PVC pipe	Internal dia.φ40, φ90, φ200, Radial thickness: > 4 mm	Horizontal drainage work Open-blind ditch work
	Geo-textile	Permeability、t > 5 mm	Surface drainage work Open-blind ditch work
	Water proof sheet	PVC , t > 2 mm	Surface drainage work Open-blind ditch work
	Gabion net	1 m×1 m×2 m	Horizontal drainage work
	Cement	Portland, Premix Grade 20	General
	Crusher run	0-20mm	General
	Natural Aggregate	14-20mm	General
	Rocksand	0-4mm	General
	Coral sand	0-7mm	General
	Rough stone	t=200mm	General
	Reinforcing steel bar		General
Machinery	Excavator	Capacity of bucket: 0.5 m^2, 1 m^2	General
	Dump truck	Max. load: 4 t, 10 t	General
	Skid steer loader	0.4m^3	General
	Bulldozer	D6-D8	General
	Loader		General
	Roller	4 ton	Access road
	Waterbowser	10m^3	General
	Concrete mixer	10/7	General
	Drilling machine	Percussion/rotary Capacity of drilling depth: >100 m Drilling direction can be changed on horizontal position.	Horizontal drainage work

6.1.4 Preparation of Bidding Documents and Bidding

a. Details on Selecting the Local Contractor

As mentioned in the JICA guideline, the competitive bidding among contractors shall be selected for the contract amount above 10 million yen to ensure the transparency of public works. Therefore, the competitive bidding method was selected for this pilot project as the contract amount for the construction was estimated to be 50 million yen.

a.1 Long list of local contractors

Table 6.1.12 Long List of Local Contractors (source: JET)

	Company name
1	General Construction Co., Ltd.
2	Sotravic Limitee
3	Transinvest Ltd.
4	Colas Ltd.
5	Gamma Civic Ltd.

b. Selecting Process and Schedule of the Bidding

According to the JICA guidelines, selective competitive bidding shall commence with the required screening before the opening of the bid. Then, the lowest bidder (below ceiling price) will be the candidate for the contract negotiation.

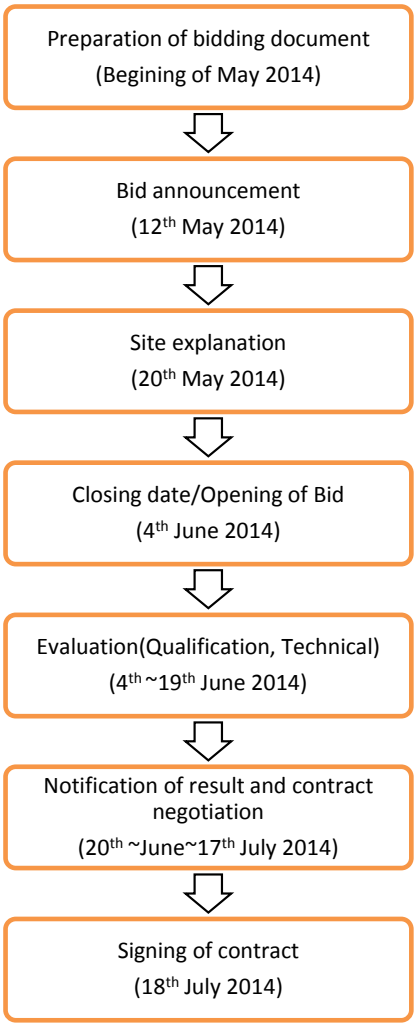


Figure 6.1.12 Schedule of the Bidding (source: JET)

b.1 Preparation of bidding documents

The bidding document was prepared based on the format of PPO. Bidding documents can be divided into three sections.

- Instruction to bidders, bidding data sheet, evaluation criteria
- Employer's requirements
- General and particular condition of contract, contract forms.

b.2 Bid announcement

The bid announcement was made to the five local contractors in the long list above.

b.3 Site explanation

The site explanation has been held on 20th May 2014. The explanation was made based on the bidding documents and four out of five local contractors participated.

b.4 Submission deadline and opening of bid

Two local contractors (Sotravic Limitee and Colas Ltd.) submitted the bidding price and technical proposal before the submission deadline.

b.5 Evaluation (requirement / technical)

The evaluation of the bid price and technical proposal of the two bidders were evaluated by the evaluation committee in two phases. First phase was the evaluation of the condition, qualification of the submitted bid and the second phase was the evaluation of the technical proposal by an engineer.

From the evaluation above, both bidders satisfied the requirements of the technical proposal. Therefore, Sotravic Limitée was selected as the first candidate for the negotiation based on the comparison of the bidding price. The result of bidding price is as shown below.

Table 6.1.13 Result of Bidding Price and Selected Bidder (source: JET)

Bidder	Bidding Price (Rs) *Upper (Excluding VAT) Lower (Including VAT)	Contract Price (Rs) *Upper (Excluding VAT) Lower (Including VAT)	Yen (¥) Equivalent of Contract Price	Result
Sotravic Limitée	14,545,723 (16,727,581.45)	14,045,723 (16,152 ,581.45)	48,766,750	Agreement of Contract
Colas Ltd	24,789,305 (28,507,700.75)	—	—	Second Candidate

Rate 1 Rs = 3.472 Yen (OANDA rate on the contract agreement (7/18))

b.6 Notification of the evaluation result and contract negotiation

The Letter of Acceptance was sent to Sotravic Limitée on 20th June 2014 and 21 days was given as the response period. The contractor prepared the Performance Security and Insurance Policies as it needs to be submitted during this period.

b.7 Signing of Contract

The Contract was signed on the 18th July 2014 with the amount of 16,152,581.45 Rs. The JET member at the site was delegated for the signing of Contract as the Project Chief was not in Mauritius.

6.1.5 Supervision

The progress and issues of the works were checked with weekly and monthly reports which were submitted by the contractor, and shared with stakeholders in the site meeting which was held at the site fortnightly.

6.1.6 Design Changes

Design of the works was changed due to unexpected issues regarding the ground condition and requests from some land owners were raised during the work period. The changed designs are shown in the table below.

Table 6.1.14 List of Changed Design Part (source: JET)

Target work	Changed item	Reason
Channel for the flood (CH-1)	Alignment	An alignment whereby less excavation soil volume than the original alignment was confirmed during the site visit
	Drainage Structure	It was confirmed that the actual ground condition is firmer than was expected based on the existing geotechnical investigation result
Bridge for pedestrian (Br-5)	Location	Land owner requested the bridge to be shifted. Upon discussions with MPI and stakeholders, the location of the bridge was shifted 15m upstream from the original position.
	Bridge Structure	In conjunction with shifting the bridge, the bridge structure was changed.
Upgrading of existing water course (UD-3)	Cancel for whole stretch of the drainage (47m)	Approval from the land owner could not be gained during the project period even though JET and MPI tried to convince the land owner in several times.
Upgrading of existing water course (RUD-1)	Drainage Structure for 70m stretch of upstream	Land owner requested that width of the drainage be made narrower than the original plan. Upon discussions with MPI and stakeholders, the drainage design was changed to one with a discharge area.
	Cancel for 35m stretch downstream	Approval from the land owner could not be gained during the project period even though JET and MPI tried to convince the land owner several times

Other minor changes were done based on discussions with MPI and land owners accordingly.

6.1.7 Future Plan

The countermeasure works of Section I at Block-A landslide has been completed in this Project. Now it is necessary that other countermeasure works are carried out continuously.

Future plan of landslide countermeasure work for the Chitrakoot area shall be carried out according the work flow shown below.

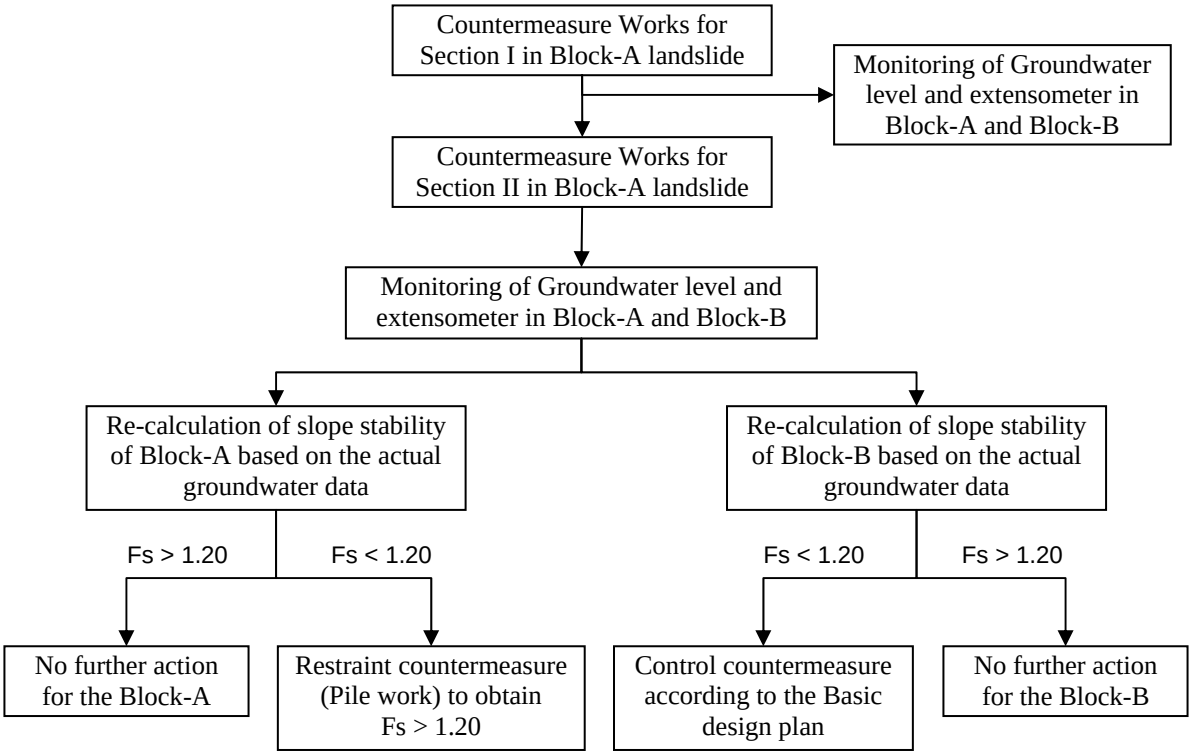


Figure 6.1.13 Flow Chart for Future Plan of Landslide Countermeasure Works in Chitrakoot Area (source: JET)

Table 6.1.15 Planned Landslide Countermeasure Works in Chitrakoot Area (source: JET)

Section		Work item	Quantity	unit	Remarks
Block-A landslide	Section II	Channel for the flood CH-2	130	m	
		Upgrading of existing water course RUD-1 (Type3 drainage)	35	m	Cancelled during Section I
		Upgrading of existing water course UD-3 (Type4 drainage)	47	m	Cancelled during Section I
		Horizontal drainage (HD-2)	210	m	
		Horizontal drainage (HD-3)	350	m	
		Surface drainage (SD-1)	75	m	
		Open-blind ditch (OB-1)	55	m	
		Open-blind ditch (OB-2)	85	m	
		Blind ditch (BD-1)	35	m	
		Blind ditch (BD-2)	32	m	
		Blind ditch (BD-3)	40	m	
		Water catch basin	5	pc	
		Bridge	2	pc	For vehicles
		Manhole for maintenance	12	pc	On the blind ditch

After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring. Since the applied groundwater level for the stability analysis

is the highest groundwater level which was observed in the rainy season, the data for the analysis shall be applied the highest groundwater level which is observed in at least one rainy season after completion of the countermeasure works of Section II.

In case that the factor of safety of Block-A landslide is more than 1.20 and no movement is detected by the extensometer, additional restraint work can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, and it shall be considered possibility of re-activation of the landslide. If rising of groundwater level or movement of landslide is detected, additional countermeasure works shall be examined.

Reference value of the groundwater level to achieve the planned factor of safety is shown below.

Table 6.1.16 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring borehole/well	Fs=1.13 (Planned)	Fs=1.20 (Final Target)	Remarks
BPP 16	> GL-2.9m	> GL-3.9m	Near the school
BPP 11	> GL-2.1m	> GL-3.1m	
W-2	> GL-3.3m	> GL-4.3m	
BPP 8	> GL-5.4m	> GL-6.4m	Out of the landslide area

GL: Ground Level

Table 6.1.17 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring Borehole	Fs=1.17 (Planned)	Fs=1.20 (Final Target)	Remarks
B-P1	> GL-3.5m	> GL-4.0m	to be installed
B-P2	> GL-3.4m	> GL-3.9m	to be installed

6.1.8 Available Countermeasure Works in Mauritius

Landslide countermeasure work shall be installed to achieve the safety factor of the target landslide to planned safety factor. If the current safety factor is not achieved to the planned safety factor after installing countermeasure work, additional work shall be considered to installed as necessary. Landslide countermeasure work in Chitrakoot area also shall be followed in same way. The landside stability in Chitrakoot shall be verified after installing the planned countermeasure works.

The countermeasure work which can be considered to be available in Mauritius in the future is as follows,

Table 6.1.18 Available Countermeasure Work in Mauritius(source: JET)

Work item		Purpose	Availability
Control work	Surface drainage work	To collect surface water and to discharge it to out of landslide area	Many experiences of the work in Mauritius.
	Open-blind ditch work	To collect surface water and shallow groundwater and to discharge it to out of landslide area	Even there is not many experiences of the work, difficulty of the work is not high
	Horizontal drainage work	To reduce groundwater level by discharge the groundwater.	The work has experienced to be carried out in the Project
	Drainage well work	To reduce groundwater level by discharge deep groundwater	Excavation of drainage will be available in Mauritius. The issue will be procure the small drilling machine to carry out horizontal drilling in the well
	Soil removal work	To reduce a sliding force of landslide by remove a head part of the landside block	Difficulty of the work is not high. However, since there are many landslide blocks in Chitrakoot area, it shall be carried out with deep caution to avoid extension of the hazard area by the work.
	Counterweight fill work	To increase resistance force against landslide by filling at toe part of the landslide block	Difficulty of the work is not high. However, since there are many landslide blocks in Chitrakoot area, it shall be carried out with deep caution to avoid extension of the hazard area by the work.
Restraint work	Ground anchor work	To stop landslide activity by tightening of anchor which is fixed on stable ground.	There is not experience of the work as landslide countermeasure work in Mauritius. The issue of the work will be procure the materials of the anchor and contractor which has many experiences of the work from abroad. Therefore, the work will be difficult to apply in Mauritius at this time.
	Pile work	To stop landslide activity by resistance force of pile which is fixed on stable ground.	Even there is not experience of the work for landslide countermeasure work done by local contractor, there are many experience of the pile work for building foundation. Therefore the work will be available to apply for landslide countermeasure work if suitable material of the pile which has required restraining force against landslide can be procured.

The additional countermeasure works shall be selected in consideration with topography of planned work area, influence to surrounding environment and workability of the work.

6.1.9 Development in the Landslide Hazard Zone after the Landslide Countermeasure Works

The mechanisms of landslide are complicated and it is very difficult to stop the landslide activity completely. Hence, the role of landslide countermeasure works is to raise the existing factor of safety (Fs) to greater than 1.2 and not to permanently prevent landslide. A landslide might be reactivated by deterioration of the soil strength on landslide slip surface or heavy torrential rain (such as rainfall exceeding a 50 year probable rainfall used to design landslide countermeasures at Chitrakoot) resulting from abnormal natural phenomenon (climate change) in future.

In the country with abundant experience of slope disaster such as Japan, the designation of landslide hazard zone will not be terminated even though after landslide countermeasure works have been implemented. Therefore, there will be no termination of the designation of the landslide hazard zone made by this Project (Chitrakoot, Vallee Pitot and Quatre Soeurs) in the future too.

All kind of development for infrastructure or housing is basically prohibited in the landslide hazard zone. However, the minor maintenance work of houses or roads can be implemented. The table below shows the advisability of the development activities in the landslide hazard zone.

Table 6.1.19 Advisability of the Development Activities in the Landslide Hazard Zone (source: JET)

Type of development	Advisability	Application
Minor maintenance of houses, school building etc.	Possible	Maintenance of roofs and walls only. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
Minor maintenance of public infrastructure such as roads, bridges etc.	Possible	Only maintenance of public infrastructure such as roads, bridges, water and sewage etc. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
New/additional construction of houses, schools etc.	Prohibited	Basically, the new/additional construction of building is prohibited
New/additional construction or replacement of public infrastructure such as roads, bridges etc.	Prohibited	Basically, the new/additional construction or replacement of public infrastructure such as roads, bridges, water supply and sewage etc. is prohibited
Development other than mentioned above	Prohibited	Basically, the development activities in the landslide hazard are is prohibited.

<Screening standard for the exceptional development>

In case there is inevitable development activities needed to be implemented in the landslide hazard zone such as new/additional construction or replacement of roads, bridges, water supply and sewage and other public infrastructures, the sufficient investigation/analysis of the points mentioned below shall be undertaken.

- Implementation of stability analysis of the landslide and confirming the factor of safety (Fs) of the landslide is greater than 1.2 after the construction.
- If the factor of safety (Fs) is less than 1.2, the landslide countermeasure works shall be implemented.
- The implementation of the landslide countermeasure works shall be implemented before the development activities.
- The fall of the factor of safety (Fs) during the construction (development activities, landslide countermeasure work and cutting/filling) shall be within 5%, and any works which exceed 5% fall in factor of safety (Fs) shall be prohibited.
- Preventing the water retention from rainfall inside and downstream of the landslide area by installing the water drainage facilities such as surface drainage, retention basins, grit chambers etc.

6.2 Early Warning and Evacuation

6.2.1 Present Situation and Issue in Mauritius

a. The Cyclone and Other Natural Disaster Scheme

The Republic of Mauritius has a robust Early Warning System within the Cyclone and Other Natural Disaster Scheme which includes a preparedness plan for disaster risk reduction. The Scheme has defined the Emergency Operation Plan for hazards likely to threaten Mauritius and/or outer islands with clear response and rehabilitation measures by the relevant authorities. Education and public awareness at community level has also been well established.

b. Landslide Emergency Scheme

Thirty seven (37) Risk Areas have been identified in the Landslide Emergency Scheme, and a program to install rain gauges to monitor rainfall in these areas is indicated.

Table 6.2.1 Five Stages in Landslide Emergency Scheme (source: JET)

Stage		Criterion	Monitored by
Pre stage	Invocation	Precipitation: 30mm/12 hours	Meteorological services
Stage 1	Preparatory Stage	Ground displacement of 2mm/day	MPI
Stage 2	Warning Stage	Ground displacement of 1cm/day, or Visual displacement confirmed	MPI
Stage 3	Evacuation Stage	Ground displacement of 2mm/day	MPI
Stage 4	Emergency Stage	Sudden Landslide or Cyclone Warning / Torrential Warning	(on Cyclone Warning)
Stage 5	Termination	Stabilization of ground movement	MPI

c. Position of MPI in Landslide Emergency Scheme

Many organizations and authorities are involved in the Landslide Emergency Scheme. Figure 6.2.1. below shows the basic flow of the information.

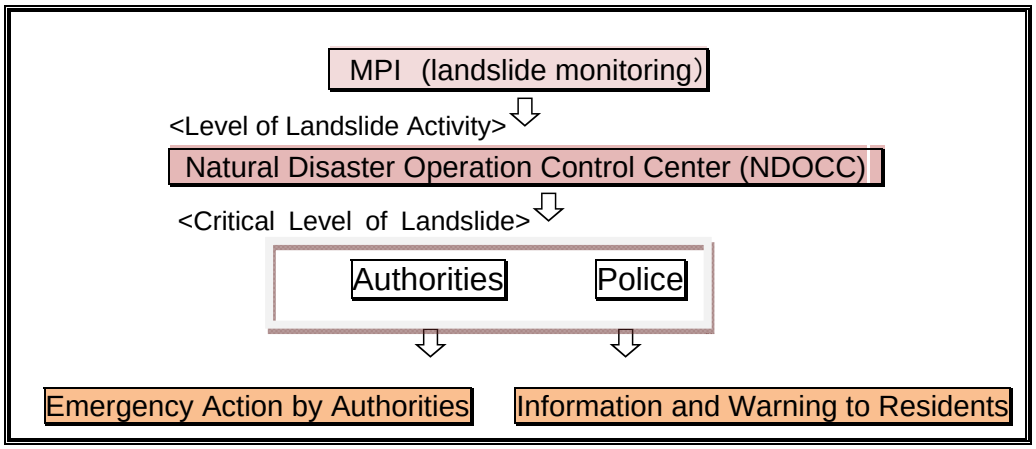


Figure 6.2.1 Circulation of the Information (source: JET)

d. Issues of Landslide Emergency Scheme to be dealt by MPI

In order to inform the risk levels of landslides in accordance with the Landslide Emergency Scheme, there are several problems that should be settled by MPI.

- MPI could not reach to the landslide risk areas in heavy rains because of blockages of roads or floods in the country.
- MPI could not exchange the information according to the stipulated communication framework due to the mobile phones system failures in the country.
- The extensometers are installed at limited places only and they cannot be installed easily because they require strong protection to prevent thefts.
- The rain gauges are installed at limited places only for the same reasons as the extensometers.
- The information system in Landslide Emergency Scheme is very huge, as it requires the information to reach the Prime Minister's Office. Most of the landslides in Mauritius are not big and sometimes only one or two houses are at risk from a landslide. The huge information system should be reconsidered whether it is necessary for such a small landslide disaster.

6.2.2 Proposal of Early Warning and Evacuation System

a. Alert Level (Threshold)

Fundamental principles of the Landslide Disaster Scheme which is the part of Cyclone and Other Natural Disasters Scheme is the following three points.

- It is early warning. (It does not include response and recovery after a disaster.)
- It protects only people's lives. (It is out of the scheme to protect their possessions including livestock and pets)
- Alert level must be the index of danger to people's lives. (It is not the index of danger to residential houses)
- The subject of Landside Disaster Scheme is only slow-moving landslides, and rockfalls, slope failure, debris flow are not the subject. (especially Chitrakoot, Vallee Pitot and Quatre Soeurs are the main subject)

Table 6.2.2 below shows proposed warning stages and their thresholds based on two years landslide monitoring in Chitrakoot, Vallee Pitot and Quatre Soeurs.

Table 6.2.2 Proposed Early Warning of Landslide Disaster (source: JET)

Warning Stage		Threshold	
		Movement of the ground (extensometer)	Deformation of each house
Stage 1	Precaution	20 mm / month or more	<new signs of landslide> New cracks are found in a house. New deformations are found on walls or floors of a house. New crack or deformation are found on the ground, a retaining wall, or a road around the house.
Stage 2	Alert	10 mm / day or more	<progress of cracks or deformation> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger.

			(Opening speed of the cracks : 2 mm/hour)
Stage 3	Evacuation	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour
Stage 0	Termination	0 mm / hour and, no abnormality can be seen in the house and around the house.	The residents of the house deformed do not return to their house without architect's inspection. *3 No abnormality can be seen in the house and around the house *2
Additional Stage	Torrential Rain & Cyclone Warning	"Cyclone Warning Class II" or "Torrential Rain Warning" may constitute for the inhabitants a "Landslide Stage 1 Warning". "Cyclone Warning Class III" : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated	

<Distinction of the proposed Warning Stages>

- Each Warning Stage is raised according to the monitoring of the extensometers and the observation of deformation of the houses.
- The proposed Early Warning System does not include precipitation as threshold.
- In heavy rain, the habitants in the landslide area should follow the Torrential Rain Warning or the Cyclone Warning, not the Landslide Warning.
- Alert level based on extensometer is hourly displacement.
- An extensometer may be able to detect a limited area in the landslide blocks.
- Deformations of a house are more important in the proposed Early Warning System.
- Warning that is based on deformations of the house is issued to only the residents in the house.
- Once the residents evacuate from their house, they never return to their house (termination is not allowed).
- This Early Warning system is effective in Chitrakoot, Vallee Pitot and Quatre Soeurs only, however it can be applied to other landslide (except rockfall, slope failure and debris flow).

b. Role of LMU in Early Warning

LMU should observe and confirm the site condition at each stage of Early Warning. Especially, LMU should visit the house and confirm the condition of the house when LMU receives the information about cracks or deformations of a house, since sometimes cracks or deformations appeared in a house for other reason than a landslide.

At Stage 1 and Stage 2 according to "Deformation of each house", the points to be confirmed by LMU are as follows;

- Observe and confirm cracks and deformations
- Decide whether cracks and deformations are caused by a landslide
- If cracks and deformations are not caused by a landslide, find what is a cause of cracks and deformations
- Decide the methods of ascertainment whether cracks and deformations are progressing or not.
- Inform the residents next door how matters stand with their neighbor (i.e. that their neighbor's house has deformations caused by landslide activity).

- Ascertain the possibility of Stage 3, and remind the residents in the house that they should take in Stage 3

At Stage 3, the residents under risk should leave their house and evacuate of their own accord. The upgrading to Stage 3 from Stage 2 is based on extensometer readings or by the level of deformation of a house as ascertained by the residents of the house. The residents in the house must leave the house immediately (self-evacuation). At Stage 3, NDRMMC controls the refugees, and LMU advises NDRMMC on technical matters.

At Additional Stage, the residents in the landslide area should follow Torrential Rain Scheme or Cyclone Scheme. LMU is not involved in the Torrential Rain Scheme or the Cyclone Scheme.

At ordinary times, LMU should work to raise the awareness of the inhabitants in landslide areas. Especially the inhabitants should understand the following things.

- They live in a landslide risk area.
- Their lives must be protected by themselves.
- Once an evacuation warning is issued, they must not care about their possessions.
- Until countermeasures such as stabilization works are complete, there is nothing that can protect their possessions.

Table 6.2.3 Proposed Early Warning of Landslide Disaster in Chitrakoot, Vallee Pitot and Quatre Soeurs (source: JET)

Warning Stage		Threshold		Action by LMU
		Movement of the ground (extensometer)	Deformation of each house	
Stage 1	**Precaution**	20 mm / month or more	<new signs of landslide> New cracks are found in the house New deformations are found on the floor or the wall of the house. New cracks or deformations are found on the ground surface, walls or a road surface	Site inspection by landslide expert (LMU) Installation of extensometer or observation points
Stage 2	**Alert**	10 mm / day or more	<progress of cracks or deformations> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger. Opening speed of the cracks : 2 mm/hour	Site inspection by landslide expert (LMU) Installation of extensometer or observation points Increase of frequency of observation Instruct the residents (monitoring)
Stage 3	**Evacuation**	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour	Evacuation (residents in the house which is deformed only, or residents in the houses which are within 50m of an extensometer)
Stage 0	**Termination**	0 mm / hour and, no abnormality can be seen in the house and around the house.	The residents of the house deformed do not return to their house without architect's inspection. No abnormality can be seen in the house and around the house.	LMU must confirm no abnormality in the house and around the house.
Additional Stage	**Torrential Rain & Cyclone Warning**	"Cyclone Warning Class II" or "Torrential Rain Warning" may constitute for the inhabitants a "Landslide Stage 1 Warning". "Cyclone Warning Class III" : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated		

** 1 the houses subject to be warned: only houses with signs of landslide activity if alert issued without the extensometer.*

6.2.3 Establishment of Early Warning and Evacuation System

An alarm was added to an extensometer as an early warning and evacuation system, to provide early warning to local residents about landslides. The alarm consists of rotary lights and a siren; the yellow rotary light operates on the warning stage, and the red rotary light and siren operate on the evacuation stage.

The alarm is connected to an active extensometer in two landslides.

Connected extensometer : Chitrakoot <E5> , Vallee Pitot <E-V1>

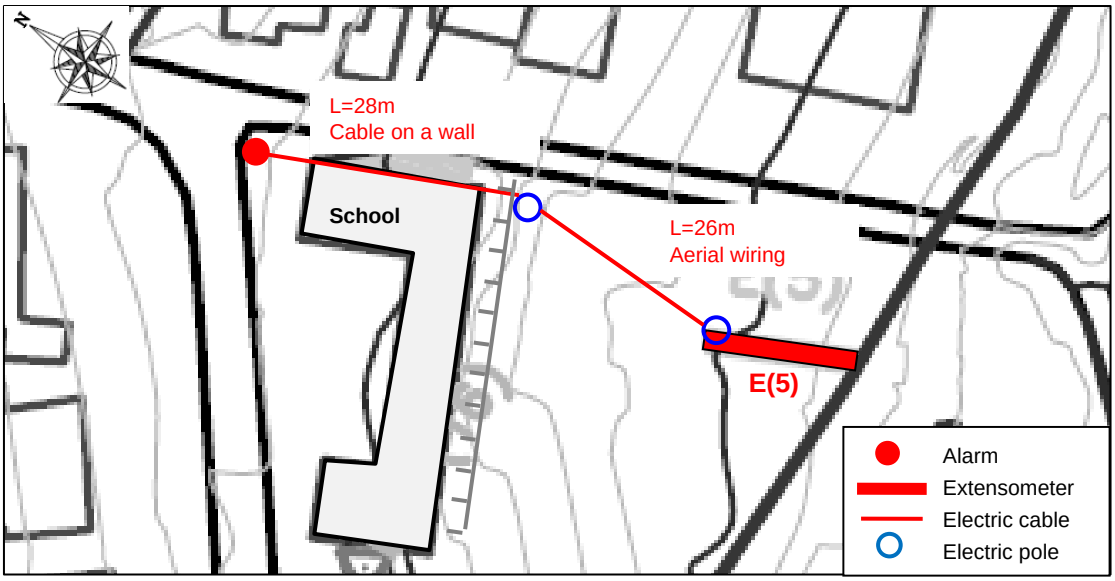


Figure 6.2.2 Location Map of Early Warning and Evacuation System in Chitrakoot (source: JET)

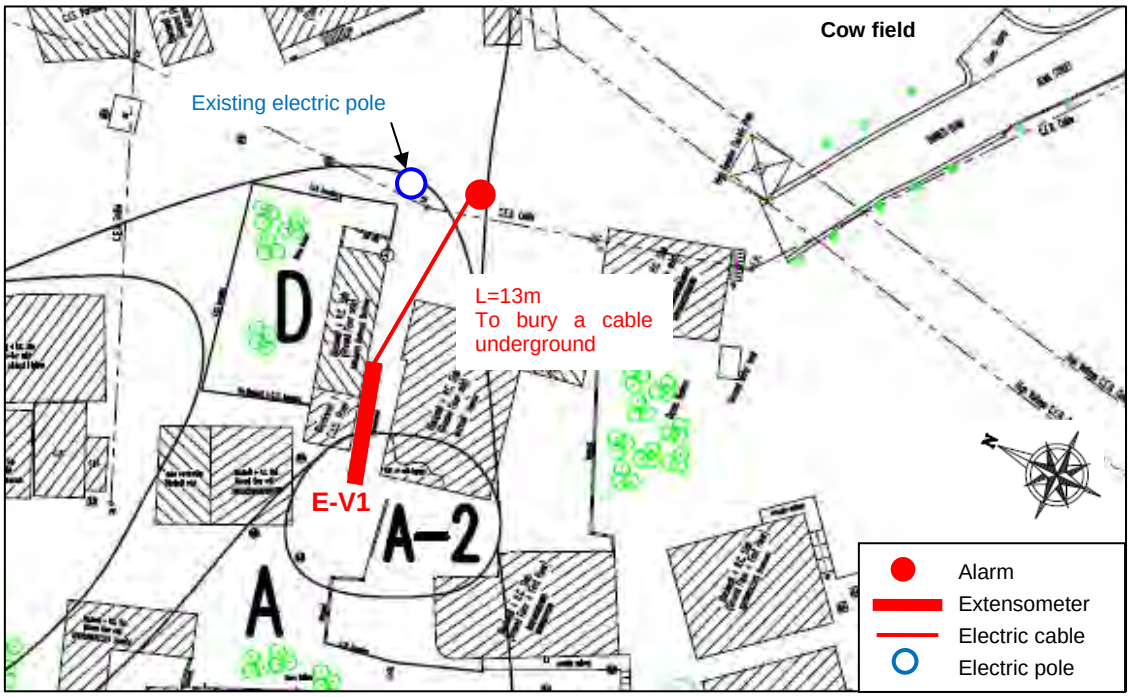
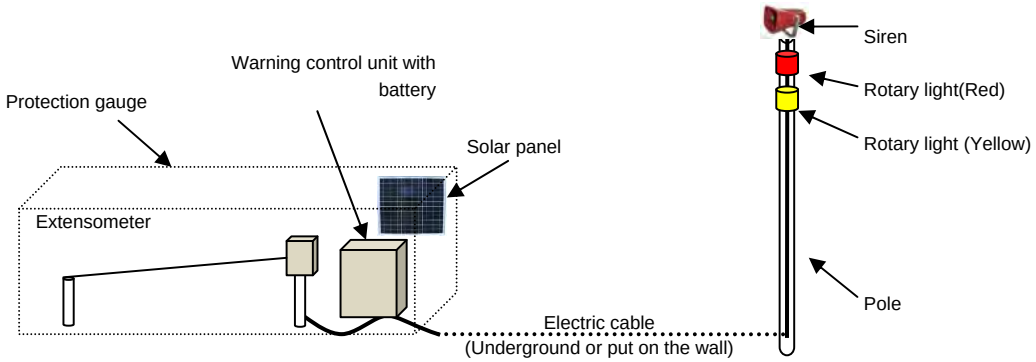


Figure 6.2.3 Location Map of Early Warning and Evacuation System in Vallee Pitot (source: JET)

Equipment

The parts of the alarm added to extensometer consist of a rotary light, a siren, a warning control box (including the battery) and solar panels.



Notice : The electric cable are less than about 80m, because the voltage declines.

Figure.6.2.4 Conception Diagram of Early Warning and Evacuation System (source: JET)

Installation of the early warning and evacuation system

- he solar panel and warning-control unit are installed inside the protection gauge of the extensometer.

➢ The siren, rotary light (red) and rotary light (yellow) are attached to a pole.

➢ They are connected to each other by an electric cable.

Figure 6.2.5 Installation of the Early Warning and Evacuation System in Chitrakoot (source: JET)

Figure 6.2.6 Installation of the Early Warning and Evacuation System in Vallee Pitot (source: JET)

6.3 Information, Education and Communication (IEC)

6.3.1 IEC in the Landslide Management Project

The Project, in collaboration with Government Authorities including national government, Local Authorities and relevant public institutions, will carry out IEC activities to disseminate necessary information for landslide management to citizens and the public. These IEC activities aim;

- To raise awareness on landslide disaster management by providing basic information and a better understanding of the importance of preparedness for landslide disasters.
- To mitigate disaster risk by controlling human activities such as urban development and improper construction in high-risk areas.
- To make residents ready for proper actions when landslide disasters occur in future.

6.3.2 IEC Activities to be implemented by the Project [Table 6.3.2 -d]

Table 6.3.1 IEC Activities to be Implemented by the Project (source: JET)

	IEC Activities to be implemented by the Project （Countermeasures for issues）		
Issues / Countermeasures	**Stakeholder Meeting for residents** at high-risk areas	**Project Newsletter**（Outline of the Project, Progress, etc.）	**Development of Awareness materials** for landslide disaster prevention
1. Community participation and ownership of relevant stakeholders in disaster risk reduction, is not sufficient.	◎	○	○
2. Residents do NOT have necessary information such as evacuation sites and hazardous spot around residence, so that they are feeling a sense of insecurity against landslide disasters.	◎	○	◎
3. Most of residents do NOT know existing restrictions for development actions and building construction in a hazard area.	◎	○	◎
4. Education programme for landslide management is NOT implemented at schools and communities.	◎	○	◎
5. NO programmes for local risk assessment and disaster preparedness implemented in schools and institutions of higher education such as University of Mauritius.	-	○	○
6. Awareness materials, which are required to develop under the Disaster Scheme, have been NOT done yet.	○	○	◎
7. Most of residents are NOT familiar with the existing warning system.	◎	-	◎
8. Residents at priority areas have requested for sharing the progress of Project activities and the monitoring results on a regular basis (from comments given by participants of stakeholder meeting held in Chitrakoot).	◎	◎	○

9. The existing Landslide Emergency Scheme is lack of preparedness perspective and component of evacuation plan. Also, implementing and responsible agency for IEC activities is NOT identified clearly.	◎	-	◎

※ ◎Directly contributed, ○Indirectly contributed

6.3.3 Stakeholder Meeting for Residents at Priority Areas

a. Purpose of the Stakeholder Meeting

The Landslide Management Plan is in the process of planning formulation based on the results of baseline surveys conducted since May 2012, and has been discussed through a series of meetings with CP staff of the MPI and other relevant stakeholders.

To conduct effective landslide countermeasures, taking a land ownership and use into consideration, consensus should be built with local stakeholders, and interests should be coordinated and system should be established with local communities.

It is also desirable that the concept of the Plan including: the need for the Project, selection process of the priority areas, outline of project implementation, and resident's roles and responsibilities should be shared with local residents in the early planning stage. Such interactive communication process with local residents will result in a more realistic plan that reflects the community's real needs.

b. Implementation Plan

Table 6.3.2 Implementation Plan of Stakeholder Meeting (source: JET)

No.		Implementation schedule	Objective	Contents
1	At the start of the Project	Sep. 2012	To explain the outline of the Project and request residents' cooperation	1) To explain the outline of the Project 2) To request their cooperation and understanding for the field survey and monitoring
2	After drafting of Project Implementation Plan	Apr. 2013	To build consensus on Project Implementation Plan and F/S	1) To share the results of field surveys 2) To share the monitoring results, particularly during rainy seasons 3) To collate residents' views on the basic policy of countermeasures (basic design of construction work, soft (non-structure) countermeasures)
3	Before finalization of Project Implementation Plan	Nov. 2013	To build consensus on Project evaluation, EIA and the proposed early warning and evacuation system	1) To collate residents' views on the draft design of construction work 2) 3) To gain agreements on the land use for construction work (house-to-house visit was also be conducted) 3) To share the results of Project evaluation

				4) To inform of the proposed early warning and evacuation system
4	Before starting Pilot Project	Jul. 2014	To build consensus on contents of Pilot Project	1) To explain the outline of Pilot Project 2) To share the results of field survey and monitoring 3) To review the practicability of the proposed early warning and evacuation system (to identify effectiveness and lessons learnt) 4) To conduct site visit
5	At the end of Pilot Project	Dec. 2014	To share the results of Pilot Project, feedback to the Landslide Management Plan	1) To review the whole project activities 2) To report the results of Pilot Project 3) To explain the early warning and evacuation system (by using IEC materials) 4) To announce the future plan after the Pilot Project 5) To conduct site visit

c. Reports of Results of Stakeholder Meetings

The outline and results of all the stakeholder meetings were summarized in the Main Report.

6.3.4 Questionnaire Survey for Residents at Three Priority Area

(1) Level of landslide awareness

- ✧ The majority of residents living in three priority areas have a basic knowledge of landslides. However, almost half of residents who live outside of landslide block in Vallee Pitot had some general knowledge of landslides, but did NOT know that they are living in a landslide-prone area.
- ✧ More than 1/3 of residents in Chitrakoot and Vallee Pitot did NOT know MPI is conducting landslide monitoring while all residents in Quatre Soeurs were aware of the monitoring.
- ✧ In Chitrakoot, 25 % of residents still did NOT know that MPI/JICA is now implementing countermeasures on site.

(2) NDRRMC

- ✧ Most of the residents did NOT know about NDRRMC.

(3) Early warning and evacuation system

<Early warning system in Chitrakoot and Vallee Pitot>

- ✧ The early warning system is well-known to residents who live in both Chitrakoot and inside the landslide block in Vallee Pitot. However, in Vallee Pitot, less than 50 % of residents who live outside of the landslide block did NOT know of the system.

<Simple rain gauge system in three priority areas>

- ✧ Most of residents in Chitrakoot and Quatre Soeurs knew about simple rain gauge system. In Vallee Pitot, only 40% of residents who live inside the landslide block knew of the system while NONE of residents who live outside of the landslide block knew of the system.

<Communication at each stage>

- ✧ Police is the first contact organization for residents if they have noticed cracks/subsidence in their buildings. For evacuation, more than 30 % of residents have requested assistance from a relevant authority.
- ✧ The Project has assigned some people who will contact the police when a warning is issued. However, most residents in Vallee Pitot and Quatre Soeurs believed that they should call the police by themselves. Approx. 60 % of residents in Chitrakoot knew that delegated persons should contact the police as their representatives.
- ✧ Most people in three areas did NOT know the contact number of the delegated persons who will contact the police when conditions reach the warning stage.
- ✧ People believed that local police would inform them of the timing of the warning and evacuation stages.

<Evacuation order issued in Chitrakoot in March 2014>

- ✧ 25 % of residents were not at home at that time while no one evacuated even though the evacuation order was issued. The major cause of this was that residents did not take it seriously. Also, some of them were also not aware of where to evacuate.

<Future plan of evacuation>

- ✧ Approx. 40 % of residents in Chitrakoot and Vallee Pitot replied “No” or “Not sure” when asked whether or not they would evacuate in the event of an evacuation order being issued in future. The main cause of this was that residents did NOT know where they should evacuate to. All residents in Quatre Soeurs were sure of where to evacuate to.

<Responsibility of landslides and associated disasters>

- ✧ Over half of residents felt that they would be responsible for anything that might happen to them as a result of not evacuating. Less than one third of residents insisted that the government should take more responsibility on this.
- ✧ Most of residents in three areas believed that MPI should be responsible for landslide monitoring and countermeasures, following by Local Authorities.

<Necessary information and arrangement for evacuation>

- ✧ The evacuation center is expected to be the place where residents will evacuate to.
- ✧ 100 % of residents in Quatre Soeurs knew about the location of evacuation center and appropriate route while less than 60 % of residents in Chitrakoot and Vallee Pitot knew the location.
- ✧ Over 70 % of residents in three areas have felt the need of assistance from relevant assistance for evacuation.

<Review of current system>

- ✧ Most residents were uncertain if the current system is functioning well or not as they had never experienced a warning issued by the early warning system.

(4) IEC and others

- ✧ Almost all households have experienced attending the stakeholder meetings which were organized by MPI and JICA.
- ✧ The three main sources of information related to landslide is; TV, Stakeholder meeting on site and radio. Some people also get information by word of mouth such

as from their neighbors.

- ✧ Residents in three areas knew about JICA Project but most of them who live outside of landslide block in Vallee Pitot did NOT know about it.

a. Conclusions

- ✧ Awareness activities such as stakeholder meetings should be conducted not only for residents who live inside of the landslide block but also for the ones who live outside of the landslide block as they will be affected by landslide disaster as well. These people should be included in the evacuee list.
- ✧ NDRRMC should make more effort to raise awareness of the mission of the organization much more. (by mass media, etc.)
- ✧ At this stage, the Project can't conclude that the current early warning and evacuation system is working or not as not much experience in operation has been accumulated. The survey provided some matters to be considered as follows;
  - The early warning system are easily visible to residents as it has been located in a visible place outside. However, the difference between yellow and red lights should be reminded to residents.
  - It might be difficult for residents to identify which households own simple rain gauge unless they did obtain information in the stakeholder meeting.
  - Contact point should be the same for any landslide inquiries including during warning and evacuation stages. Police will be the best organization for this.
  - The presence of contact person(s) will be useful for the government such as MPI to obtain information of actual site conditions, but for residents, it would be better to let anyone contact police. If this is not the case then all of the residents need to know the phone number of the contact person(s) so that they can contact them to report an emergency.
  - "Self-evacuation" should be promoted but assistance for evacuation by relevant authority is still required for some people, especially for elderly. It is important for the government to identify the persons who need assistance in advance.
  - The government should not hesitate to issue warning and evacuation orders when it reaches each level. The location of evacuation center and appropriate route should be well informed in advance. And, transport for people who need assistance should be arranged at evacuation stage. Residents will not be able to blame the government if something happens to them because they have not followed instructions and when the government has done everything that it is supposed to do.
- ✧ Stakeholder meetings in at risk communities are an effective tool to disseminate information, especially specific information to the locality such as location and route of evacuation center. TV and radio are also informative but will be effective to disseminate landslide information in general.

6.3.5 Project Newsletter

The Project issued Project Newsletter (vol.1 – vol.5) every six months. The Newsletter explained about the Project and the progress of Project activities in a manner easily understandable to readers. Two versions of the leaflet, in English and French, were issued since most of residents cannot understand English well. The Project leaflet was drafted by JICA Experts and finalized by reflecting comments given by MPI CP and Permanent Secretary of MPI. The copies of the finalized leaflet were distributed to the local households in priority areas, and also shared with relevant organizations. Both English and French versions of the leaflet are attached in Supporting Report.

6.3.6 IEC material - Landslide Disaster Prevention Handbook -

The Project developed the Landslide Disaster Prevention Handbook. In developing the handbook, the contents were generalized and simplified using simple text, many illustrations and photos that enables any age group including school kids to use it. The handbook outlines necessary information people should know about landslide disasters, and emphasizes the importance of disaster prevention, which is a key concept to cope with landslides.

The Handbook was published under joint authorship with MPI and NDRRMC. The handbook was distributed to residents who live in three landslide priority areas and relevant organizations during the 5th stakeholder meeting, Technical Seminar and Steering Committee.

Photo 6.3.1 Handbook, (Left: French Version, Right: English Version)

Photo 6.3.2 Awareness Activity for Residents Using the Handbook (Chitrakoot)

6.4 Technical Summary of the Pilot Project

A combination of “hard” countermeasures and “soft” countermeasures on landslides have been implemented for the first time in Mauritius in the Project.

Hard countermeasures are structural countermeasures in Chitrakoot. JET and C/P have implemented the basic design/detailed, design/cost, estimation/construction, and plan/bidding/contract/construction/supervision for large-scale channels, horizontal drilling, open/blind ditches, surface ditches, river improvement (widening and revetment work), bridges and a collecting channel for the purposes of limiting the inflow of water into the landslide area and draining of water away from the landslide area.

Although large-scale channels, open/blind ditches and surface ditches have been constructed for preventing floods, it is the first time such measures are to be trialed for mitigating landslides in Mauritius. Therefore, explanations of the effectiveness of such measures for landslides were needed to gain the understanding of the C/Ps. Regarding horizontal drilling, which is a major countermeasure for landslides in Japan, JET has explained the purposes, procedures, maintenance, etc., to the C/Ps over and over since the planning stage. As the C/Ps are civil engineers, once they understood the technical grounds and the significance of the works, they conducted the design and construction independently, while asking for advice from JET from time to time. Therefore their cooperation highly contributed to the completion of construction of the abovementioned countermeasures within the schedule. Thanks to the understanding of the C/Ps on the significance and methods of the hard measure procedures, the Pilot Project was able to be divided into Section I by JET and Section II by MPI. It is planned to be conducted next year, 2016.

The effectiveness of the countermeasure works cannot yet be identified. Consequently, it is necessary to wait for the monitoring results of the piezometers and extensometers. However, the effectiveness of these gauges is assumed to be very high as judged from the damage from the activity of a small landslide in Chitrakoot in January 2015. The small landslide generated by heavy rainfall from the Cyclone Bansi in the middle of January in Section II, where MPI will construct the countermeasure works in the next fiscal year. Although the landslide damaged six (6) houses in this area, there was no damage in Section I where the countermeasure works were constructed, such as the horizontal drilling, by JET. This indicates that the landslide disaster was minimized by restraining the whole landslide movement through the countermeasure works in this Pilot Project. The whole of the active landslide area in Chitrakoot would be stabilized by the construction of landslide countermeasures (proposed by JET) in Section II by MPI next year.

Soft countermeasures are the early warning and evacuation systems in the three (3) priority sites, Chitrakoot, Quatre Soeurs, and Vallee Pitot. On the basis of the monitoring results of this Project, JET proposed a new early warning system that is based on the reference values of extensometers and changes in the state of the houses. This proposal was the result of investigations looking into the issues of the current system in the Disaster Scheme of Mauritius. It is proposed to set reference value in the occurrence of cracks or changes on the houses and displacement of borehole extensometers. The thresholds are; “preparation (pre stage)”, “warning (stage 1)”, “evacuation (stage 2)”, and “warning lifted (stage 3)”. The revolving lights (red and yellow) and sirens have been installed to enable voluntary evacuation using the thresholds. Liaison members and communication systems as well as evacuation routes/areas for the early warnings and evacuations have been established.

The early warning and evacuation systems in the Disaster Scheme were purely theoretical because even though no extensometers or rain gauges had been installed to monitor landslides, there were 37 risk sites that were supposed to be monitored by these nonexistent extensometers and rain gauges. JET looked into the issues of the current system in the Disaster Scheme and established a practical and effective system on the three (3) priority sites. The system of voluntary communication and evacuation by local residents and the reference values of "in-home changes" (damage within houses) are considered to be breakthrough initiatives in Mauritius's development of an early warning and evacuation system.

A landslide that exceeded the threshold reference value occurred at Vallee Pitot in January 2015 due to heavy rainfall by the Cyclone Bansi, and the "warning (stage 1)" was issued. Followed by the warning/evacuation protocol installed by JET, the local residents called the local police, the police requested MPI to check immediately at the site, and then MPI (and JET) investigated the extensometers, damage to houses and landslide conditions. MPI checked the conditions regularly until the "warning lifted (stage 3)" (fortunately the landslide has been stabilized because of no rainfall). The C/Ps understand the significance and the responsibility even of soft countermeasures, and voluntarily fulfill the duties based on advice given by JET. This, it can be said, is a direct result of the Pilot Project implementation. MPI will continuously work to raise awareness of local residents under normal conditions, and check the areas and give advice to the related organizations in emergency conditions.

Reference for Chapter 6

[1] Japan Road Association: Highway Earthwork Series: Manual for slope protection, pp. 404, 2009
[2] Construction Industry Development Board: National Schedule of Rates (First edition), 2012

Chapter 7

Technical Transfer

7 Technical Transfer

7.1 Methodology

7.1.1 Objectives of Technical Transfer

The objectives and inputs of each item of the technical transfer are summarized as the following table to ensure the technical transfer is effective.

Table 7.1.1 Objectives and Inputs on Technical Transfer (source: JET)

Item	OJT (On-the-Job-Training)	Pilot Project	Training in Japan
Objectives	1. Grasp the flow of survey, analysis, monitoring, design, countermeasures on landslide 2. Propose the institution plan, manual/guideline, actual early warning system	1. Understand actual method of plan/design/cost estimation/construction/maintenance of countermeasures 2. Understand cooperation of residents and stakeholders for construction of countermeasures	[1st] Understand "what is a landslide?" and "what is disaster management?" for landslide management in Mauritius in the future. [2nd] Understand actual landslide countermeasures and their significance/method for landslide countermeasure work in Mauritius in the future.
Inputs	・Collaboration on reconnaissance, monitoring, construction ・Technical transfer seminar ・Workshop ・Establishment of manual ・Establishment of guideline ・Proposal of early warning system	・Collaboration on plan/design/cost estimation/construction/maintenance of countermeasures ・Stakeholder meetings ・Examination for local residents	・Visit Land, Infrastructure and Transportation Ministry in Japan (including information about administrative activities, evacuation, consensus building) ・Visit local authorities in Japan (including information about administrative activities, evacuation, consensus building) ・Visit universities and research institutes ・Visit private consultant

7.1.2 Method of Technical Transfer

a. Confirm MPI's Capacity

b. Proposed Gradual Technical Transfer

Table 7.1.2 Each development stage of the CD (source: JET)

Development Stage
① Basic survey, monitoring, analysis of landslides, and establishment of countermeasure plan
② Discussion, design, cost estimation, work volume on actual landslide countermeasures
③ Construction and supervision of countermeasures on pilot site
④ Sustainable survey/design/construction/supervision/maintenance and establishment of systems/frameworks for emergencies

7.1.3 Basic Policy of Technical Transfer

a. Consideration of Measures Appropriate to Socioeconomic Conditions in Mauritius

b. Steering Committee

c. Advisory Committee in Japan

d. Regular Meetings

e. Promote Understanding among Local Residents

f. Recommendations for Sustainable Improvement

7.2 Structure of Technical Transfer

For the effective and smooth technical transfer, the idea is to form groups based on the respective expertise of both the JET and C/P. The groups are basically comprised as follows in Table 7.2.1. The concept of the technical transfer is to transfer a basic understanding and know-how of landslide surveys, analysis, design, and construction to all the members of the C/P.

Table 7.2.1 The JICA Expert Team Members by Group of Expertise (source: JET)

	Group	JET	MPI
1	**Management** (Chief adviser, Vice chief adviser/ Landslide management)	K. ICHIKAWA T. KUWANO	M. R. JEWON D. CHINASAMY V. RAMDHAN S. P. ANADACHEE M. K. MOSAHEB R. RAMDHAN L. BISSESSUR B. DABYCHARUN
2	**Survey/Analysis** (Landslide survey and analysis, Landslide monitoring, Geophysical prospecting, GIS/Topographic survey)	T. IWASAKI F. YOKOO Y. KASAHARA M. SUGITA	
3	**Design/Construction** (Design/Cost estimation, Environmental and social consideration)	T. HARA T. KURATA	
4	**"Soft" countermeasure** (Policy and planning of urban development and land use, Institution/system analysis/capacity development, Information/education/ communication)	Y. GONAI K. SAITO S. ICHIKAWA Y. KAWABATA H. YOSHIDA M. TOKUDA	

The schematic image of the technical transfer is shown in the Figure 6.2.1. The transfer is made from the group of Japanese experts to the C/P group so that the transfer will benefit most of the C/P regardless of the C/P's expertise. In addition, C/P will learn not only one expertise but also total landslide management skills.

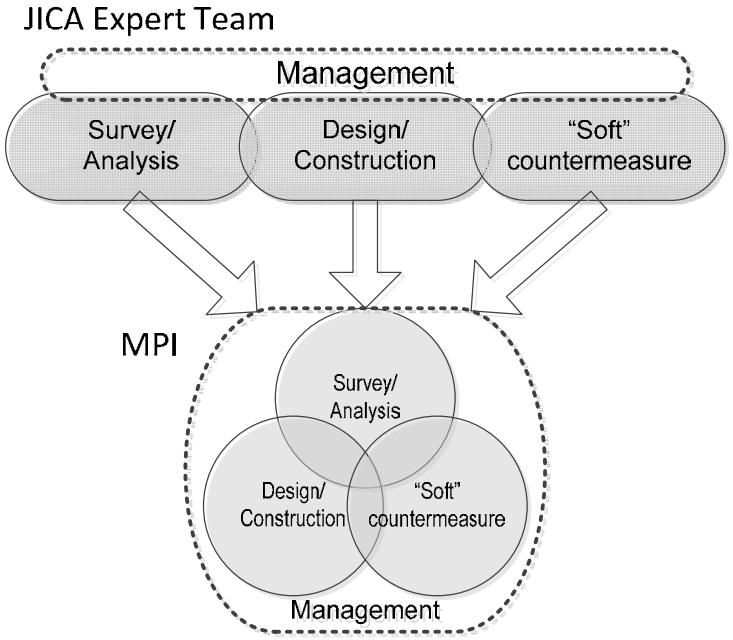


Figure 7.2.1 Structure of Technical Transfer (source: JET)

7.3 Technical Transfer Seminar

7.3.1 1st Technical Transfer Seminar

The 1st technical transfer seminar was held on 10 October 2012 aimed to inform relevant stakeholders of the contents, policy, and procedure of the Project and the results of the basic survey. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI and followed by keynote speech by Mr. K. Ichikawa, Chief Adviser of JET. The Minute of Meeting is in the Supporting Report.

7.3.2 2nd Technical Transfer Seminar

The 2nd technical transfer seminar was held on 20 November 2013 aimed to inform relevant stakeholders of the results of the basic surveys, the landslide management plan and the F/S, and the outline of the pilot project. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI. The Minute of Meeting is in the Supporting Report.

7.3.3 3rd Technical Transfer Seminar

The 3rd technical transfer seminar was held on 20 January 2015 aimed to inform relevant stakeholders of the results of the pilot project and the early warning system among all activates. The seminar was presented by both the JET and C/P. The Seminar was initiated by Mr. V. Lutchmeeparsad, Permanent Secretary of MPI. The Minute of Meeting is in the Supporting Report.

7.4 Workshop

Several workshops for certain themes have been conducted by the JET to accelerate C/P's understanding for landslide survey, analysis, evaluation and countermeasure in the Project as follows.

Table 7.4.1 Summary of Landslide Workshop (source: JET)

Date/time	Theme	Venue	C/P	JET
19 June, 2012 9: 30-11: 30	Fundamentals and Basics on Landslides	Phoenix, MPI	23	Ichikawa, Kuwano, Iwasaki, Togami, Kasahara, Saito
10 July, 2012 9: 30-12: 30	Landslide Reconnaissance	Phoenix, MPI Chitrakoot, Port Louis	7	Iwasaki, Yokoo, Kasahara, Gonai, Yamamoto
26 July, 2012 10: 00-11: 30	Monitoring device	Phoenix, MPI	11	Yokoo
30 July, 2012 10: 00-12: 00	Land Use Policy for Landslide Disaster	Phoenix, MPI	11	Gonai
6 September, 2012 10: 00-11: 30	Interpretation of Aerial Photo for Landslide	Phoenix, MPI	15	Hara
31 October, 2012 9:30-12:00	Landslide investigation/ analysis/monitoring	Phoenix, MPI	12	Dr. Fukuoka, Kuwano, Iwasaki, Yokoo, Kasahara
31 October, 2012 13:30-14:00	Geotechnical Site Characterization and Constant Volume Direct Shear Test	Phoenix, MPI	10	Dr. Fukuoka, Kuwano, Iwasaki, Yokoo, Kasahara
5 November, 2012 13:00-15:00	Training of the Landslide Monitoring	Quatre Soeurs Landslide	6	Iwasaki, Yokoo, Kasahara
25 February, 2013 13:30-16:00	Monitoring Result and Early Warning	Phoenix, MPI	6	Iwasaki, Yokoo, Hara, Gonai, Yoshida
26 February, 2013 9:30-11:30	Review of Planning Policy Guidance	Phoenix, MPI	19	Gonai
5 March, 2013 13:30-16:00	Stability Analysis and Countermeasures	Phoenix, MPI	6	Iwasaki, Hara, Yokoo, Kuwano
7 March, 2013 10:00-12:00	Monitoring log for pilot site	Phoenix, MPI	4	Yokoo, Iwasaki
16 October, 2013 14:30-16:00	Countermeasure works	Phoenix, MPI	4	Hara, Iwasaki, Yoshida, Tokuda

7.5 Training in Japan

The training in Japan was conducted twice in the Project to ensure that the technical transfer is successfully implemented, and to experience and learn techniques at the sites and research institutes of several organizations. The training in Japan was scheduled for November to December 2012 and August to September 2013. The summary of the training is as follows.

Table 7.5.1 Contents of Training in Japan (source: JET)

Item	1st	2nd
Date	20 November to 15 December, 2012 (26 days)	14 August to 8 September, 2013 (26 days)
Overall goals	1. To understand necessary/utilizable technologies on structural countermeasures, which are suitable in Mauritius, based on landslide countermeasures in Japan. 2. To understand necessary/utilizable technologies and methodologies on early warning/evacuation and consensus building for local residents, which are suitable in Mauritius, based on landslide countermeasures in Japan. 3. To grasp workflows, concepts and perspectives on landslide management and disaster management in government. 4. To comprehend basics of the monitoring and the investigation technologies employed in Mauritius in the project. 5. To gain a better understanding of the significance of the project for achieving the project outputs.	
Purposes	Understand actual landslide countermeasures and their significance/method for landslide countermeasure work in Mauritius in the future.	Understand “what is a landslide?” and “what is disaster management?” for landslide management in Mauritius in the future.
Number	5 members	5 members
Participants	• Mohammad Naim EARALLY • Lalitsingh BISSESSUR • Vishwahdass RAMDHAN • Mohammad Khalid MOSAHEB • Bhoopendra DABYCHARUN	• Mahmad Reshad JEWON • Deevarajan CHINASAMY • Madun BALLOO • Selvanaden Pearia ANADACHEE • Visham RAMCHURN
Visit place	・ Visit Land, Infrastructure and Transportation Ministry in Japan ・ Visit local authorities in Japan ・ Visit universities and research institutes ・ Visit private consultants	

7.6 Steering Committee

The Steering Committee (hereinafter SC) is held with relevant organizations in Mauritius, in order to establish smooth cooperative system, to have common understanding about the progress and issues on the Project, and to facilitate decision making and problem solving. The establishment and operation of the SC should be handled by C/P, and JET helps the C/P to precede the meetings.

Table 7.6.1 Plan of SC (source: JET)

Item	Contents
Contents	• Approval of activity plan • Confirmation of progress • Discussion of issues • Discussion of necessary matter on the Project
Members	Chairman: MPI PS Member: MPI Civil Engineering Division Director, MPI Civil Engineering Division Deputy Director, PMO, MoEPU, MoHL, MoLG, MoESD, MoFED, PD, MSS, Local Authority, University of Mauritius, Other related organizations, Japan Embassy of Madagascar, JICA Madagascar Office, JET
Schedule	Each period based on report submission
Participants	Around 20

The initial SC was held on 29 May, 2012 to explain the role of the SC followed by the explanation of outline of the Project, the contents of IC/R and the role of stakeholders to the concerned organizations and agencies.

The 2nd SC was held on 11 November, 2012 to explain the results of basic surveys, the outline of the landslide management plan and the F/S to the concerned organizations and agencies. Dr. Fukuoka, a member of the Advisory Committee in Japan, Kyoto University, had special lecture in the SC.

The 3rd SC was held on 21 November, 2013 to explain the result of investigation/analysis, the Pilot Project and the collaboration with other projects to the concerned organizations and agencies.

The 4th SC was held on 19 January, 2015 to inform the result of the Pilot Project and the early warning system among all activities and the collaboration with other projects to the concerned organizations and agencies.

7.7 Advisory Committee in Japan

Advisory Committee (AC) is organized in Japan as a supports mechanism of the Project. The AC advises and deliberates the Project from the technical and engineering point of view.

The schedule of contents to deliberate is as follows.

Table 7.7.1 Schedule of Contents to Deliberate in the Advisory Committee (source: JET)

Item	1st	2nd	3rd	4th
Theme	Determination of P/R	Determination of outline of Pilot Project	Determination of Interim Report	Determination of Draft Final Report
Date	31 August, 2012 Before discussion of P/R	28 May, 2013 Before selection/ design of pilot site	30 October, 2013 Before the pilot project	24 December, 2014 Before completion of pilot project
Contents	1. Results of basic survey, landslide condition (type, volume, risk etc.) 2. Outline of landslide management plan 3. Risky site, outline of F/S (countermeasure)	1. Outline of pilot project 2. Detail of management plan (system/ framework, countermeasure)	1. Results of management plan (except feedback from pilot project)	1. Results of pilot project 2. Results of management plan and F/S 3. Proposal for Final Report

The 1st AC was held on 31 August, 2012 to discuss the results of basic survey, the landslide condition (type, volume, risk etc.), the outline of landslide management plan, the risky site, and outline of F/S (countermeasure).

The 2nd AC was held on 28 May, 2013 to discuss the hazard evaluation for three targeted landslide sites, the hard countermeasures (pilot project), the early warning system, the PPG and the development plan on organization..

The 3rd AC was held on 30 October, 2013 to discuss the priority site and Pilot Project site, the hard countermeasures (pilot project) in Chitrakoot, the early warning system and evacuation, the Disaster Scheme, the PPG and the Feasibility Study.

The 4th AC was held on 24 December , 2014 to discuss the result of the Pilot Project and the early warning system among all activities..

7.8 Results of Technical Transfer

The technical transfer has been conducted with C/Ps shown in the following table through all activities such as investigation, analysis, design and supervising. The C/P members in MPI have improved their organization and system for landslide countermeasure and management by the activities in the Project so that they will be able to conduct the basic activities for the landslide countermeasure and management by themselves after the Project.

Table 7.8.1 Technical Contents to be Transferred to C/P (source: JET)

Item	Name
Organization	Landslide Management Unit, Civil Engineering Division, Ministry of Public Infrastructure, National Development Unit and Land Transport
Persons	Mahmad Reshad JEWON Deevarajan CHINASAMY Vishwahdass RAMDHAN Selvanaden Pearia ANADACHEE Mohammad Khalid MOSAHEB Rameswurdass RAMDHAN Lalitsingh BISSESSUR Bhoopendra DABYCHARUN

The items and outputs of the technical transfer for the C/P in the Project are evaluated for each component as follows.

[Basic survey]

The methodology of basic surveys for landslides has been transferred so that the C/Ps understand the basic methodologies. However, the C/Ps are civil engineers have difficulty understanding the geology and topography of landslides. To overcome this learning difficulty, regular activities on basic surveys for landslides will need to be kept up.

[Formulation of a Landslide Management Plan]

At the start of the project the C/Ps had no knowledge of landslide investigations, monitoring or analysis. Therefore, thought was given into the best ways of conducting such activities. The C/P could systematically obtain the basic knowledge for carrying out activities such as installing and measuring with monitoring devices, field reconnaissance of damaged houses and utilization of the Disaster Scheme and the Planning Policy Guidance etc. However the training and experience of geological analysis/interpretation, stability analysis and disaster inspection will be needed to be conducted by themselves.

Although C/Ps are civil engineers have difficulty in understanding geology and topography, most surveys in the Landslide Management Plan could be contracted out to private consultants. The C/Ps have enough understanding of the outline and concept of the activities to be able to adequately contract them out.

[Implementation of the F/S in Priority Areas]

Activities in the F/S such as the prioritization for project sites and the policy planning have

been conducted with C/P through OJT so that they understand the contents and will be able to conduct them by themselves.

Allocation of the budget since next year as well as reinforcement of the organization for landslide countermeasures was successfully proceeded. Regarding the Environmental Impact Assessment, the surveys could be contracted out to private consultants. C/P has enough understanding of the outline and concept of the activity to be able to adequately contract them out.

[Implementation of the Pilot Project]

All activities in the Pilot Project such as planning/design/supervising of the countermeasure works and the early warning/evacuation system have been conducted with the C/Ps through on-the-job training (OJT), and they have shown sufficient understanding of the contents and will be able to conduct them in future. Although the IEC for landslide in this pilot project was the first time it had been conducted in Mauritius, the C/Ps understand the importance and will be able to conduct it as well.

The implementation of “hard” (physical or structural) and “soft” (non-physical) countermeasures on landslides is largely dependent on enough experience. Continuous training on the landslide countermeasures will be needed. In addition, the target of this Project in 2012-2015 is for landslides, not for other slope disasters such as slope failures, rockfalls and debris flows. Since the landslide project will come to an end right after the completion of the countermeasures in the pilot project in Chitrakoot, the maintenance work of the countermeasures is not included in the Project as outlined in the following table.

Table 7.8.2 Contents of the Project in 2012-2015 (source: JET)

	Investigation/ analysis	Design	Construction/ supervision	Maintenance
Landslide	Contents of the Landslide Project in 2012-2015			
Slope failure				
Rockfall				
Debris flow				

Since the mechanisms and patterns of each kind of slope disaster are different, the method and the concept for countermeasures are also different. Therefore, countermeasures that do not take into consideration the different mechanisms of slope disasters may accelerate the damage of the disaster.

Table 7.8.3 Classification of Hazard Areas on the Disaster Scheme (source: JET)

General		Sub classification		
Slope	15 areas	Landslide	6	areas
		Slope failure	7	areas
		Rock fall	1	areas
		Debris flow	1	areas
Other	22 areas	Stream erosion	10	areas
		Damage of embankment	4	areas
		Damage of wall	5	areas
		Damage of house	1	areas
		Cavern	2	areas
		Total	37	areas

The Government of Mauritius has designated 37 disaster sites in the Disaster Scheme as shown in the table above. The slope disasters like landslides, slope failures, rockfalls and debris flows are especially serious disasters in which the countermeasures are almost impossible to implement by MPI only without JICA's support.

MPI has repeatedly requested JET through the Project to support the investigation and analysis for the emergency disasters such as slope failures and rockfalls. On 26 April 2014, a significant rockfall (4m*2m*2m) occurred, causing the closure of a national road. JET has provided technical assistance to MPI for implementing the emergency countermeasures. The permanent countermeasures are inevitable for these kinds of disasters.

MPI has strongly requested JICA to support the survey, analysis, design and construction of countermeasures for slope failures, rockfalls and debris flows. MPI has also learned the importance of maintenance for the countermeasures in the training in Japan in 2012 and 2013 during the Project and has requested to support the maintenance of landslide countermeasures. Therefore, the further technical assistance on slope disasters is necessary for MPI.

7.9 Future Plans by MPI and the Related Organizations

7.9.1 Future Plans by MPI

With regards to the landslide countermeasure construction works which has been completed by JET on December 2014, the constructed works of the Pilot Project site in Chitrakoot are officially handed over from JET to MPI under the terms and conditions stipulated below. MPI shall take the necessary measures to maintain the works after the handover.

a. The Types and Quantity of Works to be Handed Over.

The types and quantity of works which has been constructed by JET are as below. The detailed plan maps and structural figures of each construction works are attached.

- River Type-1 (5m)
- River Type-2 (10m)
- River Type-3 (140m)
- River Type-5 (55m)
- New Channel CH-1 (217m)
- Bridge Br-1
- Bridge Br-2
- Bridge Br-3
- Bridge Br-4
- Bridge Br-5
- Horizontal Drainage (5 boreholes)

The major amendments of design which was made during the construction are as below.

- ✓ River Type 1 & 2: The height of stone masonry was increased, while the vegetation was shortened.
- ✓ River Type 3: The design of the wall on the right side was changed to straight wall at some point.
- ✓ Bridge Br5: The structure of handrail was changed from fence to steel pipe.

b. Further Construction Works to be Conducted by MPI

MPI shall conduct the further construction works for Section II as follows including the works which was cancelled in Section I. After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring.

- Reconstruction of the bridge at the end point of river (scheduled by National Development Unit in MPI)
- Channel for the flood CH-2 (130 m)
- Horizontal drainage (HD-2) (210 m)
- Horizontal drainage (HD-3) (350 m)
- Surface drainage (SD-1) (75 m)
- Open-blind ditch (OB-1) (55 m)
- Open-blind ditch (OB-2) (85 m)
- Blind ditch (BD-1) (35 m)
- Blind ditch (BD-2) (32 m)

- Blind ditch (BD-3) (40 m)
- Water catch basin (5 pc)
- Bridge (2 pc)
- Manhole for maintenance (12 pc)

b.1 The cancelled works in Section I.

- Upgrading of existing water course RUD-1 (Type3 drainage) (35 m)
- Upgrading of existing water course UD-3 (Type4 drainage) (47 m)

b.2 The monitoring for ground water level.

- BPP 16
- BPP 11
- W-2
- BPP 8
- B-P1
- B-P2

c. Cleaning and Maintenance of the Ditches, Channels, Bridges and Horizontal Drainages by MPI

The ditches, channels, bridges and horizontal drainages constructed by JET shall be cleaned periodically to ensure the smooth water flows in the drainage. The maintenance of the works shall be undertaken to maintain its function as below.

c.1 Cleaning and maintenance of ditches and channels

- ✓ Cleaning of soils accumulated in the ditch and channel using shovel and high pressure water.
- ✓ Removing any garbage inside the river.
- ✓ Repairing any cracks occurs along the ditch and channel works

c.2 Cleaning and maintenance of bridges

- ✓ Cleaning of soils accumulated under the bridges using shovel and high pressure water.
- ✓ Removing any garbage under the bridges
- ✓ Repairing any cracks occurs on the bridge works

c.3 Cleaning and maintenance of horizontal drainage

- ✓ Cleaning of soils accumulated inside the drainage pipe using high pressure water (flushing).

c.4 Maintenance of the fences

Fences shall be checked periodically in case of damages by rock fall and debris flow and repaired if necessary.

d. Site Restriction (No Trespassing and Throwing Garbage into the Site)

- ✓ Installation of [No Trespassing] signboard at site
- ✓ Education of the inhabitants regarding the disaster prevention.

e. Utilization of the Landslide Disaster Prevention Handbook

The utilization of handbook for the education of the inhabitants and students is highly expected.

7.9.2 Future Plans by the Related Organizations

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalized as follows:

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

Table 7.9.1 Main Responsible Organizations Based on Disaster Classification, Objects of Protection and the Scale of Protection (source: JET)

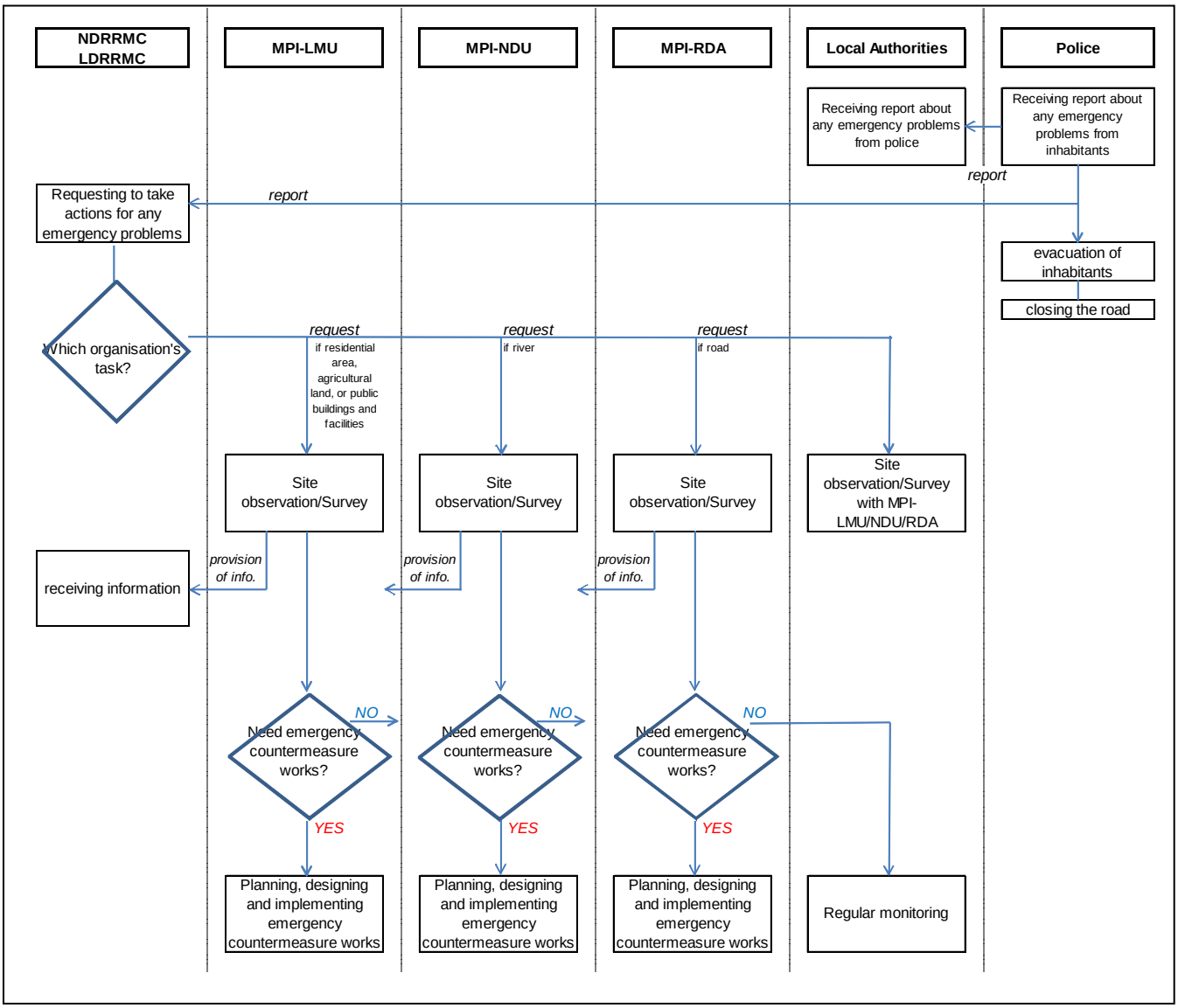
Disaster		Object of protection	The main responsible organisation	
			Large scale disaster	Small scale disaster
Slope disaster	Landslide (mass movement)	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Rock fall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Slope failure	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
Slope and river disaster	Debris flow	Residential houses	LMU/NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU/NDU	
River disaster	Stream erosion	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
	Flood	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
Others	Damage of embankment	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	

	Damage of wall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of house	Residential houses	-	Local authorities
		Agricultural fields		
	Cavern	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	RDA/local authorities

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

Table 7.9.2 Task Flow for Emergency Situation for All Sites (source: JET)



- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

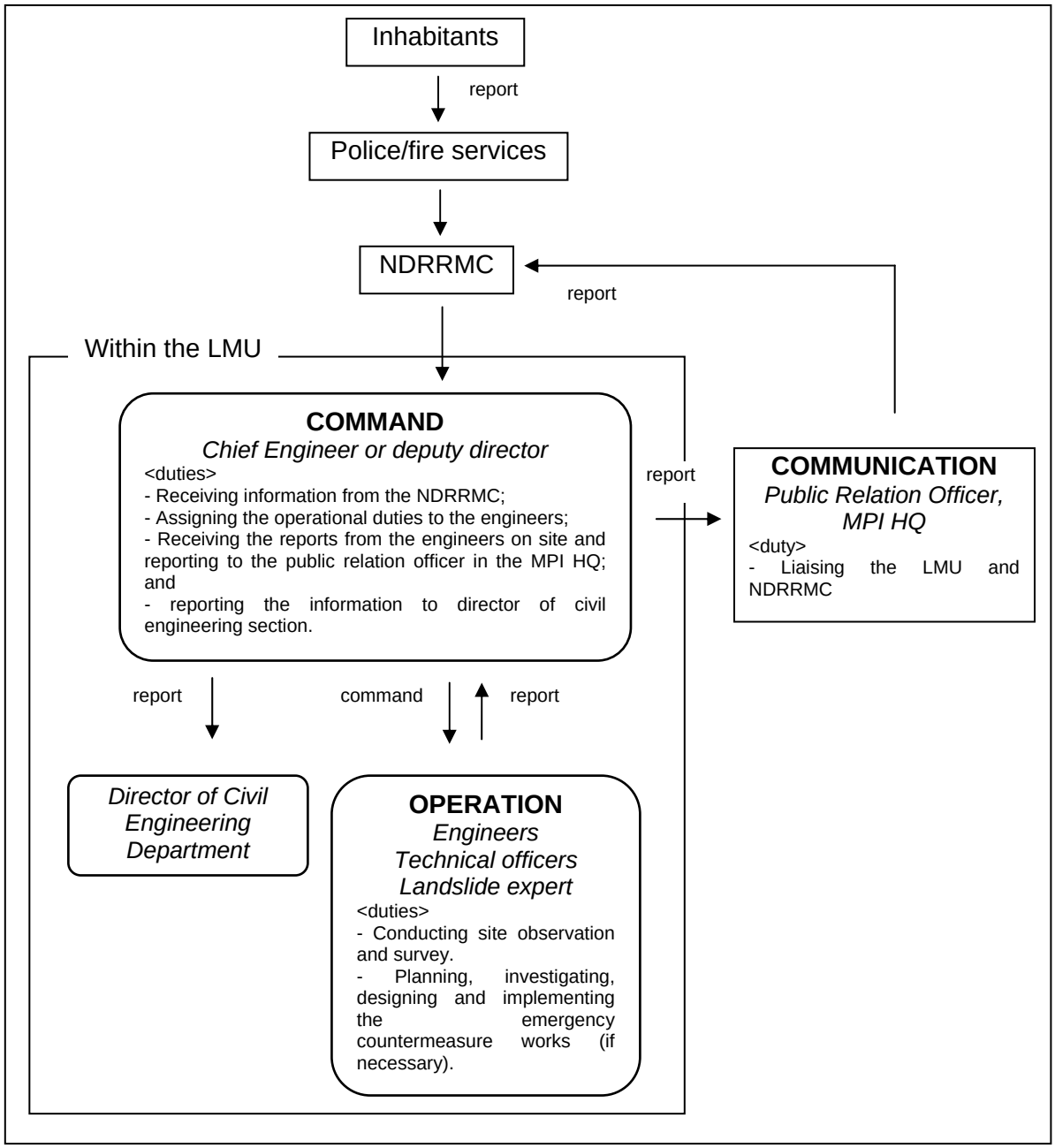
As a result of defining the tasks and responsibilities for all stakeholders, it is expected that all stakeholders will be actively involved in tackling the landslide issues. Moreover, as the stakeholder meeting will be regularly organized in order to share landslide information, the collaboration of all stakeholders will be enhanced.

LMU has actively participated in the stakeholder meetings, for example, LMU engineers presented the tasks and responsibilities of landslide management by themselves in the one day seminar on the 27th of November 2014. This fact proves that the LMU engineers have enhanced their knowledge and understanding of landslides, and are contributing in raising awareness and knowledge among other organizations.

a.1 Emergency operational system within the LMU

The emergency operational system within the LMU is established as follows.

Table 7.9.3 Emergency Operational System within the LMU (source: JET)



a.2 Establishment of public/private cooperation system

The hiring of expert(s) on a retainer basis is considered in order to support the LMU's task of landslide management. The JICA Expert Team supported to define the scope of work for the expert on a retainer basis and the LMU has submitted the scope of work to the MPI headquarters. The MPI intends to employ a local or international geotechnical engineer.

Chapter 8

Environment, Climate Change Adaptation and Disaster Management

8 Environment, Climate Change Adaptation and Disaster Management

8.1 General

Followed by the aforementioned global action, the Project has launched as a component of the Program of JICA Environment, Climate Change Adaptation and Disaster Management Scheme. The Project should also share the view of the Climate Change Adaptation, Environment and Disaster Management in Mauritius to produce the synergistic effect with other components (or projects). The effective technical transfer shall first consider in relation with political and administrative capability of Mauritius together with the collaboration with other relevant Projects by other Development Partners. Figure 8.1.1 shows the relation of JICA Project components and respective Mauritius organizations.

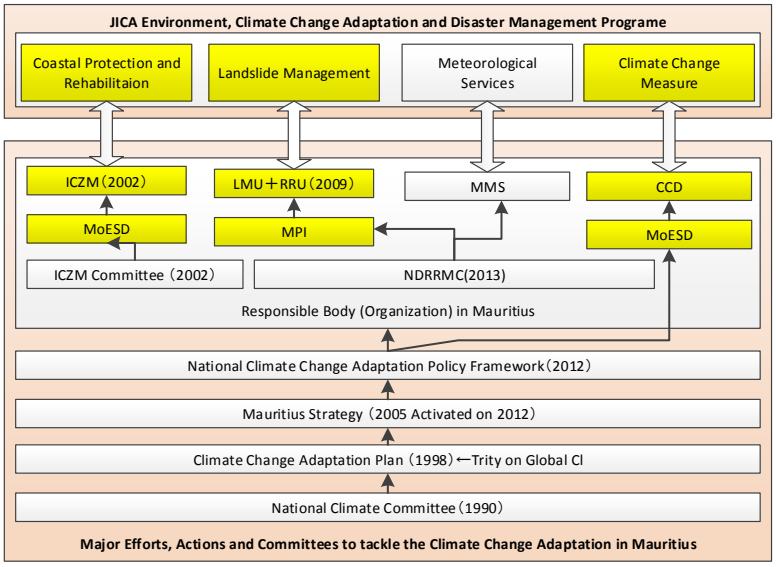


Figure 8.1.1 JICA Environment, Climate Change Adaptation and Disaster Management Program and Related Mauritius Agencies (source: JET)

8.2 The Project and Related Organizations

8.2.1 Government Agencies and Organization of Mauritius

Disaster management scheme in Mauritius basically depends on the “Cyclone and Other Natural Disasters Scheme” as the national strategy against the expected natural hazards in the country. The “Maurice Ile Durable” has begun its action in 2013. It describes the MoESD is the coordination ministry in relation with the environmental issues. The result of AAP was compiled as “National Climate Change Adaptation Framework for the Republic of Mauritius (hereinafter NCCAPF) in 12 December 2012. The Climate Change Information Center was established in August 2013.

8.2.2 Development Partners

a. IOC (Indian Ocean Committee)

Almost half of the fund is from AFD and EU. IOC has commenced the Risk and Natural Disaster Management Project (Risques Naturels de la COI) for five island counties of Madagascar, Seychelles, Le Union, Mauritius and Comoros from 2011 until 2016. There are altogether 16 components including the Chitrakoot Landslide Monitoring Program which is currently undertaken by JICA. The project components and schedule after 2012 are shown in

the figure below.

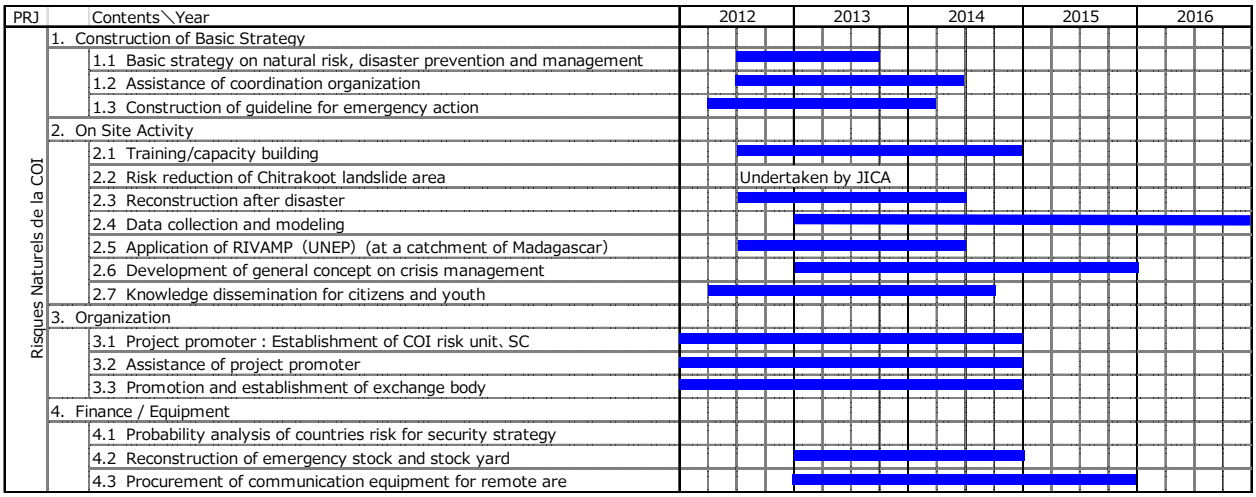


Figure 8.2.1 Major Components of IOC Program[1]

Other than JICA's project component of Chitrakoot Landslide Monitoring Program, the similar or duplicated components are as follows;

2.1 Training/capacity building

2.3 Reconstruction after the disaster

2.6 Development of general concept against risk management

2.7 Education activities for citizens and youth

Information on these areas of duplication is to be shared with IOC, and adjustment of the respective actions will be discussed. The Stakeholder meeting was held on 22 June 2012. The current status and the future direction were discussed. Following the meeting, the site excursion of Chitrakoot was conducted. The explanation of the landslide and the future activities were made by JET to the stakeholders of IOC on 23 June 2012.

The second Steering Committee meeting was called in December 2012. According to the recent information, the ISLANDS project is becoming more active compared to RN-COI.

b. AAP (African Adaptation Program) - "National Climate Change Adaptation Framework for the Republic of Mauritius"(12 December 2012)

AAP is targeted to 20 African countries for Climate Change Adaptation funded by Japan. Several components are covered by the program and it was started in December 2009, and expected to be finalized in December 2012. The Program is titled Development of a DRR Strategic Framework and Action Plan, (December 2012, Studio Galli Ingegneria S.p.A. in association with Centro Euro-Mediterraneo per I Cambiamenti Climatici S.c.a.r.l and Desai & Associates Ltd. Contents of the Project are as follows;

Table 8.2.1 Contents of DRR[2]

No.	Contents
1	Climate change analysis and scenarios
2	National Risk Profile
2.1	Hazard profiling for flooding
2.2	Risk assessment of coastal inundation
2.3	**Hazard profiling for landslides**
2.4	Vulnerability assessment
2.5	Comprehensive national risk profile
3	DRR strategic Framework and action plan
3.1	DRR strategy
3.2	Integrated risk management strategy
3.3	Action Plan
3.4	Detailed actions

This Program targets the risk analysis of landslide, flood and coastal inundation disasters from the macro point of view though risk assessment map utilizing Digital Elevation Models (hereinafter DEM) and satellite imagery. However, the project period was only 6 months and lack of site investigation resulted that frequency of landslide hazards are high in the surroundings of basaltic high mountainous area. It seems to be a general conclusion, and everyone can expect this result. Also integrated risk management strategy and its action plan have some aspects which cannot be realistically executed. Some parts may be utilized in our project, especially the DEM based profile maps.

The results of AAP were projected to the action plan namely “National Climate Change Adaptation Framework for the Republic of Mauritius” (12 December 2012). This framework is currently conducted by Climate Change Division (CCD) of MoESD. The Climate Change Information Center was established in August 2012 under the CCD.

Including DRR, in total 39 projects are planned within five categories, of which cross sectorial programmes have the highest priority. The project period is set from 2013 to 2015, and the major projects (funded projects) are as follows;

1. Preserve healthy natural environment (45,000,000 Rs)

2. Coastal Management Plans for Inundation (45,000,000 Rs)

3. Sound Spatial Data Infrastructure (270,000,000 Rs)

4. Flood Management Plans (937,000,000 Rs)

Currently the Project of Coastal Management Plans for Inundation is active. However only the project “Preserve healthy natural environment” has budgeted and others are still in the preliminary phase without budget. Other 35 projects including the cross sectorial ones are not started. The goals to achieve the results on those projects are still far.

8.3 Summary on Environment, Climate Change Adaptation and Disaster Management by JICA

The major outcomes of this project on the disaster management are summarized as follows;

1. The cyclones and heavy rains, particularly torrential rains are intensive in Mauritius. The ability to reinforce and plan measures on landslides, floods and sediment disasters is enhanced.

2. Directional contribution has been made on policies on the disaster management and on landslide disaster measures to MPI and NDRRMC through survey, monitoring, disaster reduction measures and emergency alarm system as disaster prevention measures within the framework of JICA Climate Change Adaptation and Disaster Management package to the government of Mauritius.

3. The action plan for disaster prevention were transferred not only the policy level but to the communities at the dangerous area through the disaster education and sensitization (community disaster management).

These contributions are summarized in flow chart presented in Figure 8.3.1

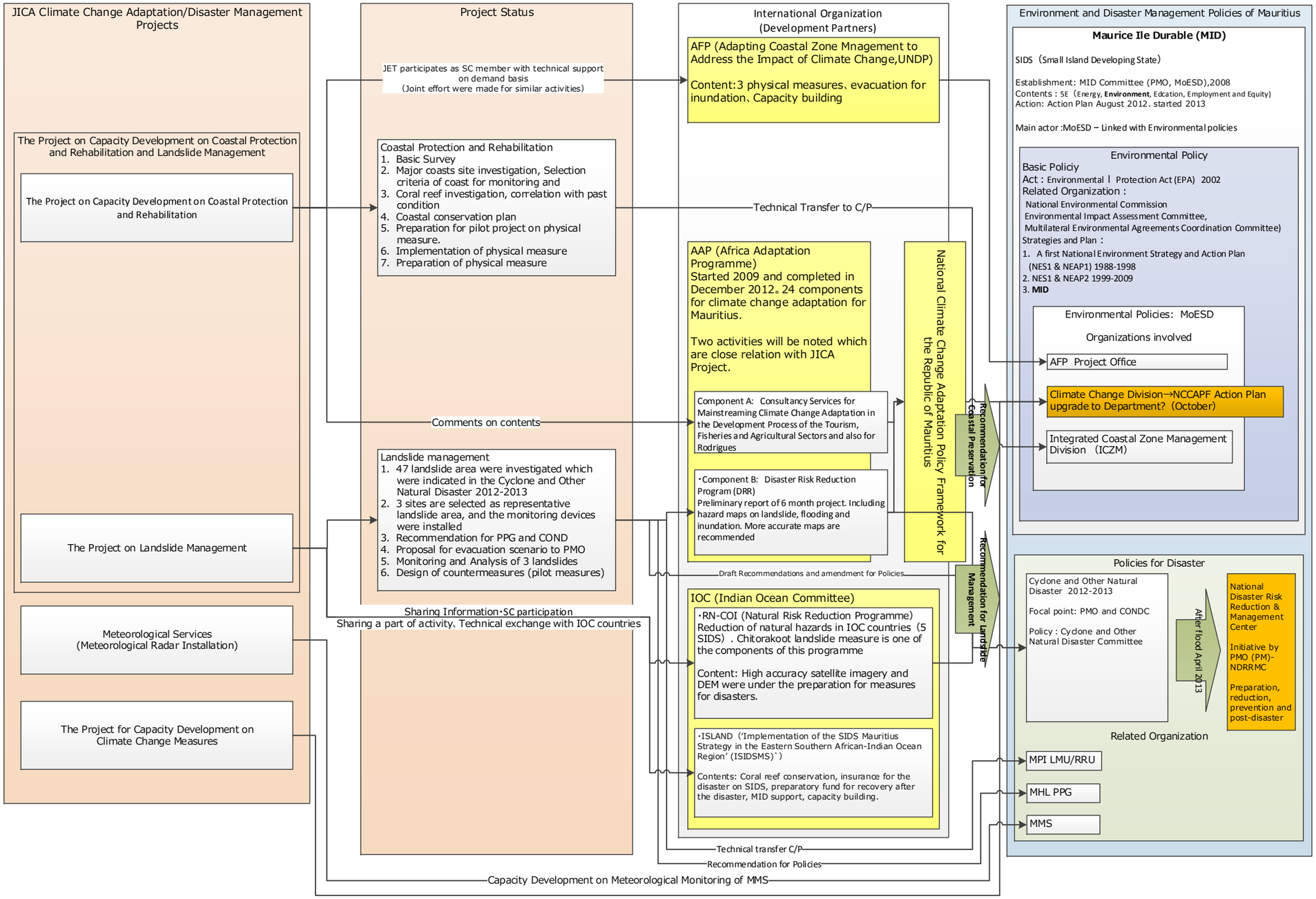


Figure 8.3.1 JICA Climate Change Adaptation/Disaster Management Projects and the Relation with Other International Development Partners, and the Related Policies of Mauritius

8.4 Technical Exchange with the Southwest Indian Ocean Islands

a. Background

In line with the work plan of this project, the regional seminar on the landslide and coastal zone management in the southwest Indian Ocean islands was organized in order to share the outcomes of the project with the neighboring islands.

b. Expected Effects on Climate Change Measures and Disaster Risk Reduction Measures

1) Sharing the outcomes of the JICA's activities in Mauritius to the other southwest Indian Ocean islands which could be an example of JICA's technical exchange on disaster risk reduction for the SIDS at the Third United Nations World Conference on Disaster Risk Reduction in Sendai in 2015;

2) Highlighting the JICA's presence in the southwest Indian Ocean islands as well as the measures on climate change and natural disasters implemented by the Government of Japan as linking the regional seminar to the International Year of Small Island Developing States in 2014 and the Third International Conference on SIDS held in Samoa in September 2014;

3) Emphasizing aid coordination and cooperation of the regional seminar by linking the seminar with the Third International Conference on SIDS held in 2014;

4) Following the JICA's south-south cooperation as the regional seminar provides an opportunity for Mauritius and the neighboring islands for technical exchange;

5) Extending the outcomes of JICA's project on coastal rehabilitation and protection and landslide management in Mauritius to the neighboring islands through the presentation and field visits; and

6) Sharing the issues in the southwest Indian Ocean islands with a consideration of the regional centre such as CCIC in Mauritius.

8.4.1 Summary of the Regional Seminar

a. Seminar Outline

1) Schedule: 5 March 2015 to 6 March 2015 (Day 1: presentation, and Day 2: field visits)
2) Participating islands: Mauritius (including Rodrigues), Madagascar, Seychelles, Comoros and Reunion
3) Participants: one management officer and two technical officers from Madagascar, the islands of Seychelles, Comoros and Reunion, and concerned officers of JICA project from Mauritius (including Rodrigues)

b. Purposes of the Seminar

1) Extending the outcomes of JICA's project on landslide management and coastal protection in Mauritius to the neighboring islands;
2) Organizing the seminar in collaboration with the international organizations in order to initiate the disaster risk reduction including landslide management and coastal protection; and
3) Promoting technical exchange between Mauritius and the neighboring islands.

c. Regional Seminar

Table 8.4.1 Presentation Details (source: JET)

presenter	Presentation details
Mauritius MPI (landslide C/P)	• Landslide management in Mauritius • Classified landslide sites and main related organizations • Landslide monitoring • Countermeasure works in Chitrakoot
Mauritius MESDDBM (coastal C/P)	• Coastal zone issues in Mauritius (i. e. coastal erosions, coral reef destructions, siltation of lagoon, sea level rise, natural calamities, overfishing, uncontrolled development on the coast, and marine litter) • Coastal zone management (i.e. legal framework, and implementing organizations project details) • JICA's coastal protection and rehabilitation project
Mauritius MESDDBM (climate change C/P)	• Impacts of climate change in Mauritius • Visions and initiatives on climate change and natural disasters
Madagascar	• Natural and human made disasters in Madagascar (i.e. cyclones, landslides, ocean pollution, and oil spills) • Responses for the disasters (i.e. human development, and organizational reinforcement) • Issues of landslide (i.e .soil, environmental degradation, and lack of data)
Seychelles	• Hazard profile in Seychelles (i.e. storm surges, landslides, coastal erosions, heavy rainfalls, and flash floods) • Responses for disasters (i.e. organisational set up, and project implementation) • JICA's project on coastal erosion and flood
Comoros	• Natural disasters in Comoros (i.e. landslides, coastal erosions, and floods) • Impacts caused by the disasters • Responses for the disasters
Reunion	• Natural disasters in Reunion (i.e. landslides, coastal erosions, floods, and sea level rise) • Projects implemented for the natural disasters

d. Discussions

Table 8.4.2 Discussion Details (source: JET)

Answered by countries/ organizations	Discussion details
1. What kind of disaster risk reduction measures are taken in each island?	
Comoros	• Mangrove plantation
Madagascar	• Enhancement of the research activities • Introduction of early warning system at the community level • Mangrove plantation
Reunion	• Enhancement of sensitization activities • Establishment of effective and efficient disaster risk reduction measures in the limited budget • Enhancement of soft countermeasures (i.e. information sharing with local residents)
Seychelles	• Enhancement of multi-agency cooperation before and after the disaster in order to prevent duplication of the activities • Establishment of the early warning system • Mangrove plantation • Enhancement of awareness raising activities
2. What are required for disaster risk reduction in future?	
Mauritius	• Enhancement of vulnerability analysis • Establishment of a platform where officers at technical and management level are able to share the information in the region • Capacity building in terms of data collection and monitoring
Comoros	• Enhancement of academic knowledge on coastal zone management • Establishment of a platform to share information and experience in the region • Organizational reinforcement in terms of human resources and equipment
Reunion	• Establishment of a platform to share the information beyond the country
Seychelles	• Collection of data and experience • Accessing fund
IOC	• Cooperation beyond the different level of development and organizational capacity in the islands • Understanding the issue of accessing data rather than lack of data. Firstly data sharing among the different ministries in the same country needs to be strengthened and the data sharing system at the national level is required. • Establishment of database for information and data sharing in the region • Promoting the technical exchange beyond the country
3. What are the ways of cooperation among the southwest Indian Ocean islands?	
Mauritius	• Utilization of the Climate Change Information Centre (CCIC) established by the JICA's support • Sharing the data and materials collected at the CCIC
IOC	• Development of the training programme for island technical officers in order to deal with the island specific issues
4. Landslide early warning system	
MPI Mauritius	• three stages of warning, evacuation and termination • The device has the yellow light for warning stage and red light with alarm for evacuation stage.
5. Landslide monitoring	

MPI Mauritius	• Consulting the monitoring works to the Mauritian private company • Conducting monitoring at three sites
6. climate change adaptation measures for coastal zone	
MESDDBM Mauritius	• Shifting from hard countermeasures to soft countermeasures
7. Examples of information sharing in the region	
IOC	• Sharing the information such as waves and water quality on the website of Mauritius Oceanography Institute (MOI)
8. Any actions taken at the community level for demonstration project	
MESDDBM Mauritius	• Awareness raising of the local residents through beach beautification organized once a month at Grand Sable • Organized stakeholder meeting for more than five times before the demonstration project

e. Outcomes of the Regional Seminar

The outcomes of the JICA'S project on coastal protection and rehabilitation, and landslide management in Mauritius were shared through the presentation in the first day and field visits in the second day. Technical knowledge and experience of the other islands were also shared. Moreover, cooperation on climate change and disaster risk management was emphasized, and participants had a fruitful discussion for continuous cooperation in future.

Reference for Chapter 8

[1] JET compiled based on project brochure of COI-RN
[2] Development of a Disaster Risk Reduction Strategic Framework and Action Plan, (December 2012)

Chapter 9

Proposal for Future Tasks

9 Proposal for Future Tasks

9.1 Proposal on a Landslide Management Plan

9.1.1 Disaster Inspection

Thirty-seven (37) slope disaster hazard areas are defined in the Disaster Scheme, which means that the 37 areas are officially identified by the Mauritius Government as “high hazard areas for slope disasters”. Therefore countermeasures which mitigate the risk of disasters are necessary to protect the citizens and the infrastructures in Mauritius

However it is impossible to immediately conduct countermeasures and to diminish the risk completely in a short period for the 37 slope disaster hazard areas because of the limited budget and human resources and the lack of technology. It would take several to a dozen years to complete all of the countermeasures for the areas because they will be conducted one by one.

Therefore a regular disaster inspection is a better risk management method to identify ominous signs that may cause a serious disaster before a slope disaster happens, which should last until the completion of countermeasure construction and the confirmation of effectiveness of the countermeasures. The disaster inspection procedures JET has proposed to MPI will be conducted continuously in the Project.

9.1.2 Disaster Scheme

Figure 9.1.1shows the outline image of the draft recommendation for the Disaster Scheme.

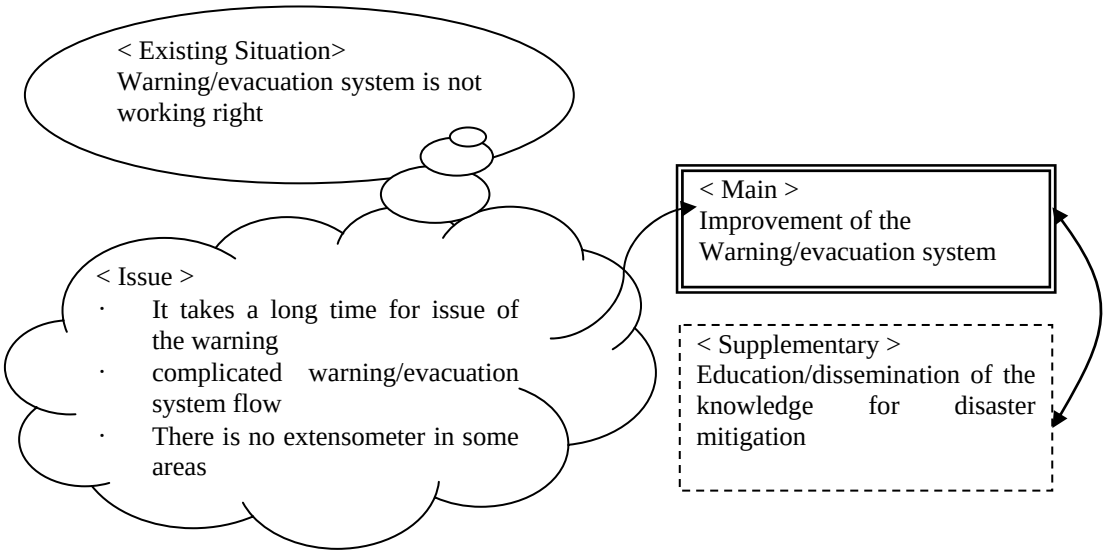


Figure 9.1.1 Outline Image of the Draft Recommendation for Disaster Scheme (source: JET)

- The Disaster Scheme is basically the manual for the warning/evacuation system in a time of disaster/emergency. Therefore, it is required that the response by the related ministries/agencies should be simply described at each stage for prompt action.
- Regular activities for education/dissemination/drill will be required in order for the warning/evacuation system to work properly.

- The education/dissemination has no immediate relationship to the Disaster Scheme as a manual of the warning/evacuation system. Therefore, it is difficult to incorporate the education/dissemination into the Disaster Scheme. But education/dissemination is a matter related to the Disaster Scheme. The incorporation of the contents to the guideline/manual by this project is proposed as a supplemental recommendation.

Based on the above, Table 3.9.3 in the Main Report shows the existing disaster scheme article, draft proposal of addition/modification, reason of addition/modification and necessity as a recommendation for the disaster scheme. Part of the draft proposal of addition/modification is attached to the Supporting Report.

9.1.3 Recommendation of PPG

Figure 9.1.2 shows the outline image of the draft recommendation for PPG.

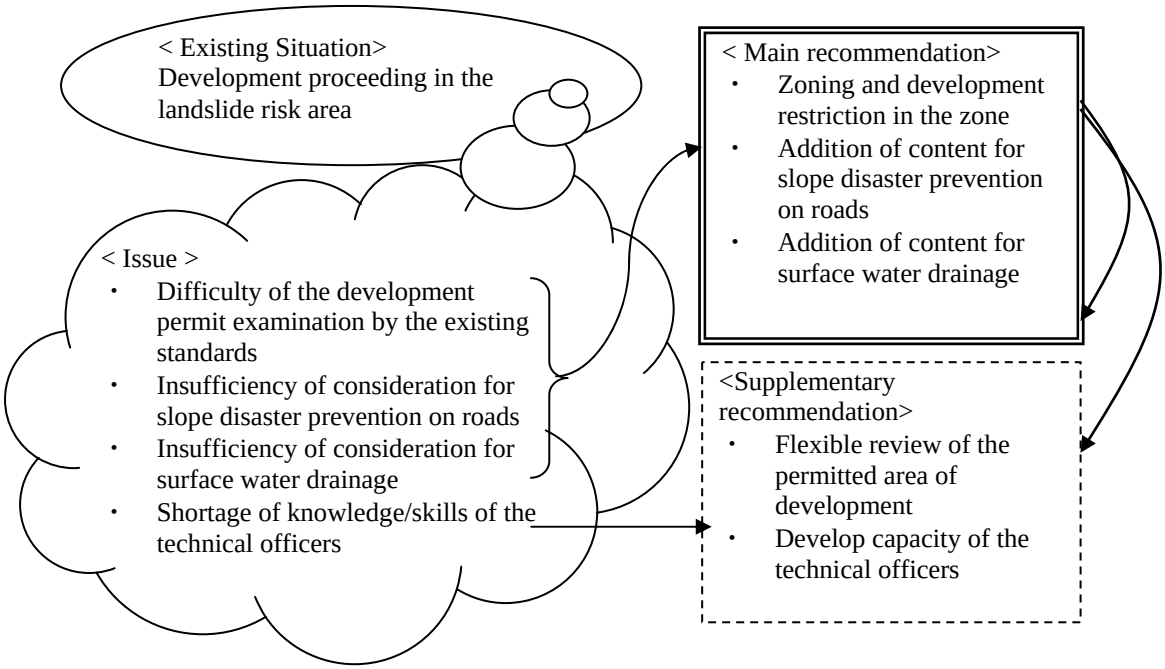


Figure 9.1.2 Outline Image of the Draft Recommendation for PPG (source: JET)

< Existing situation >

PPG has the following criteria regarding development restrictions on sloping sites.

- Development will not normally be permitted on slopes steeper than 1:5 (20%).
- Development above slopes of 1:10 (10%) will be approved conditional on survey completion and implementation of slope stability works.
- Buildings and structures should be set back far enough from ridges and cliff edges so that the structure does not appear to be perched on the edge.

PPG has little content on development restriction in landslide risk areas, but development is proceeding in the risk area.

< Issue >

According to the interview survey result of the local authorities/related ministries, the

following issues are confirmed.

- There is no clear zoning of the restriction on a map. It is therefore difficult to identify the restricted area. As a result, a development/building permit application for the landslide risk area can pass the review process by the building/planning/works inspector.
- There is a shortage of an administrative officer/engineer who has knowledge/skills regarding the development restriction at sloping sites.

<Main recommendation>

The following solutions are proposed as a main recommendation to the above issues:

- Designate the hazard zone for a slope disaster
- Restrict development in the hazard zone.

Based on the above, Table 3.10.6 in the Main Report shows the existing PPG Article, Draft proposal of addition/modification, Reason of addition/modification and necessity as a recommendation for PPG. Also, the part of the draft proposal on addition/modification is attached in the Supporting Report.

9.1.4 Technical Guideline for Initial Survey

The Guideline covers what and how landslide disasters should be dealt with, and includes the procedures MPI should implement on landslide disasters. The procedures are composed of literature survey, initial site survey, emergency response, detailed survey plan, etc. The detailed survey/analysis/monitoring and the design/construction after the discussion of the survey plan are described in “Procedure Manual for Landslide” which is elaborated in the next section.

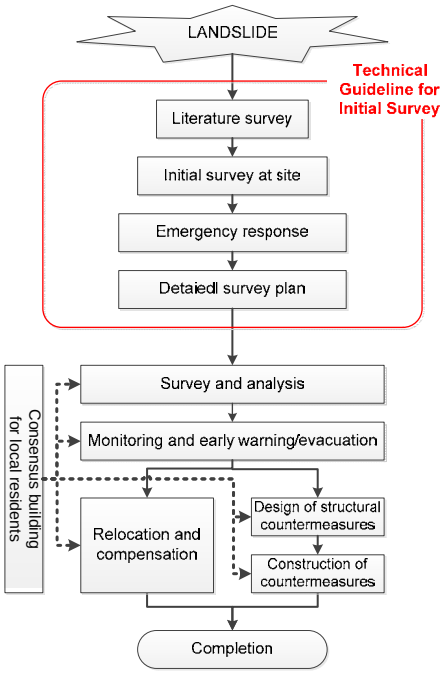


Figure 9.1.3 The Scope of Application of the Technical Guideline for Initial Survey (source: JET)

Table 9.1.1 The Contents of the Technical Guideline for Initial Survey (source: JET)

Cp.	Title	Contents
1	Introduction	- Contents, purpose, flow of the guideline - Outline of landslides in Mauritius - Workflow of initial survey
2	Literature survey	- Data to be collected ant their utilization - Regulation of law and land-use
3	Initial site survey	- Setting of target areas - Site survey and analysis - Monitoring for initial survey
4	Emergency response	- Structure measure - Evacuation and relocation - Early warning system
5	Detailed survey plan	- Outline of detailed survey - Outline of countermeasure policy

Although the Guideline is prepared by mainly JET in the Project, LMU should renew appropriately the contents of the Guideline after the Project so that it becomes more usable and rational based on the case examples and issues in Mauritius.

9.1.5 Procedure Manual for Landslide

The Manual covers what and how to undertake countermeasures to mitigate the disaster risk of landslides, and how to support MPI in conducting surveys/analysis and planning/design/construction of countermeasures for landslides by themselves. It is also formulated based on the review of the early warning/evacuation procedures and PPG. The manual includes strategic methods to induce development and important points to remember, as well as problems found in the F/S and the pilot project and solutions, and how the solutions were reached.

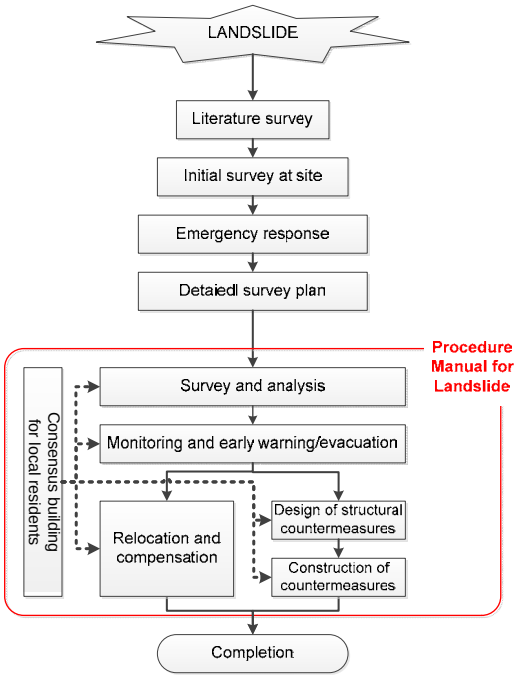


Figure 9.1.4 The Scope of Application of the Procedure Manual for Landslides (source: JET)

Table 9.1.2 The Contents of the Procedure Manual for Landslides (source: JET)

Cp.	Title	Contents
1	Introduction	- Outline of landslides in Mauritius - Contents, purpose, flow of the Manual - Application, composition of the Manual
2	Survey and analysis	- Topographic survey, aerial photo identification, field reconnaissance, drilling, geophysical exploration, laboratory test, water analysis - Installation of monitoring devices - Cross section, active areas/blocks, direction of movement, volume, discussion of slip surface - Basic factor and trigger - Stability analysis and safety factor
3	Monitoring and early warning/evacuation	- Monitoring system and information transmission - Setting of threshold for warning and evacuation - Responsibility and role of related organizations - Evacuation procedure
4	Relocation and compensation	- Existing law (PPG etc.) and planning scheme - Caution area and special caution area - Area setting for relocation/compensation - Implementation of relocation - Implementation of compensation
5	Consensus building for local residents	- Significance of consensus building - Flow of consensus building - When and what to be built for local residents - How to deal opinions and comments from residents
6	Design of structural countermeasures	- Basics of design of landslide countermeasures - Design of restraint works and control works - Environmental and social considerations
7	Construction of structural countermeasures	- Construction plan - Checkpoints for construction - Construction and supervision
8	Initial survey and emergency response	[Excerpt of “Technical Guideline for Initial Survey”]

Although the Manual is prepared by mainly JET in the Project, LMU should renew appropriately the contents of the Manual after the Project so that it becomes more usable and rational based on the case examples and issues in Mauritius.

9.2 Proposal on a Feasibility Study

9.2.1 Promotion of Fund Raising

The "promotion of fund raising" in the Project is to secure a budget from the Mauritius Government and to procure fund from other donors in order to implement landslide countermeasures in a sustainable manner. JET has discussed the promotion of fund raising with the related organizations such as MPI based on the schedule and budget for implementation of landslide projects.

MPI declares that LMU will be focused on landslide projects in the future and secure the budget for the countermeasures by themselves. Indian Ocean Commission (hereinafter IOC), which is implementing the natural disaster prevention projects including landslide disasters in Mauritius, has no plan to procure additional funds for landslide countermeasures for the time being. Therefore, basically, the landslide projects are going to be conducted by the budget in Mauritius Government. The schedule and budget for implementation are planned based on the MPI's stance.

a. 2013 Fiscal Year

In 2013 fiscal year, LMU has 3,457,980Rs as "Acquisition of Equipment for Landslide Management" which has been applied last year. Therefore, JET suggests that LMU makes use of the earmarked budgeted funds towards the investigation required for Vallee Pitot and the monitoring in La Butte as per the following table. MPI agreed to the breakdown of budget in 2013.

Table 9.2.1 Breakdown of Budget in 2013 (source: JET)

No.	Contents	Budget (Rs)
1	Detailed investigation and monitoring in Vallee Pitot	3,400,000
2	Monitoring in La Butte	
3	Acquisition of Equipment for Landslide Management	
4	Approval of Environmental Impact Assessment in Chitrakoot	50,000
	Sum	3,450,000

However the proposed budget in 2013 has not been executed, and it was carried over to 2014. The project will be implemented in late 2014.

b. 2014 Fiscal Year and After

In 2014 fiscal year and after, it is reasonable that countermeasures will be conducted in the areas designated as high priority in the disaster inspection (Chapter 3) among the 37 designated areas in the Disaster Scheme.

In 2014 fiscal year, additional countermeasures will be implemented in the highest priority areas, Vallee Pitot and Chitrakoot; among Rank A areas (Rank A requirescountermeasures as soon as possible, which can seriously affect residents and/or infrastructures).

In 2015 fiscal year, countermeasures and detailed investigations will be implemented in the remaining six (6) areas among Rank A areas. Moreover, data aquisition for the landslide

hazard mapping will be needed.

In 2016 fiscal year after the completion in the Rank A areas, countermeasures will be implemented in Rank B areas (Rank B areas require countermeasures due to the potential impact of a landslide disaster on residents and/or infrastructure. However the priority is not higher than Rank A. Therefore the countermeasures can be implemented after the completion of Rank A countermeasures). Moreover, data aquisition for the landslide hazard mapping will be needed. The higher priority is Rank B in the Port Luis area where population, industy and traffic are concentrated.

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1,000,000 Rs, and 2) overtime and allowance: 500,000 Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2014 – 2016 are indicated as follows;

- 2013 FY: 3,450,000 Rs
- 2014 FY: 16,500,000 Rs
- 2015 FY: 36,500,000 Rs
- 2016 FY: 35,500,000 Rs

Table 9.2.2 List of Countermeasures and Budgets in 2014-2016 (source: JET)

FY	No.	Rank	Item	Rs	Detailed works
2014	10	A	Construction of countermeasures in Vallee Pitot	9,000,000	Surface drainage work Subsurface drainage work Repair of existing canal
	9	A	Construction of additional countermeasure in Chitrakoot	6,000,000	Large scale canal
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2015	8	A	Construction of countermeasures in L'Eau Bouillie	5,000,000	Concrete ditch along road Re-pavement/repair of road
	16	A	Construction of countermeasures in Boulevard Victoria, Montagne Coupe	7,000,000	Soil excavation of upper steps Reinforcement of gabion (reinforcement with strong wire net)
	17	A	Construction of countermeasures in Pailles: (i) access road to Les Guibies	7,000,000	Slope cutting/vegetation Raising up of existing retaining wall Surface drainage on slope
	19	A	Construction of countermeasures in Pailles: (iii) Soreze region	3,000,000	Repair of existing ditch Removal of unstable rocks Geotechnical investigation for detailed countermeasures
	26	A	Construction of countermeasures in Riviere des Anguilles, near the bridge	9,000,000	Gabion/concrete wall along river Installation of extensometer near houses
	33	A	Construction of countermeasures in Piper Morcellement Piat	3,000,000	Retaining wall Surface drainage work
			Data aquisition for the landslide hazard mapping	1,000,000	
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	
2016	15	B	Investigation in Old Moka Road, Camp Chapelon	3,500,000	Geotechnical investigation for detailed countermeasures
	34	B	Investigation in Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	2,500,000	Geotechnical investigation for detailed countermeasures
	11	B	Construction on countermeasures in	2,000,000	Ditch

			LePouce Street		
	12	B	Construction of countermeasures in Justice Street (near Kalimata Mandir)	8,000,000	Soil excavation in the back of retaining wall Retaining wall Surface drainage on slope and new culvert
	14	B	Construction of countermeasures in Pouce Stream	6,000,000	Increasing height of existing retaining wall Gabion along river
	18	B	Construction of countermeasures in Pailles: (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	3,000,000	Extension of outlet to ditch Concrete wall and filling
	19	A	Construction of countermeasures in Pailles: (iii) Soreze region	9,000,000	Surface drainage work Subsurface drainage work Rockfall protection wall/fence/net
			Maintenance and repair of monitoring equipment	1,000,000	
			Overtime and allowance	500,000	

Although JET proposed that MPI should apply the budget within 2013 to the Ministry of Finance, the budget has not been submitted and carried over to 2014. MPI has reconsidered the budget by themselves in 2013 and 2014 as follows.

c. 2015 Fiscal Year and After

In 2015 fiscal year and after, countermeasures are supposed to be conducted in the 37 designated areas in the Disaster Scheme. Detailed investigation and installation of monitoring devices will be implemented in 2015 fiscal year and the construction of countermeasures in 2016 fisical year and after. MPI will reconsider the priority of countermeasures based on the results of the detailed invastigation and analysis in 2015 so that they will start the construction of countermeasures form the high priority areas (Table 5.5.3).

In addition to the above budget for the countermeasures, a further budget application was made for 1) maintenance and repair of monitoring equipment: 1.0 million Rs, 2) overtime and allowance: 0.5 million Rs, 3) preparation of hazard maps: 1.5-2.0 million Rs and 4) expert on retainer basis: 1.0-2.5 million Rs. The breakdown of budget has been proposed by JET and applied to MPI head office. The applied budget and breakdown of the countermeasures on landslide management in LMU in 2015 – 2017 are indicated as follows;

- 2015 FY: 55,650,000 Rs
- 2016 FY: 40,100,000 Rs
- 2017 FY: 44,700,000 Rs

Table 9.2.3 List of Countermeasures and Budgets in 2015-2017[1]

No.	Area name	Disaster	2015 (Rs)	2016 (Rs)	2017 (Rs)
1	Construction Works in Chitrakoot (Block A) - Section 1	Landslide	2,250,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block A) - Section 2	Landslide	400,000		
	Construction Works in Chitrakoot (Block A) - Section 2	Landslide	8,000,000		
	Consultancy Services for Countermeasure Construction Works in Chitrakoot (Block B)	Landslide		400,000	
	Construction Works in Chitrakoot (Block B)	Landslide		6,000,000	

2	Consultancy Services for Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	450,000		
	Countermeasure Construction Works at Vallee Pitot (near Eidgah)	Landslide	9,000,000		
3	Remote Monitoring System in Chitrakoot, Vallee Pitot, Quatre- Soeurs and La Butte	Landslide	7,000,000		
4	Maconde Region Baie du Cap - Phase 2	Rock fall	10,000,000		
5	Morcellement Hermitage, Coromandel	Slope failure	250,000		
6	L'Eau Bouillie	Damage of embankment	250,000	5,000,000	
7	Boulevard Victoria, Montagne Coupe	Damage of wall	7,000,000		
8	Pailles access road to Les Guibies and along motorway, near flyover bridge	Slope failure	350,000	7,000,000	
9	Pailles Soreze region	Slope failure	500,000	3,000,000	
10	Riviere des Anguilles, near the bridge	Stream erosion	450,000	9,000,000	
11	Post Relocation Works at Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide	250,000		
12	Piper Morcellement Piat	Stream erosion	150,000	3,000,000	
13	Temple Road, Creve Coeur	Damage of wall	100,000		Budget will depend on results of detailed investigations and expert recommendations. Around 40 million Rs is forecasted
14	Congomah Village Council (Ramlakhan)	Stream erosion	100,000		
15	Congomah Village Council (Leekraj)	Damage of wall	100,000		
16	Congomah Village Council (Frederick)	Damage of wall	100,000		
17	Congomah Village Council (Blackburn Lanes)	Damage of Embankment	100,000		
18	Les Mariannes Community Centre (Road area)	Slope failure	100,000		
19	Les Mariannes Community Centre (Resident area)	Stream erosion	100,000		
20	Le Pouce Street	Stream erosion	100,000		
21	Justice Street (near Kalimata Mandir)	Damage of wall	400,000		
22	Pouce Stream	Stream erosion	300,000		
23	Old Moka Road, Camp Chapelon	Landslide	575,000		
24	Pailles access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Stream erosion	150,000		
25	Plaine Champagne Road, opposite "Musee Touche Dubois"	Slope failure	100,000		
26	Chamarel near Restaurant Le Chamarel and Road Side	Damage of embankment	100,000		
27	Baie du Cap: (i) Near St Francois d'Assise Church	Debris flow	100,000		
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure	100,000		
29	Trou-Aux-Cerfs	Slope failure	100,000		
30	River Bank at Cite L'Oiseau	Stream erosion	100,000		
31	Louis de Rochecouste (Riviere Seche)	Stream erosion	100,000		
32	Candos Hill, LallBahadoor Shastri and Mahatma Gandhi Avenues	Landslide	125,000		
33	Montee S, GRNW	Stream erosion	100,000		

34	Consultancy Services for Preparation of Hazard Maps		1,500,000	2,000,000	1,500,000
35	Consultancy Fees for Expert on Retainer Basis		2,500,000	2,500,000	1,000,000
36	Overtime Work by Landslide Management Counterparts		1,200,000	1,200,000	1,200,000
37	Maintenance and Repairs of Equipment		1,000,000	1,000,000	1,000,000
Budgetary Forecast for Financial Years 2015 to 2017					44,700,000

It is judged that the Mauritius Government including MPI is so positive towards and allocates ample budget for the landlside countermeasures that they have enough sustainability for future landslide disaster management projects.

9.2.2 Organizational Reinforcement Plan

a. Technical Knowledge

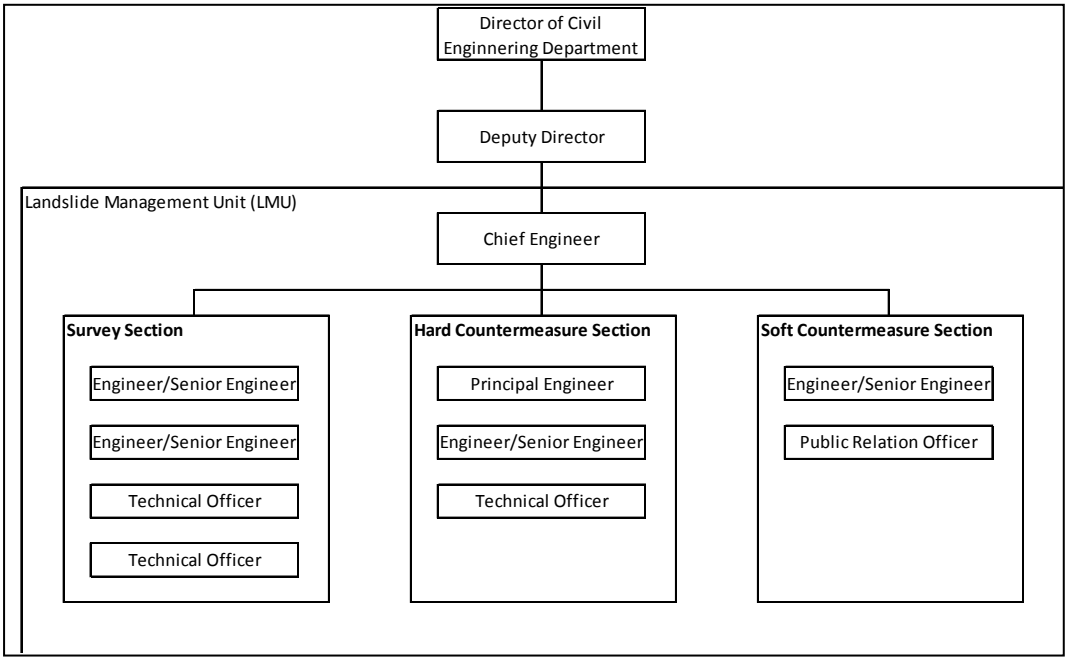
Technical transfer regarding landslide investigation/analysis, design and construction/supervision has been achieved through the project activities such as the daily on the job training, seminars and training in Japan. The LMU engineers understand and obtain knowledge on landslide investigation and countermeasure works. One of the LMU technical engineers is currently applying for JICA's ABE initiative in order to study geotechnical engineering in master's degree and obtain academic knowledge on landslides. Moreover, MPI has applied JICA's landslide adviser in which MPI aims at enhancing technical experience adding to the abilities obtained through this project. LMU will be the main and lead organization for landslide management with academic knowledge and technical experience.

b. Organizational Establishment

As full-time staffs have not been posted to the LMU since its establishment in September 2009, engineers of the other sections in Civil Engineering Department have been assigned. Engineers have taken additional duties and responsibilities over their normal work. However, posting six Engineers/Senior Engineers was decided in March 2014. Following its decision, one engineer has been posted to the LMU since October 2014. The rest of Engineers/Senior Engineers will be posted after the selection is completed. Together with six Engineers/Senior Engineers, posting three Technical Officers and one Public Relations Officer was decided at the same time. However, creation of a Public Relations Officer position is pending and one Intern under the Service to Mauritius (STM) programme will be recruited instead.

There are seven Engineers and Technical Officers working for the LMU as of November 2014. The LMU is divided into three sections and engineers and technical officers for one of these sections in order to define clearer responsibilities for each engineer and technical officer.The LMU will conduct the landslide management with the assignment of the following full-time staff.

Table 9.2.4 Full-time Staff Assignment (Long Term Goal) (source: JET)



c. Coordination with the Other Stakeholders

As collaboration of all stakeholders is essential to deal with landslide issues in Mauritius, the tasks and responsibilities of LMU as well as the other stakeholders were defined and finalised with the procedure below:

1) The tasks and responsible stakeholders in the ordinary and emergency situations were discussed among LMU engineers and technical officers;

2) Based on the discussions above, the responsible organizations and their tasks were summarized in the task flow;

3) The draft task flow was explained to MPI headquarters and the flow was approved by the permanent secretary of the MPI;

4) MPI organized several meetings and invited all main stakeholders such as NDRRMC, police, NDU, RDA, Mauritius Meteorological Services and local authorities to discuss the tasks and responsibilities of each organisation; and

5) The tasks and responsibilities of LMU and the other stakeholders were defined and finalized.

The MPI organized one day seminar on the 27th of November in 2014. MPI headquarters, LMU, MPI/National Development Unit (NDU), MPI/Road Development Authority (RDA), NDRRMC, Ministry of Housing and Lands (MHL) and local authorities participated in the seminar and the tasks and responsibilities for ordinary and emergency situations were finalized. The finalized tasks and responsibilities are as follows:

- Responses to the classified landslide prone areas (37 sites)

The main organizations are identified based on the disaster classification, objects of

protection and the scale of disaster. The main responsible organizations will implement the countermeasure works from the high prioritized areas according to the results of annual slope inspection.

Table 9.2.5 Main Responsible Organizations based on Disaster Classification, Objects of Protection and the Scale of Protection (source: JET)

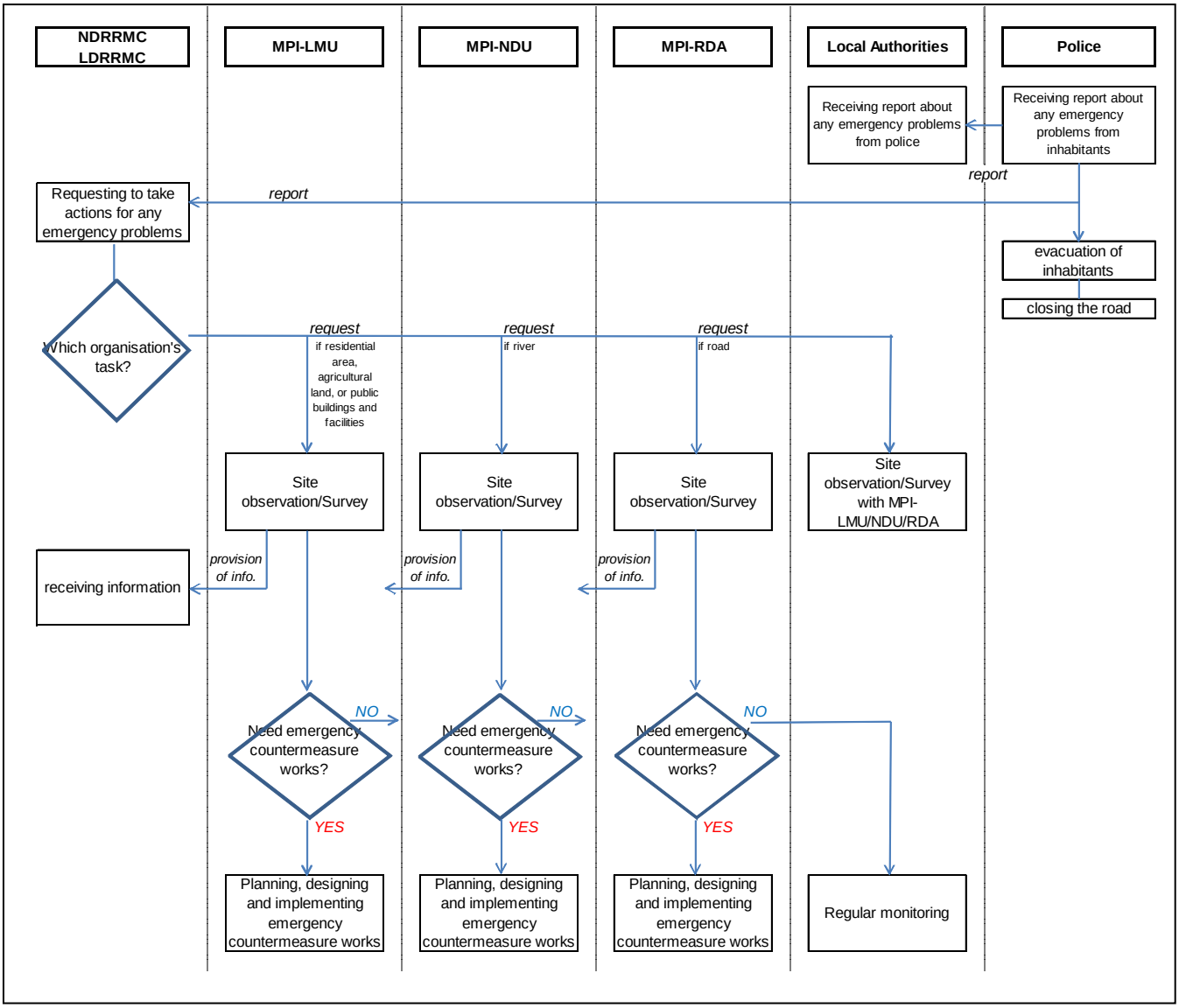
Disaster		Object of protection	The main responsible organisation	
			Large scale disaster	Small scale disaster
Slope disaster	Landslide (mass movement)	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Rock fall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Slope failure	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
Slope and river disaster	Debris flow	Residential houses	LMU/NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU/NDU	
River disaster	Stream erosion	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
	Flood	Residential houses	NDU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads		
Others	Damage of embankment	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of wall	Residential houses	LMU	Local authorities
		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	
	Damage of house	Residential houses	-	Local authorities
		Agricultural fields		
	Cavern	Residential houses	LMU	Local authorities

		Agricultural fields		
		Public buildings and facilities		
		Roads	RDA/LMU	RDA/local authorities

- Responses for emergency situations

In terms of responses for emergency situations, police and local authorities are responsible for taking immediate actions such as evacuation of inhabitants and roadblocks. LMU, NDU and RDA are responsible for the site investigation, consideration of countermeasures and its implementation with the same methodology for 37 classified sites.

Table 9.2.6 Task Flow for Emergency Situation for All Sites (source: JET)



- Responses for the new sites with utilization of a hazard map

LMU will develop a hazard map in order to identify the new landslide prone areas apart from 37 classified sites.

- Early warning

The early warning system is applied for three pilot sites of the project (Chitrakoot, Quatre Soeurs and Vallee Pitot) according to the National Disasters Scheme and protocol. The same early warning system as used at the pilot sites will be established for those new landslide prone areas if identified by the hazard map.

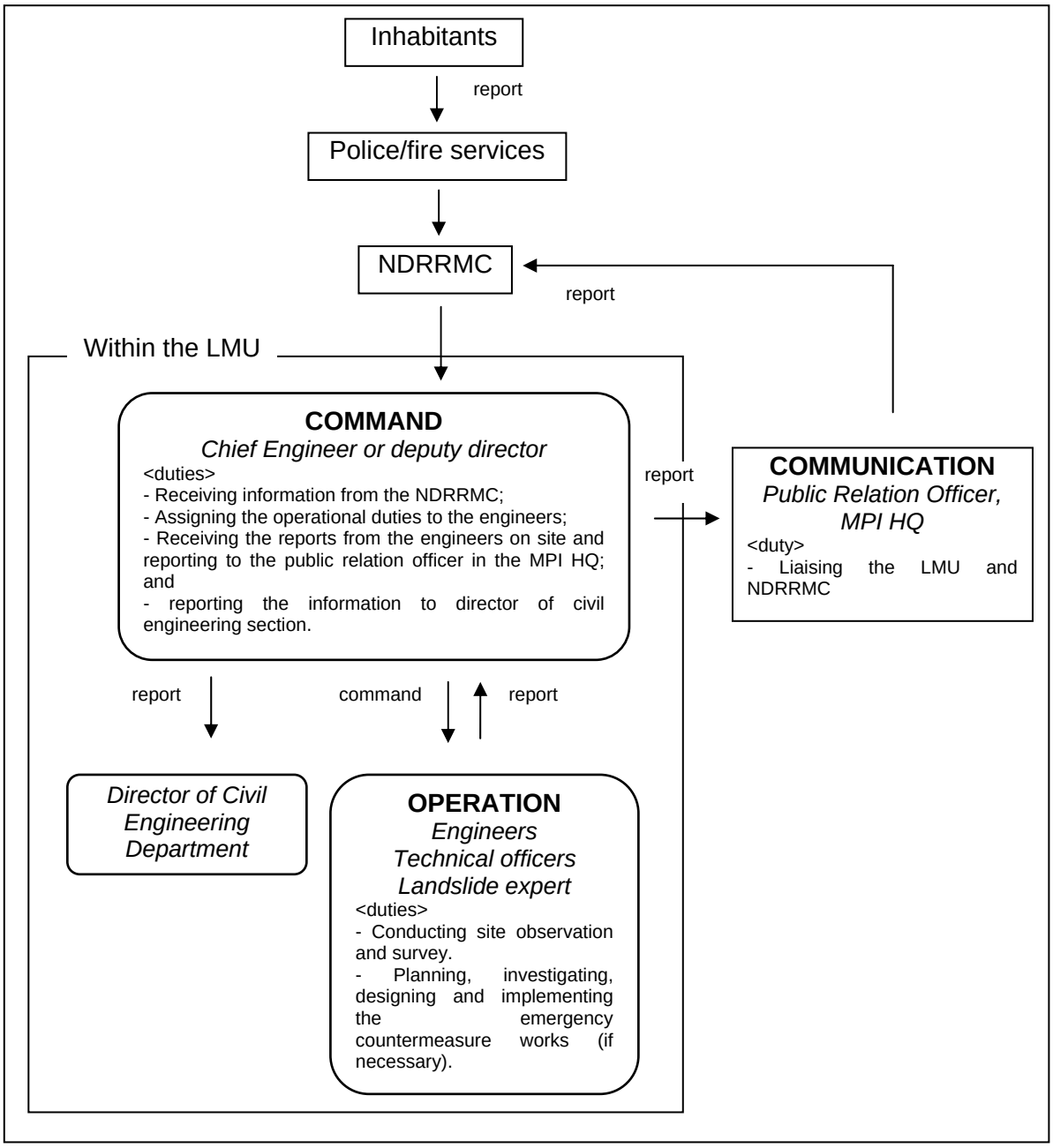
As a result of defining the tasks and responsibilities for all stakeholders, it is expected that all stakeholders will be actively involved in tackling the landslide issues. Moreover, as the stakeholder meeting will be regularly organised in order to share landslide information, the collaboration of all stakeholders will be enhanced.

LMU has actively participated in the stakeholder meetings, for example, LMU engineers presented the tasks and responsibilities of landslide management by themselves in the one day seminar on the 27th of November 2014. This fact proves that the LMU engineers have enhanced their knowledge and understanding of landslides, and are contributing in raising awareness and knowledge among other organizations.

d. Emergency Operational System within the LMU

The emergency operational system within the LMU is established as follows.

Table 9.2.7 Emergency Operational System within the LMU (source: JET)



The LMU reviewed the operations in the past emergency situations and considered the emergency operational system to allocate the engineers and technical officers. Several options such as a monthly roster system were discussed, and the LMU has decided to allocate two responsible engineers and technical officers to each region of Rivière du Rempart, Pamplemousses, Port Louis, Black River, Plaines Wilhems, Moka, Flacq, Grand Port and Savanne (three engineers and technical officers are allocated to Port Louis). The emergency operational system will be revised and updated if necessary.

e. Establishment of Public/private Cooperation System

The hiring of expert(s) on a retainer basis is considered in order to support the LMU's task of landslide management. The JICA Expert Team supported to define the scope of work for the expert on a retainer basis and the LMU has submitted the scope of work to the MPI headquarters. The MPI intends to employ a local or international geotechnical engineer.

9.3 Proposal on a Pilot Project (Landslide Countermeasures)

9.3.1 Structural Countermeasures (Future Plan)

The countermeasure works of Section I at Block-A landslide has been completed in this Project. Now it is necessary that other countermeasure works are carried out continuously.

Future plan of landslide countermeasure work for the Chitrakoot area shall be carried out according the work flow shown on Figure 9.3.1.

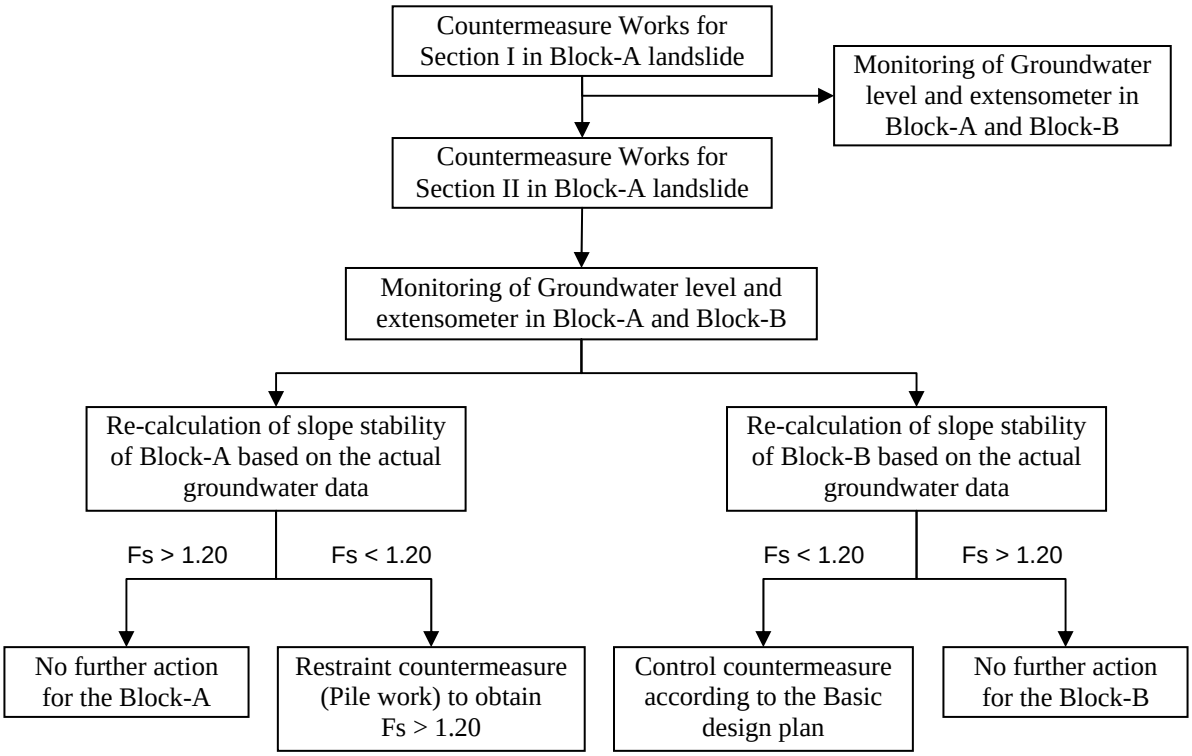


Figure 9.3.1 Flow Chart for Future Plan of Landslide Countermeasure Works in Chitrakoot Area (source: JET)

a. The Types and Quantity of Works to be Handed Over.

With regards to the landslide countermeasure construction works which has been completed by JET on December 2014, the constructed works of the Pilot Project site in Chitrakoot are officially handed over from JET to MPI under the terms and conditions stipulated below. MPI shall take the necessary measures to maintain the works after the handover.

The types and quantity of works which has been constructed by JET are as below. The detailed plan maps and structural figures of each construction works are attached.

- River Type-1 (5m)
- River Type-2 (10m)
- River Type-3 (140m)
- River Type-5 (55m)

- New Channel CH-1 (217m)
- Bridge Br-1
- Bridge Br-2
- Bridge Br-3
- Bridge Br-4
- Bridge Br-5
- Horizontal Drainage (5 boreholes)

The major amendments of design which was made during the construction are as below.

- ✓ River Type 1 & 2: The height of stone masonry was increased, while the vegetation was shortened.
- ✓ River Type 3: The design of the wall on the right side was changed to straight wall at some point.
- ✓ Bridge Br5: The structure of handrail was changed from fence to steel pipe.

b. Further construction works to be conducted by MPI

MPI shall conduct the further construction works for Section II as follows including the works which was cancelled in Section I. After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring.

At present, countermeasure works of Section I for Block-A landslide has been done. After this, the planned countermeasure works of Section II including the cancelled works in the Section I due to issue of land acquisition shall be carried out by the MPI. According to the design of the countermeasure works, planned safety factor of the target landslides will be secured after installation of all planned countermeasure works. Even now a time when the countermeasure works of Section I, monitoring of groundwater level and landslide activity by the extensometer and pipe strain gauges shall be carried out continuously to check the difference from before and after installation of the countermeasure works. It is recommended that the landslide stability analysis shall be carried out to check the change of factor of safety of landslide after installation of the works based on the groundwater level.

Since the work site of Section II is located in a residential area, land acquisition shall be proceeded cautiously. In case that it is difficult to acquire the planned land for the works, it can be changed the location or alignment of the drainage accordingly.

Table 9.3.1 Planned Landslide Countermeasure Works in Chitrakoot Area (source: JET)

Section		Work item	Quantity	unit	Remarks
Block-A landslide	Section II	Channel for the flood CH-2	130	m	
		Upgrading of existing water course RUD-1 (Type3 drainage)	35	m	Cancelled during Section I
		Upgrading of existing water course UD-3 (Type4 drainage)	47	m	Cancelled during Section I
		Horizontal drainage (HD-2)	210	m	
		Horizontal drainage (HD-3)	350	m	
		Surface drainage (SD-1)	75	m	
		Open-blind ditch (OB-1)	55	m	
		Open-blind ditch (OB-2)	85	m	

Section		Work item	Quantity	unit	Remarks
		Blind ditch (BD-1)	35	m	
		Blind ditch (BD-2)	32	m	
		Blind ditch (BD-3)	40	m	
		Water catch basin	5	pc	
		Bridge	2	pc	For vehicles
		Manhole for maintenance	12	pc	On the blind ditch

c. Monitoring and Stability Analysis

After completion of the works of the Section II, groundwater level and landslide activity shall be confirmed by the monitoring. Since the applied groundwater level for the stability analysis is the highest groundwater level which was observed in the rainy season, the data for the analysis shall be applied the highest groundwater level which is observed in at least one rainy season after completion of the countermeasure works of Section II.

Regarding the stability analysis to check the factor of safety of landslide after completion of the countermeasure works, analysis landslide model shall be used the model which was used in the design stage. Parameter for the analysis such as cohesion, internal friction angle or unit weight shall not be changed, but only groundwater level which is observed as the highest level during the rainy season.

In case that the factor of safety of Block-A landslide is more than 1.20 and no movement is detected by the extensometer, additional restraint work can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, and it shall be considered possibility of re-activation of the landslide. If rising of groundwater level or movement of landslide is detected, additional countermeasure works shall be examined. Reference value of the groundwater level to achieve the planned factor of safety is shown below.

Table 9.3.2 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring borehole/well	Fs=1.13 (Planned)	Fs=1.20 (Final Target)	Remarks
BPP 16	> GL-2.9m	> GL-3.9m	Near the school
BPP 11	> GL-2.1m	> GL-3.1m	
W-2	> GL-3.3m	> GL-4.3m	
BPP 8	> GL-5.4m	> GL-6.4m	Out of the landslide area

GL: Ground Level

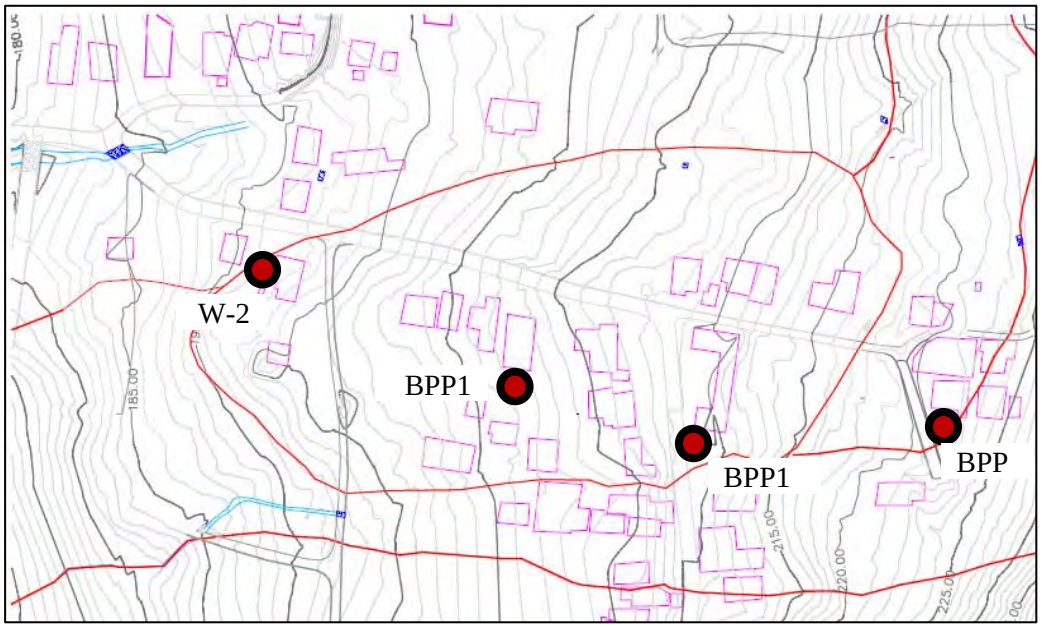


Figure 9.3.2 Location of Monitoring Borehole for Block-A Landslide (source: JET)

Groundwater level at BPP8 shall not be used for evaluation of stability of the landslide directly due to it is out of the landslide area. In case that the groundwater level at other three boreholes is confirmed as the reference values, it can be assumed that stability of the target landslide is achieved the planned factor of safety.

In case that the factor of safety of Block-A landslide is less than 1.20, restraint work shall be planned. According to the condition of topography and land use at the site, pile work shall be recommended. Planning and design of the pile work shall be done in reference to the "Procedure Manual for Landslide" which is prepared in this project.

The countermeasure works for Block-A landslide can be considered to contribute to the stability of the Block-B landslide. Thus, monitoring of groundwater level and landslide movement for the Block-B shall be carried out to check the factor of safety of the landslide. However the existing monitoring borehole namely BPX 2 is not available to measure a groundwater level. Therefore, it can be recommended to install new monitoring borehole on the Block-B landslide area (refer to Figure 9.3.3). The reference value of the groundwater level at each monitoring borehole to achieve the planned factor of safety is shown in Table 9.3.3. In case that factor of safety of the Block-B landslide is more than 1.20 and no movement is detected by the extensometer, the planned countermeasure works for the Block-B landslide can be put on hold. However, the monitoring of groundwater level and landslide movement shall be carried out continuously, as there is a possibility that the landslide may become active again.

About the rainfall and the groundwater relationship monitored continuously, MPI should submit a report to JICA.

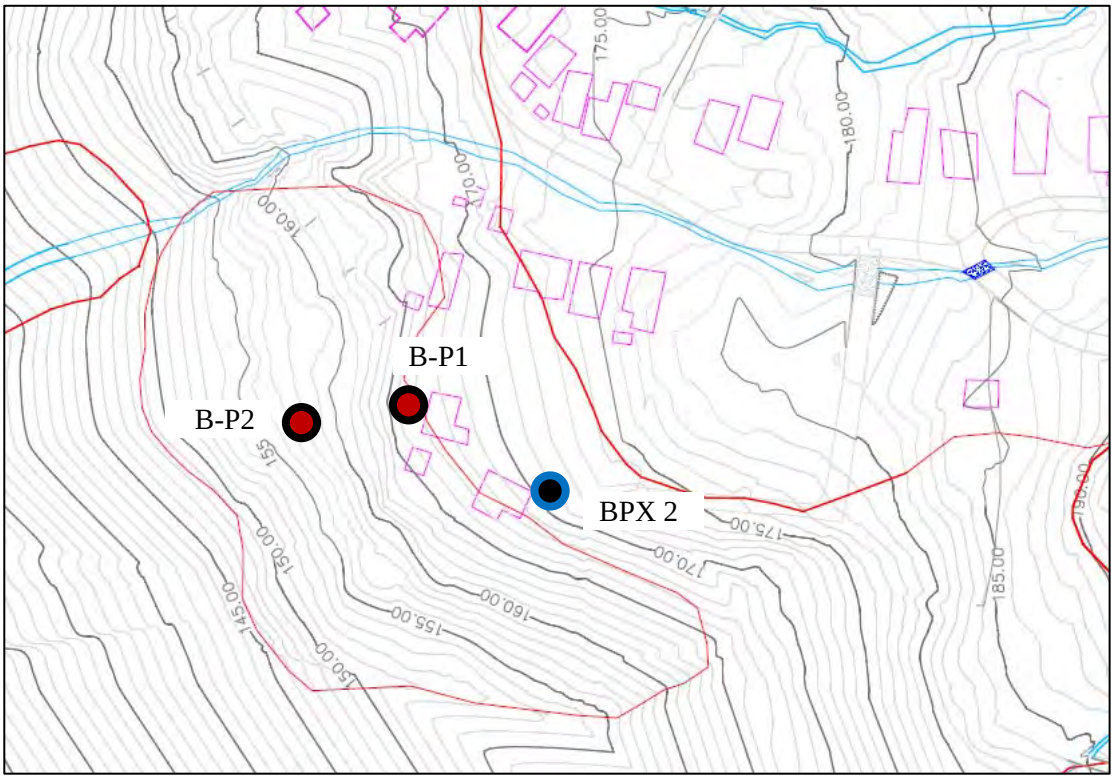


Figure 9.3.3 Location of Monitoring Borehole for Block-B Landslide (source: JET)

Table 9.3.3 Reference Value of the Groundwater Level to Achieve the Planned Factor of Safety (source: JET)

Monitoring Borehole	Fs=1.17 (Planned)	Fs=1.20 (Final Target)	Remarks
B-P1	> GL-3.5m	> GL-4.0m	to be installed
B-P2	> GL-3.4m	> GL-3.9m	to be installed

d. Cleaning and Maintenance of the Ditches, Channels, Bridges and Horizontal Drainages by MPI

The ditches, channels, bridges and horizontal drainages constructed by JET shall be cleaned periodically to ensure the smooth water flows in the drainage. The maintenance of the works shall be undertaken to maintain its function as below.

d.1 Cleaning and Maintenance of Ditches and Channels

- ✓ Cleaning of soils accumulated in the ditch and channel using shovel and high pressure water.
- ✓ Removing any garbage inside the river.
- ✓ Repairing any cracks occurs along the ditch and channel works

d.2 Cleaning and Maintenance of Bridges

- ✓ Cleaning of soils accumulated under the bridges using shovel and high pressure water.
- ✓ Removing any garbage under the bridges
- ✓ Repairing any cracks occurs on the bridge works

d.3 Cleaning and Maintenance of Horizontal Drainage

- ✓ Cleaning of soils accumulated inside the drainage pipe using high pressure water (flushing).

d.4 Maintenance of the Fences

Fences shall be checked periodically in case of damages by rock fall and debris flow and repaired if necessary.

e. Site Restriction (No Trespassing and Throwing Garbage into the Site)

- ✓ Installation of [No Trespassing] signboard at site
- ✓ Education of the inhabitants regarding the disaster prevention.

f. Utilization of the Landslide Disaster Prevention Handbook

The utilization of handbook for the education of the inhabitants and students is highly expected.

9.3.2 Development in the Landslide Hazard Zone after the Landslide Countermeasure Works

The mechanisms of landslide are complicated and it is very difficult to stop the landslide activity completely. Hence, the role of landslide countermeasure works is to raise the existing factor of safety (Fs) to greater than 1.2 and not to permanently prevent landslide. A landslide might be reactivated by deterioration of the soil strength on landslide slip surface or heavy torrential rain (such as rainfall exceeding a 50 year probable rainfall used to design landslide countermeasures at Chitrakoot) resulting from abnormal natural phenomenon (climate change) in future.

In the country with abundant experience of slope disaster such as Japan, the designation of landslide hazard zone will not be terminated even though after landslide countermeasure works have been implemented. Therefore, there will be no termination of the designation of the landslide hazard zone made by this Project (Chitrakoot, Vallee Pitot and Quatre Soeurs) in the future too.

All kind of development for infrastructure or housing is basically prohibited in the landslide hazard zone. However, the minor maintenance work of houses or roads can be implemented. The table below shows the advisability of the development activities in the landslide hazard zone.

Table 9.3.4 Advisability of the Development Activities in the Landslide Hazard Zone (source: JET)

Type of development	Advisability	Application
Minor maintenance of houses, school building etc.	Possible	Maintenance of roofs and walls only. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
Minor maintenance of public infrastructure such as roads, bridges etc.	Possible	Only maintenance of public infrastructure such as roads, bridges, water and sewage etc. Maintenance involving excavation of the foundation, cutting/filling is prohibited.
New/additional construction of houses, schools etc.	Prohibited	Basically, the new/additional construction of building is prohibited
New/additional construction or replacement of public infrastructure such as roads, bridges etc.	Prohibited	Basically, the new/additional construction or replacement of public infrastructure such as roads, bridges, water supply and sewage etc. is prohibited
Development other than mentioned above	Prohibited	Basically, the development activities in the landslide hazard are is prohibited.

<Screening standard for the exceptional development>

In case there is inevitable development activities needed to be implemented in the landslide hazard zone such as new/additional construction or replacement of roads, bridges, water supply and sewage and other public infrastructures, the sufficient investigation/analysis of the points mentioned below shall be undertaken.

- Implementation of stability analysis of the landslide and confirming the factor of safety (Fs) of the landslide is greater than 1.2 after the construction.
- If the factor of safety (Fs) is less than 1.2, the landslide countermeasure works shall be implemented.
- The implementation of the landslide countermeasure works shall be implemented before the development activities.
- The fall of the factor of safety (Fs) during the construction (development activities, landslide countermeasure work and cutting/filling) shall be within 5%, and any works which exceed 5% fall in factor of safety (Fs) shall be prohibited.
- Preventing the water retention from rainfall inside and downstream of the landslide area by installing the water drainage facilities such as surface drainage, retention basins, grit chambers etc.

9.3.3 Early Warning and Evacuation System

Table 9.3.5 below shows proposed warning stages and their thresholds based on two years landslide monitoring in Chitrakoot, Vallee Pitot and Quatre Soeurs.

Table 9.3.5 Proposed Early Warning of Landslide Disaster (source: JET)

Warning Stage		Threshold	
		Movement of the ground (extensometer)	Deformation of each house
Stage 1	Precaution	20 mm /month or more	<new signs of landslide> New cracks are found in a house. New deformations are found on walls or floors of a house. New crack or deformation are found on the ground, a retaining wall, or a road around the house.
Stage 2	Alert	10 mm / day or more	<progress of cracks or deformation> Opening of the cracks become wider The deformations on the floor or the wall become bigger. The cracks or deformations around the house become bigger. (Opening speed of the cracks : 2 mm/hour)
Stage 3	Evacuation	20 mm / day or more	<further progress of cracks or deformations> New cracks are found in the house. The cracks and deformation become bigger and bigger in the house. The house next door or walls around the house collapses. Opening speed of cracks: 20 mm/hour
Stage 0	Termination	0 mm / hour and, no abnormality can be seen in the house and around the house.	The residents of the house deformed do not return to their house without architect's inspection. *3 No abnormality can be seen in the house and around the house
Additional Stage	Torrential Rain & Cyclone Warning	"Cyclone Warning Class II" or "Torrential Rain Warning" may constitute for the inhabitants a "Landslide Stage 1 Warning". "Cyclone Warning Class III" : cessation of all normal activities, inhabitants of the landslide prone areas may be evacuated	

a. Additional Stage (Torrential Rain Waning and Cyclone Warning)

There are cases where a landslide becomes active in torrential rain or cyclone when it also becomes difficult to travel on roads (i.e. due to traffic congestion). In such cases, the inhabitants in the landslide area must follow the Torrential Rain Scheme or Cyclone Scheme regardless of landslide activity.

b. Termination

Once a house has become deformed, the house may not have enough structural strength. Even if the landslide activities have terminated and it is stable, the residents can not return and stay in the house. Architects decision is required before the residents return to their house.

If the residents are evacuated according to the extensometer indication, the residents should return after the landslide expert confirm the stability of the landslide.

c. Role of LMU in Early Warning

LMU should observe and confirm the site condition at each stage of Early Warning. Especially, LMU should visit the house and confirm the condition of the house when LMU

receives the information about cracks or deformations of a house, since sometimes cracks or deformations appeared in a house for other reason than a landslide.

At Stage 1 and Stage 2 according to “Deformation of each house”, the points to be confirmed by LMU are as follows;

- Observe and confirm cracks and deformations
- Decide whether cracks and deformations are caused by a landslide
- If cracks and deformations are not caused by a landslide, find what is a cause of cracks and deformations
- Decide the methods of ascertainment whether cracks and deformations are progressing or not.
- Inform the residents next door how matters stand with their neighbor (i.e. that their neighbor’s house has deformations caused by landslide activity).
- Ascertain the possibility of Stage 3, and remind the residents in the house that they should take in Stage 3

At Stage 3, the residents under risk should leave their house and evacuate of their own accord. The upgrading to Stage 3 from Stage 2 is based on extensometer readings or by the level of deformation of a house as ascertained by the residents of the house. The residents in the house must leave the house immediately (self-evacuation). At Stage 3, NDRMMC controls the refugees, and LMU advises NDRMMC on technical matters.

At Additional Stage, the residents in the landslide area should follow Torrential Rain Scheme or Cyclone Scheme. LMU is not involved in the Torrential Rain Scheme or the Cyclone Scheme.

At ordinary times, LMU should work to raise the awareness of the inhabitants in landslide areas. Especially the inhabitants should understand the following things.

- They live in a landslide risk area.
- Their lives must be protected by themselves.
- Once an evacuation warning is issued, they must not care about their possessions.
- Until countermeasures such as stabilization works are complete, there is nothing that can protect their possessions.

9.3.4 Information, Education and Communication (IEC)

- Awareness activities such as stakeholder meetings should be conducted not only for residents who live inside of the landslide block but also for the ones who live outside of the landslide block as they will be affected by landslide disaster as well. These people should be included in the evacuee list.
- NDRRMC should make more effort to raise awareness of the mission of the organization much more. (by mass media, etc.)
- At this stage, the Project can’t conclude that the current early warning and evacuation system is working or not as not much experience in operation has been accumulated. The survey provided some matters to be considered as follows;
  - The early warning system are easily visible to residents as it has been located in a visible place outside. However, the difference between yellow and red lights should be reminded to residents.
  - It might be difficult for residents to identify which households own simple rain gauge unless they did obtain information in the stakeholder meeting.
  - Contact point should be the same for any landslide inquiries including during warning and evacuation stages. Police will be the best organization for this.

- The presence of contact person(s) will be useful for the government such as MPI to obtain information of actual site conditions, but for residents, it would be better to let anyone contact police. If this is not the case then all of the residents need to know the phone number of the contact person(s) so that they can contact them to report an emergency.
- "Self-evacuation" should be promoted but assistance for evacuation by relevant authority is still required for some people, especially for elderly. It is important for the government to identify the persons who need assistance in advance.
- The government should not hesitate to issue warning and evacuation orders when it reaches each level. The location of evacuation center and appropriate route should be well informed in advance. And, transport for people who need assistance should be arranged at evacuation stage. Residents will not be able to blame the government if something happens to them because they have not followed instructions and when the government has done everything that it is supposed to do.

- Stakeholder meetings in at risk communities are an effective tool to disseminate information, especially specific information to the locality such as location and route of evacuation center. TV and radio are also informative but will be effective to disseminate landslide information in general.

9.4 Proposal on a Landslide Management Plan for Other Landslide Areas

The Disaster Scheme describes 37 hazard areas in Mauritius. Among them, 15 areas are slope disasters. Of these 15 areas six (6) areas are classed as landslides as defined in the Project (shown in the tables below). The Project has implemented basic surveys, detailed surveys, F/S and a Pilot Project in three (3) priority areas, Chitrakoot, Quatre Soeurs and Vallee Pitot, out of the six (6) abovementioned areas. These three priority areas were selected based on hazard evaluations and requests from the Mauritius Government. In this section, the necessary tasks to formulate landslide management plans on other landslide areas such as La Butte, Old Moka Road and Candos Hill are summarized and proposed.

Table 9.4.1 Classification of Hazard Areas (source: JET)

General classification			Sub classification		Summary
Disaster	Slope	15 areas	Landslide	6 areas	Can be classified as a Landslide Hazard Area
			Slope failure	7 areas	
			Rock fall	1 areas	
			Debris flow	1 areas	
	Other	22 areas	Stream erosion	10 areas	Because it is not a "Landslide", it cannot be classified as a Landslide Hazard Area
			Damage of Embankment	4 areas	
			Damage of wall	5 areas	
			Damage of house	1 areas	
			Cavern	2 areas	
			Total	37 areas	

Table 9.4.2 Hazard Evaluation Results of the 6 Landslides (source: JET)

No.	Area name	Kind of the disaster		Score of landslide hazard evaluation			
		General classification	Sub classification	Landslide landforms and characteristic	Damage to buildings, houses	Existing record of landslides	Total
9	Chitrakoot, Vallee des Pretres	Slope	Landslide	2	2	2	6
10	Vallee Pitot (near Eidgah)	Slope	Landslide	2	2	2	6
13	Mgr. Leen Street and nearby vicinity, La Butte	Slope	Landslide	2	1	2	5
15	Old Moka Road, Camp Chapelon	Slope	Landslide	2	1	0	3
27	Quatre Soeurs,	Slope	Landslide	2	2	2	6
34	Candos Hill	Slope	Landslide	2	1	0	3

9.4.1 Hypothesis on Landslides in Mauritius

Hypotheses for mechanisms and countermeasures on landslides in Mauritius have been discussed based on the survey, analysis and the Pilot Project as follows;

- Slip surface is the boundary between the base rocks like basalt and alluvium/colluvium. The depth is around 5－10 m.
- Length and width of the landslides range from a couple dozens of meters to several km in diamter. Landslides often consist of several small landslide masses.
- Landslides are generated over and over on the locations where landsilide movement was observed.
- Landslide activity is highly correlated with ground water level. A landslide becomes active through increases in the groundwater level.
- However, according to geology and geomorphology, groundwater level is not necessarily correlated with rainfall amount. A landslide may occur without rainfall and conversly may not occur even after heavy rainfall.
- Drainage works for surface/ground water are effective as hard countermeasures.
- As for soft countermeasures, by building an early warning/evaluation system using thresholds for each landslide based on continuous monitoring may be able to reduce the risk posed to humans and the potential for human casualties.
- Relocation of the local residents is one of the countemesures from the viewpoints of cost, effectiveness and requests from the residents.

9.4.2 Proposal on Formulation of a Landslide Management Plan

Proposals on formulation of a landslide management plan in Mauritius are summarized as follows in consideration of the hypotheses for mechanisms and countermeasures on landslides described in the previous section. Actual procedures of the proposed activities are explained in each chapter of the reports: “Technical guidelines for initial surveys” and “Procedure manual for landslides”.

1. The following basic surveys are necessary to grasp the landslide activities, volumes, areas and the relation with circumferences;

(1) Topographic surveys (plan map and cross section)

(2) Site reconnaissance, survey on damage to houses

(3) Laboratory tests (physical tests, dynamics tests, and water quality tests)

(4) Monitoring (rain gauges, extensometers, inclinometers, strain gauges, and ground water level meter)

(5) Geophysical explorations (elastic wave explorations and two-dimensional resistivity explorations)

(6) Drilling surveys

2. The Disaster Scheme and the PPG are reviewed to propose the early warnings and evaluation protocols and other soft countermeasures.
3. The current activities on landslides are determined by the stability analysis using landslide cross sections based on the basic surveys.
4. The relations among the activities, groundwater level and rainfalls are discussed with

the results of the monitoring.

5. Best countermeasures (hard and soft) are considered from the viewpoint of the activities, priorities, request form residents, and budgets.
6. For hard countermeasures, suitable drainage works are selected based on the results of the investigation on surface/ground water conditions. Horizontal drilling is judged to be effective from the results of the pilot project.
7. For soft countermeasures, early warning/evaluation system using a threshold for each landslide is operated. The soft countermeasures are useful until the completion of the construction of hard countermeasures.

Reference for Chapter 9

[1] MPI