Democratic Socialist Republic of Sri Lanka
National Building Research Organisation

PROJECT FOR CAPACITY STRENGTHENING ON DEVELOPMENT OF NON-STRUCTURAL MEASURES FOR LANDSLIDE RISK REDUCTION IN SRI LANKA

FINAL REPORT

October 2022

Japan International Cooperation Agency

Earth System Science Co., Ltd.
Nippon Koei Co., Ltd.

INDEX

Project Location

Potos of Project Activities

Abbreviation

Chapter 1 Outline of the Project 1

1.1. Background and Purpose 1

1.2. Outline of the Project 2

1.3. Scope of the Project 2

1.4. Plan and Achievement 3

1.4.1. Workflow 3

1.4.2. Achievement of Inputs 4

Chapter 2 Activities 6

2.1. Responses to COVID-19 Pandemic 6

2.2. Overall Project Activities 7

2.2.1. Joint Coordination Committee (JCC) 7

2.2.2. C/P Training in Japan 9

2.2.3. Technical Seminars 12

2.2.4. Public Relation Activities 13

2.3. Activities on Output 1 17

2.3.1. Review existing manuals, hazard and risk assessment methods, system of the landslide record management (Activity 1-1) 17

2.3.2. Improvement the system to manage landslide records (Activity 1-2) 18

2.3.3. Collect records on past sediment disasters in Sri Lanka and analysis the relationship of rational characteristics (Activity 1-3) 21

2.3.4. Prepare draft manuals on hazard mapping and risk assessments (Activity 1-4) 23

2.3.5. Evaluation and improvement of existing LHZM (Activity 1-4: additional) 27

2.3.6. Conduct hazard and risk assessment at pilot sites (Activity 1-5) 32

2.3.7. Conduct flow path simulation to identify potential damage zone of debris flows and update hazard zonation maps (Activity 1-6) 36

2.3.8. Organize a working group at pilot sites and conduct a workshop to share the results of hazard and risk assessments (Activity 1-7) 37

2.3.9. Finalize the above manuals and conduct a workshop (Activity 1-8) 38

2.3.10. Conduct site specific hazard and risk assessments in the areas other than pilot sites (Activity 1-9) 39

2.4. Activities on Output 2 41
2.4.1. Review the systems and contents regarding issuance of risk information and early warning (Activity 2-1) 41
2.4.2. Revise rainfall criteria for landslide early warning based on regional characteristics (Activity 2-2) 43
2.4.3. Draft a manual on early warning for sediment disasters including protocol for issuance of early warning (Activity 2-3) 48
2.4.4. Strengthen warning and evacuation system at pilot sites (Activity 2-4) 49
2.4.5. Share information on landslide early warning system in the working group (Activity 2-5) 52
2.4.6. Finalize the manual on landslide early warning (Activity 2-6) 53
2.5. Activities on Output 3 55
2.5.1. Review land use planning in Sri Lanka (Activity 3-1) 55
2.5.2. Drafting a guideline for land use regulation / development standards guideline (Activity 3-2) 57
2.5.3. Development of land use regulation / development standards (draft) at pilot sites (Activity 3-3) 60
2.5.4. Finalizing land use regulation / development standards though WG and workshops (Activity 3-4,5) 63
Chapter 3 Challenges, Actions and Lessons Learned 67
3.1. Continuation of the Project during terrorist attacks and COVID-19 67
3.2. Issue to introduce Yellow/Red zoning 70
3.3. Involvement of pilot Local Authorities 73
Chapter 4 Achievement of the Project 75
4.1. Achievement of Output 1 75
4.2. Achievement of Output 2 75
4.3. Achievement of Output 3 76
4.4. Achievement to the Project Purpose 76
Chapter 5 Recommendation to Achieve Overall Goal 79

ANNEX

Minutes of Meeting of Joint Coordination Committee (JCC)

List of Property Lending

Manuals / Guidelines

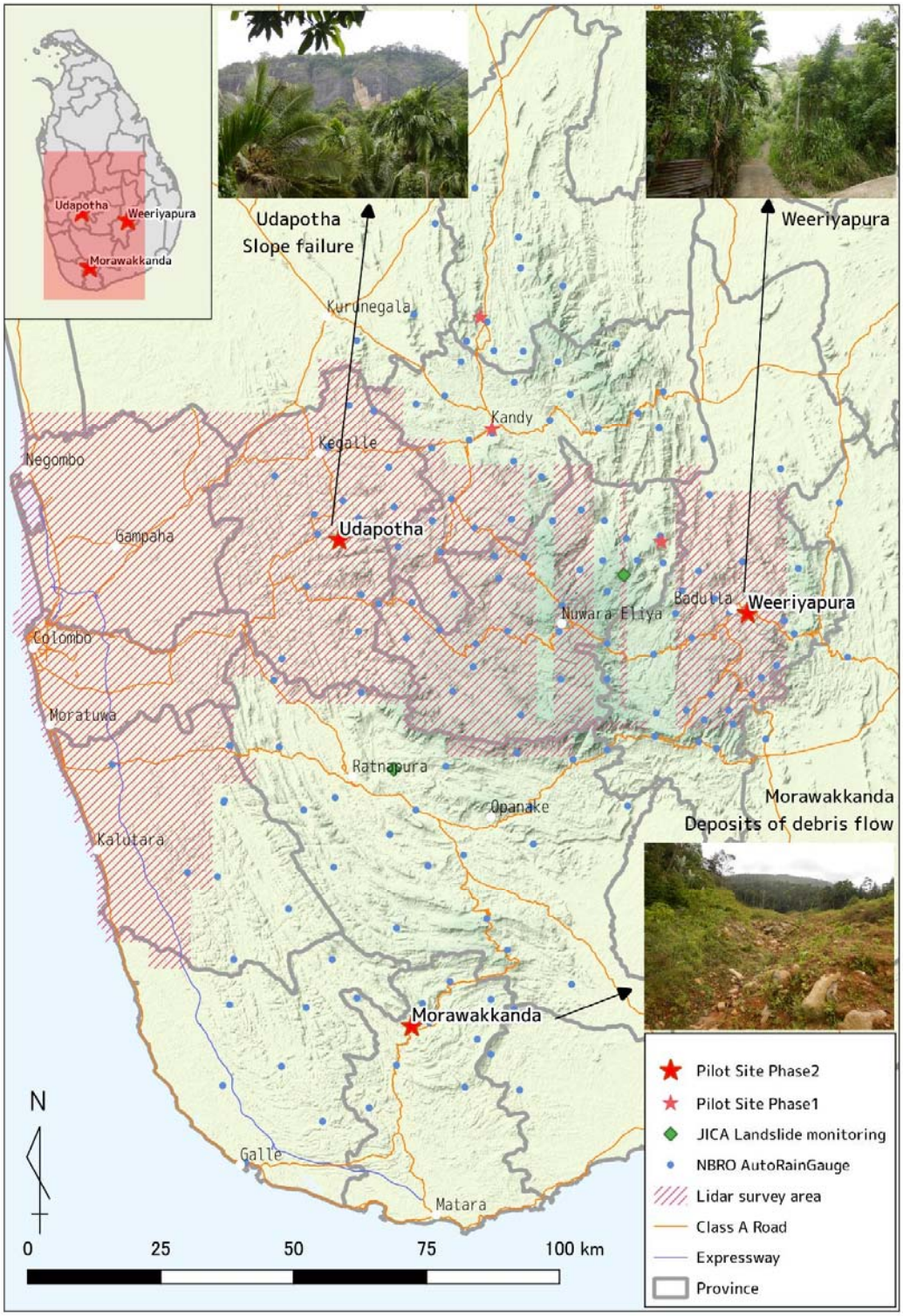
Manual on Site-Specific Landslide Hazard Zoning

Manual on Risk Assessment for Landslide Yellow/Red zone

Manual on Landslide Early Warning

Guideline for Disaster Resilience Land Use Regulation / Development Standards

Local Sediment Disaster Risk Reduction Plans for Pilot Sites (Draft)



Project Location

Potos of Project Activities (2019)

Kickoff meeting with NBRO DG and WG members on February 5, 2019

Discussion with secretary of Ministry of Disaster Management on February 9, 2019

Meeting with Kotapola PS chairman and DS divisional secretary for Morawakkanda site on February 12, 2019

Meeting with Badulla MC major for Weeriyapura site on February 13, 2019

Meeting with Bulathkohupitiya PS chairman for Udapotha site on February 14, 2019

1st Joint Coordination Committee (JCC) on February 25, 2019

Potos of Project Activities (2020)

Project meeting with Project Manager and WG members on Febury 5, 2020

Discussion on land use regulation by WG3 members with Local Authority on February 6, 2020

Field verification of Yellow/Red zones prepared by WG1 members on February 10, 2020

Discussion on Yellow/Red zoning between WG members and DDMCU Kegalle district on February 11, 2020

Field visit with short-term experts from MLIT at Morawakkanda on February 19, 2020

A seminar in NBRO by short-term experts on February 21, 2020

Potos of Project Activities (2021-2022)

Field verification on candidate sites for landslide remote monitoring system at Udapotha on December 30, 2021

Installed landslide remote monitoring system in Weeriyapura, Badulla on January 25, 2022

Community workshop on landslide planning at pilot site Udapotha site on March 3, 2022

Workshop at a NBRO site office on Landslide Information Management System (LIMS) on March 7, 2022

4th Joint Coordination Committee (JCC) on June 10, 2022 (on-line)

Field visit during 2nd C/P training in Japan on July 21, 2022

Abbreviation

Abbrev.	Full name in English
CEA	Central Environmental Authority
CL	Critical Line
C/P	Counterpart
DDMCU	District Disaster Management Coordinating Unit
DEM	Digital Elevation Model
DMC	Disaster Management Center
DoM	Department of Meteorology
DS	Divisional Secretariat
EOC	Emergency Operation Center
GFS	Global Forecast System
GN	Grama Niladhari
HSPTD	Human Settlement Planning and Training Division
ID	Irrigation Department
JCC	Joint Coordinatioon Committee
JICA	Japan International Cooperation Agency
LA	Local Authority
LDPP	Landslide Disaster Prevention Project
LHM	Landslide Hazard Map
LIMS	Landslide Information Management System
LKR	Sri Lankan Rupee
LRRMD	Landslide Research and Risk Management Division
LUPPD	Land Use Policy and Planning Department
MC	Municipal Council
M/M	Minutes of Meetings
MoFEPD	Ministry of Finance, Economic and Policy Development
MoD	Ministry of Defence
MoPAHAPCLG	Ministry of Public Administration, Home Affairs, Provincial Councils and Local Government
RBFN	Radial Basis Function Network
NBRO	National Building Research Organization
NILIM	National Institute for Land and Infrastrucuture Mangement
NPPD	National Physical Planning Department
NWP	Numerical Weather Prediction
PM	Project Manager
PS	Pradeshiya Sabha
RDA	Road Development Authority
SWI	Soil Water Index
TCLMP	Technical Cooperation for Landslide Mitigation Project
UC	Urban Council
UI	User Interface
UDA	Urban Development Authority
WG	Working Group

Chapter 1 Outline of the Project

1.1. Background and Purpose

Sediment Disaster is one of the most serious natural disasters in Sri Lanka. In the central and southern mountainous area, sediment disasters such as slope failures, landslides and debris flows frequently occur in the monsoon period because of the fragile geology and steep topography. In recent years, sediment disasters caused by heavy rainfall in the spring monsoon season become severer. It is still fresh memory that the large-scale landslide in Aranayake, Kegalle district killed 130 lives in May 2016. In addition, increasing exposure to the hazards due to rapid reclamation and development has been raising sediment disaster risks in urban and rural areas. Establishment and improvement of the early warning system and legal arrangement for land use planning and development standards are urgent issues in Sri Lanka.

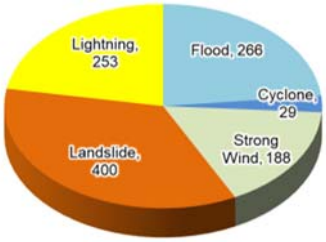


Figure 1.1: Number of death and missing by natural disaster in the past decade (DesInventar)

National Building Research Organization (NBRO) under Ministry of Public Administration and Disaster Management (MPADM) is responsible for implementing the mitigation measure both structural and non-structural for sediment disasters. The NBRO has made efforts of prevention and mitigation for sediment disasters such as preparation of sediment disaster hazard maps, technical support for land use planning and development standards in the mountainous area, capacity development of relevant agencies, awareness and education activities for developers, search and rescue, recovery and reconstruction, resettlement of disaster victims. Regarding slope disaster prevention along roads, the NBRO is an advisory agency to Road Development Agency (RDA), which is the responsible for maintenance and management of the national highways.

JICA has implemented an ODA loan “Landslide Disaster Prevention Project (LDPP)” to strengthen road transportation network in seven (7) districts in Sri Lanka since March 2013. In addition to the LDPP, JICA implemented a technical assistance project “Technical Cooperation for Landslide Mitigation Project (TCLMP)” in the high risk areas of sediment disasters in Kandy, Matara, Nuwara Eliya and Badulla districts since September 2014. The TCLMP supported to construct counter measures for three types of sediment disasters (rock fall, landslide and slope failure) and develop standards and manuals for the constructions, and strengthened the capacity of NBRO through introducing knowledge and know-how in Japan on structural and non-structural measures for sediment disaster.

Through the LDPP and TCLMP, JICA has supported strengthening national highway in sediment disaster prone area and improving knowledge and capacity of NBRO for countermeasures. However, in order to further mitigate sediment disaster risks along national highway and neighboring residents, accurate risk assessment, early warning mechanism and land use planning are required. This project (the Project) aims at strengthening capacity of NBRO on non-structural measures such as sediment disaster risk assessments, improving early warning system using existing observation network, and land use and development standards based on the risk assessment.

1.2. Outline of the Project

(1) Overall Goal

In high risk areas of sediment disasters, non-structural measures based on strengthened hazard and risk assessments are implemented

(2) Project Purpose

NBRO's capacity to implement non-structural measures for sediment disasters based on enhanced hazard and risk assessments are strengthened.

(3) Outputs

Output 1: Capacities to conduct hazard mapping and risk assessments are strengthened.

Output 2: Capacities to issue landslide early warning alerts are strengthened.

Output 3: Capacities to apply risk assessments of sediment disaster (s) to land use planning / development standards are strengthened.

1.3. Scope of the Project

(1) Project Period

January 2019 to December 2021 (extended to October 2022)

(2) Target Area

Colombo and 3 Pilot Sites (Morawakkanda, Matara District / Udapotha, Kegall District / Weeriyapura. Badulla District)

(3) Implementation Agencies

- Ministry of Public Administration and Disaster Management (MPADM)
- Disaster Management Centre (DMC)
- Urban Development Authority (UDA)
- National Physical Planning Department (NPPD)
- Land Use Policy Planning Department (LUPPD)
- Central Environment Authority (CEA)
- Ministry of Provincial Councils and Local Government (MPCLG)
- Road Development Authority (RDA)
- Department of Meteorology (DOM)
- Ministry of National Policies and Economic Affairs (MNPEA)
- Local Authorities (LA) of Pilot Sites

1.4. Plan and Achievement

1.4.1. Workflow

The Project was planned to be implemented from the middle January 2019 to the end of December 2021. However, due to the influence of COVID-19 pandemic since January 2020, the travel of JICA expert team (hereinafter referred to as "the Team") and activities of NBRO C/Ps were restricted. Therefore, the Project extension about 6 months was agreed at the 3rd JCC on July 2021, furthermore, another 3 months extension was agreed at the 4th JCC on June 2022, to implement the 2nd C/P training in Japan and to confirm scaling-up of the Project outcomes by October 2022.

The implementation stages and the activities planned at the beginning are show in Figure 1.2.

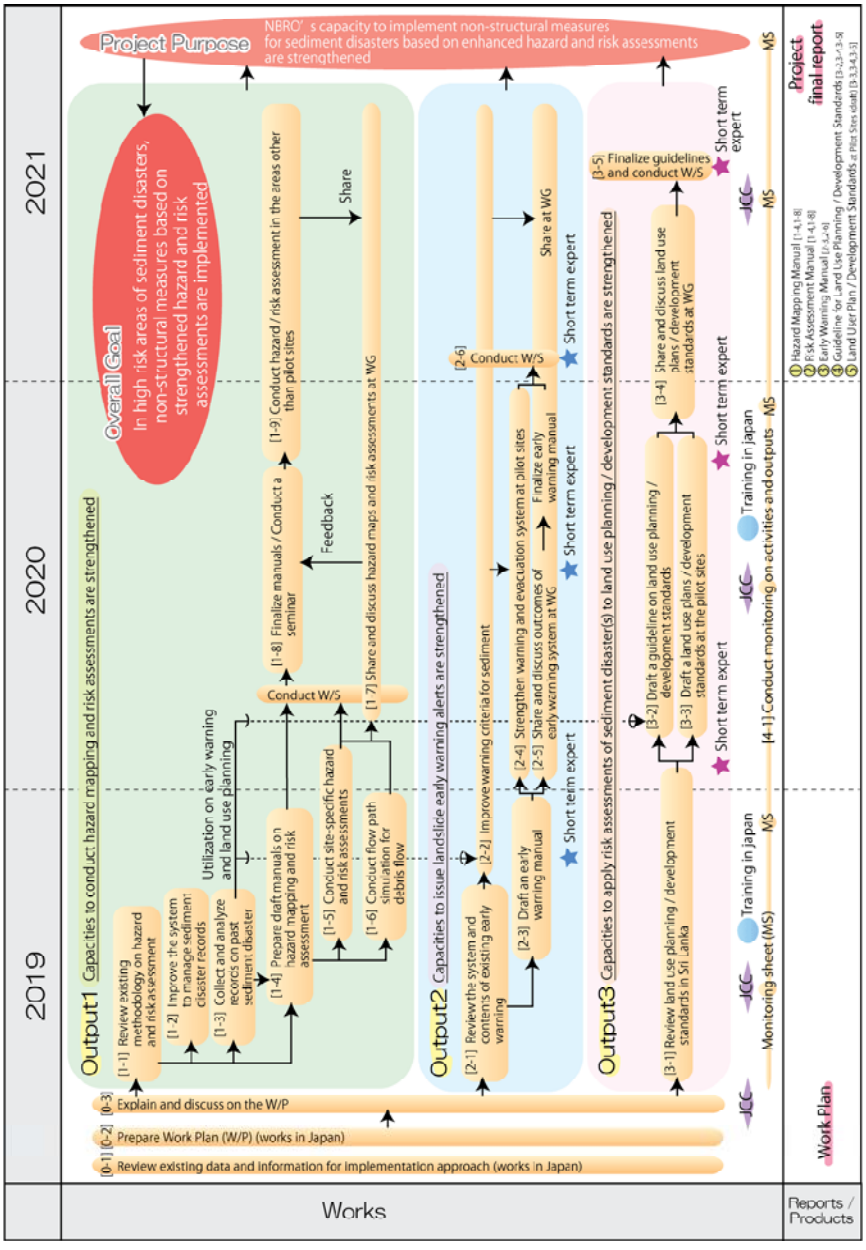


Figure 1.2: Work Flowchart (at the beginning of the Project)

1.4.2. Achievement of Inputs

(1) Dispatch Experts

The achievement of expert dispatches is shown in Table 1.1. Through the Project period, the Team proposed revisions of Project implementation. The additional dispatches due to these revisions are shown in Table 1.2Table **1.2**.

Table 1.1: Achievement of expert dispatch

Discipline of experts	Achieved	Plan
Team Leader / Sediment Disaster Risk Reduction / Facility Planning	11.40 MM	10.40 MM
Vice Team Leader / Sediment Disaster Risk Reduction / Facility Planning	1.50 MM	4.00 MM
Disaster Record Analysis and Management	8.07 MM	6.50 MM
Sediment Disaster Risk Assessment	8.90 MM	8.40 MM
Land Use Planning / Development Standards	8.00 MM	8.00 MM
Early Warning System 1	13.63 MM	8.63 MM
Debris Flow Analysis /. Sabo Project Evaluation	3.53 MM	3.60 MM
Early Warning System 2 / Training Planning / Coordinator	6.50 MM	6.50 MM

Table 1.2: Achievement of additional dispatch

Additional activities	Discipline of experts	Achieved	Plan
Developing verification of exiting Landslide Hazard Zoning Map (LHZM)	Disaster Record Analysis and Management	1.00 MM	1.00 MM
	Early Warning System 1	2.00 MM	2.00 MM
Strengthening landslide early waning by landslide remote monitoring system	Early Warning System 1	2.00 MM	2.00 MM
Developing Landslide Information Management System (LIMS)	Sediment Disaster Risk Reduction / Facility Planning	0.50 MM	0.50 MM

In addition to the dispatch of the Team, the following short-term experts were dispatched by JICA. The detailed activities by the short-term experts will described in Chapter 2.

Table 1.3: List of Short-term Experts

Supporting fields	Organization	Dispach 計画
Improvement of landslide early warning	Sabo Dept., National Institute for Land and Infrastructure Management, MLIT	October 27, 2019 - November 2, 2019
Land use policy / development standards	International Center for Water Hazard and Risk Management (ICHARM)	February 14, 2020 - February 22, 2020
Landslide hazard area identification	River Dept., Kanto Regional Development Bureau, MLIT	February 16, 2022 - February 22, 2020

(2) C/P Training in Japan

In the Project, two-batches of the C/P training in Japan were carried out. The outline of the C/P trainings are shown in Table 1.4.

Table 1.4: Achievement of C/P Training in Japan

Batches	Aims of the Training	Contents
1st Batch September 2019	[Landslide non-structural measures] Target: WG members in NBRO Aims: To enhance the knowledge on non-structural measures for landslide risk reduction in Japan. The participants were required to bring the necessary data which will be used for practical training.	▪ Practical training on landslide risk evaluation at NILIM ▪ Various risk assessment methodology by institutional agencies ▪ Topographical processing in LiDAR, and landslide extraction ▪ Early warning mechanism between JMA and prefectural government ▪ Municipality efforts on disaster response
2nd Batch July 2022	[Risk-based land use regulation] Target: NBRO site offices, HSPTD, UDA, LA chairmen. Aims: To understand the administrative efforts to promote land use regulation in Japan. To understand the mechanism to coordinate between landslide risk reduction and city development planning.	▪ Lecture on Sabo in Japan ▪ Lecture on city planning in Japan ▪ Training and site visit at the sites of mitigation measures by national and prefectural government ▪ Training on practical implementation of landslide risk reduction and city planning ▪ Training on coordination and financial mechanism between prefectural and municipal government for the disasters

(3) Equipment Procurement

The following equipment were procured and provided to NBRO for the effective implementation of the Project.

Table 1.5: List of procured equipment

No.	Item	Qty	Purpose
1	Workstation for rainfall analysis	1 set	▪ To analyze the rainfall data transmitted to NBRO existing server machine, which includes OS, Web-server application, security rooter and other necessary items
2	Landslide remote early warning system	1 set	▪ To strengthen the landslide early warning at the 2 pilot sites of Weeriyapura and Udapotha by monitoring landslide movements. ▪ It includes the system development to operate the existing rainfall observation system and landslide monitoring system

(4) Subcontract

To collect and manage the landslide related information and reports as an activity in Output 1, the following subcontract was proposed and implemented.

Table 1.6: List of subcontracts

No.	Item	Qty	Purpose
1	Developing Landslide Information Management System	1 set	▪ To develop an on-line database system to manage the various landslide reports prepared at NBRO site offices, as an activity of Output 1.

Chapter 2 Activities

2.1. Responses to COVID-19 Pandemic

Due to the COVID-19 pandemic since January 2020, travel of the Team as well as activities of C/Ps has been more or less restricted

- March 2020: All members of the Team have emergently come back to Japan.
- October 2020: The Team planned to resume travel because the new cases of infection had been low level, however due to sudden increase of cases in Gampaha district, the travel was canceled.
- April 2021: Because the new cases had been decreasing, the Team started to prepare travel in May. The Team resumed the activities in Colombo but forced to stay in their hotel due to curfew responding to the increasing cases after Sinhara new year.
- August 2021: The cases of new infections again increased to highest records. Sri Lankan government issues curfew until October.
- October 2021: The cases of new cases were suddenly dropped because of the curfew and the wide spreading vaccination in Sri Lanka. The Team resumed the travel after the middle of October until end of the Project.

NBRO is a semi-government agency that is earning about half of their revenue from private businesses such as consulting work, soil and material testing. Due to the impact of the spread of COVID-19, NBRO has been facing a serious management situation as revenue has plummeted. There were concerns about the shortage of human resources because of temporarily cancelling the continuous employment of non-permanent staffs. Most of the Project C/Ps has been continuously engaged, and NBRO responded to complement necessary staff as C/Ps as necessary.

During the restriction of the travel of the Team, regular on-line meetings had been continuously held (monthly WG leaders meeting and induvial WG meeting 2-4 times in a month) to proceed the Project. In addition, during restriction of activities at pilot sites, each WG members have made maximum efforts to have meeting with Local Authorities and other agencies.

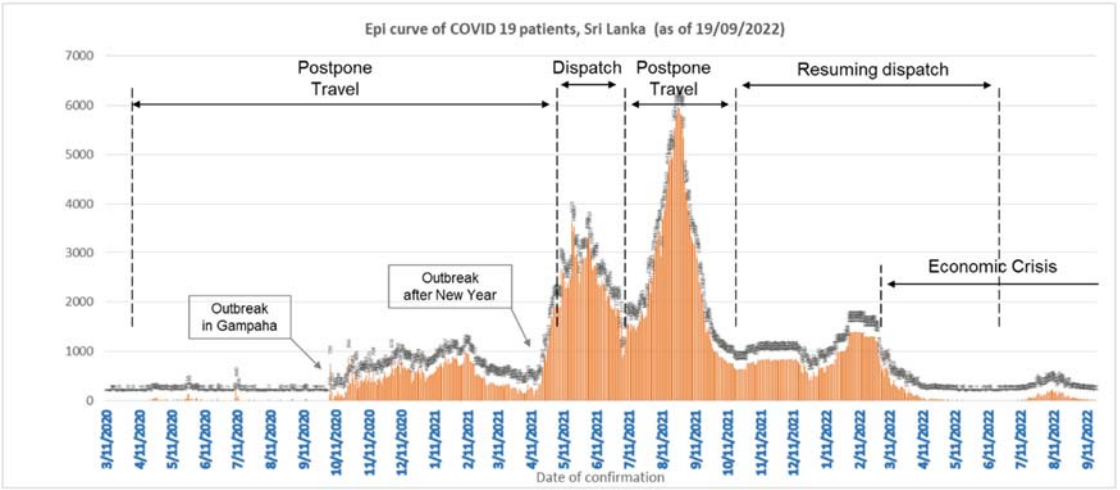


Figure 2.1: Number of new cases of COVID-19 infection in Sri Lanka)
Source: Ministry of Health, Sri Lanka

2.2. Overall Project Activities

2.2.1. Joint Coordination Committee (JCC)

(1) 1st JCC (February 25, 2019)

The 1st JCC was held on February 25, 2019, chaired by the Secretary of the Ministry of Public Administration and Disaster Management. In addition to all the JCC members agencies, Local Authorities of Mayor of Badulla MC, Chairmen of Kotapola PS and Bulthkohupitiya PS of the pilot sites participated in it.

In the JCC, the Team explained the outline of the Project, the implementation structure and the pilot site. From NBRO, national efforts on non-structural measures for landslide risk reduction (development of hazard maps, early warning and risk assessment, etc.) were introduced.

In Sri Lanka, the Local Authorities have not been involved in disaster risk reduction activities. Disaster risk reduction has been mandatory in the central government agencies. Thus, the Local Authorities seemed to be listening to the explanation of NBRO with great interest. During the discussion, many remarks were made such as in difficulties of preventing illegal development and issues to aware local residents to comply with land use regulations. Possible solutions such as simplifying development application procedure according to the risk levels to prevent illegal development were proposed by many agencies. All Local Authorities of pilot sites confirmed their full cooperation for the Project.

(2) 2nd JCC (October 29, 2019)

The 2nd JCC was held on October 29, 2019, chaired by the Director General of NBRO. Like the 1st meeting, most of the JCC members as well as Local Authorities of pilot sites, Chirmen of Kotapola PS and Bulthkohupitiya PS participated.

After the explanation of the overall progress of the Project and Project Monitoring Sheet by the Team, each WG leaders reported the progress of activities and the lessons learned during the 1st C/P training in Japan. The all JCC members confirmed that there were no significant delays or obstacle in the progress of the Project.

During the discussion, the Local Authorities made statements about the need to develop legal systems for the implementation of land use regulations, and that they would actively cooperate with the Project to raise awareness of residents. A short-term expert dispatched from MLIT addressed that “even in Japan, the establishment of sediment disaster hazard area and special hazard area was not immediately understood by residents. After many years and many disasters occurrences, the importance of establishing hazard areas was recognized. It will take time to develop laws, but it is important to proceed with what we should do now to protect the human lives."

(3) 3rd JCC (July 14, 2021)

The 3rd JCC on July 14, 2021, was the first JCC since the travel restrictions due to the COVID-19 pandemic. Since it was difficult for the JCC members from relevant agencies to gather at one place, NBRO decided to have the meeting on-line. Even in such situation, all the members participated in the JCC to share the progress and discuss the Project.

In the JCC, each WGs reported the activities during the COVID-19. Finally, it was decided to extend the Project period for half a year (6 months) because of the following reasons.

At the meeting, while the progress of each WG's activities was reported, it was decided to extend the project for half a year (6 months) for the following reasons.

- Delays in activities due to travel restriction of the Team and domestic travel of NBRO staff.
- Development of LIMS cannot be completed for the actual operation in time.
- Due to domestic travel restriction, it is not possible to install equipment for the landslide remote monitoring system which is the activity as a part of WG2.
- Discussion with Local Authorities for land use plan has been delayed.
- 2nd C/P training in Japan has not been resumed.

Accordingly, NBRO side started official procedures for extending the project period specified in the R/D, and the signing of the agreement was completed in November 2021.

(4) 4th JCC (June 10, 2022)

The 4th JCC was held on June 10, 2022. It was virtually the last JCC of the Project, and about 50 people, including NBRO C/Ps, Local Authorities Chairmen at three pilot sites, and the central government agencies participated in the final JCC and confirmed the entire achievements of the Project in three and half years.

The Urban Development Authority (UDA) stated that site-specific landslide risk assessment is essential for the development planning in urban-declared areas and requested that Yellow/Red zoning should be expanded to the other area as soon as possible. The Land Use Physical Planning Department (LUPPD) stated that if the Yellow/Red zone were to become an ordinance, they would like to reflect it in the land use plan. The Central Environment Agency (CEA) indicated that if the Yellow/Red zone is developed, it will be possible to proceed with the disaster impact assessment more quickly, desired to be developed as soon as possible. The Local Authorities commented that it is essential to develop a legal system in order to implement land use regulations based on risk assessment, and that various guidelines should be developed in Sinhala to disseminate the outcomes to officials in Local Authorities.

Consequently, the following items were exchanged in the minutes as JCC agreement.

- Project period shall be extended about 3 months to carry out the 2nd C/P training in Japan
- The following activities shall be taken by WG1;

・To extend the Yellow/Red zoning to the areas other than pilot sites
・To update the Landslide Hazard Zonation Map (LHZM)
・To input the existing reports into Landslide Information Management System (LIMS)

- The following activities shall be taken by WG2;
  ・To continue to verified the Soil Water Index (SWI) and landslide occurrences
  ・To maintain and update the existing rainfall observation network
- The following activities shall be taken by WG3;
  ・To formulate Local Landslide Risk Reduction Plan for the areas other than pilot sites
  ・To consider feasible approaches to implement the land use regulation
- Based on the lessons learned in the 2nd C/P training in Japan, all the participants should make best efforts to extend the Project outcomes.

2.2.2. C/P Training in Japan

(1) 1st Training in Japan

The 1st C/P training in Japan was held from September 1 to 14, 2019. Five members were nominated from each WG members as trainees. The training curriculum is shown in Table 2.1.

In the first half of the training, the trainees visited the central government agencies and research institutes such as the Sabo Department of the MLIT, Japan Meteorological Agency, the National Institute for Land and Infrastructure Management (NILIM). In the latter half of the training, the trainees visited Nagano Prefecture to observe local government systems for dissemination of landslide warning information, cooperation between the national and prefectural governments in Sabo projects, and reconstruction projects in Nagiso Town, which was damaged by debris flow in 2014.

Table 2.1: Curriculum of the 1st C/P training in Japan

Date	Time	Contents	Lecturer
Sep. 01		Arriving at Japan	
Sep. 02	10:00-12:00	JICA Briefing	JICA Tokyo International Center
	13:00-13:30	Courtesy to Sabo Department, MLIT	Sabo Dept. MLIT
	15:00-16:30	Outline of sediment disaster prevention measures in Japan	Sabo Dept. MLIT
Sep. 03	10:00-12:00	Rainfall forecasting / early warning	Japan Metrological Agency
	14:00-16:00	JICA supporting sediment disaster related project (in Brail)	Center for Sabo and landslide Technology
Sep. 04	10:00-12:00	Sediment disaster forecasting technology in Japan	NILIM
	14:30-16:30	Landslides distribution mapping / rainfall experiment facility	National Institute for Earth Science & Disaster Management
Sep. 05	10:00-12:40	Introduction of landslides extraction using AI technology	Nippon Koei Co., Ltd.
	14:00-16:00	Civil supports as sediment disaster prevention measures	NPO Sediment Disaster Prevention Publicity Center
Sep. 06	10:00-12:00	Data processing of LiDAR data	Aero Asahi Corporation
	14:00-17:00	Exercise of topographic interpretation using high resolution DEM	Teikyo-Heisei Univ.
Sep. 07	11:00-12:30	Visiting disaster management facilities in Tokyo	

Date	Time	Contents	Lecturer
Sep. 08	AM	Moving (Tokyo to Nagano City)	
Sep. 09	10:00-12:00	Designation of sediment disaster risk area in Nagano prefecture	Construction Dept. Nagano Prefecture
	13:30-15:00	Sediment disaster early warning mechanism in Nagano prefecture	JMA Ngano Office
	15:00-17:00	Disaster record and response	Jizukeyama Landslide
Sep. 10	8:00-11:30	Moving (Nagatno City to Nagiso) Stop at Ushibusegawa Sabo facility	Kiso Construction Office, Nagano Prefecture
	15:00-15:40	Damages by debris flow in 2014 and reconstruction efforts	Kiso Construction Office, Nagano Prefecture
Sep. 11	9:00-12:00	Site visit reconstruction and Sabo facility sites for debris flow in 2014	Kiso Construction Office, Nagano Prefecture
	14:00-16:00	Community awareness activities by local authority of Nagiso	Nagiso Administration Office
Sep. 12	08:00-14:00	Moving (Nagiso to Tokyo)	
Sep. 13	09:00-12:00	Preparation of Action Plan	JICA Tokyo International Center
	13:00-15:00	Presentation of Action Plans	
	15:00-16:00	Training evaluation and closing	
Sep. 14		Leaving for Sri Lanka	

(2) 2nd Training in Japan

Due to the spread of COVIT-19 infection and the economic crisis in Sri Lanka, the implementation of the 2nd C/P training had been in doubt, but it became possible to implement in July 2022 (As a result, the project period was extended by 3 months). Although there were various uncertainties and behavioral restrictions, 10 trainees participated in all the training courses.

The curriculum of the 2nd training focused on the implementation of land use regulations and system development according to the landslide risks. For this objective, staffs from NBRO regional offices, which are in direct contact with Local Authorities, 3 from the NBRO's Human Settlement Planning and Training Division (HSPTD), which has jurisdiction over the resettlement program, 1 from the UDA, 3 mayor and chairmen from pilot Local Authorities were selected. The training curriculum is shown in Table 2.2.

As a border measure to prevent the spread of COVID-19, all trainees are required to stay at a hotel

for eight days after entering Japan. During the period, the trainees received online lectures on landslide risk reduction measures at the national level. After the quarantine period, the curriculum were focused on visiting to prefectures and municipalities and on-site inspections.

Table 2.2: Curriculum of the 2nd C/P training in Japan

Date	Time	Contents	Lecturer
July 12		Arriving at Japan	
July 13	10:00-12:00	JICA briefing	JICA Tokyo Center [Online]
	12:10-12:30	Action Plan development	Facilitated by Team [Online]
July 14	10:00-12:00	Review on SABO project outputs	Facilitated by Team [Online]
	13:00-15:00	Outline of sediment disaster prevention measures in Japan	Sabo department, MLIT [Online]
July 15	10:00-12:00	DRR measures in urban development and supporting policies	Urban Bureau, MLIT [Online]
	13:00-15:00	Group discussion	Facilitated by Team [Online]
July 16-18		Self-study	
July 19	10:00-12:00	Current sediment disasters prediction technics in Japan and the foresight	NILIM [Online]
July 20	9:00-9:30	JICA briefing	JICA Tokyo
	13:15–15:00	Yui Landslide Control Project	Fuji Sabo office, MLIT
	16:00-17:00	Osawa Sabo Project	
July 21	10:00-15:00	Countermeasures for steep slopes by prefectural government	Sabo office, Kanagawa Prefecture
	16:00-17:00	Visiting an honoring monument of President J. R. Jayewardene	Kamakura Great Buddha
July 22	9:30-11:30	Investigation of a geo-disaster mechanism	Institute of Industrial Science, The University of Tokyo
	14:00–16:00	Promotion of Green Infrastructure and disaster prevention and mitigation	Japan Federation of Construction Contractors [Online]
July 23		Preparation of Action Plan	
July 24			
July 25	9:00– 0:30	A landslide disaster by Typhoon No.19 in 2019 at Takumi ward	Gunma University
	10:30-12:00	Site visit: Recovery works for Takumi landslide area	Sabo office, Land Development Bureau, Gunma Prefecture
	14:00–16:00	Dissemination of risk information by LA, and self-evacuation plan	Risk Management office, Tomioka City
July 26	9:00–15:00	Landslide DRR efforts by prefecture Landslide countermeasures River management system Land use regulation / city planning Development permit system	Construction Management office, Land Development Bureau, Gunma Prefecture
July 27	9:00-9:30	Courtesy to Director of SABO Div.	Sabo department, MLIT
	10:30-12:00	Preparation of Action Plan	JICA Tokyo International Center
	13:00-15:00	Presentation of Action Plans	
	15:00-16:00	Training evaluation and closing	
July 28		（Leaving for Sri Lanka	

2.2.3. Technical Seminars

The technical mini seminars had started in the previous JICA-NBRO project "TCLMP (2014-2018)", to introduce not only landslide related technology but also entire disaster management as well as Japanese cultures for all NRBO staff members.

The Project also held the technical mini seminars irregularly with contents shown in Table 2.3: List of Project Mini-seminars, however it has been suspended since it has become difficult to convene the participants after the COVID-19 pandemic.

Table 2.3: List of Project Mini-seminars

No.	Date	Contents
1	Jul. 3, 2019	[Sabo project in Japan] Basic principle of basin sabo planning / designing standards
2	Jul. 23, 2019	[Natural disaster in Japan] Japanese government's efforts on natural disaster risk reduction
3	Aug. 28, 2019	[Landslide records in Sri Lanka] Data analysis on landslide records collected by WG1
4	Sep. 6, 2019	[Yellow/Red zoning in Japan] Difference of Yellow/Red zoning between Japan and Sri Lanka
5	Sep. 23, 2019	[Sabo project formulation] Basic of Sabo Act and Sediment Disaster Prevention Act
6	Feb. 3, 2020	[Land use regulation in Japan] City Planning Act, Residential Land Development Act, etc.
7	Feb. 21, 2020	[Non-structural measures in Japan] Issues on application of Yellow/Red zoning in Sri Lanka

2.2.4. Public Relation Activities

(1) Project Newsletter

Project Newsletters were prepared and circulated for the purpose of promoting the Project. The Newsletter were prepared in Japanese and English according to the activity progress. After starting facebook for a public relation activity, it was ended up with Vol. 4.

Table 2.4: List of Project Newsletters

No.	Date	Contents
Vol. 1	Mar. 29, 2019	▪ Introduction of the Project (Purpose, Outputs, Target Area) ▪ Utilization of outcomes of previous JICA project (LiDAR DEM) ▪ 1st JCC
Vol. 2	Jun. 26, 2019	▪ Seminar on topographic interpretation for hazard analysis ▪ Drone survey by NBRO staff members ▪ Soil Water Index for improvement of landslide early warning ▪ Launching Project facebook
Vol. 3	Nov. 8, 2019	▪ Site inspection for the debris flow affected area / Simulation ▪ 1st C/P training in Japan ▪ Land use regulation / Introduction of Sabo project in Japan
Vol. 4	Feb. 5, 2020	▪ Training on improvement of landslide inventory ▪ 2nd JCC ▪ Dispatch short-term experts from MLIT ▪ Project introduction at NBRO annual symposium

Figure 2.2: Project Newsletter

(2) Project facebook

A facebook page for the Project was launched with the aim of introducing the daily activities of the WG members. The facebook page is also posted on the official NBRO web sites. Due to the regulations regarding information dissemination using social networks of JICA, the every posting have been approved by JICA Sri Lanka office.

As of August 2022, there are 444 followers. Of the audience, 78% are male, 22% are female, and more than half of the audience is concentrated in the age group of 25-34. By region, 91% of visitors were from Sri Lanka, 3% from Japan, and 21% of Sri Lankan visitors were from Colombo, followed by Kandy and Gampaha.

(3) Mass media

The Team had an interview with Nikkei Newspaper. The results of the interview were published dated September 30, 2019. In the article, it was introduced that the name “SABO” is becoming recognized as a common global term, and that JICA and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) are working together to provide technical support for “SABO” in various countries. In the article, field survey at Morawakkanda site was published.

(4) JICA PR Magazine

The Team also had an interview with JICA magazine “mundi”. The Project activities were introduced in the magazine in May 2020, along with the Landslide Disaster Prevention Project (LDDP: loan project).

Source: JICA

(5) Academic conference and symposium

1) Presentation in Japan Landslide Society

As part of public activities for the project, the Team member participated in the 58th conference of the Japan Landslide Society held in August 2019 and gave an oral presentation on the activities on landslide early warning system supported by the Project. A team from the SATREPS project currently underway at NBRO also participated in the study meeting, and there was a lively discussion on issues and assistance in strengthening the early warning system in Sri Lanka.

2) Contribution to “SABO and River Control”

Regarding the 1st C/P training in Japan, the Team were requested from Japan Sabo and River Control Association to contribute an article to the Association’s official newsletter “Sabo and River Control”. The article was published in December 2019.

3) Presentation in International Symposium

In order to widely publicize the project results, we contributed to the international symposium "Multi-Hazard Early Warning and Disaster Risk Reduction" held in December 2020 and made a presentation at the symposium. The symposium is organized by the Disaster Management Center (DMC) and Cabaret (an EU-financed project) and is co-sponsored by JICA. The Project members both Japanese and NBRO made presentations and contributions as shown in Table 2.5.

Table 2.5: Presentation at Multi-Hazard Early Warning and Disaster Risk Reduction

No	Title	Presenter
1	Inventory Survey of Slope Failures in Sri Lanka	Yang P.
2	Determination of the Feasibility of the Uses of Hyper KANAKO A Debris Flow System to Predict the Landslide Damage Zone of Sri Lanka, a Case Study to the Landslide at Meeriyabedda, Koslanda, Badulla, Sri Lanka	Hemasinghe H., Suzuki K., Matsumoto N., Uchida T.
3	Study on Landslide Early Warning by Using Rainfall Indices in SriLanka	Wada T., Gamage H.G.C.P., Senadeera W., et al.
4	Rainfall Triggered Landslide Early Warning System Based on Soil Water Index Gamage	H.G.C.P., Wada T., Senadeera W., Aroos M.S.M., Bandara D.M.L.

4) Presentation in World Landslide Forum 5

The Team participated online in the World Landslide Forum 5 (WLF5) held in November 2021 and presented some of the outcomes of the project. WLF5 has many participants from landslide disaster-related projects implemented by JICA in various countries, so it is also valuable for mutual information sharing. Presentation titles from the Project are shown in Table 2.6.

Table 2.6: Presentation at World Landslide Forum 5

No	Title	Presenter
1	Strengthening non-structural measures for Landslide Risk Reduction in Sri Lanka – Achievement in Project SABO -	Koike T. (Team Leader)
2	Identification of Debris Flow Hazards in Sri Lanka	Yang P., Nishikawa T., Hemasinghe H. H., Jayathissa H.A.G.

5) Presentation at NBRO Annual Symposium

Every year around December, NBRO holds a symposium inviting domestic and foreign researchers and disaster management related agencies. During the Project period, it was not held in 2020 due to the spread of COVID-19, the 10th in 2019 and 11th in 2021 were successfully held with sponsorship of JICA Sri Lanka office.

At the 10th symposium, as the keynote speech on the second day of the symposium, the Team gave a lecture on the history of landslide-related legal system in Japan, and response of the government to the recent landslide disasters. The Project C/Ps presented their achievement related to the Project as shown in Table 2.7.

At the 11th meeting, a member of the Team joined at a panel discussion on the first day of the symposium and addressed that the importance of road slope management and securing human resources for the daily maintenance. On the second day of the symposium, a special session for the Project was organized, and the Project C/Ps gave presentations shown in Table 2.8.

Table 2.7: Presentation at 10th NBRO Annual Symposium

No	Title	Presenter
1	Keynote Speech 02 on Soft Interventions for Sediment Disaster Risk Reduction in Japan	Koike T. (Team Leader)
2	Application of yellow zone and red zone concept to identify debris flow prone sites in Sri lanka	Hemasinghe H. H. (WG1)
3	Determination of Rainfall Thresholds for Landslide Occurrence in Sri Lanka, A Case Study: Kaluganga Basin	Rajapaksha W.D.G.D.T. (WG1,2)

Table 2.8: Presentation at 11th NBRO Annual Symposium

No	Title	Presenter
1	Development of Local Rainfall Thresholds for Landslide Occurrence in Sri Lanka; A Case Study in Kalu River Basin	Rajapaksha W.D.G.D.T. (WG1,2)
2	Accuracy assessment of flow path of debris flow of slope failure using yellow zone / red zone concept; A case study of Aranayake landslide in Kegalle district, Sri Lanka	Karunarathne M. D. S. S.(WG1)
3	Review and validation of slope failure hazard zonation method in Sri Lanka	Wada T. (Expert team)
4	Soil Water Index as a Determining Factor for Initiation of Landslides and Issuing of Landslide Early Warning in Sri Lanka	Rathnayake R. M. S. A. K, (WG2)

2.3. Activities on Output 1

2.3.1. Review existing manuals, hazard and risk assessment methods, system of the landslide record management (Activity 1-1)

(1) Activities

The current methods that had been implemented by NBRO were reviewed to identify issues related to capacity building in hazard analysis and risk assessment addressed in Output 1.

Since around 1995, NBRO has developed a numerical assessment system to quantitatively evaluate landslide susceptibility. The current method of creating Landslide Hazard Zoning Maps (LHZM) follows in principle the method used at that time. This method assigns certain weights to layers consisting of six factors: 1) bedrock geology and geological structure, 2) surface deposits, 3) slope gradient, 4) hydrology and drainage, 5) land use, and 6) landform, and uses the summing scores to classify the sediment disaster potential (susceptibility) of the slope into four susceptibility classes. Since the LHZM was prepared as a 1:10,000 scale, it was necessary to create a more detailed (site-specific) scale hazard map that also showed the sediment flow path and affected areas to contribute to early warning and land use regulation, which was the subject of this project. In addition, the white circled area in Figure 2.3 was the Weeriyapura area, the pilot site of this project, and it was recognized as a high landslide hazard area due to the deformed houses and other structures, however, it was evaluated as low hazard in the LHZM. Because slides present frequently gentle slopes, it was also recognized that sediment movement types like slide were not properly assessed.

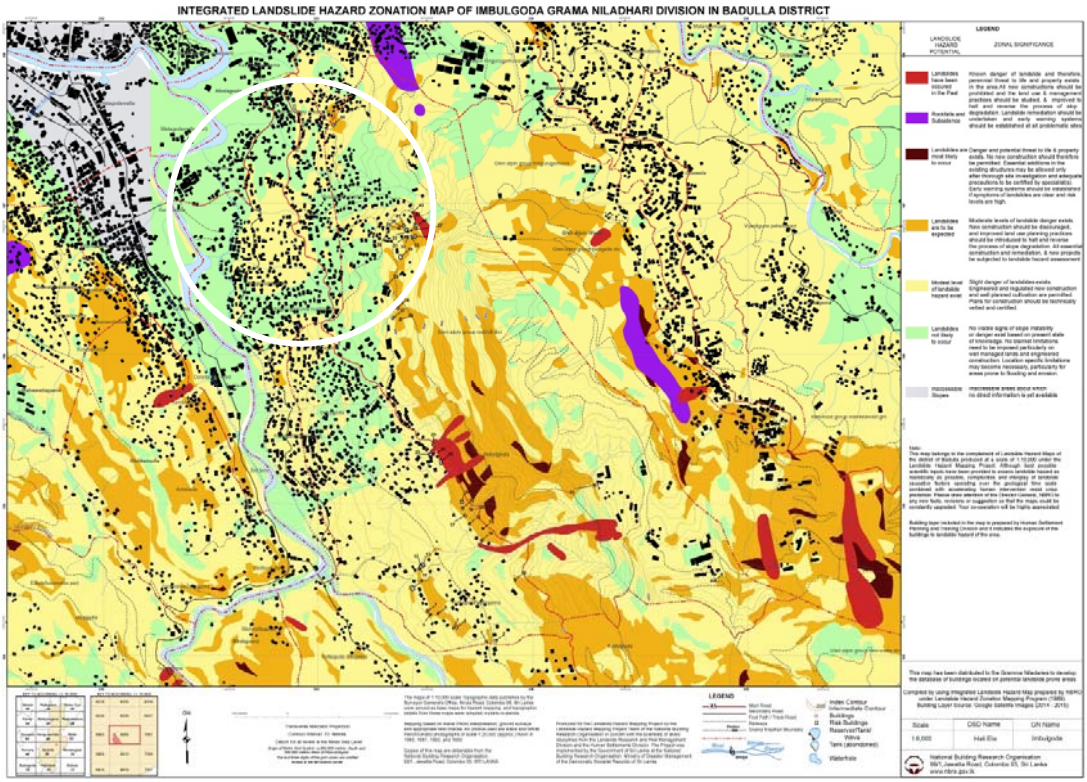


Figure 2.3: An example of the existing LHZM (Werriyapura area of Badulla District)
Source: NBRO LRRMD

RAMMES model was used to identify the affected area of sediment disasters and to thereby assess the risk. The areas classified as Class 1 with the highest potential in the above LHZM were used as the source, and the extent of sediment flow path from the source was analyzed. Afterward, the risk assessment was conducted based on the affected areas identified from land use conditions and the density of houses, by using the hierarchical analysis method (AHP method).

(2) Challenges and Actions

This activity was conducted at the same time as this project was initiated. C/Ps gave presentations on the current analysis and evaluation methods, and constructive discussions on the issues and the contents addressed in this project were carried out to promote C/Ps' understanding of the Project and to help to build a trusting relationship with C/Ps from the early stage of the Project.

2.3.2. Improvement the system to manage landslide records (Activity 1-2)

(1) Activities

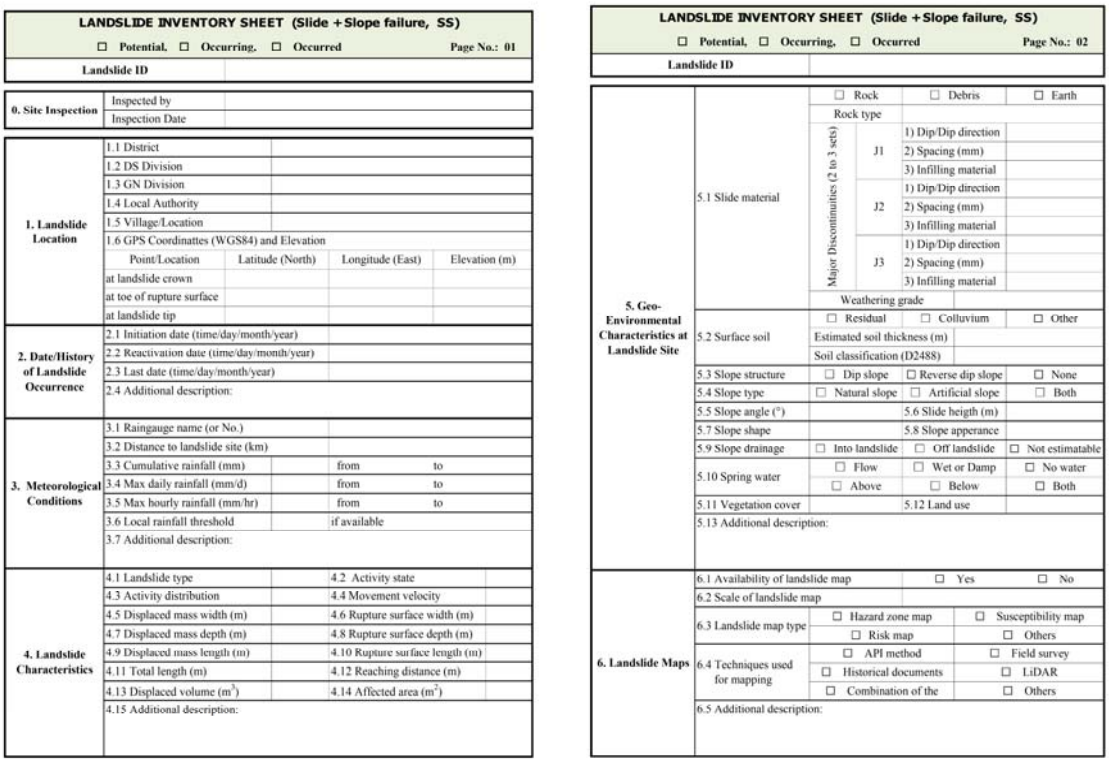
1) Development and dissemination of sediment disaster inventory sheets

Records of past sediment disasters are important basic data for considering appropriate countermeasures. NBRO had also maintained such records in the form of sediment disaster records and disaster investigation reports. However, the following issues were identified.

- There was a system to transmit sediment disaster records from NBRO site offices to NBRO head office, however, the record format and report format were not standardized, and records of sufficient quality had not been accumulated.
- The current records covered only cut slope failures and slides.
- There was a lack of data items useful for sediment disaster countermeasure consideration and hazard map preparation.
- Records were accumulated only on paper media.

To solve the above issues, WG1 developed a "Landslide Inventory Sheet" as a unified format for recording sediment disasters. Three types of landslide inventory sheets were developed: slide and slope failuyre (SS), debris flow and earth flow (DE), and tipple and rockfall (TR) (Figure 2.4), from the analysis results of the actual sediment disasters occurred in Sri Lanka. In addition, a guide, “Guide to Inventory Sheet Records” was prepared to show how to fill out these inventory sheets.

WG1 finalized “Landslide Inventory Sheets” and “Guide to Inventory Sheet records” following comments from NBRO head office and all regional offices. After finalization, NBRO announced that the inventory sheets would be used to record sediment disaster data in the future at the regular meetings with regional offices. The finalized inventory sheets and guide were distributed to all NBRO regional offices.



LANDSLIDE INVENTORY SHEET (Slide +Slope failure, SS)

☐ Potential, ☐ Occurring, ☐ Occurred — Page No.: 01

Landslide ID

0. Site Inspection	Inspected by			
	Inspection Date			
1. Landslide Location	1.1 District			
	1.2 DS Division			
	1.3 GN Division			
	1.4 Local Authority			
	1.5 Village/Location			
	1.6 GPS Coordinattes (WGS84) and Elevation			
	Point/Location	Latitude (North)	Longitude (East)	Elevation (m)
	at landslide crown			
	at toe of rupture surface			
	at landslide tip			
2. Date/History of Landslide Occurrence	2.1 Initiation date (time/day/month/year)			
	2.2 Reactivation date (time/day/month/year)			
	2.3 Last date (time/day/month/year)			
	2.4 Additional description:			
3. Meteorological Conditions	3.1 Raingauge name (or No.)			
	3.2 Distance to landslide site (km)			
	3.3 Cumulative rainfall (mm)		from	to
	3.4 Max daily rainfall (mm/d)		from	to
	3.5 Max hourly rainfall (mm/hr)		from	to
	3.6 Local rainfall threshold		if available	
	3.7 Additional description:			
4. Landslide Characteristics	4.1 Landslide type		4.2 Activity state	
	4.3 Activity distribution		4.4 Movement velocity	
	4.5 Displaced mass width (m)		4.6 Rupture surface width (m)	
	4.7 Displaced mass depth (m)		4.8 Rupture surface depth (m)	
	4.9 Displaced mass length (m)		4.10 Rupture surface length (m)	
	4.11 Total length (m)		4.12 Reaching distance (m)	
	4.13 Displaced volume (m^3)		4.14 Affected area (m^2)	
	4.15 Additional description:			

LANDSLIDE INVENTORY SHEET (Slide +Slope failure, SS)

☐ Potential, ☐ Occurring, ☐ Occurred — Page No.: 02

Landslide ID

5. Geo-Environmental Characteristics at Landslide Site	5.1 Slide material	☐ Rock	☐ Debris	☐ Earth	
		Rock type			
		Major Discontinuities (2 to 3 sets)	J1	1) Dip/Dip direction	
				2) Spacing (mm)	
				3) Infilling material	
			J2	1) Dip/Dip direction	
				2) Spacing (mm)	
				3) Infilling material	
			J3	1) Dip/Dip direction	
				2) Spacing (mm)	
				3) Infilling material	
		Weathering grade			
	5.2 Surface soil	☐ Residual	☐ Colluvium	☐ Other	
		Estimated soil thickness (m)			
		Soil classification (D2488)			
	5.3 Slope structure	☐ Dip slope	☐ Reverse dip slope	☐ None	
	5.4 Slope type	☐ Natural slope	☐ Artificial slope	☐ Both	
	5.5 Slope angle (°)		5.6 Slide heigth (m)		
	5.7 Slope shape		5.8 Slope apperance		
	5.9 Slope drainage	☐ Into landslide	☐ Off landslide	☐ Not estimatable	
	5.10 Spring water	☐ Flow	☐ Wet or Damp	☐ No water	
		☐ Above	☐ Below	☐ Both	
	5.11 Vegetation cover		5.12 Land use		
	5.13 Additional description:				
6. Landslide Maps	6.1 Availability of landslide map		☐ Yes	☐ No	
	6.2 Scale of landslide map				
	6.3 Landslide map type	☐ Hazard zone map	☐ Susceptibility map		
		☐ Risk map	☐ Others		
	6.4 Techniques used for mapping	☐ API method	☐ Field survey		
		☐ Historical documents	☐ LiDAR		
		☐ Combination of the	☐ Others		
	6.5 Additional description:				

Figure 2.4: Parts of the developed Landslide Inventory Sheets (examples of slide/slope failure sheets)

WG1 held a workshop on the key points to improve the sediment disaster inventory sheet including the implementation status of landslide emergency and restoration measures and how to fill out the data sheet, etc. on April 2019, and a seminar regarding the introduction of the developed landslide inventory sheets and database for NBRO regional office staff in July of the same year in Matale district. Further, a workshop was held regarding the record of "Landslide Inventory Sheet" for NBRO staff during October 2019. A total of about 50 staff from NBRO head office and regional offices joined the workshop.

A site workshop on the record of "Landslide Inventory Sheet" for NBRO regional office staff

2) Developing Landslide Information Management System (LIMS)

NBRO planned to develop Landslide Information Management System (LIMS) as a part of the Project activities, and secured the C/P budget for the development. The LIMS is to manage all of landslide investigation and risk assessment reports prepared by NBRO site offices and integrate them on-line. It was expect to develop a mobile application so that the officers at the site offices can enter the landslide related information at the fields and directly shared with NBRO head office. Since the

landslide inventory sheet developed in the Project also be combined into the LIMS, the Team has made advise on the bidding documents of the LIMS. However, due to the spread of COVID-19 and the economic crises, the C/P budget for the LIME also be cut, so the procurement of the system development has been suspended.

During the COVID-19 pandemic, even for NBRO officials, it was restricted to travel and conduct site survey at the remote area. It was required to accumulate the field investigations by site offices immediately and accurately to the head office. Such real-time information will also contribute to improving the accuracy of early warning thresholds for the activity of Output 2. Accordingly, it was decided to support development of LIMS in the Project.

Based on the verification of technical and financial proposal, the Team made a contract with the "Science Land IT" in July 2021. The contract period wase set to the end of November of the same year at the beginning, however the contract period was extended until March 2021 due to delay of work under travel restriction to the NBRO site offices. Through the contract period, many consultation meetings were held between NBRO, the Team and the Science Land IT. Besides, the Science Land IT repeatedly visited all the NBRO site offices to understand the real needs to improve the system. The system was finally completed at the end of March 2021.

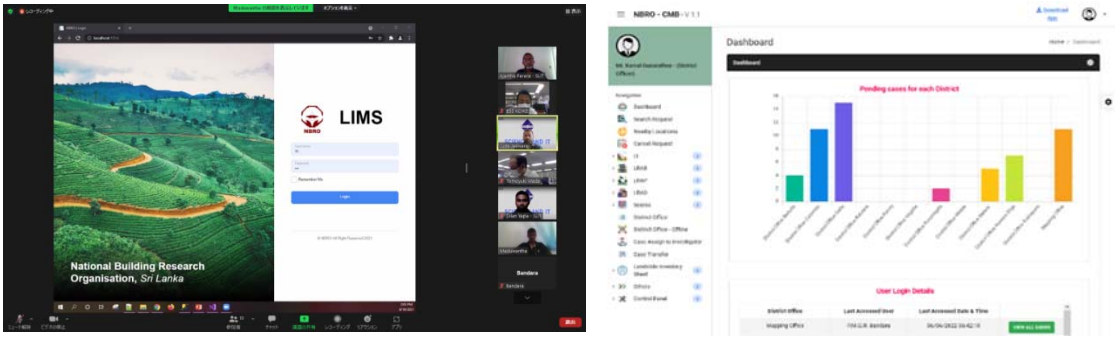


Figure 2.5: Online meeting for LIMS development and an example of developed Dashboard

There are more than 100,000 paper-based reports including 30,000 landslide investigation reports at NBRO head office and site offices. Before operation of the LIMS, those existing data should be stored in the LIMS. Due to the financial difficulties of NBRO, many of non-permanent staffs at site offices have been

Due to the financial difficulties caused by the spread of COVID-19, many of the non-regular staff at the local offices have been dismissed. Therefore, the Team decided to employ assistants to assist data entry at each site office. As of October 2022, more than 10,000 records have been stored in the LIMS. The data entry will be continued by NBRO site offices after the completion of the Project, and new investigation reports will be created on LIMS.

(2) Challenges and Actions

1) Reflection of the comments from NBRO regional office Staff who are users of the inventory sheets

The inventory sheets will be used primarily by regional office staff who will conduct inventory surveys in the field. To ensure the sustainable use of the inventory sheets, regional office staff had to be fully convinced of its use. Therefore, at the workshop for regional office staff nationwide held in October 2019, after the on-site practice of filling out the inventory sheet, all participants exchanged

opinions and discussed points to be improved on the sheet, which were then reflected in the finalized inventory sheet and guide to inventory record. All participants were divided into groups, and after discussion, a representative of each group made a presentation to all participants. Groups with excellent presentations and recommendations were given awards and incentives for their efforts.

2) Development of landslide information management system (LIMS)

In developing the database, it was important to accurately grasp the actual needs of users for the system to be used sustainably, and the subcontractor was required to interview with all regional offices in the pre-development stage and to then design the system. Furthermore, using the prototype, NBRO head office staff and the subcontractor jointly conducted inventory records of many sediment disaster examples at each regional office. During this process, various problems arose, and NBRO and the subcontractor cooperated to solve them in detail, and a system was constructed that met the requirements of disaster inventory record.

2.3.3. Collect records on past sediment disasters in Sri Lanka and analysis the relationship of rational characteristics (Activity 1-3)

(1) Activities

1) Collection, organization and on-site confirmation of past sediment disaster data

Based on the past 3,144 disaster data (from 1985 to 2017) collected by NBRO, the occurrence of sediment disasters by type across Sri Lanka was organized and evaluated. Of these, 61 slide and slope failure disasters and 19 debris flow disasters that recently occurred were collected and recorded with the prepared “Landslide Inventory Sheet” prepared in Activity 1-2, and the necessary information was collected from NBRO sediment disaster investigation reports, the Internet, newspapers, satellite photos before and after the occurrence, etc., and if further information was lacking, a site survey was conducted to supplement and confirm such data, and to interview local residents, especially regarding sediment reaching distance and damage situation.

2) Analysis of the actual sediment disaster occurrence

To examine the methodology for the hazard mapping manual and risk assessment manual developed in Activity 1-4, a statistical analysis was performed on the width, length, depth, slope inclination, and reaching distance of slope failures by using the collected-above disaster cases. The analysis results showed that in Sri Lanka slope failures occurred mostly at slopes of 25-45 degrees and tended to rapidly increase especially at slopes of 25 degrees or more. In addition, the height of slope failures was mainly between 5 and 40 meters, accounting for about 80% of the total slope failures collected (Figure 2.6). The sediment disaster occurrences and their topographical characteristics were summarized as empirical trends and used as the basis for establishing criteria for hazard maps (Yellow/Red zones).

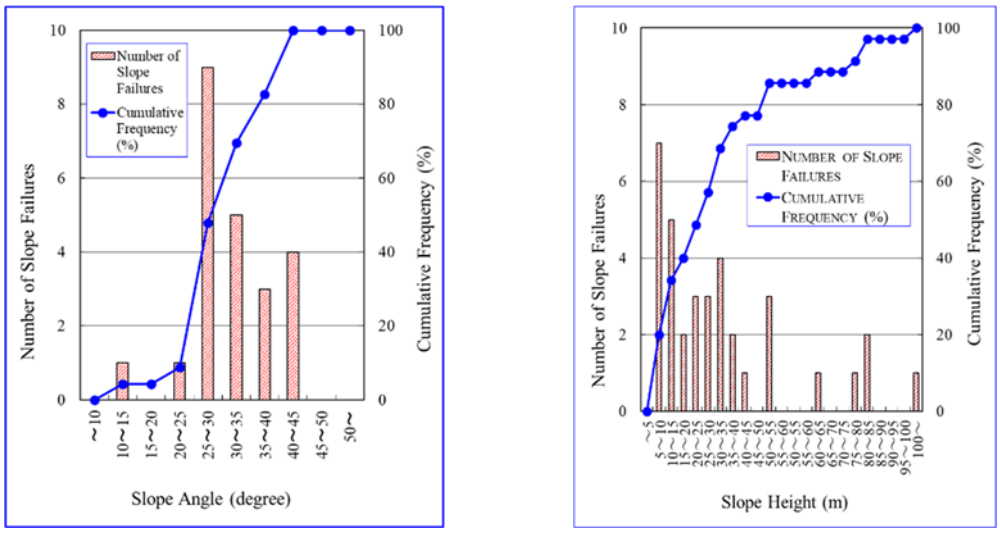


Figure 2.6: Topographical characteristics of slope failures in Sri Lanka
(Left figure: slope angle, Right figure: slope height)

3) Analysis and organization of the damage situation

The damage situation was analyzed for each type of sediment disasters, focusing on human casualties and damage to houses. The analysis results of 58 slope failures showed that the same degree of human damage occurred in the source areas and their affected areas, as shown in Figure 2.7 (left).

On the other hand, as shown in Figure 2.7 (right), human casualties from debris flows occurred not in the source areas but in the flow path and depositional areas. In Japan, residential houses are widely distributed below the exit of mountain streams, but in Sri Lanka, residential houses are also located along mountain streams. Therefore, it was found necessary to consider not only the depositional zone but also the flow path when designating Yellow/Red zones for debris flow.

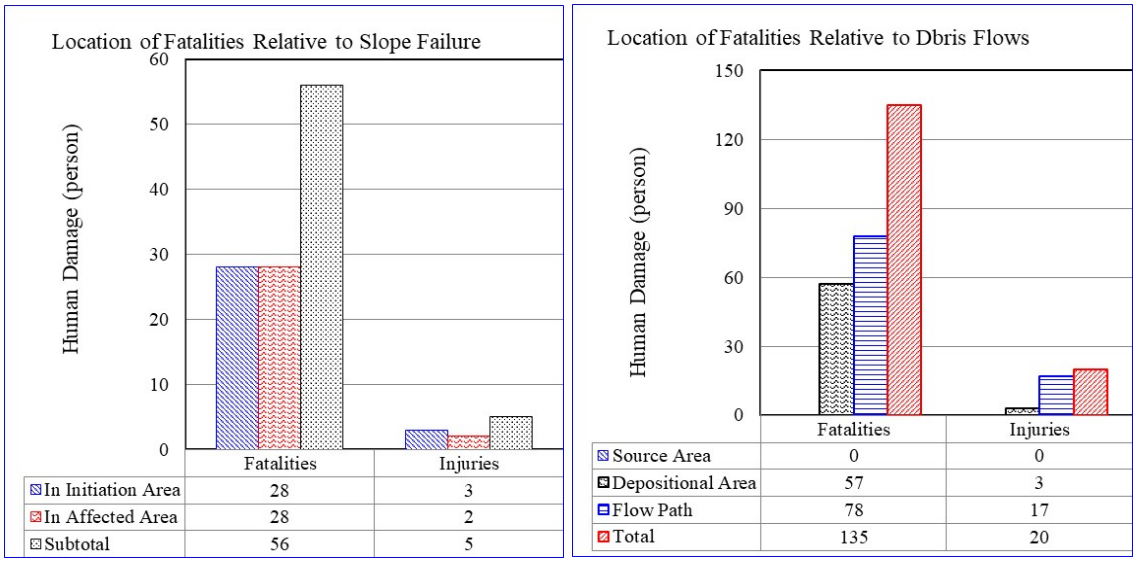


Figure 2.7: Location of fatalities and injuries due to slope failures (left) and debris flows (right)

4) Summary of sediment disaster inventory survey

As a basis for designation standard for Sri Lanka-specific Yellow/Red zones, the results of the sediment disaster inventory survey were presented in the REFERENCE DATA of "Manual on Site-specific Landslides Hazard Zoning". On the other hand, there were only limited sediment disaster records for which data can be collected to provide a basis for designation standard for Yellow/Red zones, therefore, we confirmed with C/Ps the importance of continuing to collect sediment disaster records to further verify and revise the designation standard by using the inventory sheets and LIMS in Activity 1-2. It is expected that NBRO will take the lead in recording and accumulating future sediment disaster data in the LIMS to verify and review the designation standard for Yellow/Red zones.

Part of the sediment disaster inventory survey results was presented jointly by C/Ps and the Team at an international symposium hosted by DMC in December 2020 and at World Landslide Forum 5 (WLF5) held in Kyoto in November 2021.

(2) Challenges and Actions

1) Promoting understanding of classification of sediment disasters

The TCLMP has consistently provided technical guidance that even though the phenomena are collectively referred to as sediment disasters, each of them, such as slope failure, slide, debris flow, etc., has different characteristics and requires different countermeasures. In Activity 1-3, the past sediment disaster records were analyzed separately for each sediment disaster type, and for the first time, topographic features and trends were identified in the source and depositional areas of each sediment disaster in Sri Lanka. C/Ps were instructed to relate these topographical features to the empirical designation standard for the Yellow/Red zones established in Activity 1-5, which led to an understanding of the significance of the sediment disaster inventory survey.

2) Efficient collection and organization of past sediment disaster data

Because past sediment disaster reports were maintained on a paper basis, and because the items necessary for analysis were not adequately described in these reports, it was difficult to collect and organize sediment disaster data. In response to this, priority was given to sediment disaster cases that were recently recorded and for which information was easy to collect, and the necessary information was collected from NBRO sediment disaster investigation reports, the Internet, newspapers, satellite photos taken before and after the disaster occurrence, etc. In cases where information was insufficient, information was collected through on-site confirmation and interviews with local residents regarding the damage situation. In addition, information was efficiently collected by utilizing local employee.

2.3.4. Prepare draft manuals on hazard mapping and risk assessments (Activity 1-4)

(1) Activities

1) Preparation of hazard mapping manual

Through discussions in WG1, it was agreed with NBRO to develop a Site-specific hazard map for

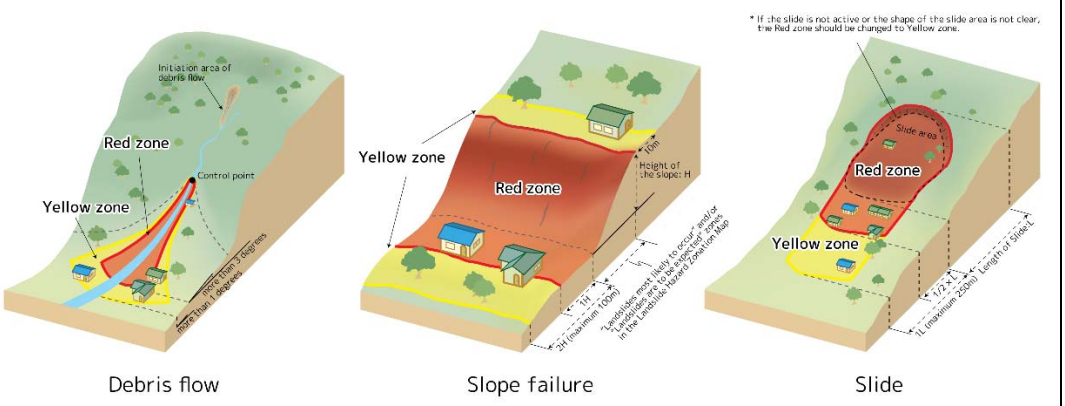
this Project using the concept of the “Sediment disaster hazard zone (called as Yellow/Red zone)” which is used in Japan. Through the previous JICA project “TCLMP” and other assistance program, C/Ps were familiar with the concept of the Yellow/Red zone in Japan. It was also well understood that this methodology is a method to solve the problem of the existing LHZM, “site specific map showing the sediment flow and affected area is required”.

The Yellow/Red zoning method in Japan classifies sediment-related disasters into three categories: “steep slope failure”, “slides”, and “debris flows”. The criteria for setting each zone are based on the analysis of past landslide cases that occurred in Japan. Therefore, direct application of the Japanese criteria to Sri Lanka is not appropriate.

In Activity 1-3, past landslide disaster cases in Sri Lanka were analyzed. The relationship between topographical features with a high probability of occurrence of landslide disasters in Sri Lanka and the extent of damage was determined as the criteria for setting the Yellow/Red zone (Figure 2.8). Based on the results in Activity 1-3, the types of disasters were “slope failure”, “slide” and “debris flow” similar to those in Japan. The definition of Yellow/Red zone is the same as in Japan. Landslide Hazard Yellow Zone” is defined as the area that is susceptible to landslide and called as “Yellow zone”. The resistance capacity of normal residential buildings in Yellow zone is expected to be larger than moving debris force acting on residential buildings, thereby causing a partial or less damage to the residential buildings in Yellow zone, and consequently posing a lower risk to the residents in Yellow zone. “Landslide Hazard Red Zone” is defined as the area where there is a high risk of damage to buildings and threat to people due to landslide, and called as “Red Zone”. The moving debris force acting on residential buildings in Red Zone is expected to be larger than the resistance capacity of normal residential buildings. Therefore, normal residential buildings in Red zone would be completely destroyed by the moving debris and earth of landslides, consequently having an even higher risk to the residents in Red zone.

Yellow/Red zone of slope failure was the most controversial in setting standards. Through the activity 1-3, it was found that slope failures occurred frequently on slopes with slopes of 25 degrees or more and slope heights of 5 to 40m in Sri Lanka. This was applied at the pilot site as the criteria for setting the Yellow/Red zone of slope failure. However, when it was applied to the Aranayake in Kegalle district, the entire slope was evaluated as Red zone where residential houses were also located in the middle of the long slope. WG1 faced the problem that the social impact was too large in such all slopes are designated as the hazard map. Then, new criteria were examined to exclude slopes of 50 degrees or more from the target slope because those slopes tend to be bedrock slopes, but the results of Yellow/Red zones did not change significantly. Regarding this issue, the Team repeatedly discussed with not only WG1 members but also Project Director, Project Manager and other WG leaders, and concluded to use the area of “Landslides most likely to occur” (highest risk) and “Landslides are to be expected” (second most likely to occur) in LHZM created by NBRO as initial area for possibility of slope failure, not using newly created criteria based on slope angle. Therefore, the Team confirmed with the C/P that the accuracy of LHZM is extremely important for setting the Yellow/Red zone.

The hazard mapping manual consists of five parts: Chapter 1 Introduction, Chapter 2 Characteristics of Landslides in Sri Lanka, Chapter 3 Hazard Zoning for Slope Failure, Chapter 4 Hazard Zoning for Slide, and Chapter 5 Hazard Zoning for Debris Flow. Each chapter also includes data that serves as the basis for setting criteria. In addition, Japanese criteria and technical notes on interpretation of landslide topography are attached at the end of the manual.



Debris flow | Slope failure | Slide

	Debris Flow	Slope Failure	Slide
Japan	▪ The lowermost end of the Yellow zone is the point where the grand gradient is 2 degrees. ▪ The moving debris force acting on residential buildings in Red Zone is expected to be larger than the resistance capacity of normal residential buildings.	▪ The target area to be selected for slope failure shall be a steep slope having a gradient more 30 degrees and height of 5 m. ▪ Yellow zone is the area located within a horizontal length of 10 m from the upper edge of a steep slope and the area located within twice the height of the steep slope area from the lower edge.	▪ Yellow zone is inside the slide block and the area which has same length and width of slide area at lower slope. ▪ The moving debris force acting on residential buildings in Red Zone is expected to be larger than the resistance capacity of normal buildings during 30 minutes after starting movement.
Sri Lanka	▪ The target mountain stream is a river basin that includes "Landslides most likely to occur" or "Landslides are to be expected" areas in LHZM or basins with alluvial fans. ▪ The lowermost end of the Yellow zone is the point where the grand gradient is 1 degrees with consideration of loading flow. The spreading angle outside on plane is 30 degrees on one side. ▪ The lowermost end of the Red zone is the point where the grand gradient is 3 degrees. The spreading angle outside on plane is 15 degrees on one side. ▪ In Sri Lanka residential houses or public buildings are often located along the mountain stream above the top of alluvial fans. Control point should be shifted to upper when residential houses located in the stream.	▪ "Landslides most likely to occur" or "Landslides are to be expected" in LHZM will be set for source area of assumed slope failures. ▪ The Yellow Zone shall be set to include the area located within a horizontal length of 10 m from the upper edge and the area located within the distance equivalent to twice the height of the source area from the lower edge. ▪ The Red Zone shall be set to include the source area with Brown and/or Orange zones in LHZM and the area located within the distance equivalent to the height of source area from the lower edge.	▪ In the case that a slide block is active and the shape of the block slear, Red zone is inside the slide block and the area which has half of length and width of slide area at lower slope. ▪ In the other cases, Yellow zone is inside the slide block and the area which has same of length and width of slide area at lower slope.

Figure 2.8: Major differences of Yellow/Red zone setting criteria in Japan and Sri Lanka

In Sri Lanka, many houses are located even on mountain slopes. Rockfalls from the rock cliffs on the upper slopes also cause damage of residential houses. However, there are almost no records that accurately indicate the place of occurrence and range of reach. It was difficult to analyze the hazard area (reachable distance) for rockfalls based on past disaster records. WG1 attempted to collect the data on existing rockfall occurrence locations and their sources in the Weeriyapura area. However, due to the spread of COVID-19, WG1 members were unable to conduct a sufficient investigation, consequently excluded rockfalls from the Yellow/Red zoning in this manual.

2) Preparation of Risk Assessment Manual

Since "risk assessment" is broadly defined, its content will vary depending on the purpose. The definition and methodology of risk assessment for this Project was discussed by WG1 and WG3 in February 2020, involving short-term experts. In Japan, risk assessment of landslides is generally not carried out because the Yellow/Red zoning already includes an element of building resistance. Short-term experts advised that some prefecture government in Japan and other local governments independently conduct quantitative assessments of the importance of facilities and other factors for each hazard zone in order to determine project priorities for designated areas.

Therefore, the risk assessment related to the site-specific hazard mapping in the Project is not to divide the risks in Yellow/Red zones, but the risk assessment is defined as an evaluation of the priority of countermeasures in each hazardous area (i.e., how many objects and population to be preserved are located in the hazardous area, the importance of the preservation facilities, and whether or not there is a history of past damage). Based on this concept, the risk assessment methodology (priority evaluation) and its elements were defined according to actual situation in Sri Lanka.

A Technical Note "Conceptual Planning of Structural Measures around the Designated Red Zones" for structural measures, which is part of the development standards, was prepared and attached to the end of the risk assessment manual.

The planned activity in PDM is to “update” the existing risk assessment manual. However, considering above situation, it was decided not to update the existing manual, but to prepare a new risk assessment manual for the purpose of prioritizing of hazardous area for countermeasures.

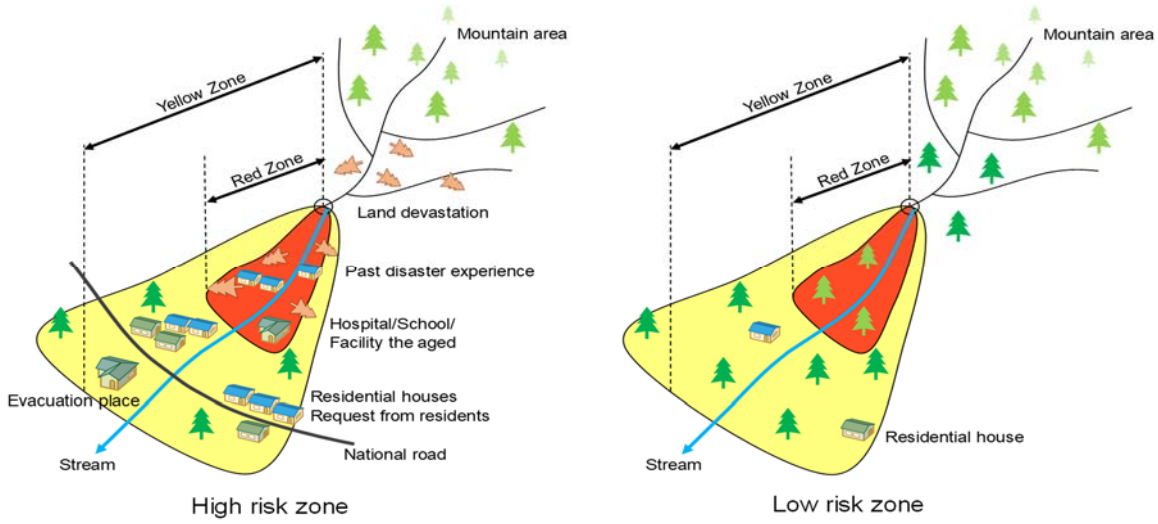


Figure 2.9: Conceptual diagram for risk assessment related to Yellow/Red zoning

(Source: Risk Assessment Manual)

(2) Challenges and Actions

1) Feedback to manuals for practical issues

In the initial work plan, the Team supposed that the manual would be prepared firstly and then applied to the pilot site. However, in order to make the manual more practical, any criteria was applied at the pilot sites in parallel with the preparation of the manual, and the issues and solutions that emerged were fed back to the manual. Through this process, the manual became more effective and practical and the C/P's understanding of the content of the manual was further deepened.

2) Read through the full text of the manual with the project manager and WG leader

The Team, Project Managers and WG1 leaders read the full text of the manuals in order to exchange the understanding among all members. Although the work took time, by making understanding of the Project Manager regarding Yellow/Red zoning concept, the activities to apply the Yellow/Red zoning became smooth and effective.

3) Manual in Sinhala language

In addition to the English manual, WG1 also prepared a manual in Sinhala. This work made it possible to understand in a more familiar language and improved the sustainability of manual utilization, especially for local staffs.

4) Consideration of Vulnerable People and Gender in Risk Assessment

It is important to consider disaster vulnerable people such as handicapped people, elderly, pregnant women, infants, foreigners etc., in the process of risk assessments, who may need someone's supports in the disaster events. Therefore, WG1 decided to include the items for disaster vulnerable people and existing facilities in risk assessment (priority evaluation for countermeasures).

2.3.5. Evaluation and improvement of existing LHZM (Activity 1-4: additional)

(1) Activities

In this project, the Yellow/Red zone designation methods were applied for "Site-Specific" hazard zonation, which was separated from the existing regional maps (LHZM) developed by NBRO. However, it takes long time to prepare the Yellow/Red zonation maps for whole landslide hazard areas in Sri Lanka. Thus, it is necessary to utilize the regional LHZM as a basis for land use restriction and planning. Therefore, it was decided to add an activity to evaluate the regional LHZM and propose make recommendations to improve the LHZM based on the actual landslide records which occurred in the recent years.

1) Evaluation of the existing regional LHZM based on the actual landslide records

Levels of landslide hazards in the existing LHZM are designated based on points of six factors including geology, slope, hydrology and so on. In order to evaluate adequacy of the six factors, the existing LHZM and the actual past landslides which occurred in Ratnalura and Kalutara districts in mainly 2017 and 2018 were compared and validated the accuracy of LHZM. The actual landslide areas were divided into initiation areas of landslides and affected areas located below the initiation

areas by satellite image analysis. In addition, correlation between the six factors and the initiation areas of actual landslides were also analyzed to evaluate significance of the factors. The data utilized for the analysis was prepared by collaboration of C/P and the Team.

The result of the analysis shows that ca. 90% of the past landslide initiation areas in the study areas are located in the "Modest" hazard zone (third hazardous zone) or higher hazard zones of the LHZM; it indicates that the landslide capturing rate of the existing LHZM is quite high (Figure 2.10). However, ca. 70% to 80% of the areas are originally designated as "Modest" or higher hazard areas in the LHZM. The high capturing rate of landslides seems to be a result of too wide designated landslide hazard areas. Thus, it is required to optimize the LHZM by reducing high hazard areas without decrease of capturing rate of landslides.

Regarding the six factors utilized to designate landslide hazard zones, correlation between "slope" and "hydrology (drainage basin shape)" factors and the actual initiation areas of landslides were relatively high. On the other hand, "geology" factor shown negative correlation (Figure 2.11). To improve the regional LHZM, review and exclusion of the factors which are not effective is an option, but further study based on more landslide records in wider regions is required.

The capturing rate of "affected area" by LHZM was lower than it of "initiation area". This is because the flow down process of debris flows is not taken into account in the LHZM. The C/P requested that the flow path of debris flows should be incorporated into the LHZM to improve accuracy.

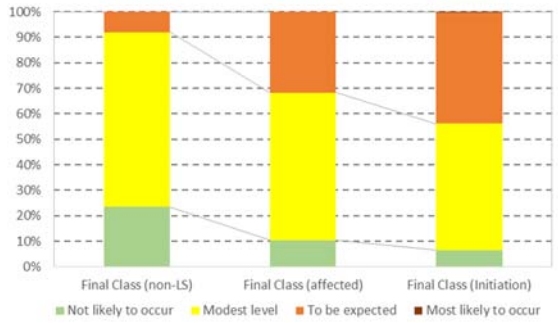


Figure 2.10: Area ratio of each hazard level areas in the existing LHZM
Left: no landslide areas
Middle: "affected area" of past landslides
Right: "initiation area" of past landslides

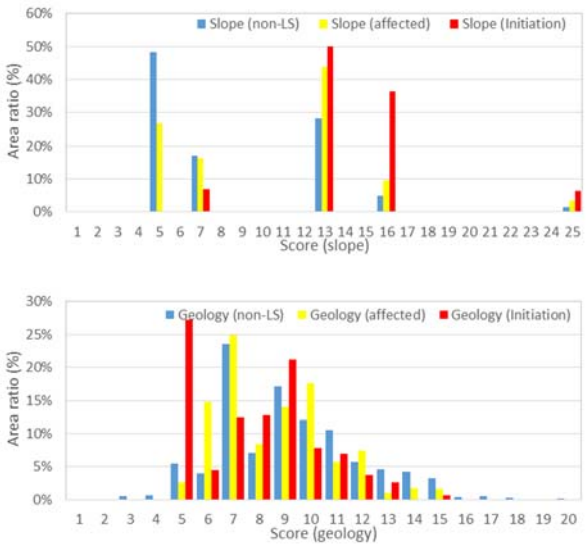


Figure 2.11: Comparison between scores of "slope" and "geology" factors and the past landslide areas

(Upper: slope factor, Lower: geology factor)

2) Study to revise the existing landslide hazard zonation mapping method based on the actual landslide records

a) Revision of thresholds for landslide hazard evaluation

Optimization of the LHZM by reducing too wide landslide hazard zones through revision of the thresholds which are utilized to determine landslide hazard levels was proposed to NBRO.

The landslide hazard levels are determined depending on the total score of the six factors and the thresholds which divide hazard levels. It is proposed that the threshold for "Modest" hazard level should be increased from 40 to 48, and the too wide "modest" hazard area which covers ca. 80% of the total area should be decreased to ca. 50% (Figure 2.12). Instead of decreasing hazard areas, the landslide capturing rate will decrease from ca. 90% to 80%, but the capture rate can still remain high.

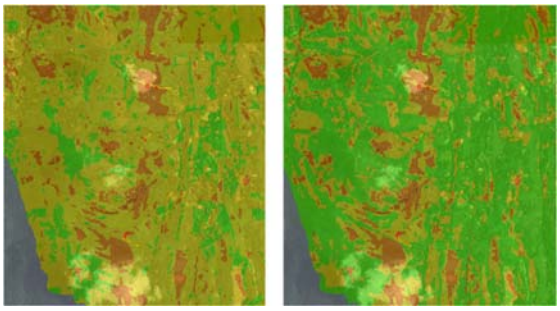


Figure 2.12: Comparison of current LHZM and LHZM after revision of the threshold
Left: current LHZM
Right: LHZM after revision of the threshold
(Yellow hazard areas decrease)

b) Yellow/Red areas of slope failures

The Yellow/Red zone method to estimate affected areas is not applied to the regional LHZM. Therefore, the affected areas below/above slope failure initiation areas tend to be underestimated in the LHZM. Thus, an automatic calculation application to calculate the "affected areas" based on the WG1 method by using the LHZM and DEM, in order to easily evaluate hazard zones in widespread areas.

The WG1 method was applied to extract the slope failure Yellow/Red zones based on the LHZM including the "affected areas" in the downslope and upslope areas. The results showed that the capturing rate of slope failures was improved (Figure 2.13). However, the number of landslide records which are able to be utilized for the validation of hazard zonation is still small. More landslide records need to be accumulated and analyzed.

The application developed by the Project was provided to C/P through the workshops and utilized to prepare hazard maps in the pilot sites.

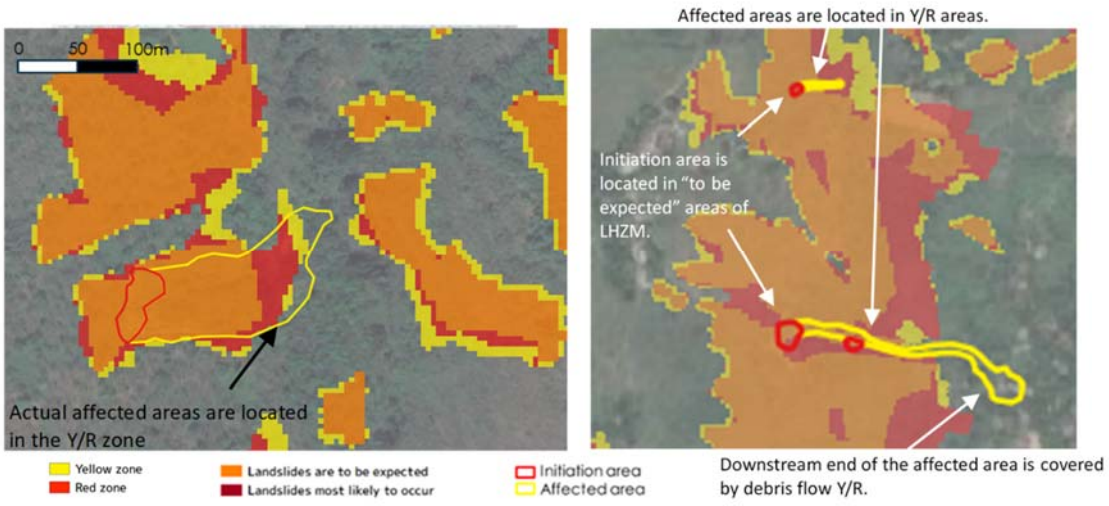


Figure 2.13: Comparison among "to be expected" or higher hazard zones of the existing LHZM, Yellow and Red zones of affected areas and actual initiation/affected areas of disasters

c) Hazard areas of debris flows

In order to estimate "affected areas" which extends outside of the hazard areas of LHZM, an application to estimate probability of debris flow. The application was developed based on "Flow-

R" algorism, which can be applied for wide areas. Moreover, the hazard areas of the existing LHZM are able to be inputted to the application as initiation points of debris flows.

Figure 2.14 shows a comparison between simulated debris flow prone areas and actual debris flow in Morawakkanda. The simulated "affected area" is reasonable, compared to the actual debris flows. Thus, this analysis method seems to be valid. Figure 2.15 shows slope failure Yellow/Red zones in the study area of Kalutara District, debris calculated flow hazard areas and an actual "initiation area" and "affected area" of the past disaster. The actual "initiation area" is located in the slope failure Red area. The actual "affected area" extends outside of the Red area of slope failure, but it is covered by a simulated debris flow hazard area.

Figure 2.14: Hazard area validation in Morawakkanda
Background image:
drone image after debris flow
Blue: simulated hazard probability of debris flow

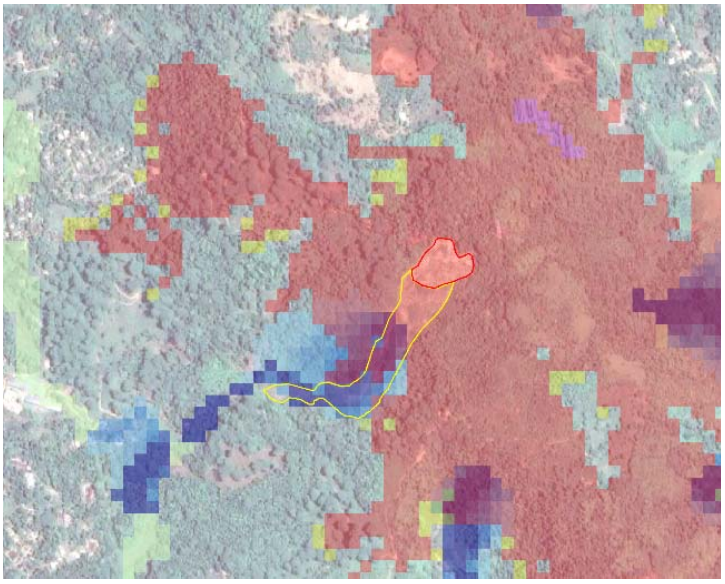


Figure 2.15: Hazard area validation in Kalutara
Red polygon: "initiation area" of debris flow
Yellow polygon: "affected area" of debris flow
Yellow/Red: slope failure Y/R hazard areas
Blue: simulated hazard probability of debris flow

NBRO and the Team compared the Flow-R method with the Yellow/Red zone method developed by WG1, and concluded that the WG1 method is appropriate method for debris flow hazard mapping in Sri Lanka. Regardless of which method is used, it is essential to incorporate the estimated "affected area" into the LHZM through calculation of flow down process in order to improve the accuracy of the LHZM.

3) Workshop and technical seminars regarding improvement of the regional LHZM

An online seminar regarding improvement of the regional LHZM was held in October 2021, based on the results of the analysis. Contents of the online seminar was as follows; 1) review and recommendation on the methods to develop LHZM, and 2) validation and recommendation for the current regional LHZM.

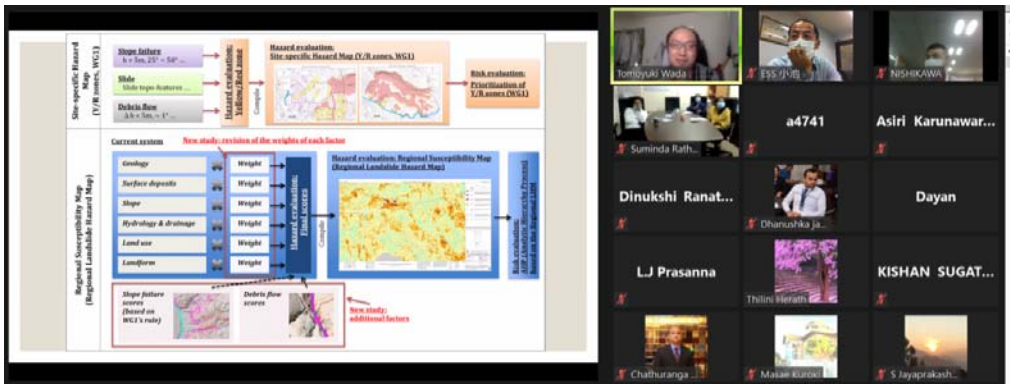
It is pointed out that the method utilized to prepare regional LHZM was developed in 90's, but reports of actual landslides have been accumulated in 00's. Furthermore, it is important to develop hazard zonation methods considering disaster types. Therefore, it was noted that review and revision of the current method is significant. The Tean recommended that it is essential to verify the LHZM using

actual landslide disaster records. Thus, it is important to collect and accumulate appropriate disaster data using the landslide disaster data sheet which was newly created in the project. NBRO agreed with these comments.

Subsequently, the results of analysis for improvement of the reginal LHZM were shared with C/P and discussed. C/P commented as follow; 1) the current hazard zonation methods are not well validated by actual landslide data, 2) even if most of the actual landslides are located in the medium or high hazard areas of LHZM, the accuracy of LHZM is not high since more than half of the entire area is designated as medium or high hazard areas, and 3) validation of the actual landslide capturing rate of the current LHZM was requested.

Considering the comments of C/P, the analysis was done. Details of the analysis is shown in the previous section of this report. A technical workshop regarding review and revision of the LHZM was held in November 2021 for scientists and engineers of NBRO. In the workshop, the revision of thresholds of hazard levels was proposed. In addition, practical training for slope failure Yellow/Red zoning and estimation of debris flow prone areas was conducted.

Because the technical workshop was an online training, there were some difficulties to support the participants when they operate the analysis application. However, the NBRO mapping team (the actual working unit for hazard mapping) and other members continued to operate and verify the application themselves after the training. The Team also continue follow-up their works, remotely.



Online technical workshop

(2) Challenges and Actions

Despite the limited available data, the Team collected and analyzed as much data as possible in cooperation with the NBRO. Even so, the study area was small compared with landslides prone regions in Sri Lanka. Thus, further landslide data collection and analysis are needed to improve the existing reginal LHZM.

The NBRO has begun to verify the landslide data and study, considering the recommendation in the technical seminars on the calculation of slope failure Y/R and debris flow hazard areas, the presentations at annual seminars, the proposal to revise the hazard level thresholds and discussions on the incorporation of slope failure and debris flow affected areas into the wide-area LHZM. Continuous efforts to improve the regional LHZM by using the accumulated landslide hazard data will be crucial in the future.

2.3.6. Conduct hazard and risk assessment at pilot sites (Activity 1-5)

(1) Activities

1) Preparation of base map

A base data of the target areas was collected to conduct hazard analysis and risk assessment of the pilot site. LiDAR DEM was used for Weeriyapura and Udapotha sites. Because Morawakkanda is out of coverage or the LiDAR DEM, the contour lines were generated from the 1:10,000 scale topographic map of Survey Department and used to prepare the base map. In addition, NBRO HSPTD created ortho images of each pilot site using drones.

2) Topographic interpretation

Topographic interpretation using aerial photograph is the first important step in landslide hazard analysis. Therefore, WG1 obtained aerial photographs of each pilot site, and created red-blue stereoscopic images from digital elevation data (DEM). WG1 conducted topographic interpretation for the pilot sites using these photographs and images. At the start of this work, a topographic interpretation seminar was held for WG1 members. The Team gave guidance on the formation of topographic features related to landslide disasters and key points for interpretation.

Guidance on aerial photograph interpretation

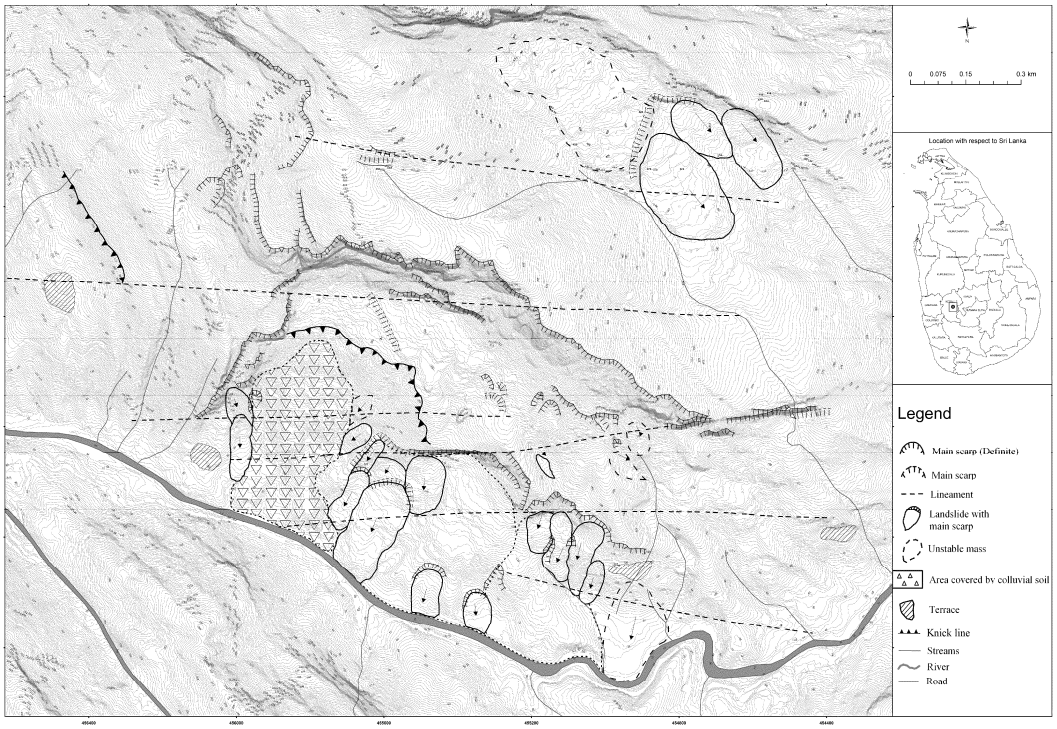


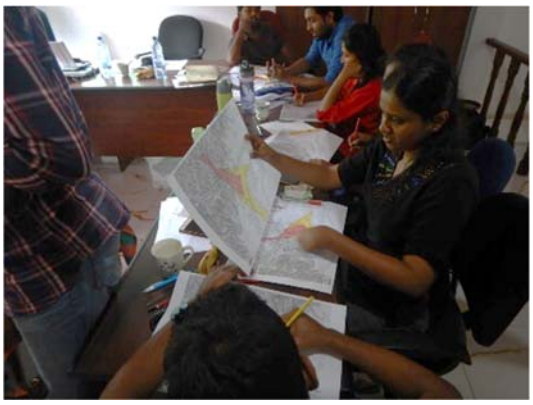
Figure 2.16: Landslide Topographical Interpretation for Udapotha site by C/Ps

3) Setting Yellow/Red zones

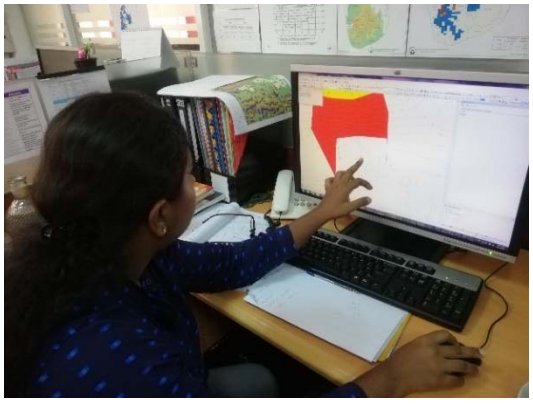
According to the draft manual prepared in Activity 1-4, the Team carried out trainings on setting up the Yellow/Red zones at the pilot sites. WG1 repeated setting on desk and conducting filed verification at the sites.

The mapping team of NBRO LRRMD is responsible for landslide investigation and hazard mapping across the country and is indispensable for the future development of the Yellow/Red zoning in Sri Lanka. On November 2019, the mapping team was gathered at the NBRO Kegalle office, and held exercise workshop to set up the Yellow/Red zones using the hazard mapping draft manual. In the workshop, in order to promote understanding of the setting methodology, the Team instructed manual setting of the Yellow/Red zones using a paper topographic map. The participants set their own Yellow/Red zones for each sediment disaster type, compared the completed drawings each other, and discussed where and how they differed. Regarding slide type, topographic interpretation to extract the slide block prior to Yellow/Red zoning. This extraction work of slide topographies tends to vary by each person. Therefore, it was decided that the slide block setting should be a process in which multiple scientists or engineers work together to unify their opinions.

Explanation of the Yellow/Red zoning to NBRO's mapping team



Group discussion for Yellow/Red zones which participators set



Desk work for Yellow/Red zoning for the pilot site

Filed verification with mapping team and NBRO site officers

The following pages show the Yellow/Red zones of each pilot site prepared by WG1.

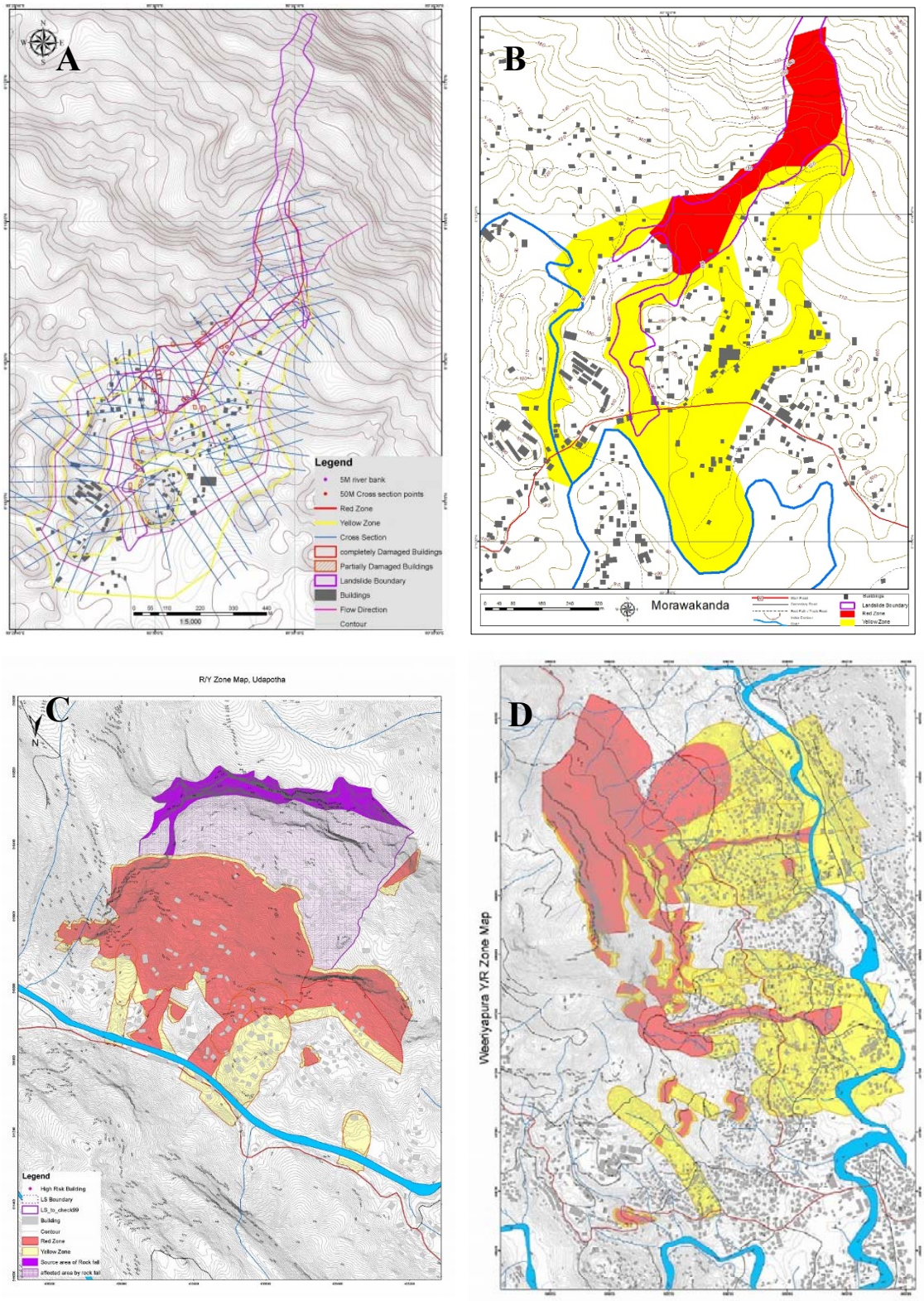


Figure 2.17: Yellow/Red zones for Each Pilot Sites
A: Manual Work for Morawakkanda、B:Yellow/Red zones for Morawakkanda
C:Yellow/Red zone for Udapotha、D: Yellow/Red zone for Weeriyapura

4) Risk assessment at pilot sites

In this Project, the risk assessment was conducted based on the presence or absence of conservation objects and existing countermeasures in the restricted area indicated in the Yellow/Red zones.

Necessary information for risk assessment (location, census data, public facilities, environmental and social information, etc.) was collected for each pilot sites. Based on the information, priority of each Yellow/Red zones were evaluated using prepared risk assessment sheet. These results were included in the "sediment disaster risk reduction plan" prepared in Output 3. In addition, the information and data that was used for risk assessment and the priority evaluation results have been utilized for site selection of landslide remote monitoring system and evacuation planning.

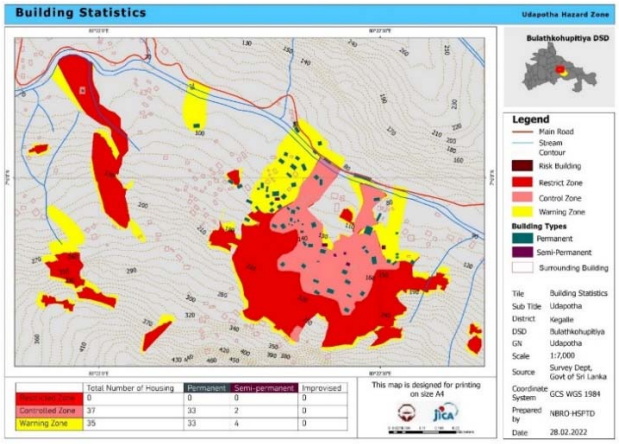


Figure 2.18: An example of risk assessment results
(Total number of houses in Yellow/Red zone in Udapotha site)

(2) Challenges and Actions

1) Ensuring consistency with existing LHZM

Since the LHZM developed by NBRO and Yellow/Red zoning have different concepts and setting methodology, WG1 decided to use LHZM as a regional scale map and Yellow/Red zone as a site-specific map. However, through discussion in WG1 meetings, it was realized that it would be a problem if the results of the LHZM and the Yellow/Red zones were significantly different. For this issue, the Team and WG1 members have discussed following solutions:

- LHZM category 1 (most likely occur) and category 2 (expected to occur) areas are displayed as Red zones in addition to Yellow/Red zones, and LHZM category 3 (modest level) is displayed as Yellow/ Displayed additionally as Yellow in Red zone.
- LHZM categories 1 to 3 are displayed as a single color overlaid on the Yellow/Red zone diagram.
- In addition to LHZM, it was also examined a setting method of Yellow/Red zone that takes into consideration the conversion point of the topography.
- Consequently, the WG1 decided that LHZM category 1 and 2 are regarded as initiation area of landslides in Yellow/Red zonings. In addition, WG1 decided to limit the application of the Yellow/Red zoning to the areas that have already been developed or areas that are likely to be developed in the future.

By repeating these trial and error with the C/P, Yellow/Red setting method was not directly imposed, and the advantages of each method were combined. Through these discussions, WG1 members deeply understood the challenges of Yellow/Red zoning in Sri Lanka.

2) Enhancement of landslide topography interpretation technology

Since the extraction of slide blocks is an important process when setting Yellow/Red zones for slide type, the Team held landslide topography interpretation seminars continually. In addition, a training video for this technology was created and distributed to the C/Ps. A technical note titled "Aerial Photograph Interpretation of Landslides" was created to summarize key points for the interpretation and attached as an attachment to the "Manual for Site-Specific Landslide Hazard Zoning" prepared in Activity 1-4.

3) Development of work assistance program for yellow/red zone setting

Yellow/Red zoning takes time and manpower to set manually for each slope using GIS. Therefore, The Team developed a Yellow/Red zone drawing assistance program for slope failure and debris flow types as a part of activities related to 1-4. This program can make rough Yellow/Red zones in a short time. However, it was difficult to ensure the accuracy of the Site-specific Yellow/Red zone, such as 1/2,500 scale, so it should be used as a tool to roughly check the Yellow/Red zones as a wide area.

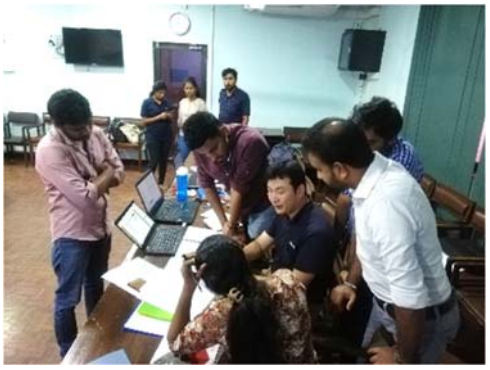
2.3.7. Conduct flow path simulation to identify potential damage zone of debris flows and update hazard zonation maps (Activity 1-6)

(1) Activities

Regarding the debris flow simulation, in TCLMP, short-term experts conducted trainings using HyperKANAKO program. In addition, through a joint research program between NBRO and National Institute for Land and Infrastructure Management (NILIM), some of NBRO staffs were invited to Japan for trainings. It was an advantage that some C/Ss already understand the use of HyperKANAKO program. In this Activity, considering the C/Ps capacity, trainings and lectures were held considering practical exercise and site investigation including way of setting flow peak discharge and sediment concentration for the input condition.

Because major disaster type of Morawakkanda is a typical debris flow phenomenon, it was used for the exercise for the training. In previous trainings by TCLMP and NILIM were carried mainly concentrate in table-top simulation. So, at first, the trainings were carried out focusing on how to obtain the field data at Morawakkanda. Through this, the C/Ps could understand the way of sampling and appropriate sampling locations.

On July 2019, an intensive training for flow-path simulation using HyperKANAKO was held for WG1, WG3 members. About 20 participants including three who had experiences of the training by NILIM, were instructed on how to set up the simulation boundary conditions (hydrograph, sediment volume, etc.), and to implement an example simulation using the software. The results of the debris flow simulation in the Morawakkanda area were also used to verify the designation methods for Yellow/Red zone for debris flow.



Instruction on flow path simulation

In addition, to better understanding of flow path simulation, a seminar was also held on how to apply simulation to the areas other than Morawakkanda. In this seminar, flow path simulations of the same location were carried out using several programs other than HyperKANAKO such as J-SAS, RAMME and Flow-R, the results of each program were compared and verified with actual debris flow events, and the applicability of each program was discussed. C/Ps deeply understood the advantages of each model and different results so that it is important to employ the appropriate model for the phenomenon.

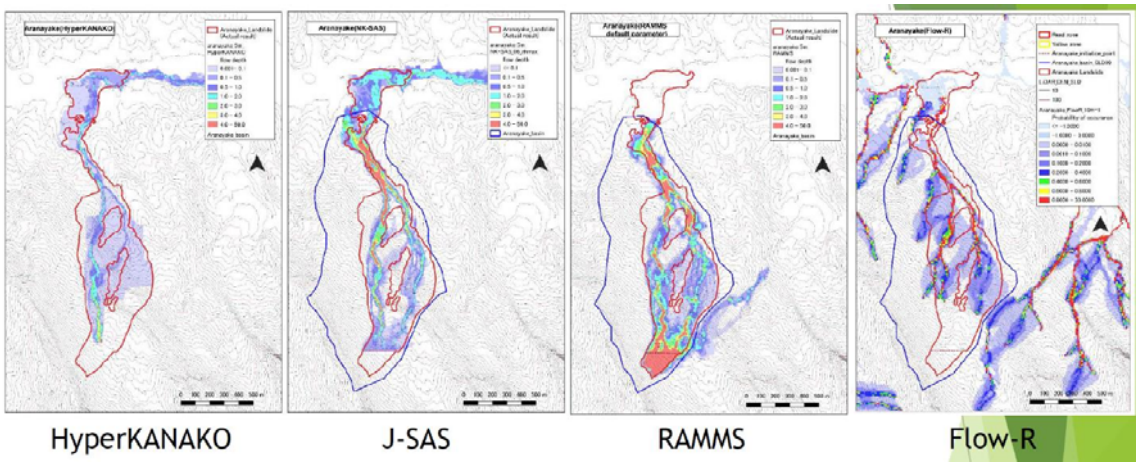


Figure 2.19: Applicability consideration of simulation by programs other than HyperKANAKO

(2) Challenges and Actions

To promote C/Ss understanding on flow-path simulation as well as a part of public relation activities, the results of the flow path simulations by C/Ps were presented at NBRO annual symposium in December 2019 and international symposium in December 2020.

Considering C/Ps capacity and past experience on flow path simulation, the Team had practical trainings considering including table-top simulation as well as field investigation and data collection. Through these practical input, C/Ps have had capacity to conduct flow-path simulations under the condition given as a tutorial. For further utilization of the flow path simulation in such planning of Sabo projects with various conditions and inputs, continuous supports by NILIM are expected

2.3.8. Organize a working group at pilot sites and conduct a workshop to share the results of hazard and risk assessments (Activity 1-7)

(1) Activities

WG1 members and the NBRO mapping team always shared the results of hazard and risk assessment among the members. Disaster Management Center (DMC), a focal point of user of hazard and risk assessment, had been invited to the discussion in WG1 meetings and seminars on regular basins and to discuss how to define and designate Yellow/Red zones in future. The “Guide to Inventory Sheet Records” and “Manual on Site-specific Landslide Hazard Zoning” were also shared with DMC.

WG1 also shared the mapping results with the DDMCU (District Disaster Management Coordination Unit) of Kegalle district, who is the responsible for any DRR related activities in the district, such as

awareness raising, coordination, early warning and disaster responses. WG1 members discussed with DDMCU how to dominate the maps and train local people. Important suggestions were delivered from DDMCU as a user of the hazard maps.

WG1 had a meeting with director of DMC

Meeting with DDMCU of Kegalle District

(2) Challenges and Actions

The major activities of WG1 were concentrated in the first half year of the Project. The WG1 meetings had been held at lease once a month to confirm the progress of the work and share the results of mapping and simulation. Through these sharing, all the works had been proceeded under the consensus of all members including the Project Manager.

2.3.9. Finalize the above manuals and conduct a workshop (Activity 1-8)

(1) Activities

The issues and lessons learned from the above activities conducted at the pilot sites were fed back into the manuals, and the manuals on hazard zoning and risk assessment were finalized.

An online workshop was held on July 2021 for the prepared disaster record inventory sheet, hazard map manual, risk assessment manual, pilot site hazard map, and examples of Yellow/Red zonings created for the other areas by WG1 members. A total of 13 people from the Sri Lankan side participated in the workshop reviewed all activities and discussed the results and outputs. WG1 leaders gave presentations in Sinhala for deepening the understanding of the presenters and participants. WG1 members had a constructive exchange of opinions between DMC staff and C/P.

Figure 2.20: Manual on Site-specific Landslide Hazard Zoning
and Manual on Risk Assessment for Yellow/Red zone

(2) Challenges and Actions

In finalizing the manual on hazard zoning, reference documents and statistical analyzed data (especially the Yellow/Red zone setting criteria for slope failures) were attached for explicit knowledge. NBRO will be able to analyze disaster cases that will occur in Sri Lanka in the future and verify the validity of these methods and standards.

2.3.10. Conduct site specific hazard and risk assessments in the areas other than pilot sites (Activity 1-9)

(1) Activities

NBRO mapping team took the lead in applying the Yellow/Red zoning methodology to areas other than the pilot site. The applied areas were 12 sites in Kegalle District, Bandarawela District and Welimada District in Badulla District, and Dorekkanda District in Ratnapura District.

The results of the 12 sites in Kegalle district were handed over to the District secretariate at the NBRO annual symposium held in December 2021. After that, the Keglle district secretariate issued an official request letter to the Ministry of Land to impose usage restrictions on the Red zone.

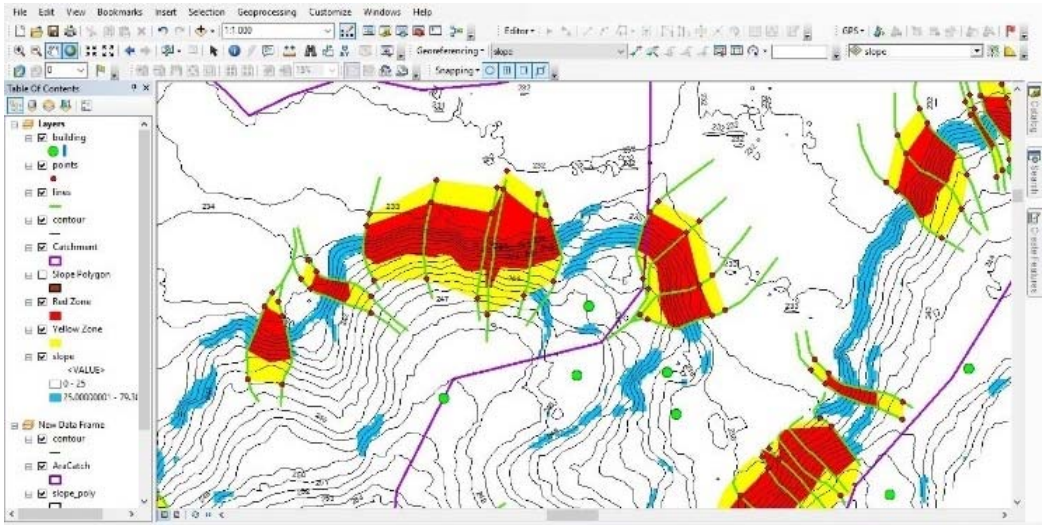


Figure 2.21: Yellow/Red zones for the area other than the pilot sites prepared by Mapping Team of NBRO

In order for the NBRO to expand the activities to other regions in the future, it would be effective to incorporate the hazard zoning and risk assessment methodology they learned in this project into the NBRO's existing training system. Initially, it was planned to incorporate the outputs of this project into the training program. However, due to the impact of COVID-19, many of the NBRO training programs have been cancelled. The Team and WG1 member discussed and extracted items that should be incorporated into the training program in future.

(2) Challenges and Actions

Since this activity coincided with the period of travel restrictions due to the spread of COVID-19, activities were conducted mainly remotely with C/Ps. Online seminars were held to check the results in areas other than the pilot site, and the Team always provided comments on the Yellow/Red zones prepared by the C/Ps not only at pilot sites but also for the other areas.

2.4. Activities on Output 2

2.4.1. Review the systems and contents regarding issuance of risk information and early warning (Activity 2-1)

(1) Activities

In recent years, NBRO has been continuously making efforts to improve landslide early warnings through the improvement of rainfall monitoring system and warning issuance system. In order to support further improvement of landslide early warnings, basic information on NBRO efforts related to early warning was collected through interviews with officials and field surveys. A summary is shown in Table 2.9.

Table 2.9: Current situation of landslide early warning

Items	General description
Rainfall monitoring system (NBRO)	▪ As of 2019, 291 rainfall gauging stations were installed. Furthermore, NBRO install more gauges, smart gauging stations and soil water content sensors ▪ Observed data is transmitted to servers in real-time and stored in DB. NBRO and relevant agencies can watch the real-time rainfall data ▪ Function of rainfall time series charts is weak to monitor rainfall conditions
Rainfall monitoring system (Department of Meteorology)	▪ More than 400 manual gauging stations are existing in Sri Lanka. However, the observed data is daily rainfall, which is not suitable for landslide early warning ▪ Two C-band radar will be installed by JICA grant project ▪ 9km mesh NWP is downscaled to 5km mesh. The forecasted rainfall image is shared with relevant agencies
Landslide monitoring	▪ JICA TCLMP installed landslide monitoring equipment in the two sites. In addition, JICA disseminating Japanese technologies project installed real-time remote landslide monitoring system in the other two sites
Manual rainfall observation	▪ In collaboration with the DMC, manual rain gauges are distributed for community disaster management activities; the NBRO warning criteria are also utilized in the communities
Insurance of landslide early warnings	▪ Early Warning Center (EWC) of NBRO monitors real-time rainfall. When rainfall exceeds warning thresholds, NBRO issues landslide early warnings and sends to EOC and relevant agencies ▪ NBRO issues warnings once in a day until 2016. At present, NBRO monitor rainfall 24/7 and issues warnings even in night time, flexibly
Criteria of landslide early warning	▪ Three levels of warning are issued based on 24h rainfall ▪ The minimum unit of warnings is the DS Division. Warnings are valid for 24 hours after issuance ▪ The warning thresholds are unique throughout the country. Regional characteristics are not considered
Dissemination of early warning (dissemination path)	▪ Landslide early warnings are disseminated from NBRO to EOC and media ▪ EOC disseminate warnings to DDMCU, DS, GN by fax, SMS and etc. ▪ Warning dissemination from DS/GN to local people is by mobile call and direct-visit (loudspeakers are utilized in some areas)
Dissemination of early warning (evacuation order)	▪ Evacuation orders are issued based on NBRO warning information, manual rain gauges in communities, residents' reports and etc. Decision makers to issue evacuation order vary depending on the location. Generally, district or DS division issue the evacuation order ▪ The meaning of NBRO warning is not well known at local level. Actual evacuation decisions are largely based on the experience of residents.
Evacuation drill and hazard map	▪ Large-scale hazard maps have not developed, and residents do not know necessary information to evacuate to safe place

Figure 2.22 shows the dissemination path of landslide early warnings from NBRO to local people. Early warnings issued by EWC of NBRO are mainly disseminated to local people through the DMC line. It takes approximately 2-4 hours for residents to complete evacuation after a warning is issued from NBRO. Thus, it is necessary to issue the warning considering the lead time. The DMC line and the line through the local police are functioning, but the problem is that both local people and local government officials do not have enough understanding of the early warnings.

In addition, the current rainfall warning criteria do not reflect regional characteristics and the increase of landslide risks caused by continuous rainfall. Considering these issues, following activities were conducted.

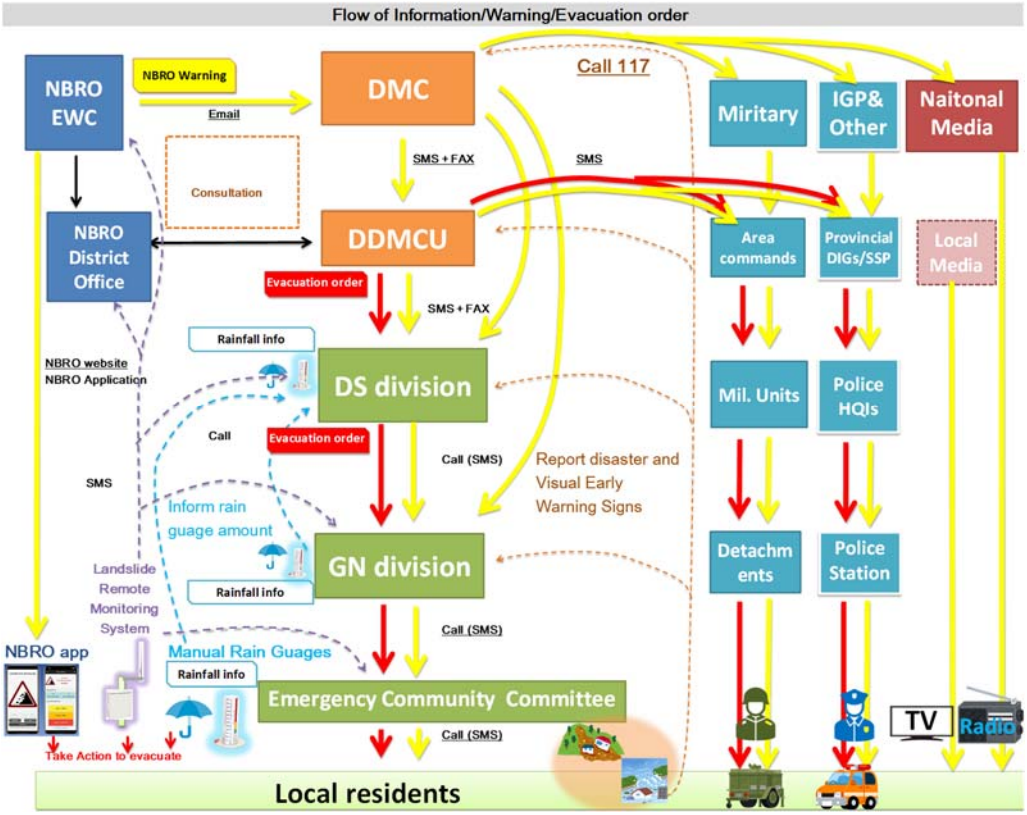


Figure 2.22: Dissemination path of landslide early warnings from NBRO to local people

(2) Challenges and Actions

In addition to interviews with the NBRO, DMC, and other relevant agencies, interviews and surveys in districts, DS divisions and the pilot communities were conducted to collect more accurate and actual information regarding warning dissemination and evacuation at the grassroots level. The NBRO C/Ps accompanied the Team during the interviews in the pilot sites. Although NBRO headquarter is in charge of issuing landslide early warnings, DMC is in charge of disseminating the warnings to residents. NBRO district offices are primarily responsible for responding to disaster reports from local people. Hence, NBRO headquarters has been less aware of how early warnings are actually utilized at the community level. The Team believes that NBRO's understanding of the actual situation of warning dissemination and evacuation at the community level was deepened through this activity conducted together with NBRO C/P.

2.4.2. Revise rainfall criteria for landslide early warning based on regional characteristics (Activity 2-2)

(1) Activities

1) Rainfall landslide correlation analysis

Knowledge to revise landslide early warning criteria utilized in Japan (e.g. Japanese landslide warning criteria and method to determine warning thresholds) was shared in the WG2 meeting. Based on the knowledge, rainfall landslide correlation analysis was conducted by WG2 members.

a) Study on landslide early warning criteria

Snake curve charts (scatter charts with X-axis: long-term rainfall indices and Y-axis: short term rainfall indices) are widely utilized to determine landslide warning criteria. Past long-term rainfall indices (e.g. Soil Water Index: SWI) and short-term rainfall indices as well as rainfall amount which caused past landslides were together plotted on the snake curve charts in order to estimate critical lines and warning thresholds. The Team studied applicability of RBFN, normal distribution and lognormal distribution methods for estimation of critical lines of landslide warning. An analysis tool for the rainfall landslide correlation analysis was developed by the project. Technic transfer regarding the analysis was done through OJT. Figure 2.23 shows snake curve charts, which were developed by collaboration works of NBRO C/P and the Team, at several rainfall gauging stations in Sri Lanka.

Soil Water Index (SWI) is a rainfall index utilized as long-term rainfall index for landslide warning in Japan. It is necessary to validate SWI calculation parameters with Sri Lankan condition when SWI is applied for landslide warning in Sri Lanka. Thus, C/P collect river discharge data from Irrigation Department and validate the SWI parameters (Figure 2.24). The result of analysis shows that the parameter sets utilized in Japan can be applicable for Sri Lankan mountainous basins. Based on the result, WG2 members calculate SWI using the parameter sets and determine critical lines of landslide warnings.

The results of rainfall landslide correlation analysis done by WG2 using past rainfall and landslide records in Sri Lankan mountainous regions show that SWI and 72 hours half-period working rainfall are more effective than 24 hours rainfall, which is utilized as warning threshold in Sri Lanka, in cases of continuous heavy rainfall. The warning thresholds appear to have regional variations of ca. 50 in SWI. In case that 0.5% rainfall probability line is assumed as a critical line, ca. 70% of landslides are able to be captured but it is difficult to predict small slope failures and deep-seated landslides; “Air-shot” rate of the warning becomes 3%.

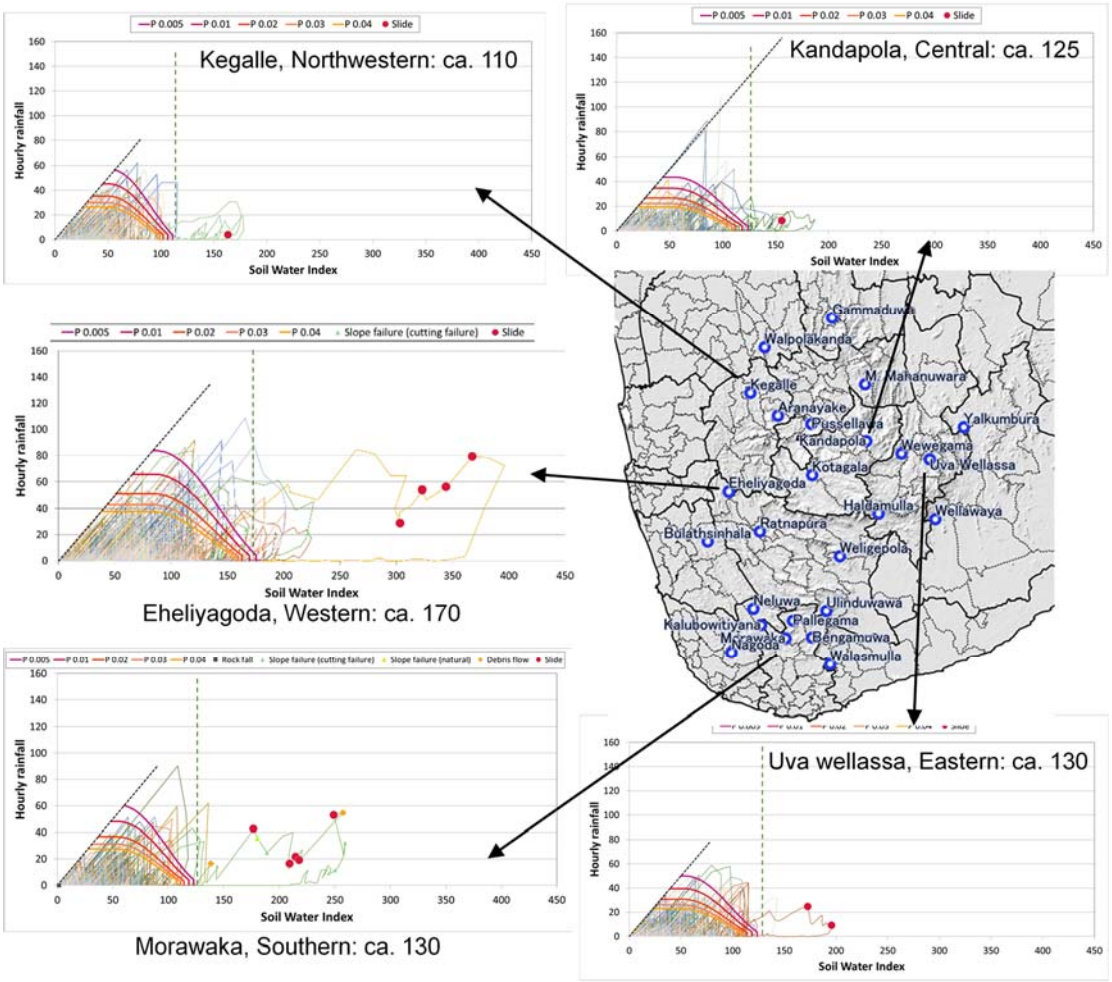


Figure 2.23: Results of rainfall landslide correlation analysis done by WG2 members and regional characteristics

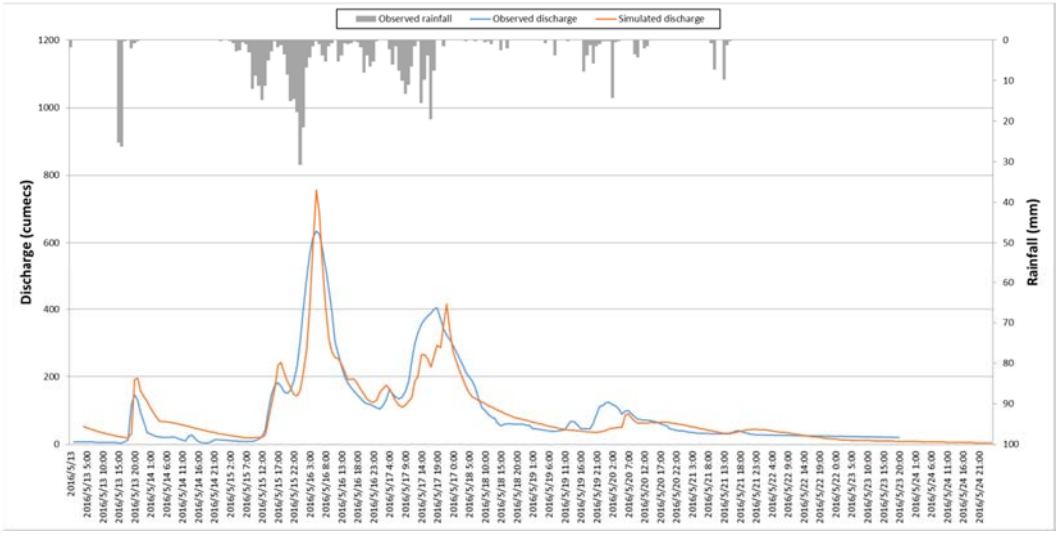


Figure 2.24: Comparison between observed and simulated discharge calculated by WG2 using tank model
(blue: observed discharge, orange: simulated discharge)

b) Policy for revision of landslide warning criteria and dispatch of short-term expert

A short-term expert of landslide early warning was dispatched in October 2019 from National Institute for Land and Infrastructure Management (NILIM). Based on the results of the rainfall landslide analysis and baseline survey regarding landslide warning and dissemination in Sri Lanka, the short-term expert gave recommendations and advice as follows.

- Utilization of SWI and snake curves as reference information to issue warnings
  Currently, 24 hours rainfall observed by manual rain gauges is widely utilized as evacuation criteria at the community level. Moreover, there is not enough past landslide data accumulation to revise warning criteria. Thus, SWI should be calculated as reference information for relevant agencies on a trial basis rather than immediately revising the warning criteria.
- Improvement of rainfall monitoring system (time series chars and snake curve)
- Accumulation of appropriate disaster records and observed rainfall for revision of warning criteria
- Clarification of the target disasters (exclude deep-seated landslides and isolated slope failures or not)
- Utilization of numerical weather prediction data and weather radar data in future
- Improvement of warning dissemination and utilization in local (community) level

Regarding the revision of the warning criteria, the accumulation of landslide disaster records and rainfall data is still not enough. In addition, the current 24 hours rainfall-based warning criteria are widely utilized in community-based evacuation systems. Considering above situation, the warning criteria will not be revised until enough data will be accumulated. SWI would be utilized as reference information to issue warnings. Warning thresholds for SWI would be determined for each region to improve the accuracy of warnings.

c) Analysis on recent rainfall events and validation of lead time

In addition to the past landslides, C/P analyzed recent landslides. Figure 2.25 shows rainfall event in 2020 analyzed by C/P. The analysis result shows that antecedent rainfall amount affects occurrence of landslides, even though short term rainfall was similar value. In that case, it is highly significant to utilize SWI for issuing early warnings since the increase of landslide occurrence can be effectively estimated by SWI.

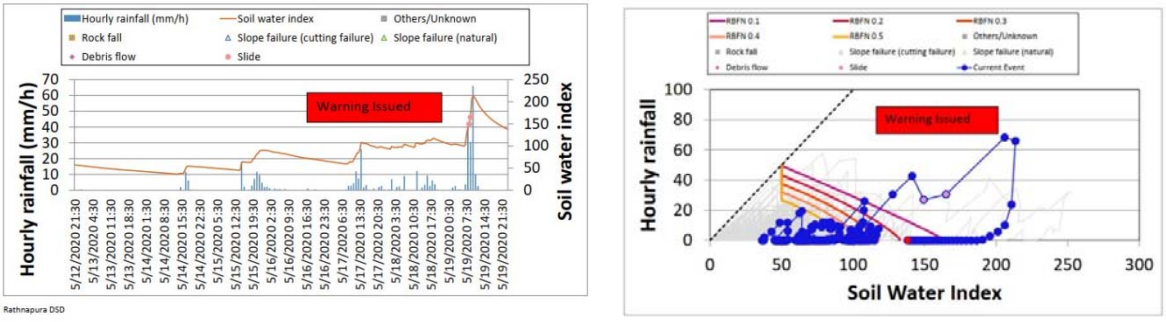


Figure 2.25: Hyetograph and Snake curve chart during Cyclone Amphan event

Moreover, C/P conducted analysis on the timing of warning issuance and landslide occurrence using actual past disaster records to verify whether enough lead time was ensured (Figure 2.26). In the case of May 2017 disaster, landslide warning was issued well before landslides occurred. However, in the case of 2020 disaster, the rapid increase of rainfall was followed by landslides in a short period. Hence, it was difficult to ensure enough lead time. In order to deal with such cases, it is essential to utilize rainfall forecasts. However, accuracy of current numerical rainfall prediction is not accurate to issue landslide early warnings. Therefore, it is recommended to issue warnings earlier considering forecasted heavy rainfall. It is hoped that the introduction of weather radar will enable more accurate rainfall monitoring and short-term rainfall forecasts.

These results of analysis and discussions were presented at the WG2 meeting and international symposium by the C/P in charge of the analysis. At the NBRO annual symposium, C/P suggested the utilization of SWI as a supplemental indicator to the current 24 hours rainfall warning criteria.

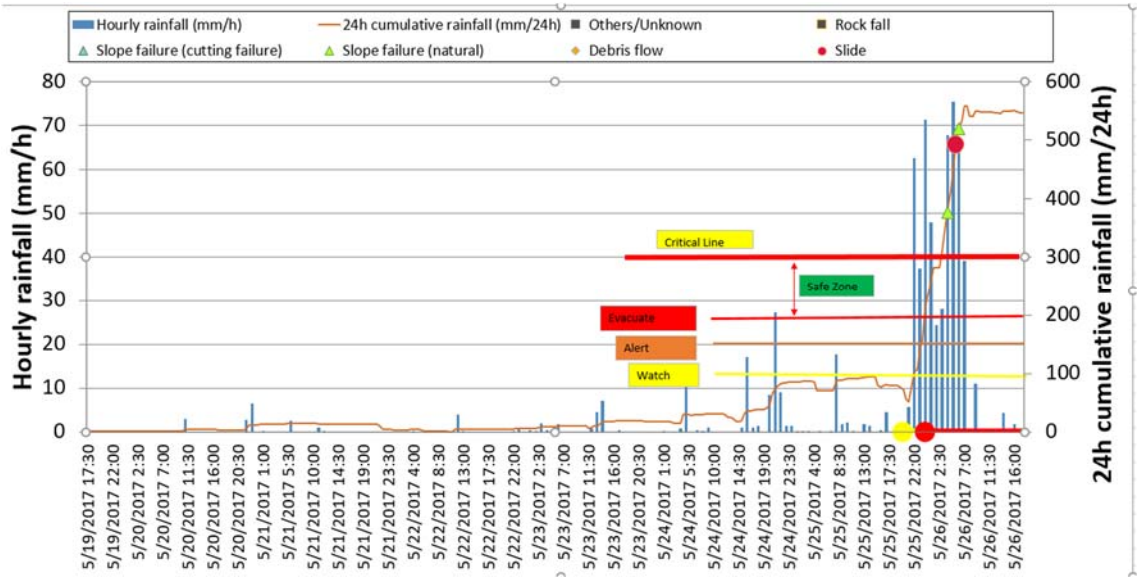


Figure 2.26: Validation of actual time of warnings issuance and critical line

2) Rainfall monitoring system

Based on the recommendations of the short-term expert dispatched in 2019, a rainfall and SWI monitoring system was developed to support issuance of appropriate early warnings. The main monitoring functions of the system are as follows.

- Incorporation of real-time rainfall observed by the existing NBRO rainfall monitoring system and the landslide remote monitoring system in the pilot sites into the system
- Display of time series charts and maps of rainfall and SWI
- Display of snake curve chars (SWI + critical line)
- Input of critical lines and SWI calculation parameters

The rainfall/SWI monitoring system is open to registered users (NBRO and related organizations). The system support for them to understand current status of rainfall and estimate disaster risks.

Initially, it was planned that the system development would be carried out by a hired local IT engineer, but the COVID-19 pandemic caused a temporary suspension of oversea trip. During the suspension period, the installation of a landslide remote monitoring system in the pilot sites was added to Activity

2-4. As the result, this rainfall monitoring system development was carried out as a part of the installation of the landslide remote monitoring system.

In November 2021, an IT engineer dispatched from OSASI inc., which is the equipment supplier of the landslide monitoring system, stayed at NBRO and installed the rainfall/SWI monitoring system. At that time, technical guidance was provided to the NBRO C/P regarding system management such as installation, backup, and restoration. In addition to that, a local IT engineer and the NBRO system manager worked together to develop a function to transfer real-time rainfall data from the existing NBRO rainfall monitoring system to the rainfall/SWI monitoring system in real time.

The rainfall/SWI monitoring system receives NBRO's nationwide rainfall observation data and OSASI's rainfall observation data installed in the pilot sites, and calculate real-time SWI. The system provides real-time SWI maps, time-series charts and snake curve charts on a web-site (Figure 2.27). Individual warning threshold and critical lines are able to be set to each rainfall gauging station on the system. Through inputting the warning thresholds and critical lines for each region estimated by the analysis conducted by C/P, the rainfall situation at each gauging station can be easily monitored. By June 2022, WG2 have completed inputting warning thresholds and critical lines for each region to the system.

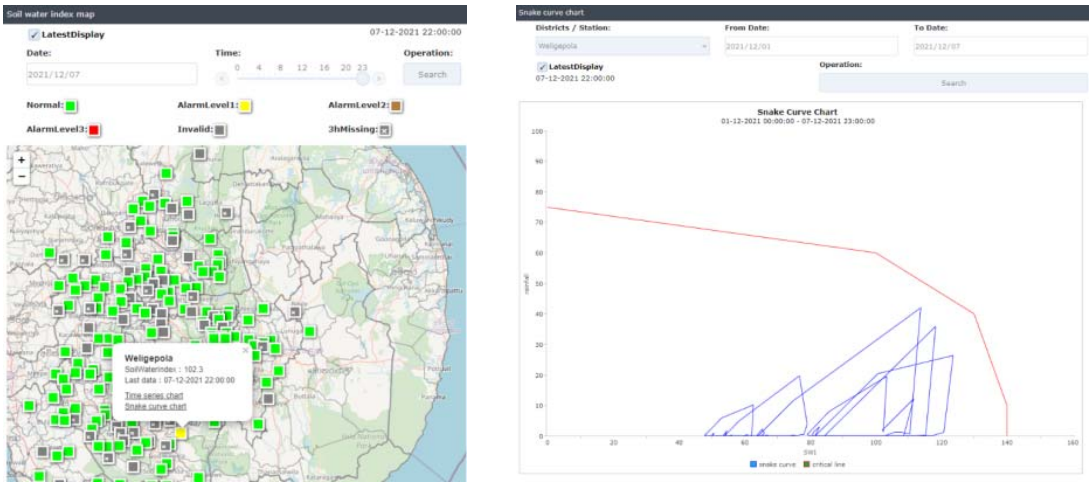


Figure 2.27: User interface of rainfall/SWI monitoring system

(2) Challenges and Actions

Regarding the rainfall landslide correlation analysis, it seems that C/P can independently analyze the relationship between rainfall and the occurrence of landslides using observation data and analysis tools. C/P are actively trying to utilize the knowledges and findings through discussing rainfall characteristics during landslide events and proposing new functions of the analysis tool.

The results of the analysis were discussed in WG2; C/P and the Team made presentations at the International Online Symposium held at the DMC and the NBRO Annual Symposium.

2.4.3. Draft a manual on early warning for sediment disasters including protocol for issuance of early warning (Activity 2-3)

(1) Activities

The draft of manual on landslide early warning was developed. The manual consists of following three parts; 1) tasks in normal period: study and revision of warning criteria, 2) tasks in emergency period: protocol to issue warnings, and 3) information for communities and relevant agencies: explanatory note of early warnings and publicity materials.

At present, long-period rainfall observation data and landslide records are not sufficient. Furthermore, the current warning thresholds are utilized for activities of community disaster risk management. Thus, it is difficult to revise the warning thresholds at this moment. Therefore, the contents of the manual are how to study the warning criteria (chapter 2) and protocol to issue warning considering new criteria (chapter 3) so that NBRO can revise warning criteria after necessary data will be accumulated. The warning dissemination and awareness program in the communities (chapter 4), and publicity materials are prepared for relevant agencies since those activities are out of NBRO's responsibility. However, those parts are essential to make the landslide early warnings effective. Thus, those materials were developed as a part of the manual for further improvement of landslide early warnings. The contents of the manual discussed at WG2 inter-agency meeting is shown in Table 2.10.

Table 2.10: Contents of manual on landslide early warning

	Contents	Recommendation
1	Introduction	Overview of landslide early warning
2	Tasks for landslide early warning - in normal periods -	Data collection of rainfall/disasters and analysis to determine warning criteria (for NBRO)
3	Tasks for landslide early warning - in emergency periods -	Protocol to issue early warnings (for NBRO)
4	Utilization of landslide early warning	Explanatory note of early warnings and publicity materials including utilization of hazard maps (for DMC and local people)
Appendix	▪ Publicity materials for DMC and local people ▪ Manual for rainfall analysis	

The practical procedures of rainfall-landslide correlation analysis (Figure 2.28) are prepared as appendices of the manual since this part is technical. WG2 members conducted the analysis using the materials in the activity 2-2. Commentary regarding warning clearance was added to the manual since WG2 members requested to add procedures on warning clearance to the manual. Even if the rainfall amount becomes low, clearance of warning should be decided referring SWI and rainfall forecast.

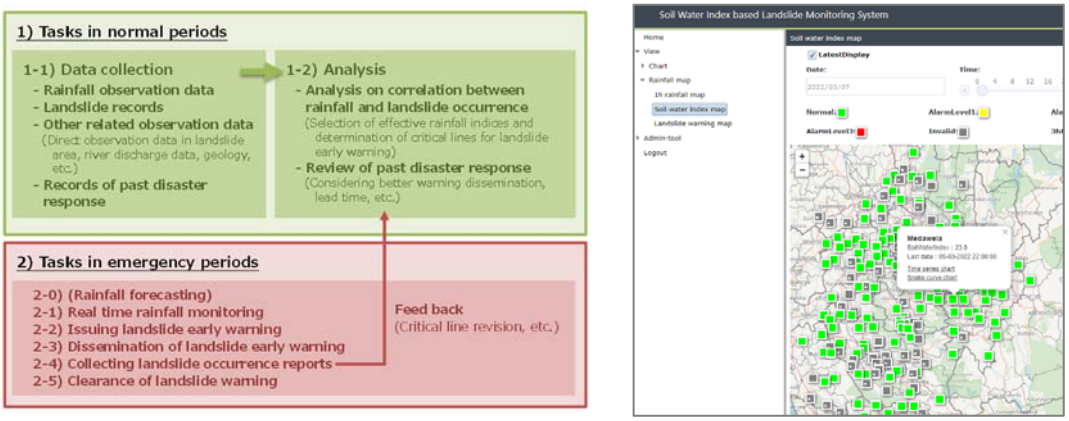


Figure 2.28: Routine workflow for issuing an early warning (left) and SWI monitoring system as a reference when warnings are issued (right)

(2) Challenges and Actions

The draft manual was prepared through the activities of WG2, incorporating the opinions and feedback of the C/Ps. The Team also takes into account the advice of the short-term experts (e.g., limitation on the target disaster types, selection of rainfall indicators to be used for warnings, etc.).

In addition, easily understandable public materials for local people and relevant agencies were prepared as a part of the manual by using the user interface of the landslide remote monitoring system introduced in Activity 2-4.

2.4.4. Strengthen warning and evacuation system at pilot sites (Activity 2-4)

(1) Activities

Based on the information on warning dissemination and evacuation system in the pilot sites collected in Activity 2-1, the warning and evacuation system was strengthened. In the two pilot sites (Udapotha and Weeriyapura), a landslide remote monitoring system was installed to enhance direct landslide observation and warning dissemination. In the Morawakkanda pilot site, where no equipment was installed, the Team made efforts to improve the existing scheme for landslide early warning issuance based on observed rainfall and warning dissemination.

1) Installation of landslide remote monitoring system in the pilot sites

In the activities of Output 3, the Project supported the development of a basic SABO plan including outlines of countermeasures, land use regulations based on Yellow/Red zones and strengthening of evacuation warning systems. By installing a landslide remote monitoring system in the pilot sites based on these plans, local and central government agencies will be able to detect the occurrence of landslides in advance. As a result, it is expected to make a significant contribution to strengthening the early warning and evaluation system in the sites. Considering the above background, additional activities to install the landslide remote monitoring systems in the pilot sites of Weeriyapura and Udapotha were approved and initiated in October 2020.

The introduced landslide remote monitoring system is the same as the OSASI system which had been already introduced to other sites by the JICA PPP program called "Verification Survey with the

Private Sector for Disseminating Japanese technologies for the Landslide Remote Monitoring System", a JICA project to support overseas deployment of small and medium-sized enterprises. By using the same equipment and system, running costs of the system were reduced, and the user interface was standardized.

Specifications and quantities of the landslide remote monitoring system equipment, installation location of sensors, installation procedures, and user interface of the monitoring system were discussed with OSASI since beginning in October 2020. Finally, a specification document was prepared. The system monitors ground displacement and inclination as well as rainfall in real time. The observed data is transmitted to the server at the NBRO headquarters. The system also receives real-time rainfall data from the existing NBRO and calculates SWI. The system contributes for the appropriate issuance of landslide warnings.

Selection of installation sites of the landslide monitoring instruments

The WG2 meeting was held in March 2021 to discuss the development and procurement of the landslide remote monitoring system and related matters (e.g., IP acquisition for the system server, visa procedures, sharing draft of website and travel schedule of the Team). Since that meeting, WG2 members actively supported the system development and procurement.

A contract for the equipment procurement was signed with OSASI in April 2021, but the installation was postponed several times due to the COVID-19 pandemic. Finally, installation of the equipment at the pilot sites was successfully completed in January and February 2022.

In advance to the installation of the instruments, WG1 and WG2 leaders and the mapping team participated in the field survey in December 2022 to determine the installation locations of each instrument for the landslide remote monitoring system in Weeriyapura and Udapotha sites.

For Weeriyapura, two landslide blocks were targeted as originally planned. For Udapotha, it was decided to install each instrument in the landslide block where the most houses were concentrated based on the results of the field survey (Figure 2.29).

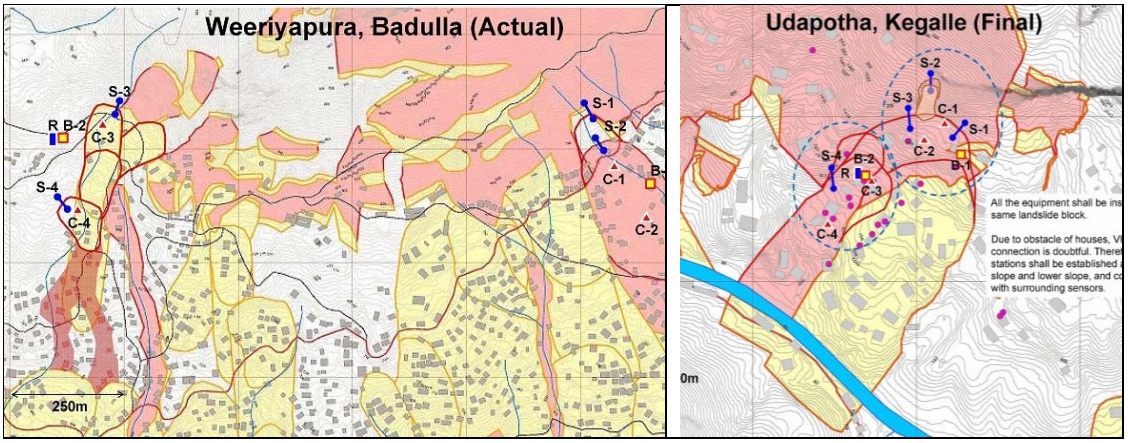


Figure 2.29: Locations of the instruments of landslide monitoring system
(left: Weeriyapura, right: Udapotha)

2) Workshops in the pilot sites

After the installation of the landslide remote monitoring system, stakeholder meetings were held in the Udapotha, Weeriyapura, and Morawakkanda pilot sites in March 2022. Community residents and GN officers were invited to the meeting. The mechanism of landslides, the concept of SWI introduced by the project, and the NBRO's early warning dissemination path were explained to the attendees.

Figure 2.30 Leaflet of landslide early warning for the pilot communities

The pilot sites did not initially have a community disaster management organization called the Emergency Community Committee, which receives NBRO early warnings from GN officers. Therefore, the Emergency Community Committee was set up during the hearing of residents' opinions on land use regulations in WG3, which started in November 2021, and NBRO manual rain gauges were also provided. The Emergency Community Committee consists of LA Chairman, secretary and 3~5 additional members. WG2 workshop also introduced how to use manual rain gauges and take log sheets. The active participation of the community members encourages that review of the members of the Committee was conducted through the workshop to ensure certain warning dissemination to the entire community after NBRO's warnings were received by the LA chairperson.

In Udapotha and Weeriyapura sites, where the landslide remote monitoring system was installed, the location of the monitoring instruments and its function were explained to the local people. At the stakeholder meeting, the community assigned persons in charge of receiving the warning SMS and persons in charge of monitoring and maintenance of the equipment, such as mowing the grass around the equipment. The keys of the equipment were provided to the persons in charge. Instructions on how to stop the siren in case of false warnings were also given to the local people.

Pilot site workshop on the landslide remote monitoring system with community people
(left: Weeriyapura, right: Udapotha)

Before and after the meetings at each pilot site, WG2 members visited DDMCU and NBRO district offices in Kegalle, Badulla, and Matara districts to explain the installed landslide remote monitoring system and SWI. Since the NBRO district office will play an important role in equipment maintenance activities in the future, WG2 members also instructed them how the equipment works and how to maintain it.

(2) Challenges and Actions

In order to reduce the maintenance cost, the equipment with the same specifications which had already installed by the previous JICA project were utilized to the system. In addition, the user interface was also integrated with the existing system to facilitate nationwide monitoring. Regarding maintenance of the instruments, WG2 members discussed countermeasures to prevent damage to the equipment by monkeys, ants, rats, and others.

Prior to the project, community disaster management organizations in the pilot sites did not exist or inactive. Therefore, the NBRO established Emergency Community Committees through the project. Furthermore, workshops on early warning were held involving the Committees and local residents to raise awareness of disaster management and to confirm the actual warning dissemination route in order to ensure reliable warning dissemination. Regarding equipment, active participation of NBRO district offices as well as residents was expected; keys of the instruments were also provided to local focal points to increase ownership. Inspections by the NBRO district offices are conducted only once every three months. The Team aims to ensure that the equipment always functions properly through real-time supports and monitoring of the residents when any unusual circumstances or damage to the equipment occurs. In addition, not only the residents but also the GN Division staffs, who are the local governmental staffs, were also involved in the project activities to ensure that the community disaster management will be a continuous activity.

The receivers of the warning SMS were not only the NBRO headquarters, NBRO district offices and representatives of communities but also DDMCU, DS Division and GN Division, in order to ensure that the same early warning information is disseminated to all relevant agencies in the area, and the emergency situation is shared among the relevant agencies.

2.4.5. Share information on landslide early warning system in the working group (Activity 2-5)

(1) Activities

WG2 was established to conduct activities on improvement of early warning and information sharing. There are three levels of WG2 (Inter-agency working group: NBRO, DMC/EOC. Department of Meteorology, Irrigation Department, Internal working group: NBRO C/P in charge of early warning, technical working group: technical representative of NBRO C/P). The first WG2 was held in July 2019. Project activities and policy to define early warning criteria were reported and discussed by the Team and C/P.

The technical and internal working group meetings were held regularly for technology transfer of rainfall-landslide correlation analysis regarding activities 2-1 to 2-4, establishment of landslide monitoring system, information sharing and discussions (detail of the activities are shown in the sections 2.4.2 - 2.4.5). At the internal working group meeting in March 2022, discussion was held regarding the warning thresholds, conditions and maintenance of the landslide remote monitoring equipment installed at the pilot site.

Inter-agency meetings including the DMC were held in March 2020 and April 2022 in order to exchange views on warning dissemination, the landslide monitoring system in the pilot sites and evacuation using the landslide hazard map developed by WG1.

(2) Challenges and Actions

Information sharing and progress reports were made through WG2 so that C/P could proceed the activities even though the Team could not work in Sri Lanka due to the COVID-19 pandemic. As the result, C/P acquire skills on rainfall analysis and can discuss the actual rainfall situation which caused landslides (detail is described in the section of activity 2-2).

The operation of the landslide remote monitoring system installed in the pilot sites and the dissemination of landslide early warnings to local people require close coordination among NBRO and related organizations including the DMC. Thus, the Team focused on coordination among NBRO and the related organizations through WG2 inter-agency meetings and workshops in the pilot sites, in order to ensure smooth collaboration. Especially, proper and continuous maintenance of the landslide remote monitoring system is necessary to issue accurate early warnings. Thus, it was clarified and confirmed with WG2 members that the roles of NBRO headquarter, NBRO district offices and residents regarding maintenance of equipment as well as warning dissemination by DMC and DS divisions. A checklist and schedule for the equipment monitoring and maintenance were prepared. To enable practical monitoring and maintenance of the equipment, the WG2 members visited the sites to check the condition of the equipment and maintain the broken instruments.

2.4.6. Finalize the manual on landslide early warning (Activity 2-6)

(1) Activities

WG2 workshop was held in April 2022 inviting WG2 and WG1 members as well as Emergency Operation Center of DMC who is in charge of warning dissemination to local people, in order to finalize the manual on landslide early warning. The workshop attendees discussed following points; 1) outline of Yellow/Red zones designated through WG1 activities, 2) landslide early warning considering SWI, and 3) operation of landslide remote monitoring system installed into the pilot sites and warning dissemination.

Discussion with DMC on the manual

NBRO proposed for DMC/DDMCU, who are the responsible organization on evacuation in emergency situation, to revise current evacuation sites located in the Yellow/Red zones and to conduct evacuation drill using the landslide monitoring system. DMC mentioned that DMC has maps of evacuation sites for whole country and can overlay the NBRO's Yellow/Red zone to the evacuation maps to revise the evacuation sites. NBRO said that NBRO will share the Yellow/Red zone data to DMC after the Yellow/Red zone will be finalized.

Considering the comments of NBRO and DMC, the manual on landslide early warning was finalized.

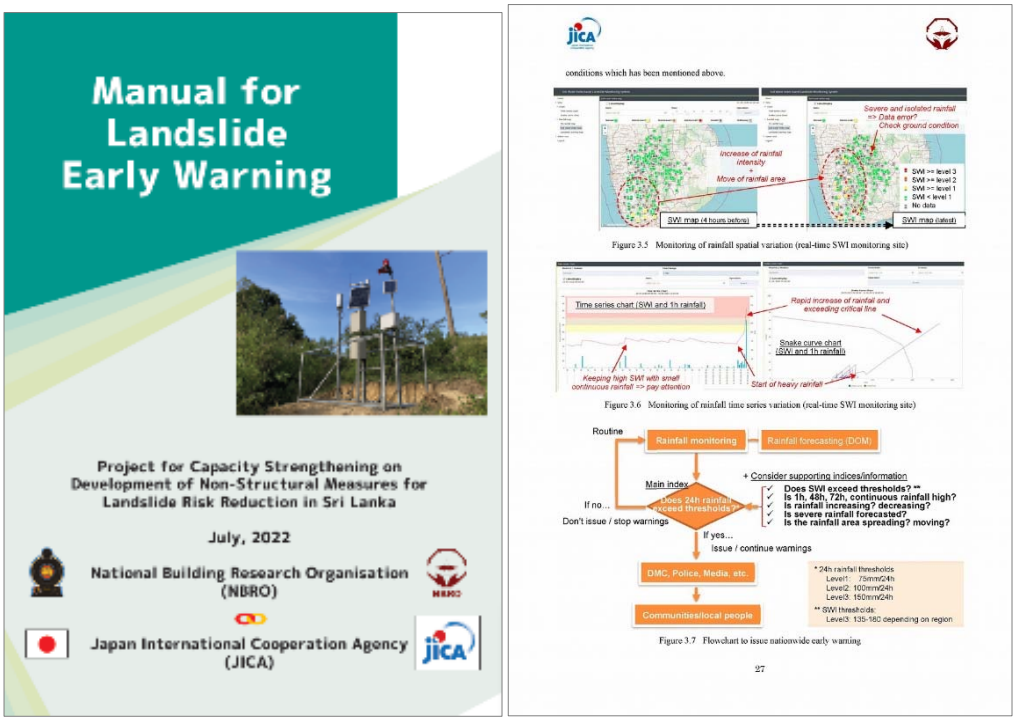


Figure 2.31: Finalized manual on landslide early warning

(2) Challenges and Actions

NBRO and DMC closely cooperate in issuing and disseminating early warnings and responding to disasters. For further cooperation, more concrete discussions based on the information collected through the activities in the pilot sites were held using the landslide hazard maps and the early warning system newly introduced by the project.

2.5. Activities on Output 3

2.5.1. Review land use planning in Sri Lanka (Activity 3-1)

(1) Activities

WG3 members grasped the current situations of development plans in Sri Lanka including land use plan, organized the concerned laws and regulations, and captured the current conditions of land use plan for the pilot sites.

1) Situations of Development Plans in Sri Lanka (including Land Use Plan)

Government of Sri Lanka promotes shifting the primary industry to the secondary or tertiary industries from the viewpoints of national economic policy as well as shifting of the human settlements from rural areas to urban areas. For development plans in Sri Lanka, there are three levels: national level, regional level, and municipal level. There are about 330 municipalities in Sri Lanka and they are divided into three: Urban Council (UC), Municipal Council (MC), Pradeshiya Sabha (PS). UC and MC are designated as urban area declared by Urban Development Authority (UDA) based on Town and Country Planning Ordinance and Urban Development Authority Law, and UDA formulates the development plans for UC and MC. PS has two types: UDA declared area and Non UDA declared area". The development plans have not been formulated and supports of its planning to Local Authorities have not been sufficient in most of the Non UDA declared areas. Non UDA declared areas occupies about 50% of national land in Sri Lanka.

2) Concerned Laws and Regulations

WG3 members listed up the laws and regulations, and manuals, which should be referred in this project and organized the outline of the concerned laws and regulations as well as those relations with sediment disasters (Table 2.11).

Table 2.11: Laws and regulations to be referred in the Project

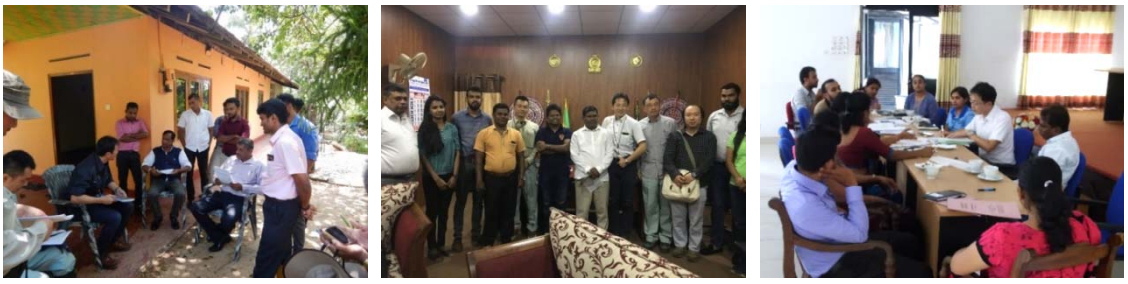
	Name of Laws / Regulations / Manuals	Outline
1	National Land Use Policy Sri Lanka	The policy is specified as policy frameworks to ensure appropriate land use, secure food self-sufficiency, and maintain economic development and land productivity. Identification of high, medium, and low risk areas of sediment disasters and introduction of prevention measures is also specified as one of the policies.
2	National Physical Planning Policy and Plan 2030	This policy and plan aim to plan, promote and regulate the integration of economic, social, physical and environmental aspects to the national territory until 2030. One of the strategies is the relocation of settlements and infrastructure from areas at risk of disaster to safer areas.
3	Town and Country Planning Ordinance	It is stipulated that the NPPD will develop the National Physical Planning Policy and Plan 2030 and regional plans. For land use and development planning at the local level, there are two types of areas: those under the jurisdiction of the UDA and the rest of the country. The UDA has jurisdiction for the former area, and the LA has jurisdiction for the latter area.
4	Urban Development Authority Law	This law was enacted in 1978 and revised four times between 1979-1988. It provides that the UDA has the authority to develop and implement land use plans for lands under the jurisdiction of the UDA and to regulate planning projects by other government agencies and officials.

	Name of Laws / Regulations / Manuals	Outline
5	A Circular no NBRO 2011/01: Obtaining the Certificate of Land Suitability	This circular is notification issued by MIWRM in 2011 to regulate land use in 10 provinces with high landslide risk. Construction and development activities in landslide risk areas in the 10 target provinces are now required to be approved through an assessment by the NBRO at the planning stage.
6	Hazard Resilient Housing Construction Manual	This manual was published by the NBRO in 2017 and includes all disaster types. For landslides, it specifies the necessary measures (specifying the distance from the cliff edge, specifying the construction of retaining walls, disapproval of construction, installing drainage facilities, and other erosion control measures) for cut soil on slope development, depending on the level of risk. Although this manual is not a legally, it is a guideline for development.

3) Conditions of Land Use Planning at the Pilot Project Sites

WG3 members visited the Local Authorities (Bulathkohupitiya PS, Badulla MC, and Kotapola PS) in charge of the three pilot sites (Udaphota, Weeriyapura, and Morawakanda, respectively) to confirm the entity in charge of land use planning in each local government, availability of land use plans, and the application process for development permits.

As for land use planning, there are urbanized areas within each of Bulathkohupitiya PS, Badulla MC, and Kotapola PS. In the urbanized areas, UDA is in charge of land use planning. Udaphotha and Weeriyapura are located within the urbanized area, while Morawakanda is located outside the urbanized area and the Local Authority is in charge of land use planning. Regarding the development permit application process, the authority in land use and development regulations is closely related to the urbanization classification of each municipality. For example, the UDA is the development permit holder for developments over 4,000 ft^2 in urbanized areas, while a Local Authority issues development permits for developments under 4,000 ft^2.



Discussion with Local Authorizes (Left: Kotapola PS, Middle: Badulla MC, Right: Bulathkohupitiya PS)

(2) Challenges and Actions

The need for land use planning and development regulations in landslide risk areas has been recognized in Sri Lanka, but specific laws and institutions are still in the process of legislation. Therefore, WG3 members reviewed relevant Japanese laws such as the Disaster Countermeasures Basic Act, Sediment Disaster Prevention Act, National Land Use Planning Act, Building Standard Law, Act on Regulation of Residential Land Development, City Planning Act, to better understand how regulations are drawn up to deal with natural disasters. The Team also provided English-language versions of these laws, in order to promote understanding from the residents' perspective.

2.5.2. Drafting a guideline for land use regulation / development standards guideline (Activity 3-2)

(1) Activities

Based on the hazard map showing Yellow/Red zones and the Flood Resilient Guideline operated by the NBRO, WG3 decided that the final land use classification would be four categories: "Development Zone," "Warning Zone," "Controlled Zone", and "Restricted Zone".

The following points were discussed between WG3 members and the Team develop a draft guideline on land use regulatoin/development standards.

1) Role of stakeholders for land use planning and implementation in Urban Area and Rural Area
2) Local Authority's governance for urban planning
3) Necessity of risk assessment reports, regulation of existing buildings and new development, and roles of relevant agencies in the Restricted Zone, Controlled Zone, Warning Zone, and Development Zone established by WG3 based on the Yellow/Red zone
4) Demarcation and relationship to the LHZM and the defined Zones
5) Basic plan for erosion control, roles of related organizations for land use planning and regulation, warning and evacuation systems, and local administrative systems

The table below was developed based on the discussions in 1) and 2). National land is divided into two, Urban Area and Rural Area. All Urban Area belongs to UDA Declared Area, and Rural Area is classified into UDA Declared Area and Non-Declared Area and Estates. The UDA Declared Area is classified into two categories: those with a Development Plan and those without a Development Plan. The roles of NBRO, UDA, Estate Company, Local Authority, and DS/GN in land use planning and land use management in each area are summarized in the table.

Table 2.12: Concerned Organizations and their Roles in Urban Area and Rural Area

	Urban Area (MC, UC)		Rural Area (PS)	
	UDA Declared Area		Non UDA Declared Area	Estates
	Without Development Plan	With Development Plan		
NBRO	Prepare hazard map showing Yellow/Red zones Support UDA and/or LA in land use planning as a part of SDRRP Support and recommend to implement SDRRP (Early Warning and Evacuation / Structural Measures)			
UDA	Prepare land use plan based on hazard map	Update land use plan base on hazard map	-	-
Estate Company	-	-	-	Cooperate with LA
Local Authority	Give development permission based on UDA standards	Issue By-laws to implement the SDRRP Give development permission based on UDA standards and SDRRP	Prepare SDRRP for catchment area with disaster risk areas based no hazard map Give development permission	-
DS / GN	Provision of Data			

For 3) and 4), WG3 examined four land use categories (Restricted Zone, Controlled Zone, Warning Zone, and Development Zone) based on the hazard map showing Yellow/Red zones examined. It was also confirmed that the four land use zones were consistent with those of the LHZM. WG3 delineated the need for risk assessment reports in each zone, regulations for existing buildings and new development, and the roles of relevant agencies in the draft guideline based on the results of the discussions in 1) and 2).

In February 2020, during the process of examining 3) and 4), WG3 hosted a short-term expert for "Land Use Policy". The expert explained the concept of land use regulations to be applied in the Yellow/Red zones in Japan. WG3 considered to divide Red Zone into Restricted Zone and Controlled Zone. The latter would allow production activities such as agricultural land use. The expert introduced practical examples in Japan and gave advice of dividing these two areas based on existing land use.

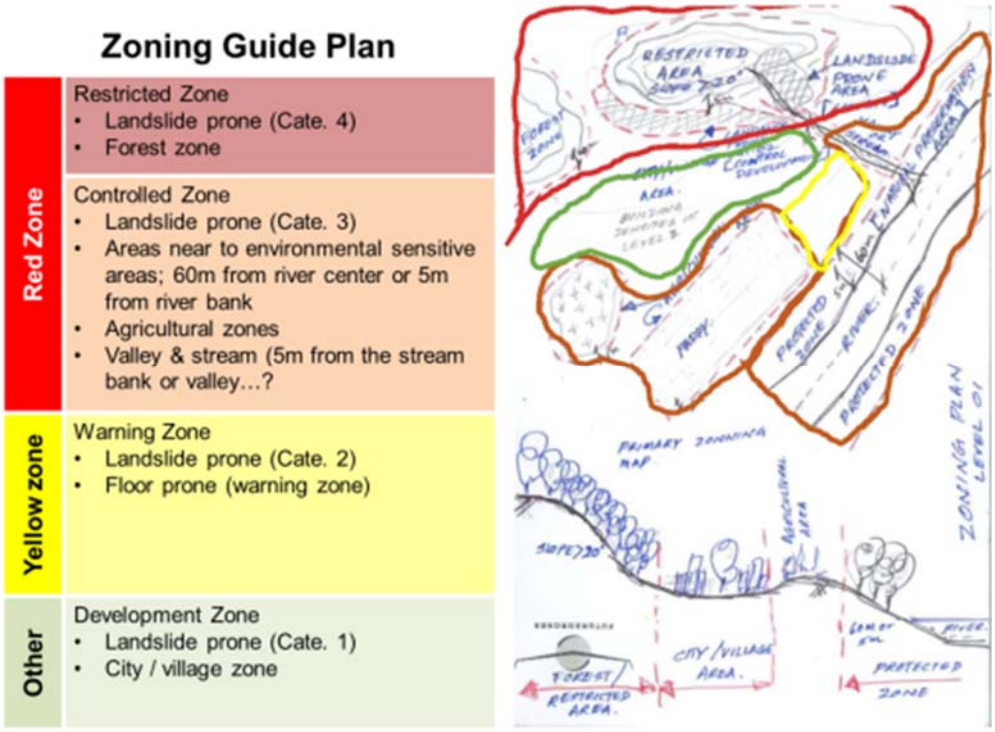


Figure 2.32: Land Use Classification based on Yellow/Red zone

In 5), WG3 discussed not only land use regulations, but also measures and approaches for structural measures such as slope control works and erosion control facilities, and the development of warning and evacuation systems and included them in the draft guideline.

The draft guidelines were updated through these discussions. According to the series of the discussions, the following information was also included in the Annex as a reference material.

- An introduction to the Japanese legal system for land use planning and regulation, mainly an overview of the National Land Use Planning Law, the land transaction system in the Law, and an overview of the City Planning Law and the background of its revision.
- Methods for establishing house density based on ground bearing capacity

(2) Challenges and Actions

Since it was required to make the draft guideline for land use regulations/development standards practical, the draft land use regulations and development standards for the pilot site in Activity 3-3 as soon as a draft of the guideline was prepared in one step and two rounds of refinement among the WG3 members was done. In the process of preparing the draft land use regulations and development standards for the pilot site, experiences or knowledges that should be fed back to the draft guidelines were identified and fed back to the draft guidelines to update the draft guidelines.

For example, it was realized in the process of Activity 3-3 that landslide risk reduction measures should be taken differently in areas where land is currently cleared and in areas where houses are already located in terms of land use in the Yellow Zone and the Red Zone. Therefore, landslide risk reduction measures according to the current land use were organized and added as shown in Table 2.13 in the draft guideline.

In the discussion on Activity 3-3, it was concluded that while commercial-based agricultural land use is allowed in Restricted Zone if there are no problems. As a result of detailed investigation by NBRO, home garden level activities can be used without a detailed investigation. This description was added to the draft guidelines.

Table 2.13: DRR Measures at Existing Residential Areas and Vacant Area in high-risk Area

<table>
<tr><th></th><th colspan="2">Red Zone</th><th colspan="2">Yellow Zone</th></tr>
<tr><td>Possible Land Use</td><td colspan="2">Restricted Zone
Only for Natural Vegetation (Forest, bushes, etc.)
(detailed investigation for agricultural)

Controlled Zone
Agricultural
(detailed investigation for Human induces activities: Parks and Playground/non-residential activities)</td><td colspan="2">Warning Zone
Agriculture
Parks and Playground/ non-residential activities
Detailed investigation for Residential, Retail & Commercial, Office, Industrial</td></tr>
<tr><td>Current Land Use</td><td>Existing Residential Area
-No special zoning regulations are in practice.</td><td>Vacant Area
-No special zoning regulations are in practice.</td><td>Existing Residential Area
-No special zoning regulations are in practice.</td><td>Vacant Area
-No special zoning regulations are in practice.</td></tr>
<tr><td>DRR Measures</td><td>-Early Warning
-Conduct detail investigation and select for DRR measures
- Land-use regulations (not to allow further development)</td><td>- Promote land-use regulations</td><td>-Early Warning
-Structural Measures (Sabo, Retaining wall, etc.)
- Other resilience constructions</td><td>- Promote land-use regulations</td></tr>
</table>

2.5.3. Development of land use regulation / development standards (draft) at pilot sites (Activity 3-3)

(1) Activities

The draft land use plans / development standards at the pilot sites were prepared starting from the Morawakkanda site, where the progress of the work was the fastest in WG1 activities, and the plan was incorporated as part of the Sediment Disaster Risk Reduction Plan. Similar steps were taken to prepare Sediment Disaster Risk Reduction Plans including draft land use regulations and development standards for Udapotha and Weeriyapura.

1) Flow of development of land use regulation / development standards (draft)

First, WG3 members confirmed the output image of the land use plan for the areas overlapping with the Yellow/Red zones, the procedure for land use planning, and the collected data. WG3 members confirmed the contents of the current land use map (Figure 2.33), which was created by WG3 based on aerial drone images, and the meanings of abbreviations in the legend indicating land use applications were confirmed.

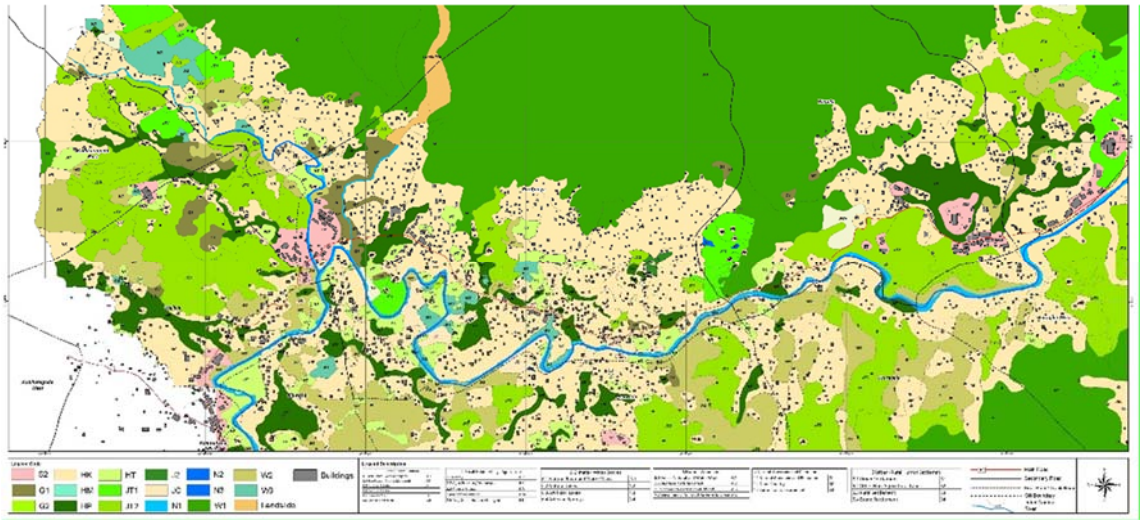


Figure 2.33: Current Land Use Map prepared by WG3 (Morawakanda)

Next, WG3 members confirmed what kind of land use is possible in the Yellow/Red zones by referring to the draft guideline prepared in Activity 3-2, and discussed the draft land use plan by overlapping the current land use map with the Yellow/Red zones, and risk assessment results discussed in WG1. The discussion included the option of not changing the use of the existing land use in the Yellow/Red zones. As a result of the discussions, as described below, the land use plan does not go into the detailed land use classification as shown in the current land use map, but shows the coverage area of the Restricted Zone, Controlled Zone, Warning Zone, and Development Zone, as well as possible land use for each zone.

2) Household Survey

In addition to land use regulations, non-structural measures such as evacuation needed to be improved to be more specific, and it was necessary to collect data to provide a basis for such improvements. In order to meet the needs, WG3 members conducted household survey and captures

family composition, age, occupation, reason for residence, and house type at each site. For Weeriyapura, it is located in the suburban area of Badulla and has a large number of households, so the survey was limited to households located in the Yellow/Red zone area where debris flow is likely to occur.

Household survey by WG3 members (left: Udapotha, right: Weeriyapura)

3) Discussion on the component of Sediment Disaster Risk Reduction Plan

The Sediment Disaster Risk Reduction Plan including land use plans / development standards (draft) is organized as shown in Table 2.14. The Yellow/Red zones concept discussed in WG1 is presented in the section 2.3 and the hazard map is presented in the section 2.4; items discussed in WG2 are presented in the section 4.1 - 4.3; the Sediment Disaster Risk Reduction Plan including land use regulations and development standards (draft) is presented in the section 2.5-3.2; the management plan is presented in the 6.1. Draft land use regulations and development standards are presented in the section 2.5 - 3.2, and the management plan is presented in the section 6.1.

Table 2.14: Composition of Sediment Disaster Risk Redution Plan

Chapter	Sub-Chapter
1. Introduction	1.1 Background 1.2 Objectives 1.3 Vision 1.4 Target Users for the SDRRP
2. Current Setting of Pilot Site	2.1 General Information of Local Authority 2.2 General Information of Hazard zone 2.3 Concept of Yellow/Red Zone 2.4 Categorized Zone based on Yellow/Red zoning and LHM 2.5 Possible Land Uses for the Zones 2.6 Approval and Enforcement of the Land Use Plan
3. Land Use Zoning Plan	3.1 Land Use Zoning Plan 3.2 Statistics in Yellow and Red Zone
4. Strength Early Warning and Evacuation	4.1 Warning Protocol in local level 4.2 Securing Evacuation Place 4.3 Awareness Activity for Early Warning
5. Structural Measures	-
6. Long-term Management Plan	6.1 Land use management plan 6.2 The land value management plan
7. Implementation	7.1 Action Plan

For 4.1~4.3, in collaboration with WG2, the communication channels for NBRO's landslide early

warnings at each pilot site, as clarified in the WG2 workshop with community disaster management organizations, were described to clarify the contact of the focal points. For Udapotha and Weeriyapura, the installed landslide monitoring system is also described in the plan to clarify all parties involved in the warning SMS issued by the system and to provide a whole picture of the early warning system in the pilot sites.

Figure 2.34:Completed Local Sediment Disaster Risk Reduction Plan at three Pilot sites

(2) Challenges and Actions

One of the key issues is to realization of the plan, so the plan was compiled as the Sediment Disaster Risk Reduction Plan, which includes not only the land use plan but also other disaster risk reduction measures in order to avail the budget for the plan. The plan was developed as a comprehensive plan including not only the land use plan and development standards discussed in WG3 but also the early warning system and evacuation sites discussed in WG2, based on the hazard map showing Yellow/Red Zones developed by WG3.

It is also one of the issues that the Project required the preparation of the plans for three pilot sites with different characteristics. In accordance with the status of WG1 activities, plans were prepared from Morawakkanda, where draft hazard map was prepared the fastest among the pilot sites. The plan for Morawakkanda was used as a reference to prepare plans for the other two sites (Udapotha and Weeriyapura). The stakeholder meetings and consultations with Local Authority were also conducted from Morawakkanda. The experience gained at Morawakkanda was used to make improvements when consultations at the other two sites were held.

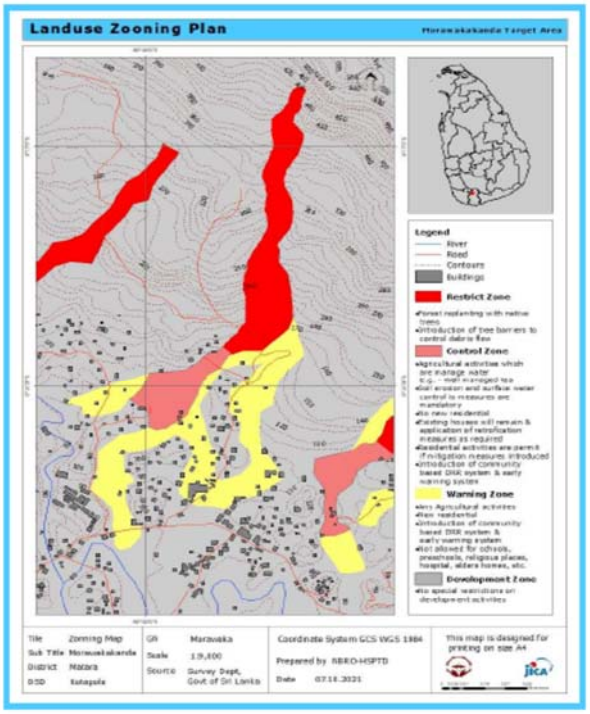


Figure 2.35: Land use plan at Morawakkanda

Another issue was how to indicate land use in the land use plan. The current land use map shows detailed land uses based on the type of agriculture and vegetation, etc. However, it is important to note that this project is mainly intended to reduce damage in the target area and not to improve the productivity of the land or the value of the products in the target area. Therefore, the land use plan for the pilot landslide risk reduction plan is limited to showing the location of the Restricted Zone, Controlled Zone, Warning Zone, and Development Zone, as well as the possible land use in each zone.

2.5.4. Finalizing land use regulation / development standards though WG and workshops (Activity 3-4,5)

(1) Activities

1) Collecting comments on land use regulation / development standards from Local Authorities and other stakeholders

The activities of WG3 have been led by members of the NBRO's HSPTD, but as mentioned earlier, in order to practically apply the land use regulations/ development standards in each pilot site, it is important to involve the appropriate development agencies depending on the level of urbanization designation of the local authority. As such, WG3 has been promoting discussions involving the Urban Development Agency (UDA), the Land Use Planning and Policy Department (LUPPD), and other agencies in addition to HSPTD members.

Discussion with PS chairman and WG3

Specifically, WG3 plenary meetings were held while involving relevant agencies. WG3 also had discussions with the UDA, LUPPD, and Local Authority with jurisdiction of the target pilot sites during their site visits.

In the discussion with UDA, UDA agreed to refer to the Sediment Disaster Risk Reduction Plan when UDA formulates and updates development plans in Udapotha and Weeriyapura, which are in UDA Declared Areas. UDA requested NBRO to establish Yellow/Red zones in other UDA Declared Areas. It was confirmed that UDA is willing to prepare development plans based on their understanding of landslide risks.

The Local Authority also endorsed the importance of land use based on an understanding of landslide disaster risk. Chairman of Kotapola PS proposed to enact By-laws for the implementation of land use regulations. This proposal took lead to the drafting of By-laws.

2) Finalize the guideline for land use regulation / development standards

WG3 members finalized draft land use regulation / development standards formulated in Activity 3-2 through discussions in NBRO and with UDA and Local Authorities.

During the plenary meeting in May 2022, there was discussion on the division of Red zone into two categories, Restricted zone and Controlled zone. If the NBRO regional offices were to operate the

said guidelines by dividing Red zone into two categories, there should be certain criteria for the division of the Red zone, and confusion would bring about if there are no criteria. WG3 discussed this issue again and came to the following conclusions.

- There are two types of zoning concepts: one for hazard and one for land use. Zoning for hazard is Yellow/Red zones, and zoning for land use is Restricted / Controlled / Warning / Development zones
- Geologists at NBRO regional offices will implement zoning for hazard. On the other hand, NBRO HSPTD will lead zoning for land use and Local Authorities, or UDA will set the land use zones.

To clarify these points, WG3 clearly showed the viewpoints for the zonings in the final version of the draft land use planning / development standards.

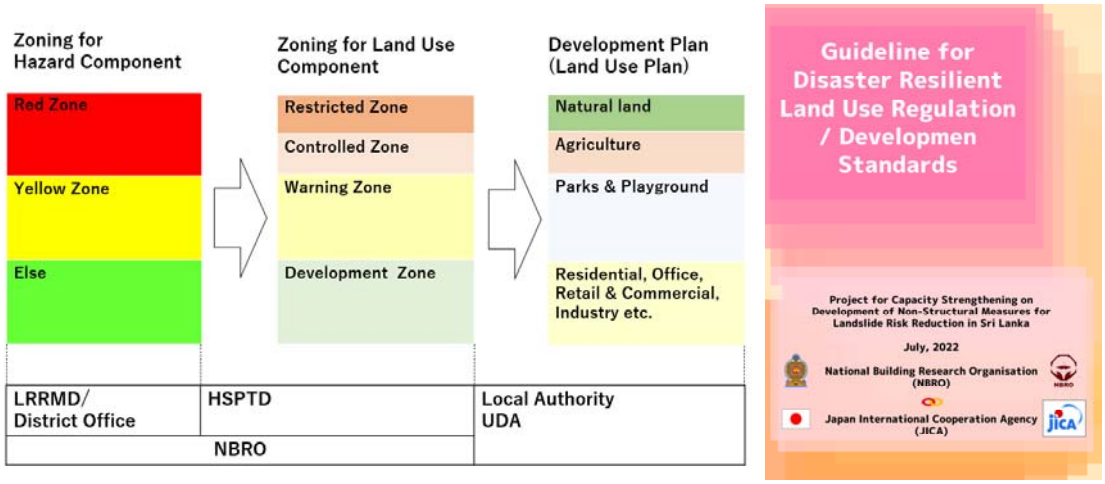


Figure 2.36: Left: Viewpoints for Hazard zoning and Land use zoning / Right: Finalized guideline

Furthermore, WG3 discussed and concluded that the Guideline, which had been prepared in a form similar to like a Manual with more than 60 pages, should be more conceptual ideas with about 20 pages during WG3 meeting in June 2022.

(2) Challenges and Actions

In order to increase the effectiveness of the draft land use regulations/development standards, it was necessary not only to promote understanding among stakeholders at the government level, but also to promote understanding among community residents and to implement disaster risk reduction activities by community residents. Therefore, at the community-level stakeholder meetings, in addition to promoting understanding of disaster risks, including the concepts of Yellow/Red zones and disaster risk reduction measures, community disaster management organizations were organized to take charge of implementing action plans for comprehensive landslide risk reduction proposals.

The developed Sediment Disaster Risk Reduction Plan for each pilot site were compiled into highly visible posters by WG3 members (Figure 2.37, Figure 2.38, Figure 2.39). The posters were distributed to each Local Authority and local assembly halls to promote understanding among Local Authority staff members and community residents. Those are effective to disseminate the main points of the draft land use regulations / development standards. WG3 confirmed that NBRO will

prepare and distribute the posters in the same manner in the future in order to roll out the project activities/outputs to other areas in Sri Lanka.

Stakeholder meeting at Udapotha

Stakeholder meeting at Weeriyapura

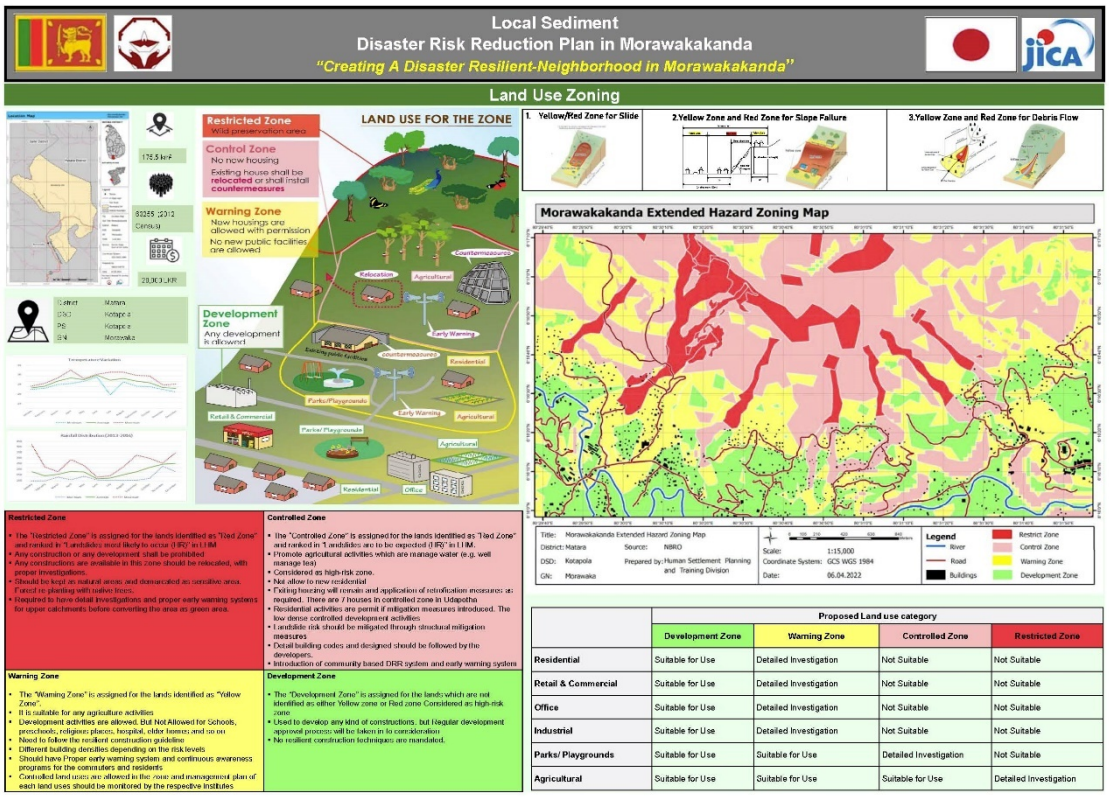


Figure 2.37:Poster explaining Disaster Risk Reduction Plan and Land Use Control (Mowarakkanda)

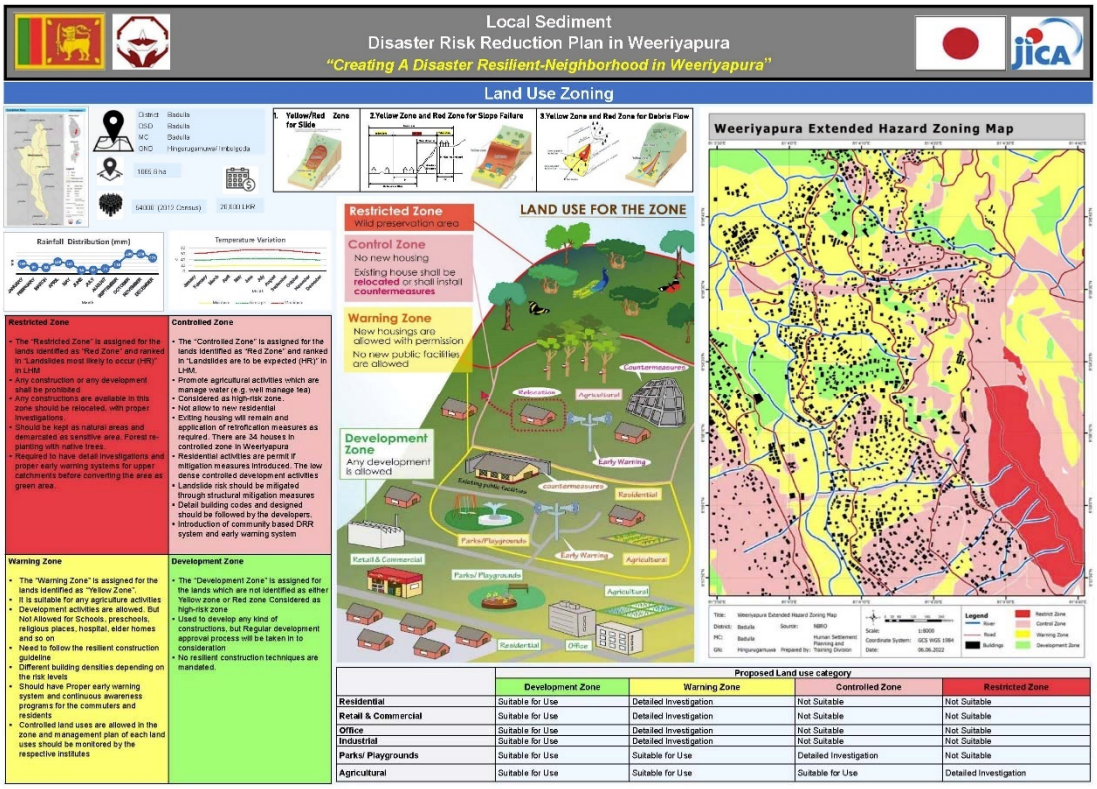


Figure 2.38:Poster explaining Disaster Risk Reduction Plan and Land Use Control (Weeriyapura)

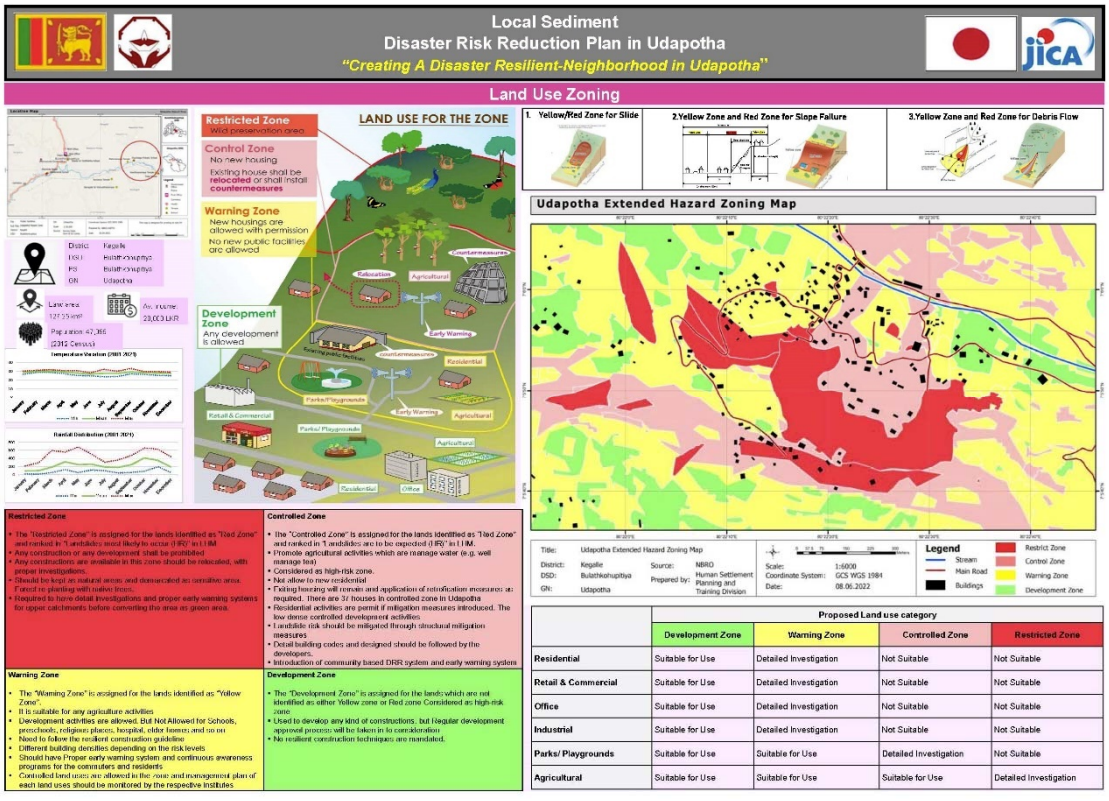


Figure 2.39:Poster explaining Disaster Risk Reduction Plan and Land Use Control (Udapotha)

Chapter 3 Challenges, Actions and Lessons Learned

3.1. Continuation of the Project during terrorist attacks and COVID-19

(1) Challenges

Shortly after the Project started in February 2019, a multiple terrorist attack occurred in Colombo on April and killed 259 people including a Japanese civil. Following the instructions of the Japan embassy and the JICA office, the Team promptly returned to Japan. Afterward, the travel of the Team had been restricted for the time being, and was unable to move to the pilots site even after resuming the travel. This affected to the Project activities, and the planned 2nd JCC was canceled.

Since March 2022, the travel restrictions due to the spread of COVID-19 continued for about one and half years. Once the Team resumed their travel on May 2021, however it has been difficult to carry out the activities due to the curfews and other restrictions. Hence, the Team and C/Ps continued remote on-line meetings and workshops until October 2021. In addition, the COVID-19 has had a major impact on the finances of NBRO, whose more than revenues are from domestic consultation, soil tests, building material tests, environmental measurements, etc. NBRO forced to be restructured by laying off large number of non-permanent staffs, including some Project C/Ps.

In March 2021, after the resuming the travels, the entire country of Sri Lanka fell into an economic crisis, and all civil servants were restricted from coming to work and moving vehicles to save fuels, making it difficult to implement the Project activities.

In technical cooperation projects, the C/Ps and the Team closely communicate each other and create the outcomes through the daily discussions and joint works. Although the on-line conference system became common worldwide, the above travel restrictions were a major issue in terms of project management and had a considerable impact on the quality and quantity of the activities in the pilot sites and discussions with Local Authorities.

(2) Actions (by C/Ps) and lessons learned

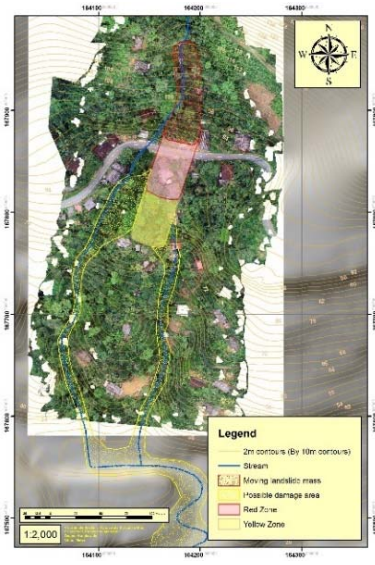
Even in the above situation, NBRO, under the leadership of the Project Director and Project Manager, the WG leaders continued activities when the Team was absent. Since a confidential relationship has been established between JICA and NBRO from the previous “TCLMP”, remote communications and online activities proceeded smoothly despite some restrictions. Especially in the COVID-19, the Team and NRBO continued to have monthly WG leader meetings and weekly or biweekly WG meetings and mutually confirming the progress of activities. The details of the activities are summarized in monthly progress reports and shared with JCC members and other stakeholders. Through these regular activities, all the agencies other than NBRO and Local Authorities understood the progress of the Project, and it made smooth to discuss in the JCCs.

The following activities made by NBRO’s during the remote period are significantly important.

1) Extension of Yellow/Red zoning at the areas other than pilot site (WG1)

At the kick-off meeting at the beginning of the Project, NBRO stated that it would like to complete the activities at the three pilot sites by the second year, and to expand the activities to areas other than the pilot sites in the third year.

Although it was not possible due to the restriction under the COVID-19 and others, right after the draft methodology of Yellow/Red zoning was established, the WG1 members started Yellow/Red zoning in Kegalle district. In Kegalle district, many lives were killed by a huge landslide in 2016. Since the current LHZM cannot identify the affected area of future possible landslides, the Yellow/Red zoning method was introduced. In addition to that, the WG1 members develop and Yellow/Red zones for the newly occurred landslide disasters in the country and verified using simulation model. These results were introduced in on-line WG1 meetings and WG leaders meetings, and utilized as subjects to be discuss in the meetings.



Verification of Yellow/Red zone applied at new landslide

2) A supporting tool for Y/R zoning (WG1/WG3)

In Japan, there is an add-in tool of ArcGIS to support drawing the sediment disaster hazard are (Yellow/Red zones). Due to the copyright reason, it is difficult to use this tool in abroad. In addition, the Yellow/Red zoning method in the Project was customized from the original based on the actual landslide disaster records in Sri Lanka. Hence, WG1 members have been manually developed the Yellow/Red zones.

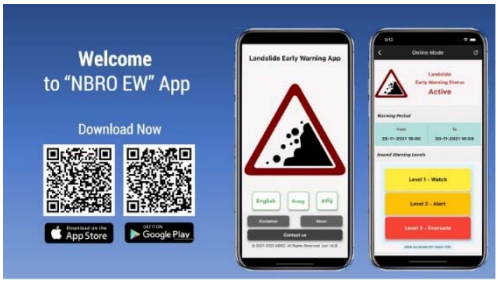
In response to requests from the district secretariates and UDA, it was necessary to develop Yellow/Red zoning early as possible, so WG1 and WG3 jointly developed a supporting tool for the zoning during the COVID-19 pandemic. This tool is different from the one which was developed for regional scale mapping program mentioned in the Activity of Output 1, this program draws auxiliary lines instead of manually setting boundaries. By using this tool, the Yellow/Red zoning work has become more efficient.

3) Rainfall analysis and verification of newly occurred landslides (WG2)

Using the analysis tool of Soil Water Index (SWI) and sake curves drawing, WG2 members continued to analyze for newly occurred landslides in the country during the COVID-19. In rainy season, a member of WG2 have reported the analysis results in everyday and shared with key officials including DG and directors in NBRO, this could promote understanding of the SWI and snake curves among relevant staffs in NBRO. Through the above efforts, at the end of the Project, a system that WG2 members analyze the rainfall and share with key officials when new landslides occur, established. These results were often reported at international and domestic symposiums.

4) Mobile App for landslide early waning (WG2)

As an initiative during the COVID-19, WG2 members played a central role in developing a mobile application for quickly disseminating landslide disaster warnings to residents. NBRO has so far sent out warning messages through the DMC EOC and through various SNS, but the problem has been that it is difficult for the warning to reach the end of the residents. In the developed mobile application, the



Mobile App developed by WG2 members

warning information is displayed immediately at the same time as the NBRO message is issued, and the users can identify their location whether they are in the warning area or not in order to make decision of evacuation. This mobile application was announced at the 11th NBRO Symposium and is in operation.

5) Coordination with the pilot Local Authorities and UDA (WG3)

WG3 members have been working closely with the UDA Uva provincial office during the activities related to land use planning in Weeriyapura, Badulla District, one of the pilot sites.

Although mainly remote discussion due to the restriction of domestic travel, UDA recognized the usefulness of Yellow/Red zoning. UDA Uva provincial office officially requested NBRO to develop Yellow/Red zoning as early as possible at Welimada town and Bandarawela town in Badulla district where urban development plannings have been on the way.

These two sites are outside the range of the high-resolution LiDAR digital elevation model supported by JICA, and the accuracy of the 1:10,000 scale topographic maps of Survey Department are not sufficient. WG3 is trying to develop the Yellow/Re zoning in appropriate way.

STATE MINISTRY OF URBAN DEVELOPMENT, COAST CONSERVATION, WASTE DISPOSAL AND COMMUNITY CLEANLINESS

Urban Development Authority

My No. 25/01/02/02/13
Urban Development Authority,
Uva Provincial Office,
No. 199/24, Keppetipola Mawatha,
Badulla.

April 2021

Director,
Human Settlements Planning & Training Division,
99/1, Jawatta Road,
Colombo 05.

Preparation of Development Plans (2021-2030)
Bandarawela and Welimada Urban Areas

This is with reference to the virtual meeting held on 17th February 2021 via zoom regarding the NBRO research finding for planning and building regulation in hilly areas.

02. Presentation and research findings were really insightful and UDA in the positive attitude to incorporate NBRO recommendation in upcoming development plans.

03. Further it was discussed to obtain NBRO's technical assistance on identifying land slide vulnerable areas in Bandarawela and Welimada. Which are to be considered in the development plans of said areas.

04. Accordingly you are kindly requested to assist us with identifying land slide vulnerable areas/disaster risk areas in Bandarawela and Welimada urban areas. (Approximate Planning Boundaries are attached herewith)

05. You may contact Town Planner Mrs. Chanuli Liyanage (Bandarawela), Town Planner Mr. Mahesh Kumara (Welimada) for further coordination.

Sugath Pemasiri
Director (Uva Province)
Urban Development Authority

Telephone: (Office) 055-2223721, Director (Uva Province), 055-2229122 Fax 055-2229950

A request letter from UDA

(3) Actions (by JICA) and lessons learned

As mentioned above, even during the period of travel restrictions due to the COVID-19, each WG member has proactively promoted the Project activities and made various efforts to produce outcomes. However, even for NBRO officials, domestic travels to the pilot sites are restricted, and it was worried that the C/P's individual motivation became lowered when it comes to carrying out scheduled activities only through on-line meetings over a long period of time. Therefore, the Team often proposed various activities that would contribute to the achievement of the Project purpose upon JICA's agreement, even those that were not originally planned. The following additional activities were proposed by the Team and implemented.

1) Additional activities on improving existing LHZM

In the Project, the concept of Yellow/Red zone has been introduced in place of LHZM, which NBRO has been developing so far. However, as mentioned in Section 2.3.5, it will take a considerable amount of time to expand the Yellow/Red zoning in entire country. In addition, it was agreed that the LHZM will be still used for evaluation of initiation areas when developing Yellow/Red zoning. Hence, it became important to improve the accuracy of the current LHZM, the Team proposed this work as an activity to carry out during COVID-19 (refer to Section 2.3.5).

This additional activity is to evaluate the LHZM that has been developed and promoted by NBRO over the past 20 years, and is very important for NBRO especially for staffs of LRRMD. All WG1 members participated in these remote workshops with great interest, and the results were presented at the NBRO annual symposium, etc. In this activity, the Team proposed a way of improvement of the LHZM and summarized it in the manual. It is required NBRO to collect more information to verify the criteria of zoning according to the prosed method.

2) Developing landslide remote monitoring system

NBRO operates and manages its own rainfall observation network to issue landslide early warnings, and the Project has worked to improve the warning criteria using the existing rainfall observation network. On the other hand, with regard to the "Landslide Remote Monitoring System" introduced through JICA's PPP program, the possibility of additional support within the Project has been considered between the Team and JICA, on precondition that this additional support will contribute to the maximize the Project outcomes.

One of the aims of the Project was to create a roadmap for Local Authorities to obtaining technical support from the central government on the premise that Local Authorities would formulate sediment disaster risk reduction plans. Landslides (deep-sheeted landslide) are the main disasters in Weeriyapura and Udapotha sites. In line with the sediment disaster risk reduction plan, the introduction of the "Landslide Remote Monitoring System" become a incentive for the nonboring Local Authorities to formulate the plans in future. In this context, it was decided in discussion between JICA and the Team to provide this additional support (see Section 2.4.4 for details).

2 sets of landslide remote monitoring systems were successfully installed at Weeiyapura and Udapotha by January 2022. In addition to these sites, there are another 2 sites where the landslide remote monitoring system have been already installed by JICA PPP program, and there are many instruments installed during the Japanese ODA loan project “Landslide Disaster Prevention Project: LDPP”. Though training on operation and maintenance at these installation sites, a synergy between several projects have been created.

3) Developing landslide information management system (LIMS)

As shown in Section 2.3.2, development of landslide information management system (LIMS), which was originally scheduled by NBRO C/P budgets, it was suspended due to the financial difficulties under the COVID-19. The Team proposed and implemented the additional supports from the viewpoint of improving landslide data management in NBRO. By accumulating landslide records and investigation reports as well as risk assessment, it will greatly contribute to updating they Yellow/Red zoning thresholds and landslide early warning criteria.

On the other hand, due to the impact of the COVID-19 and following economic crisis whole island, the number of non-permanent staffs at NBRO regional offices has been significantly reduced, and data entry for over 100,000 reports has become a challenge. Therefore, in order to input as much data as possible within the Project period, project assistants were hired at each regional office to assist the data entry into the LIMS.

3.2. Issue to introduce Yellow/Red zoning

(1) Challenges

As mentioned in Section 2.3.4, much of the project period was spent to introduce and pervade the Yellow/Red zoning concept.

As in many other countries, Sri Lanka has used the LHZM (Susceptibility Map) as a landslide hazard map. It is a method to evaluate the occurrence potential of slope failures or landslides from various factors, and this itself is a valuable approach. However, in order to promote land use regulations

according to zoning of the risks, it is essential to identify the extent of the impact area (Yellow/Red zone area) rather than the slope failure itself. In this viewpoint, designation of sediment disaster hazard area and special hazard area developed in Japan have been introduce with some customization. For the process, the following issues were realized.

1) Different residential status between Japan and Sr Lanka

Designation of sediment disaster hazard areas in Japan was developed in order to implement appropriate administrative measures and development regulations for existing residential areas and lands that may be developed in the future. For this reason, mountainous slopes, which are unlikely to be developed in the future, are not targeted, and the sediment disaster hazard areas are set for plains or gentle slopes.

In Sri Lanka, however, tea plantations and other plantations are widely extended in the mountain slopes as a means of local livelihood, and many residents are already living in the slopes. Taking a debris flow prone stream an example, in the case of Japan, a sediment disaster hazard aera (Yellow) is set up only at downstream of the stream mouth to the debris flow spreading area. If only this Japanese method is applied in Sri Lanka, it is not possible to regulate land development and building construction in the slopes along the stream.

2) Empirical method or analytical method

Japan's sediment disaster hazard areas were initially not positioned as hazard maps, but rather to legally identify areas that would serve as the basis for administrative measures. When it is designated as a hazard area or special hazard area, there are concerns that it will affect the value of individual assets (the landowners are required to explain the status of the lands when they sell the lands). For this reason, when setting up Japan's sediment hazard areas, we eliminate uncertainties such as geological conditions and soil cover as much as possible, and based on topographic as well as statistical data of past disasters, enforce the same areas regardless of who establishes them. The methodology has been established in trial and error for many years.

On the other hand, NBRO, as a geological research institute, has had various opinions from the beginning of the Project about the method of uniformly determining the Yellow/Red zones without considering geology, topography, soil cover, hydrological information, etc. Hazards should be identified based on scientific analysis, and it is well known that similar discussions are held in Japan. It has been a major controversial point throughout the Project that the purposed and scope of the use of LHZM and Yellow/Red zones.

3) Roadmap to expand Yellow/Red zoning

Designation of the sediment disaster hazard aera in Japan started in 2000, and as of the end of 2021, 670,000 hazard aeras and 580,000 special hazard areas have been designated according to the statistical date of MLIT. In case of Japan, who is the essentially carry out the basic surveys to identify the hazard and special hazard area is private consultants. In future in Sri Lanka, in order to establish a full-scale of Yellow/Red zoning, it will be impossible only with NBRO’s resources alone. It is necessary to discuss the legal and implementation system as well as budget allocation for it.

(2) Actions and lessons learned

1) Yellow/Red zoning utilizing LHZM

At a reporting meeting after the 2nd C/P training in Japan in August 2022, the NBRO DG gave a comment that "historically, people in Sri Lanka have settled in mountainous areas to escape from floods and droughts prone plain and coastal area of the island, it is important to consider such cultural backgrounds when regulating land use. When we think optimization of the settlement in the country, it is not the issues only in mountainous aera". In this way, it is impossible to apply Japan's sediment disaster hazard areas as they are to Sri Lanka. The Team and WG members have had repeated discussions about the implementation and demarcation of Yellow/Red zone and LHZM.

The details of the discussions are as described in Section 2.3.4. Through the three years discussion, it was finally agreed to set Yellow/Red zones as following manners.

- If Yellow/Red zone of slope failure is applied, many existing residential areas in mountainous areas will be designated as Red. Therefore, instead of using the Yellow/Red zoning for slope failures, the area with high LHZM risk is set as a potential aera of slope failure (Red), and Yellow zones are set above and below it.
- The areas at the end of mountain slope are generally high-risk and possible development aera, where should be identified as Yellow or Red areas to prevent development. However, in case the LHZM risk level is not high, those aera cannot be regulated. Regarding this issue, NBRO already developed "Hazard Resilient Housing Construction Manual", in which necessary measures that should be taken to develop lands near or in slopes. Therefore it was concluded that the development standards should be handled individually based no the manual.
- In addition, when selecting the possible debris flow risk streams, the risk level of LHZM will be referred.

2) Scientifical verification of Yellow/Red zones

Through discussions at WG1, the Team have promoted the understanding that it is important to remove subjective judgment as much as possible in Yellow/Red zoning. For this reason, in examining the area setting standards, we uncovered many past landslide records and showed that they were based on statistical analysis, as described in Section 2.3.3. The idea has been deepened through the verification of LHZM and Yellow/Red zones described in Section 2.3.5. WG1 members agreed to update the Yellow/Red zone setting method as appropriate while continuing similar efforts in the future.

In addition, WG1 members tried comparing the results of Yellow/Red zone and numerical analysis (debris flow simulation analysis) using past disasters as examples, and confirmed the high validity of the developed Yellow/Red zoning. The results have been compiled and reported at the NBRO annual symposium. In addition to the reports by the Project CPs, the staffs from NBRO site office, who had not been directly involved in the project, proactively tried to apply and verify the Yellow/Red zoning in his study area and reported it at symposiums. It can be said that it was a great achievement that NBRO's intention to further develop and expand Yellow/Red zoning.

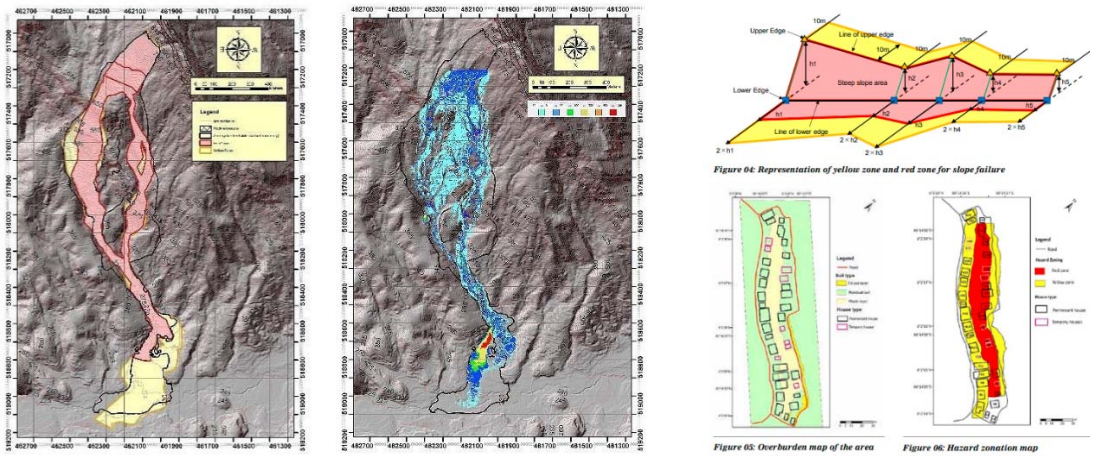


Figure 3.1: Verification of Yellow/Red zoned by WG1 members and NBRO site office
(Source: Proceeding of 11th NBRO annual symposium)

3) Discussion to expand Yellow/Red zones

NBRO has indicated its intention to extpand and develop Yellow/Red zoning in the future, but since the legal system is not developed like in Japan, it is not easy to promote this unless systematical budget measures are not taken for the activities. In the discussion of WG1 and WG3, instead of developing the Yellow/Red zoning for entire landslide pone districts, for the time being, NBRO should response to the requests from development entities and administrations such as districts, DS divisions, Local Authorities and UDA. Further, NBRO site offices should have significant role to expand the Yellow/Red zones because the know the needs of local admirations. It was also confirmed that Yellow/Red zoning should be applied when serious landslide disaster occurs, to predict similar or secondary disaster in the surrounding areas.

3.3. Involvement of pilot Local Authorities

(1) Challenges

Especially for activities related to Output 3, it is important to involve Local Authorities who have authority over land use and building permits, and to promote their understands to the project. However, until now, NBRO as well as other DRR related central government agencies have had little experience in engaging Local Authorities in their activities, and Local Authorities have little knowledge or experiences of land use regulations considering DRR. In Sri Lanka, according to the Constitution, there are two separate administrative lines of the national administration: Central government = Districts = DS divisions, and the local autonomous lines: Provincial governments = Local Authorities. There is a challenge to promote a consistent disaster prevention policy between the national administration that has been carried out DRR related activities and the local autonomous line that has the authority to issue development permits.

Land use regulations are measures that impose a considerable burden on residents. Therefore, it was expected that the politicians of Local Authorities, who was elected by residents, tend to emphasize disaster response or post-disaster compensations rather than DRR activities and investments. It may be an issue to gain the understanding from the Local Authorities.

(2) Actions and Lessons Learned

1) Closed communication by NBRO site offices

From the beginning of the project, the Project Manager and WG leaders carefully explained the Project to the chairmen of each Local Authorities at the pilot site. The Team and NBRO C/Ps visited local governments as much as possible, even if it was only for a short time during travel restriction in the COVID-19 and shared the progress of the activities. Furthermore, the chairman of the Local Authorities also often participated in workshops for the communities. Through these activities, the understanding of Local Authorities to the Project has deepened. In addition, NBRO site offices are important in collaborating with the Local Authorities. Since the staffs of site offices have a good understanding of the local situation, their coordination with Local Authorities and the DS division was essential for the implementation of the project.

2) Discussion in JCC involving Local Authorities

The JCC is an opportunity to confirm the progress of the entire Project among the stakeholders, and it is important to have the chairmen of the pilot Local Authorities participate in the JCC. Since it is generally difficult for Local Authority officials to communicate in English, the Sinhala language was used as the basis for discussion at the meeting, and NBRO DG often communicate with them in Sinhala to promote their understanding. As a result, chairmen from pilot Local Authorities participated in all four JCCs and delivered their strong commitments and positive opinions.

3) Common understanding through C/P training in Japan

NBRO requested that the Local Authorities of the pilot sites should participate in at least one of the two scheduled C/P trainings in Japan, because their understanding was essential for project management. Initially, it was planned that 5 trainees would participate in both the 1st and 2nd batches, but based on the above-mentioned request from NBRO, it was decided to increase the number of trainees to 10 people would participate in the 2nd batch. Due to the spread of COVID-19 and the impact of the economic crisis, it seemed that the 2nd training cannot be realized in the Project period. But it was finally agreed to extend the Project period and carry out the 2nd training to promote the actions on land use regulation by the Local Authorities.

When an action plan presentation at the end of the training in Japan, the trainees were divided into groups for each Local Authorities for 3 pilot site. For each group, a NBRO site office staff who is in charge of the area, and a NBRO HSPTD staff who is in charge of the resettlement program were assigned. In addition, as for the Weeriyapura group in Badulla district, participant from UDA also joined as the UDA is currently developing the urban development plan for the area. Each group worked together to discuss the issues in their areas and prepare the detailed and practical action plans.


Badulla MC Group


Koapola PS Group


Bulathkohupitiya PS Group

Chapter 4 Achievement of the Project

Through the activities of each output described in Chapter 2 and the actions taken to solve the challenges described in Chapter 3, it can be said that each output has successfully achieved in principal though some continuous efforts are requested to NBRO. The results were shared and agreed with the stakeholders at the 4th JCC held in June 2022. The status of achievement for each output and the Project purpose is as follow.

4.1. Achievement of Output 1

The hazard maps (Yellow/Red zone maps) of the three pilot sites have been finalized and are being utilized for the activities of Output 3. Hazard mapping and risk assessment manuals were also finalized. NBRO staff are the main users of each manual. The manuals are now in the process to post on the NBRO website.

The newly developed Landslide Information Management System (LIMS) has a record sheet for "Landslide Investigation Report" and "Risk assessment report (for buildings, lands, projects)". From now on, newly created reports will be stored in the system in online formats.

Table 4.1: Achievement of Output 1

Output	Verifiable Indicators	Achievement
1: Capacities to conduct hazard mapping and risk assessments are strengthened	▪ Hazard maps at pilot sites are updated with the information on hazard areas and risk assessments	▪ Hazard maps at all pilot sites were completed.
	▪ Updated hazard map development manual is uploaded on NBRO's website	▪ Site specific hazard mapping manual was finalized and in process to post on the NBRO's website
	▪ Updated manual on risk assessment (including the management of disaster record) is uploaded on NBRO's website	▪ Risk assessment manual was finalized and in process to post on the NBRO's website
	▪ Disaster data is collected according to the risk assessment manual	▪ Landslide Information Management System (LIMS) was launched, and the data and reports are being input by NBRO site offices.

4.2. Achievement of Output 2

Using the developed rainfall monitoring system, it became possible to monitor the Soil Water Index (SWI) and snake curve in real time at the NBRO early warning room. However, since the amount of data is insufficient to customize the current warning thresholds for each region at the moment. Thus, for the time being, the current thresholds are used referring the developed monitor to issue the warning. WG2 members will continue to collect newly occurred landslides and rainfall at the occurrence.

Including the above warning criteria setting method and communication protocol from NBRO to

residents, the landslide early warning manual was finalized. Since the manual is intended only for the NBRO Early Warning Room, it has been prepared only in English, and is being posted on the website. In addition to the manual, public relations materials were prepared for strengthening early warning in the community and those were disseminated through community workshops.

Table 4.2: Achievement of Output 2

Output	Verifiable Indicators	Achievement
2: Capacities to issue landslide early warning alerts are strengthened.	▪ Revised rainfall criteria and protocol for early warning are uploaded on NBRO's website	▪ Based on the developed rainfall monitoring system, the tentative thresholds were identified. The landslide warning is issued using the existing criteria referring the monitoring system.
	▪ Updated early warning manual is uploaded on the NBRO's website.	▪ Landslide early warning manual including warning criteria and protocol was finalized and in process to post on the NBRO's website

4.3. Achievement of Output 3

The guideline for land use planning / development standard was drafted in 2020. After drafting, the Project activities have been focused on developing land use planning / development standards at each pilot site. Based on the results of these activities, the guideline was finalized. Because the finalized guideline seemed to be a manual, so WG3 decided to simplify as more conceptual guideline. The developed land use planning / development standards at the pilot sites were summarized in enlightenment posters which were delivered to each Local Authorities and communities. The guideline is on process to post on the NBRO's website.

Table 4.3: Achievement of Output 3

Output	Verifiable Indicators	Achievement
3: Capacities to apply risk assessments of sediment disaster(s) to land use planning are strengthened	▪ A guideline on land use planning / development standard is developed and uploaded on NBRO's website.	▪ The guideline for land use planning / development standards were finalized and in process to post on the NBRO's website. At the same time, the land use planning / development standards (draft) at 3 pilot sites were finalized.

4.4. Achievement to the Project Purpose

Through the achievement of the above outputs, the status of the achievement on the Project purpose is summited in Table 4.4.

(1) Early warning is issued according to the revised protocol and based on local thresholds at catchment level and shared on NBRO's website

In order to set thresholds that take into consideration regional characteristics, it is essential to accumulate disaster occurrence data and the rainfall. Based on the analysis by WG2 members so far, it has reveled that there are critical rainfall trends differ between the eastern and western sides of the county. These results were introduced at symposiums and other meetings. It is expected that the accuracy of warning thresholds will be improved by further accumulation of data of landslide events. Some officers who can carry out this works exclusively have been trained in the Project.

On the other hand, warning issuing protocols have already been established among relevant agencies such as NBRO, DMC EOC and DDMCU in districts. Throughout the Project period, NBRO is advancing the landslide warning system, there is no problem in issuing the warning. In the activities in the pilot sites, it was confirmed that such warnings were not being conveyed accurately and promptly to the end revivers. In the Project, we tried to strengthen the end-to-end warning protocols through workshops on warning and evacuation. A series of activities are summarized in a manual for landslide early warning, to extend the Project activities to the other area.

(2) Land use plans at pilot sites are developed based on risk assessments

Land use plans for 3 pilot sites were formulated in conjunction with the guideline for land use regulation / development criteria guidelines. Local Authorities were always involved in the process of formulating land use plans, and the ownership of Local Authorities were evaluated as very high. However, since there are no legal restrictions on this plan, in order to promote the land use plan in the future, efforts such as the development of ordinances by the central and local governments are necessary.

In addition, the purpose of this project is not only to formulate a land use plan, but also to help local governments and local residents to accurately understand the landslide risks, and reduce the risks utilizing available resources. For this reason, instead of making a land use plan alone, it was compiled as a "Sediment Disaster Risk Reduction Plan". The activities that Local Authorities should work on in the future were compiled as action plans.

(3) (Site-specific) Landslide Risk Assessment Report (LRAR) and Landslide Investigation Report are prepared based on the risk assessment manual and the guideline for land use plan updated by the project

NBRO site offices conduct field surveys on risk of potential landslides and newly occurred landslides, and prepare “Landslide Investigation Report” and “Landslide Risk Assessment Report (for building, lands, project, etc.”. The number of these report exceeds 100,000, but since they are all stored on paper, they cannot be used for analysis. It is not possible to review the existing repots, so it was often the cases that similar reports were created in the same places.

Under these circumstances, NBRO planned to build an online Landslide Information Management System (LIMS) by a part of the C/P budget. The bidding documents for system development were prepared jointly by the Team, WG1 and WG2, and it was confirmed that the outcomes of the Project such as landslide inventory sheets, Yellow/Red zones and risk assessment result are stored in the LIMS. In other words, all information related to the landslides risk management in the Project will be integrated into the system.

In general, there are some cases where only the “system” is developed, but not contents are stored. As it is one of the systems that NBRO officials have very high expectation to become their daily works would be more effective, and they are always involved in the process of system development, so continuous operation and management are highly expected.

Table 4.4: Achievement of Project Purpose

Project Purpose	Verifiable Indicators	Achievement
NBRO's capacities to implement non-structural measures for sediment disasters based on enhanced hazard and risk assessments are strengthened.	▪ Early warning is issued according to the revised protocol and based on local thresholds at catchment level and shared on NBRO's website	▪ Early warnings have been issued refereeing the developed rainfall monitoring system. It is required to collect further disaster information to improve the warning thresholds.
	▪ Land use plans at pilot sites are developed based on risk assessments	▪ Land use plan/development standards at pilot site were finalized as part of local sediment disaster risk reduction plan.
	▪ (Site-specific) Landslide Risk Assessment Report (LRAR) and Landslide Investigation Report are prepared based on the risk assessment manual and the guideline for land use plan updated by the project	▪ Landslide investigation reports as well as landslide risk assessment reports including Yellow/Red zonings were integrated into the Landslide Information Management System (LIMS)

Chapter 5 Recommendation to Achieve Overall Goal

Overall goal and its indicators that evaluate the sustainable efforts by Sri Lankan governments and expansion to the areas other than the pilot areas after the Project are as shown in Table 5.1.

NBRO takes the initiative in all project activities proactively, and continues to improve operations to reduce landslide risks. For this reason, there is little concern about the horizontal expansion of the Project outcomes. But at the 4th JCC, the following proposals were made and agreed to achieve the overall goal.

Table 5.1: Overall goal and its verifiable indicators

Overall Goal	Verifiable Indicators
In high risk areas of sediment disasters, non-structural measures based on strengthened hazard and risk assessments are implemented.	▪ Number of updated landslide hazard zonation map utilizing the knowledge transferred through the Project ▪ Number of revised rainfall criteria for landslide early warning based on local conditions ▪ Number of land use plans developed based on risk assessments

(1) Measures taken for Output 1 (WG1)

NBRO has already started expanding to other regions in the Yellow/Red zone, so there are no concerns in this regard. However, the setting standards and methods currently shown in the manual were established based on past disaster cases collected within the Project. It is quite conceivable that there will be issues and necessity of revision (even during the project period, there were various issues in proceeding with the trial at the pilot site, and we have dealt with them one by one). Therefore, NBRO is required to develop the Yellow/Red zone and revise the manual as necessary.

In setting the Yellow/Red zone, it was decided to utilize LHZM for initiation area evaluation. The current LHZM has established based on the landslide data collected in the 1990s, but since then many large and small landslide disasters have occurred, and based on these data, the LHZM itself should be improved and updated. In the Project, the Team proposed an improvement method for adjusting the risk level threshold of LHZM and weighting each element such as geology, soil cover, landform, etc. NBRO needs to proceed with the improvement of LHZM based on the content of the proposal.

Accumulation of past landslides data is essential for the revision and improvement of the Yellow/Red zone and LHZM, and for setting the threshold for landslide early warning. NBRO needs to continue strengthening the data input capacity of each site office so that the Landslide Information Management System (LIMS) supported by the project can be used continuously.

(2) Measures taken for Output 2 (WG2)

NBRO officials have sufficient ability to evaluate the occurrence and rainfall characteristics of landslide disasters using the Soil Water Index (SWI) and snake curve. Evaluation of the relationship between short-term and long-term rainfall indexes continues. However, due to the lack of landslide occurrence data, it was not possible to set warning thresholds that reflect regional characteristics within the Project period. NBRO should continue to accumulate landslide data and develop a system to issue more accurate and appropriate landslide warnings.

More than 300 ground rain gauges have been installed in the country, but the number of rain gauges that have not been operated or cannot transmit data. Due to lack of personnel and financial resources, there are some cases where proper maintenance is not being carried out. Since there have not been weather radars in Sri Lanka, NBRO's rainfall observation network is an important resource not only for landslide monitoring but also for other related technical agencies and institutions to grasp rainfall information in a comprehensive manner. It is necessary to secure sufficient personnel and budget for the maintenance of the facilities.

(3) Measures taken for Output 3 (WG3)

From the beginning of the project, NBRO proposed to complete the activities at the pilot sites by the second year, and to expand to six sites other than the pilot sites in the third year. Due to the impact of the spread of COVID-19, this development could not be realized within the Project period. NBRO has already started working for Yellow/Red zoning to the other sites, it is also necessary to formulate land use plans based on the Yellow/Red zonings.

With regard to land use regulations, although a trial was conducted at a pilot site, the Local Authorities recommended that the legal system should be developed to ensure the enforcement of the regulations. To establish ordinance (By-law) in Local Authorities, the Provincial governments should give the authorities to the Local Authorities, so it is necessary to have discussion between the central government and the Provincial governments. In addition, there is a significant effort that Kegalle district has issued a letter to the Ministry of Land to official demarcate the Red zone as conservation area based on Law on Forest Conservation, so that the land cannot be developed in future. It is also considerable approaches to incorporate the Yellow/Red zoning into the urban development plans by UDA. Those were important lessons learned that the land use regulation will be in effect based on the existing laws or ordinances, not developing new system. NBRO is required to continue to consider approaches to ensure the effectiveness of land use regulations in cooperation with related organizations.

Minutes of Meeting of Joint Coordination Committee (JCC)

List of Property Lending